CONSTRUCTING AN EMF RADIATION HYGEIA FRAMEWORK AND MODEL TO DEMONSTRATE A PUBLIC INTEREST OVERRIDE

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ABSTRACT

Scientific views on EMF radiation dosimetry and models increasingly suggest that even a tiny increase in the incidence of diseases resulting from exposure to EMF radiation could have broad[1] implications for public health, social accounting and the economy. In South Africa (SA) there is no national EMF radiation exposure protection standard, statutory monitoring or regulations. Multinational High Court deliberations indicate the need for public interest EMF radiation exposure protection standards in South Africa. Domestic citizens, academics, as well as regulatory and legislative practitioners, are unable to effectively monitor and investigate EMF radiation exposure emissions from infrastructure sources, because industries refuse to provide the required data. Industries have, since 2003, continually obstructed access to the data and the establishment of a national EMF radiation standard, citing that it would be in conflict with their strategic economic interests. The demonstration of a public interest override (PIO) function is legislatively required to gain access to the required data.

This study constructed (1) a framework and (2) a model to perform test simulations against the (3) PIO criteria to demonstrate a PIO function and tested one PIO simulation scenario. Testing the PIO scenario firstly required the construction of a public interest framework, drawing input from multiple disciplines. The framework literature review used systematic case law and scientific-technical analysis whilst the framework science sought to understand

[1] Defined in Section 1.5

the connections, feedbacks, and trajectories that occur as a result of natural and human system processes and exchanges. The EMF radiation exposure system functions to support human wellbeing needs and to explore the benefits and losses associated with alternative futures with the goal to uncover the current and future limits thereof.

In the second instance a HYGEIA[2] model was selected as a base investigation and forecast simulation tool. The study had to uncover the key attributes and parameters necessary to construct and to run successful EMF radiation exposure simulations. Thereafter the HYGEIA model was modified to specifically identify and evaluate EMF radiation exposure hazard conditions. Through subsequent simulation runs, the constructed framework was then tested. Requested anthroposphere information was synthesized within a systems model to forecast ecosystem services and human-use dynamics under alternative scenarios. The simulation used the model, the model references and the framework for guidelines, thus allowing multiple simulation / demonstration runs for different contexts or scenarios.

The third step was the construction of a PIO checklist which guides criteria testing and provides a means of gaining pertinent information for further studies, based on this dissertation. Framework EMF radiation policy inputs into the model were intersected with identified vulnerable area facilities which were selected based on international criteria. The research output revealed potential EMF radiation violations which served as system feedback inputs in support of a demonstrated PIO function. The research recommends that the identified EMF radiation exposure violations of public health undergo a Promotion of Access to Information Act (PAIA) judicial review process to confirm the research findings. The judicial qualification of a PAIA PIO function of 'substances released into the environment' and 'public safety or environmental risk' would enable access to EMF radiation emissions data essential to future studies.

KEYWORDS: Electromagnetic Field Radiation; Dosimetry; Environmental Modelling.

Declaration

[2] Hygeia originated from the Hippocratic Oath representing a public health model that focuses on prevention in the context of public interest. Using census block data the HYGEIA model can be used to assess the vulnerability of various demographic groups over time and location and to forecast morbidity and mortality under variable conditions of current and future climate change as well as under conditions that mitigate EMF radiation extremes.

I declare that the Dissertation entitled 'Constructing an EMF radiation framework and model to demonstrate a public interest override' that I hereby submit for the degree MSc. at Rhodes University, is my own work. I also declare that this dissertation has not previously been submitted by me for a degree at this or any other tertiary institution and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

James Chrystopher Lech (*signed*)

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In line with the required protective measures by the WHO (2007:13), government and industry should promote research programmes to reduce the uncertainty of the scientific evidence on the health effects of EMF radiation exposure.

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25. Susan Basson, Quality Support Specialist – Legal Professional for Life Healthcare.
26. Thinus Rudolf, Lecturer at the Justitic College for the Department of Justice and Constitutional Development.

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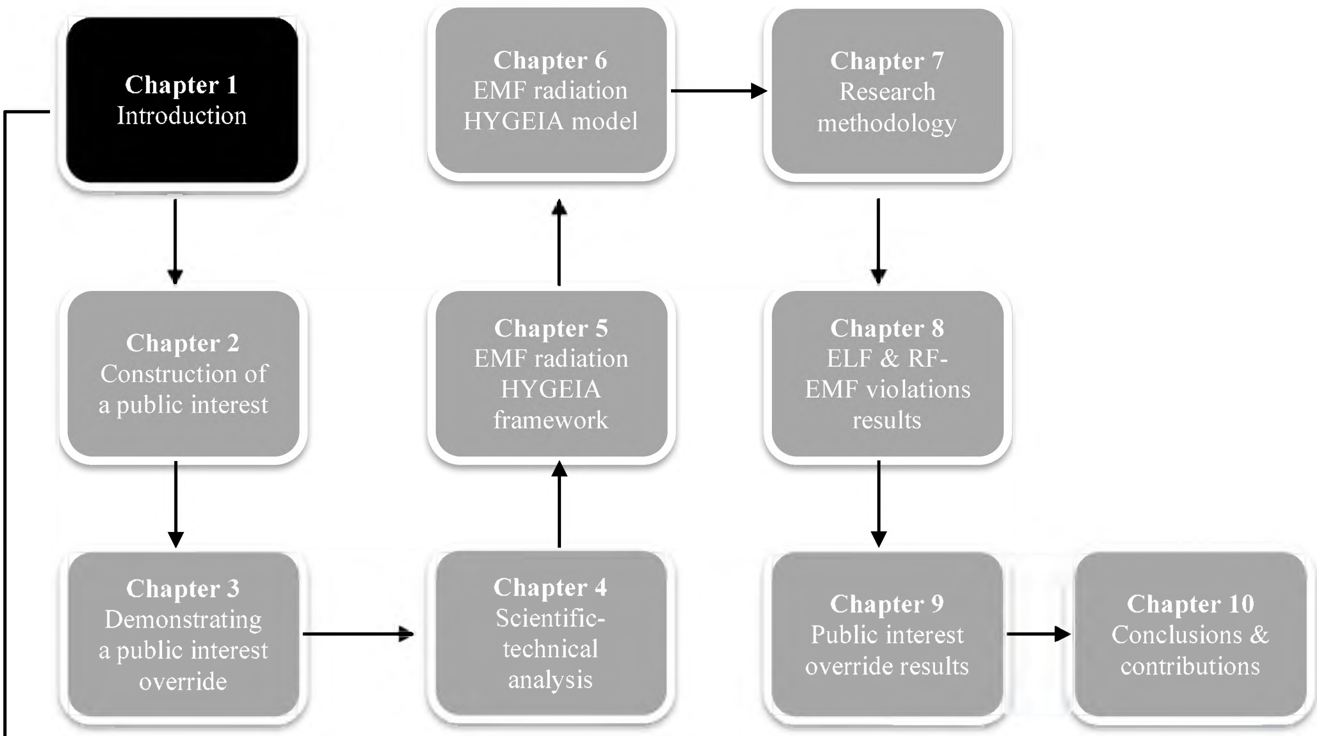
INTRODUCTION: PROJECT OVERVIEW



1.1 Introduction and background

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CHAPTER 1
Introduction and project overview

1.1 Introduction and background

This study will construct a public health EMF radiation exposure framework and model that will focus on prevention in the context of public interest. Furthermore, the study will uncover the key attributes and parameters necessary to construct and to run successful model simulations and will also create a public interest override (PIO) checklist, will guide criteria testing and will provide a means of obtaining pertinent information for further studies based on this dissertation. The focus of the PIO criteria will be based on case law relevant to the Promotion of Access to Information Act (PAIA) (PAIA, 2000). The remainder of this section contains a brief discussion of EMF radiation exposure as a public interest.

The study structure will follow the systematic process shown on the previous page to demonstrate a PIO function by constructing a public interest, reviewing how to demonstrate a PIO and, by using scientific-technical analysis, will uncover the parameters necessary to demonstrate an EMF radiation exposure public interest, will construct an EMF radiation HYGEIA framework, and model, will apply research methodologies drawing input from multiple disciplines and will evaluate the research findings to demonstrate a PIO. The study is an ambitious and mammoth task. All these steps are complex and require knowledge from diverse fields such as dosimetry [3], wave propagation physics, geospatial modelling, epidemiology, medicine, risk analysis, legal procedures and informatics. The study requires gaining sufficient knowledge in all these disciplines to demonstrate, in principle, how a multidisciplinary structure could be solved. The multidisciplinary approach to the problem space in the study does not enable a traditional linear academic study structure. Non-leaner learning follows a network (non-linear) instead of a line (linear) (CAS-DSP, 2007; Moreno & Mayer, 2007). It's about experience[4] and connecting the dots (Wilkinson, 2000). A non-linear research design follows the single learning path determined by the researcher tasked with the responsibility in mastering the topic (demonstrated in Chapter 5) (Moreno & Mayer, 2007). That means the research can select any entry point and navigate to any other in understanding the topic (Sweller et al., 2011). An approach enabling pattern recognition (Korte, 2001; Schmidhuber, 2015). Such a study design requires articulating the content with a clear

[3] Dosimetry describes the relationship between the external fields and the induced electric field and current density in the body, or other parameters associated with exposure to these fields (WHO, 2007).
[4] Practitioner research methodology: purpose of understanding, changing and improving their practices together. Intended to solve problems and enhance practice (Wilkinson, 2000).

headline, short summary and attached more detailed information source (found in the appendix). A strategy in cognitive load theory uses different principles to reduce cognitive load when handling information overload (Moreno & Mayer, 2007; Sweller, 2011). For example, the split attention effect is used when learning must process separate but related sources of information that cannot be understood without mental integration (Sweller, 2011). The outcome, a pattern recognition approach that could be used in developing a solid basis for a definite EMF radiation exposure protection procedure to recommend for South Africa.

The study will investigate and present the public interest case for EMF radiation exposure in Chapter 2. EMF radiation dosimetry scientific views (defined in Section 1.5) and models increasingly suggest that even a tiny increase in the incidence of diseases resulting from exposure to EMF radiation could have broad[5] implications for public health, social accounting and the economy (European Parliament Scientific & Technological Options Assessment, 2001; Government of Italy, 1998; European Environment Agency, 2009; Ramazzini Institute, 2010; Government of India, 2010; Council of Europe Parliamentary Assembly, 2011; Rajasthan, 2012; WHO, 2013; Belpomme et al, 2015; US Department of Health and Human Services [HHS] National Toxicology Program [NTP], 2016). The problem in South Africa is that both the World Health Organization and South Africa's (SA) Department of Health (DHSA) confirm that there are no national protection standards in SA for EMF radiation exposure regarding static, extremely low frequency (ELF) and radio frequency fields (RF) (City of Cape Town Municipality [CCPTM], 2015; DHSA, 2016c; WHO, 2016a; DHSA, 2017).

EMF radiation is emitted at different signal patterns, intensities and technical applications for varying periods of time. The development of wireless communication systems and hybrid technologies causes the pollution of the human living environment by a growing number of new EMF frequencies that have, until recently, been absent there (Bąk et al., 2010). All these EMF radiation exposure fields are collectively referred to as electrosmog (Belyaev et al., 2016). Electrosmog cannot be seen, smelt or traditionally felt (WHO, 2004b). Members of the public or government regulators would not realize their potential harm over long periods of exposure until they manifest in the form of environmental and public health issues (Bärtels & Mosler, 2008; Government of Italy, 2008; European Environment Agency, 2009; Ramazzini Institute, 2010; Government of India, 2010; Rajasthan, 2012; Sivani & Sudarsanam, 2012; Belpomme et al., 2015). This is a problem that international judicial review deliberations on electrosmog ruled as a constitutional issue (Government of Italy,

[5] defined in Section 1.5

2008; Government of India, 2010; WHO, 2015a; WHO, 2016c). Moreover, the systemic threat or the violation of human rights qualifies as a public interest (Practitioner9, 2016). The DHSA reported that unfortunately the current lack of comprehensive national regulations is problematic for both the DHSA and local municipal authorities in understanding, processing and dealing with EMF radiation exposure as a public interest and health (DHSA, 2017).

A number of regulatory bodies and legislative development authorities (listed in Section 1.4) have expressed interest in the potential findings of this research. The development of an EMF radiation framework and model and the demonstration of a public health interest are the primary contributions and relevance of this study. The output thereof may enable the development of appropriate EMF radiation protection regulations that are in the interest of public awareness and public health. A dynamic and accurate model that could define the broad implications expressed in the recent NTP (2016) model findings is required for the development of EMF radiation protection regulations in SA. The research presented here therefore has particular practical relevance.

Furthermore, to compound the issues described above, access to EMF radiation emissions pollutant data in SA, even for academic public interest research, is obstructed by industry claiming in defence that it would be contrary to their strategic economic interests (DHSA, 2005; DHSA, 2008; EMFDS12[6], 2012; EMFDS14, 2012; EMFDS13, 2012; EMFDS4, 2012; EMFDS3, 2012; DHSA, 2013; Regulator9, 2015; ATI Network, 2016; Regulator4, 2016; Practitioner18, 2016; Regulator10, 2016; Regulator7, 2016). This renders a public interest obstacle to EMF radiation exposure regulation, monitoring and enforcement in SA (NEMA, 1998; Public Interest Law Society TWEN, 2008; WEAL, 2008; Israel Ministry of Communications, 2009; Government of India, 2010; Kgomo, 2012; Rajasthan, 2012; Connor, 2013). However, as discussed in Chapter 3, gaining access to the data is achievable through PAIA (2000) sections 46 (public body) and 70 (private company), defining PIO of 'substances released into the environment' and 'public safety or environmental risk' (NEMA, 2008; De Lange and another v Eskom Holdings Limited, 2012; Kgomo, 2012; Connor, 2013; Practitioner8, 2016). As will be demonstrated in Chapter 9, the constructed HYGEIA model in Chapter 6 can provide support for a PAIA PIO. The demonstrated PIO in this study may prove an imperative tool to future HYGEIA model studies because it can provide the detailed facts and data required to accurately model and define the broad EMF radiation implications expressed in the recent NTP (2016) model findings (Boumans et al., 2015).

[6] Defined in Section 1.5, EMF radiation data sources, practitioners and regulators that participated in the study have been anonymized. The sum of the participated parties is listed in the Appendix, Section 7.1.

The obstruction of access to EMF radiation emissions pollutant data in SA therefore requires the demonstration of a qualified PIO function (defined in Section 1.5). The research will construct a proposed EMF radiation HYGEIA framework, and model to explore demonstration runs which will identify potential EMF radiation violations. The research will require the identified EMF radiation exposure public health violations to undergo a PAIA judicial review process to confirm the research findings for future studies.

In addition thereto the demonstration of a PIO is typically reliant on empirical evidence and a subjective judiciary. The study will uncover the key EMF radiation exposure attributes and parameters necessary in addressing the inherent weakness of a PAIA PIO judicial deliberation by using scientific-technical analysis in Chapter 4.

Donald Rumsfeld (2002) categorized knowledge for strategic planning into the following:

1. Category 1, there are things we know that we know ('the known').
2. Category 2, there are known unknowns. That is to say there are things that we now know we don't know ('unknown').
3. Category 3, but there are also unknown unknowns. There are things we don't know we don't know ('what we don't know').

Policies concerning human health and EMF radiation are based predominantly on 'the known' (Leszczynski, 2017). 'What we know that we do not know' (categories 2 & 3) is dismissed as irrelevant (Leszczynski, 2017). Anything that could lead to the implementation of a Precautionary measures is considered as 'scaremongering[7]' (UNEP, 1992; DHSA, 2017; Leszczynski, 2017).

Sciences is affected by conflict of interest (COI) (the office of Research Integrity, 2017) and hence public health and safety recommendations regarding the exposition (a comprehensive description and explanation of an idea or theory) to EMF radiation vary depending on the organization that they are published by (WHO, 2003:69; EDA, 2016; Environmental Health Trust [EHS], 2017; Hardell, 2017). Additionally, uniform EMF radiation susceptibility testing methods and procedures are not mandated by law in many countries, and susceptibility issues are not addressed directly (Vitale, 2005). Therefore, confusion abounds as each manufacturer presents their unique method to measure and document the ambient EMF radiation environment (Vitale, 2005). For example, following a French PIO judicial deliberation on the "PhoneGate" data, revealed that if mobile devices were tested in the ways we use them, they would violate safety standards (EHS, 2017). The data was marketed as

[7] The spreading of frightening or ominous reports or rumours.

PhoneGate because of the parallels to "Diesel Gate", the Volkswagen emissions saga. In Diesel Gate Volkswagen cars passed diesel emission tests when tested in laboratory conditions, but when the cars were driven on real roads, they emitted far more fumes. Similarly, mobile phones 'passed' laboratory radiation SAR (specific absorption rate) tests. Under very specific laboratory conditions, the tested phones are legally considered compliant. However, when the mobile devices were tested in the ways the public actually use them in real life, i.e. trouser pocket, bra, baby chew toy, the amount of absorbed radiation (SAR) emissions in the bodies violates the regulatory reference levels (EHS, 2017).

The EMF radiation dosimetry rational is broadly divided into two models of exposition, namely a short term exposure paradigm (STEP) and a long term cumulative exposure paradigm (LTCEP) model. The LTCEP model *limits* EMF radiation exposure to between 1/10th and 1/10 000th of that of the STEP model's *reference leve*l. The STEP model '*limits*' are considered as investigation levels, rather than levels that should be observed and that should not be exceeded, like the LTCEP model limits (Government of Italy, 1998; Giuliani, 2002). The correct terminology and legal accountability for the STEP model is therefore EMF radiation exposure *reference levels* and not EMF radiation exposure limits (Government of Italy, 1998; Vecchia, 2008).

Scientific evidence for EMF health risk is full of contradictions, unreplicated observations and ambivalent results that can be interpreted in diverse ways leaving room for biased opinions (WHO, 2007; Belyaev et al., 2016; Hardell, 2017; Leszczynski, 2017). Therefore, it is difficult as policy makers to make a final decision that then corrupts and generates weighted (Lai, 2010; Genuis, 2008; Huss et al., 2008; Starkey, 2016; Hardell, 2017) protection exposure standards as a result of 'echo chamber' (Leszczynski, 2017, Philip Morris and John Scruggs, 1998). In news media, the term 'echo chamber' is a metaphorical description of a situation in which information, ideas, or beliefs are amplified or reinforced by communication and repetition inside a defined system.

The construction of an EMF radiation HYGEIA framework, and model is required to address the problems highlighted above. Chapter 5 summarizes the lessons the researcher has learned from a review of cross-disciplinary research compiled in Chapters 2 to 4, as well as the PIO factors that have been distilled from examples of case law. The aforementioned resulted in the construction of the proposed framework, and model. The proposed framework, and model of multidisciplinary research linkages provide compelling evidence of the synergism between science, health, legislation, economics and the advances for policy makers that could be made by such collaboration and also elucidate the factors that enable cross-disciplinary efforts, as well as the barriers that inhibit them.

The researcher elected to use the climate change framework as a science-based modeling and implementation framework by following Wilkinson's (2000) practitioner research methodological output (defined in Section 1.3). This framework is increasingly applied by both domestic and international authorities (United Nations Framework Convention on Climate Change [UNFCC], 2014). Climate change[8] is the study of the effects of the anthroposphere on ecosystem services (UNFCC, 2014; Boumans et al., 2015). Ecosystem services (defined in Section 1.5) are assigned economic values to assist decision makers with the design and implementation of appropriate environmental and population development policies (Phillips et al., 2014; Boumans et al., 2015).

Consequently, the study aim is to develop an appropriate framework and model that can process approximation outputs that are as multiple and as complex as the real world (Boumans et al., 2015). Limited data was tested based on the model, but that was an instance of the general model.

The MIMES (multiscale integrated models of ecosystems services) framework, an information system (IS) that is capable of processing a public interest HYGEIA model, evolved from its roots in the systems theory of the climate change framework. The HYGEIA model is a broadly applicable modelling and supporting IS platform for decision making at a local scale whilst taking into consideration the potential health effects of climate change variables, as well as the effectiveness of different mitigating options (Boumans et al., 2014b). The HYGEIA model can be used to assess the vulnerability of various demographic groups over time and location by using census block data (defined in Section 1.5). It forecasts morbidity and mortality under both current and future variable climate change conditions, as well as under conditions that mitigate EMF radiation extremes.

The HYGEIA model may be used to forecast the effects of environmental change on human health and health environment interactions by focusing on prevention in the context of public interest. The use of the constructed framework inputs of the STEP and LTCEP model to forecast potential public health trends may help to develop new protection policies in the interest of public health. The MIMES framework HYGEIA model's social accounting module is able to not only simulate the potential health and economic outcomes on the population but also to simulate the potential economic outcomes on industry. The result is a

[8] defined in Section 1.5

series of different simulation scenarios based on the social accounting values risk threshold limits (defined in Section 1.5) and economic value system of a particular country, province, municipality or community.

This study aimed to construct and run a simulation combining a geospatial propagation model according to the framework EMF radiation policy inputs into the HYGEIA model, intersected with identified vulnerable area facilities which were selected based on international criteria (Gopal et. al., 2016) within the investigated Cape Town (CPT) metropole area. The research output reveals potential EMF radiation violations which serve as system feedback inputs in support of a demonstrated PIO function. The EMF radiation sources used to demonstrate a PIO are scoped to public infrastructure only. The EMF radiation infrastructure categories are high voltage powerlines, sub-stations, SMART meters, public Wi-Fi, cellular transmitters, macro radio and digital broadcast transmitters.

1.2 Problem statement

There are no generally accepted frameworks or regulations for EMF radiation exposure protecting the public in SA. Neither domestic academics, nor legislative and regulatory 'practitioners', are able to monitor, study, regulate or implement a national EMF radiation exposure protection standard because of access to data being denied. Practitioners require an investigative study and model outputs to legislatively demonstrate a PIO to gain access to required EMF radiation emissions data.

This public interest research is located within the identified problem space of current SA EMF radiation recommended voluntary guidelines that may not guarantee adequate protection against long-term exposure to EMF radiation (European Parliament Scientific & Technological Options Assessment; 2001; Government of Italy, 1998; European Environment Agency, 2009; Ramazzini Institute, 2010; Government of India, 2010; Atomic Energy Board of Namibia, 2012; NTP, 2016).

A number of regulatory and legislative developmental bodies (specified in Section 1.4) confirm that they do not have the expertise and resources to develop, implement or conform to appropriate EMF radiation exposure protection standards. Industries (specified in Section 1.1) obstructing the implementation of an appropriate LTCEP model EMF radiation exposure protection standard, because it would be contrary to their strategic economic interests, compound the problem.

Interested regulatory and legislative parties consequently have requested the study to develop an appropriate modeling tool that can aid policy makers to understand the social, economic and broad health implications of EMF radiation exposure and which potential forecast regulatory approaches would be feasible for SA. This study needs to construct a multidisciplinary public interest framework and model (defined in Section 1.5) that are broadly applicable for making decisions at the local scale, whilst considering potential EMF radiation emissions, changing variables, potential health effects and the effectiveness of different mitigating option (Boumans et al., 2014b). The study mitigation options simulation is limited to testing spatial proximity as defined by the framework EMF radiation policy inputs.

Research objectives

The goal of this research is to demonstrate a PIO using the constructed EMF radiation framework and model. Wilkinson's (2000) practitioner research methodological contribution (defined in Section 1.3) will be used to achieve this. The question will be whether they identify potential current and future public health issues related to EMF radiation exposure, as well as assist in identifying exposure mitigation, when run as a forecast simulation on a test case and investigation area (Cape Town).

The study seeks to create greater awareness regarding the problem space and to present a scientific-technical analysis basis for further exploration of the fundamental nature or essence of the EMF radiation health issues. The purpose of the study is to construct a multidisciplinary framework and model which, guided by PIO criteria, which may contribute to influencing government policy. The constructed framework and model seek to contribute by providing a comparative visual geospatial analysis of the identified geographical sensitive areas per the framework EMF radiation policy inputs; relating it to the environmental pollutant EMF radiation emitted from associated supporting infrastructures. A comparative visual geospatial analysis may aid policy makers in the development of a regulatory EMF radiation exposure standard that balances public health concerns and controls the levels of exposure, while remaining a digital economy.

The following research questions (RQ) demarcate the study by drawing from the proposed comparative visual geospatial analysis:

RQ_1: What should a multidisciplinary entities framework encapsulate to enable modeling of macro EMF radiation sources, considering domestic and international legislation and scientific opinions?

The purpose of the question is to review academic results and practitioners' dilemmas in addressing EMF radiation exposure regulation and development while drawing from multiple disciplines and taking into account consequences to legislation, case law, societal risk threshold values, the economy and public health.

RQ_2: How should a proposed framework construct a public interest EMF radiation model and how can it be used to construct public health forecast simulations in a designated area?

The purpose of the question is to draw upon framework entities (specified in Section 1.5) from multiple disciplines to establish a supporting structure of multiscale integrated models of ecosystems services (MIMES) to serve an EMF radiation public health interest. The proposed framework should help develop a public interest EMF radiation health model to represent the complex real world and to forecast simulation scenarios to demonstrate the framework.

RQ_3: How should a legislative PIO function be formulated into a quantitative checklist, or index, to be used in a simulation model?

The purpose of the question is to investigate the testing criteria in a PIO. The study shall use the methodologies of case law analysis and systematic content analysis of judicial opinions in extracting metrics to subjective opinions, based on context and interpretation of legislation representing the risk values threshold limits for the investigated community region of the study (Hall & Wright, 2008; Hsieh, 2012; Boumans et al., 2015). The extraction of metric data would serve as data inputs for the proposed EMF radiation framework, and model.

RQ_4: What are the simulation outputs when using the EMF radiation model?

The purpose of the question is to:

1. Develop an EMF radiation heat-map based on a broadly simulated geospatial propagation model;
2. Identify EMF radiation vulnerable area facilities;

3. Simulate hazard conditions per the STEP and LTCEP models' inputs.

RQ_5: How does the model demonstration runs identify potential EMF radiation violations that can be used to substantiate a PIO claim?

The purpose of the question is to:

1. Identify potential EMF radiation violations per the STEP and LTCEP models on the defined vulnerable population areas within CPT, SA;

2. Identify which potential EMF radiation violations constitute a PIO of 'substances released into the environment' and 'public safety or environmental risk' in terms of SA legislation.

1.3 Overview of the methodological approach

The purpose of this section is to introduce the initial application of practitioner research methodology. The practitioner methodological approach was applied to a new and undeveloped problem space in SA, requiring an exploration of the problem space and a demonstration run of the solution before a formal methodological recipe could be established. Wilkinson's (2000) practitioner research requires:

1. Solving a specific problem.
2. Contributing to the learning of the discipline.
3. Influencing government policy.

A proposed EMF radiation HYGEIA framework that could be used to develop a modified HYGEIA model was developed by reviewing the literature framework entities, scientific views, and domestic and international legislation. The model, based on the framework, is tested by performing demonstration runs. The model created serves as a tool to run experiments that cannot be done in the real environment. The proposed EMF radiation HYGEIA model can simulate alternative futures and is thus able to answer questions about what processes may or may not shape the future environment of the investigated region. It therefore enables future iteration developments for both the framework and model. Modelling enables an effective platform within a resource constrained environment (Kheifts, 1995). The model outputs served as a system feedback inputs in support of a demonstrated PIO function within the investigated area of Cape Town.

Quantitative metrics representing real world social values and values risk threshold values limits are needed to guide the HYGEIA model input data. The research constructed a PIO checklist which guides criteria testing and provides a means of gaining pertinent information for further studies based on this study (Hall & Wright, 2008) by examining case law and legislation, using systematic content analysis of judicial opinions for RQ_3. Criteria for the evaluation of case-based public interest research were established and several characteristics useful for categorizing the study were identified. Literature from peer-reviewed journals, municipal ordinances, domestic and international legislation, case rulings, EMF radiation research databases, activist groups and news articles were systematically reviewed. The PIO checklist is used to test the EMF radiation HYGEIA model outputs resulting from the research findings (RQ_4) of the EMF radiation HYGEIA framework and thereby demonstrating a potentially qualified PIO for RQ_5.

The methodological approach of coupled human and natural systems' (CHANS) interdisciplinary scientific research used elements of the climate change framework and MIMES framework HYGEIA model due to its success in modeling other forms of EMF radiation (Boumans et al., 2011). Hygeia originated from the Hippocratic Oath and represents a public health model that focuses on prevention in the context of public interest, thereby reemphasizing the practitioner research methodology. RQ_4 required the application of a geospatial predictive modelling methodology to heat map (defined in Section 1.5) the public interest case. The model outputs a comparative visual analysis of geospatial propagation models, identifying potential EMF radiation exposure hazard conditions concerns, based on the framework EMF radiation policy inputs. Additionally, HYGEIA is capable of forecasting outcomes for a variety of demographic conditions, e.g. age, race and income level. Using the scientific-technical analysis methodology (RQ_4 & RQ_5) the classification of vulnerable population is based on the definitions of the STEP model ICNIRP (2002), the LTCEP model standards, international High Court rulings and UNEP's (1995) classification of:

(1) Sensitivity - the degree to which a system will respond to a change in environmental conditions;

(2) Vulnerability - the extent to which the environmental change may damage or harm a system depending on a system's sensitivity and ability to adapt to new environmental conditions. The selected sensitive groups of the population are "children, the elderly, chronically ill and potentially some adults" (ICNIRP, 2002:546). The following facility types potentially fall within the scope of this public interest research:

1. Primary facilities: early development centres, special needs schools, primary schools, high schools, colleges, hospitals, clinics, orphanages, hospices, juvenile prisons;

2. Secondary facilities: community areas, parks, public tennis courts, public swimming pools, fire stations and prisons.

A proposed EMF radiation HYGEIA framework was composed to extrapolate the EMF radiation inputs from the STEP and LTCEP models. The practitioner research output of the framework will challenge existing knowledge by demonstrating a public interest (Dvzimbo, 2016; Practitioner9, 2016). The utilization of systematic content analysis in reviewing both domestic and international legislation and case rulings is an advantage because legislation is a framework whilst the case rulings are tested models based on the framework. The proposed HYGEIA model is similarly a demonstration of the HYGEIA framework (Hall & Wright, 2008). This research is thus building upon new knowledge presented in case rulings.

Major population census block data for this project was sourced from StatsSA, the Western Cape Education Department and the City of Cape Town Municipality in RQ_4. The EMF radiation HYGEIA model datasets were entered and processed into visually unique representative GIS layers. The latter included census, EMF radiation infrastructures, and potentially vulnerable area facilities transposed onto the satellite images recorded for the whole of Cape Town, South Africa. Framework EMF radiation policy inputs, composed of STEP model reference levels and LTCEP model limits, as well as associated policies and municipal bylaws, were incorporated into the GIS software as map overlays.

It has historically been proven to be politically challenging to obtain data for the GIS datasets from private companies (ATI Network, 2016). In this regard the study obtained ethical clearance before submitting a PAIA (2000) application to data sources. Discussed in Chapter 7, ethical clearance is not required for PAIA applications. Where PAIA (2000) applications were denied by the data sources, generic geospatial propagation models were constructed from literature by using the benefit transfer method. The latter were plotted as vector data points and/or polygons into the GIS using satellite images (Boumans et al, 2015).

Following the MIMES framework, expert practitioners and regulators were consulted. Practitioner consultations are incorporated as preliminary data to strengthen the development and understanding of literature. This is inline with how problem issues typically develop in inductive research and how deductive reasoning and inductive reasoning can be used to strengthen the development of an argument and understanding of a problem issue. For example, historical PAIA applications revealed a pattern of data sources not being compliant with PAIA regulations and or PAIA information officers not knowing where to source the data. The consulted experts were incorporated into the structuring of literature, providing context to the data, and used to confirm literature and other sources.

Equipment research funding applications made for an EMF radiation spectrum analyzer were unsuccessful. A cooperation agreement was established to conduct site measurements with the Regulator4 using their EMF radiation spectrum analyzer in exchange for training their personnel to use the equipment and its relation to framework EMF radiation policy inputs. However, Regulator4's EMF radiation spectrum analyzer was sent to the distributer for recalibration quite a few months ago and has still not been returned. EMF radiation on the investigated area of Cape Town was thus calculated by using a geospatial propagation model.

1.4 Research contribution

The purpose of this section is to provide an overview of the practitioner research methodological output (see Section 1.3) from which academics and practitioners may benefit, and thus offers predominantly a practical contribution. This research may contribute in practice by solving the problem of unregulated EMF radiation exposure in SA and may influence government policy development in the following ways:

1. The study, through this research, created awareness regarding the limitations of implementing national EMF radiation exposure protection standards in SA. The practitioner research output from this study is meant to challenge existing EMF radiation and public health knowledge in SA by demonstrating a public interest (SAHRC, 2014; Dvzimbo, 2016; Practitioner9, 2016).

2. The challenging of existing EMF radiation and public health knowledge in SA was achieved by critically reviewing literature and SA practitioner understanding of the STEP and LTCEP models, scientific opinions, domestic and international legislation, case rulings and framework entities used in the construction of a public interest model.

3. An EMF radiation HYGEIA framework was constructed from the literature review and in consultation with practitioners on the specific problem. The constructed framework led to the development of the EMF radiation HYGEIA model.

4. The construction of a PIO checklist was established based on academic, practitioner and population group values and paradigms used to test the EMF radiation HYGEIA model findings and concludes each iteration cycle of the constructed framework. The PIO checklist was based on reviewed legislation and SA case law.

5. The proposed EMF radiation HYGEIA framework and model were tested by demonstration runs on the investigation area of Cape Town.

6. The model simulated a single case of the potential broad implications for public health, social accounting and the economy, based on the incidence of EMF radiation intolerance by the public.

7. The proposed EMF radiation framework and model outputs identified potential serious issues in comparison with the framework EMF radiation policy inputs into the model. A potential PIO of 'substances released into the environment' and 'public safety or environmental risk' will be demonstrated.

8. It is recommended that the research findings undergo a PAIA judicial review process to confirm the PIO.

9. This research may be used in future studies of EMF radiation HYGEIA model iterations to analyze spatial variation in population vulnerability to hazards and to estimate health outcome risks for population groups through exposure functions.

10. This research may aid policy makers to develop a regulatory EMF radiation exposure standard that balances public health concerns with controlling the levels of exposure, whilst remaining a digital economy.

A future second iteration for the artifact EMF radiation HYGEIA model may produce enhanced projections of potential issues that should be noted in demographic populations under the area of environmental informatics.

To illustrate the practical validity of this research, the findings of this research, so far, have been requested by the following bodies:

- the Advertising Authority of South Africa;
- ADvTECH Group, private sector in the fields of education;
- Department of Justice and Constitutional Development – PAIA;

- City of Cape Town Municipality (CCPTM) Director of Information Systems & Tech (Chief Technology Officer) (IST);
- CCPTM Property Leasing Management (PM);
- CCPTM Planning and Building Development (PBD);
- CCPTM Energy Environment and Spatial Planning (EESP);
- CCPTM City Health (CH);
- Medi-Clinic Enterprise Project Management;
- Life Health Care Quality Support;
- Parliamentary Chief Whip of the African Christian Democratic Party and;
- Parliamentary Legislative Drafting Unit.

If of relevance, it may also be used in the development of new regulations in the interest of public awareness and public health.

1.5 Key terms and definitions

It is necessary to briefly identify and clarify the meaning of key concepts used in this and following chapters to assist the reader in understanding the intentions of this study and the problem statement. Key terms and definitions in this study require that input be drawn for multiple disciplines. The number of terms is extensive and the key terms and definitions have been moved to the Appendix, Section 1.1 to aid the reader. It is recommended that Section 1.1 should be open on the side to better familiarize the reader with the presented key terms. The study structure throughout this document is non-linear. Discussed in Section 1.1, following cognitive load theory, detailed information within the study is specifically referenced to the appendix in addressing the information overload issue.

In the study, data sources, consulted regulators and practitioners listed in the Appendix, Section7.1 have been anonymized when referenced within the study. The anonymized data categories have been coded as follows:

- EMFDS equates to EMF radiation data source. EMF data sources are referenced as EMFDS1….n.
- Regulator is a person(s)/company involved in the regulation process for EMF radiation exposure. Regulators are referenced as Regulator1….n.
- Practitioner is a person who is a practicing and experienced professional within one of the disciplines drawn from the study. Practitioners are referenced as Practioner1….n.

Following the MIMES framework methodology discussed in Section 4.3 and Chapter 7, the consulted participants are both data source providers and experts that were invited to bring into understanding the problem issue discussed in Section 1.2. In Table 1.1, an elaboration of the anonymized codes, is displayed.

Table 1.1 Anonymized coding table

Anonymized code	Synopsis	Importance of source
EMFDS [1,2]	ELF EMF data source.	ELF EMF radiation service provider that serves the public.
EMFDS [3-5,10-15,17,18]	Private body RF-EMF data source.	RF-EMF radiation service provider that serves the public.
EMFDS [7-9,16]	Public body RF-EMF data source.	Public body responsible for documenting, planning, tracking and permitting EMF radiation exposure.
EMFDS [8,9,16]	Public body RF-EMF data source associated reports and data.	Documentation that governs and relates to EMF radiation exposure to the public.
Regulator [1,2,3,4,5,6,7,9,10]	Gate keepers in the lifecycle process involving EMF radiation exposure to the public.	Heads of departments and managers in different sectors that permit EMF radiation exposure to the public.
Regulator [4,8]	Public health regulators with an EMF radiation mandate.	Heads of departments mandated with potential EMF radiation health implications.
Regulator [11]	Regulator of Pollution & Chemicals Management	Director position for environmental legislation regulator and practice.
Practitioner [7,8,9,10,19]	Legislative experts involved in protecting, enhancing and promoting legislation related to the constitution.	Heads of department and representative leaders.
Practitioner [17,18]	Private body RF-EMF public representative and gatekeeper to information.	The assigned public representative of the company to handle technical questions and communications.
Practitioner	International health exposure function	Directors of company's and

[4,5,14]	and EMF radiation propagation modelling government experienced experts.	divisions. Experts in the field.
Practitioner [11,12,13]	Health care facilities administrative practitioners.	Senior representatives involved in EMF quality control, infrastructure and encountered issues.

1.6 Dissertation structure

Chapter 1: Introduction and project overview

The chapter provides a summary of what was covered in the study, including the aim, problems, objectives, design process and what is to be expected in the next chapters.

Chapter 2: Construction of a public interest review of literature

The chapter defines the requirements of constructing a public interest and connects domestic and international reviews of EMF radiation qualifying EMF radiation exposure as a public interest. Specific domestic and international legislation and case law are discussed in detail and the processes used in the study are also provided.

Chapter 3: Demonstrating a public interest override review of literature

The requirements of demonstrating a PIO are defined in this chapter. The general challenges that affect the demonstration of a PIO are discussed. An overview of case law in demonstrating a PIO in SA is provided. A PIO function index is created and discussed in detail as it is the process used in the study.

Chapter 4: Scientific-technical analysis review of literature

The chapter addresses the technical aspects that are required to be put in place to construct a proposed EMF radiation HYGEIA framework, and model. The manner in which proposed framework entities can be linked to an EMF radiation HYGEIA solution is also outlined. Identified methods and tools for the proposed HYGEIA framework, and model (that are constructed in Chapter 5 and 6 of the study) are mapped in closure.

Chapter 5: EMF radiation HYGEIA framework

The first research contribution and output in the study, a public interest EMF radiation HYGEIA framework, is constructed in this chapter, based on the literature reviews that are discussed in Chapters 2, 3 and 4 of the study.

Chapter 6: EMF radiation HYGEIA model

The second research contribution and output in the study, a public interest EMF radiation HYGEIA model, is constructed in this chapter, based on the constructed framework in Chapter 6 and literature reviews that are discussed in Chapters 2, 3 and 4. The constructed model is a tool to demonstrate the framework in Chapter 5.

Chapter 7: Research methodology

A layout of the methodology that was used to answer the research questions is provided in this chapter. In addition thereto it outlines the manner in which the data collection process was undertaken and the limitations encountered in the construction of the input datasets for the model (Chapter 6) demonstration runs. The research design used in this study is provided in detail.

Chapter 8: Potential ELF and RF-EMF violations data analysis and results

This chapter discusses the results and findings from the research methodology (Chapter 7) and demonstration runs of the EMF radiation HYGEIA model (Chapter 6) in detail. It also presents heat maps of potential hazard conditions areas in the investigated area of Cape Town that should be noted for future studies.

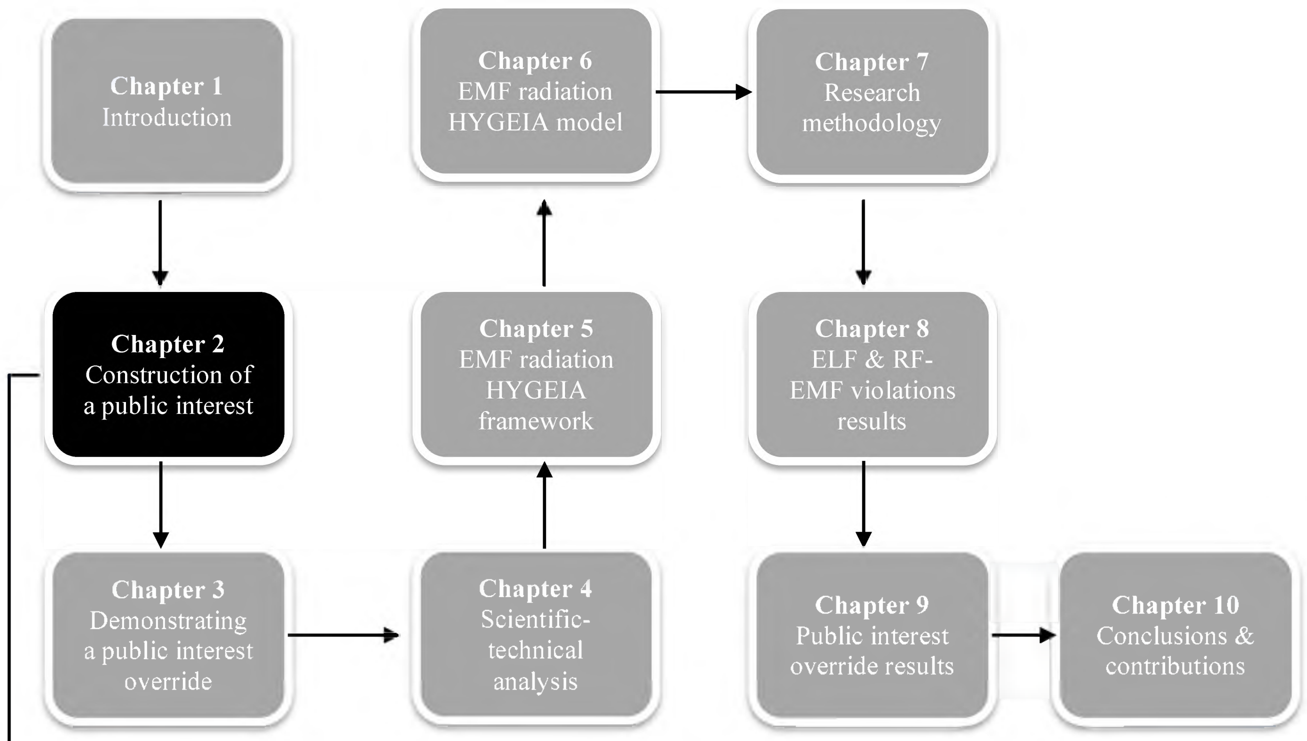
Chapter 9: Public interest override function data analysis and results

In this chapter the findings of the literature reviews and results of the EMF radiation HYGEIA demonstration runs are processed through the PIO checklist. The results are presented as demonstrating a case for a PIO of 'substances released into the environment' and 'public safety or environmental risk' on a balance of probabilities.

Chapter 10: Conclusions and contributions

This chapter focuses on reflections on the study, contributions made, how the research questions were answered and the limitations imposed on the research, as well as the conclusions.

CHAPTER 2: CONSTRUCTION OF A PUBLIC INTEREST REVIEW OF LITERATURE



2.1 Introduction

2.2 Preliminary literature review

2.3 Construction of a public interest

2.4 A summary review of regulation and practice in SA: STEP versus LTCEP EMF radiation models

2.5 Guidelines versus standards

2.6 Weighted studies

2.7 SA legislation supportive of EMF radiation protection

- 2.7.1 EMF radiation responsibilities by organs of the state
- 2.7.2 Suspended national EMF radiation standards in SA
- 2.7.3 SA municipal bylaws supportive of EMF radiation protection

2.8 International EMF radiation protection legislation

2.9 Domestic case precedents for EMF radiation protection

2.10 International EMF radiation protection legislation

CHAPTER 2
Construction of a public interest review of literature

2.1 Introduction

The previous chapter provided an overview of the aims of this study by discussing factors such as the problem statement, research problems, research questions and objectives. This and the following two chapters will focus on the review of literature for this study. In this and the following two chapters answers to the first, second and third sub-questions will be sought. The first and second sub-questions were presented in Chapter 1 as follows:

> RQ_1: What should a multidisciplinary entities framework encapsulate to enable modeling of macro EMF radiation sources, considering domestic and international legislation and scientific opinions?
>
> RQ_2: How should a proposed framework construct a public interest EMF radiation model and how can it be used to construct public health forecast simulations in a designated area?

The first disciplinary entity introduced for RQ_2 in the study (present chapter) is the construction of a public interest. The qualification of a public interest is defined by the systemic threat or violation of human rights (Practitioner9, 2016). International deliberations and High Court rulings (case law) have classified the domain of EMF radiation exposure as a public interest. (Government of Italy, 2008; Stewart, 2000:115; Government of India, 2012; Rajasthan, 2012; WHO, 2015a; WHO, 2016c).

The systematic literature review used in this chapter to answer RQ_1 and RQ_2 is presented in various sections in this chapter. Section 2.2 presents the preliminary literature review for the study to prepare the reader to understand why a literature review was carried out in establishing the intentions of this study and where the problem statement was investigated. It is necessary to briefly identify and clarify the meaning of key metrics used in the current and following literature review chapters. Section 2.3 discusses the requirements for the construction of a public interest argument, whilst Section 2.4 provides a summary overview of the EMF radiation models explored in South Africa. Sections 2.5 to 2.10 discuss the various metrics and supporting principles in both domestic and international science as well as the case law relevant to EMF radiation exposure and public interest.

2.2 Preliminary literature review

This section prepares the reader to understand why a literature review was carried out in establishing the intentions of this study and where the problem statement (discussed in Section 1.2) was investigated. It is necessary to briefly identify and clarify the meaning of key metrics used in the current and following literature review chapters.

The arisen problem space of EMF radiation exposure as a public interest has required that input be drawn for multiple disciplines, as discussed in the previous chapter. An example of the multiple discipline literature problem defined by the non-linear nature of EMF is narrated in the remainder of this paragraph. An EMF is generated when charged particles, such as electrons, are accelerated. All electrically charged particles are surrounded by electric fields, expressed as field intensity (V/m). Charged particles in motion produce magnetic fields, expressed as mG (milligauss) or nT (nanotesla). In the human body, tiny electrical currents exist due to the chemical reactions that occur as part of the normal bodily functions, even in the absence of external electric fields (WHO, 2017). To living organisms, EMFs play a crucial role in controlling and maintaining their orderly functions (European Parliament Scientific and Technological Options Assessment, 2001). An EMF hazard condition is encountered when, based on science-based studies, artificial EMFs have the capacity to affect bodily functions outside the adaptive compensatory mechanism (GRID-Arendel, 1995; WHO, 2007:5). Different types and sources of EMF display different biological responses (symptoms and or diseases), thereby EMF radiation emissions has been broadly categorized into three regulatory assessments for static, ELF and RF (high frequency) (WHO, 2007; WHO, 2016c). An EMF hazard condition is formulated through the combination of emissions intensity, duration of exposure, occupational context, and population category vulnerability threshold. ELF-EMF induces circulating currents within the human body (WHO, 2017). The strength of these currents depends on the intensity of the magnetic (mG) and electric (V/m) field from the external environment (anthroposphere) (WHO, 2017). Depending on the EMF category (ELF and RF) and human biology to adapt to said exposure, each population category has a different compensatory adaptability and vulnerability threshold (Perov et al., 2009).

The literature review followed Krauss's (2017) inverted pyramid of style of writing and this review led to the identification and clarification of a knowledge gap. WHO (2007:14) specified the essential part for this study's health assessment is to identify gaps in knowledge concerning the possible health effects of exposure to EMF fields. The introduction to key issues and themes in the previous paragraph and chapter was followed by a process of systematic literature review from multiple disciplines, moving from the known, general and global (Chapters 2-4) to the unknown, specific and local, leading to the identification and confirmation of the knowledge gap (Chapter 8 and 9). This is followed by conclusions in the final chapter of the study.

The inverted pyramid of style of writing methodology addressed the first three sub-questions with regard to science-based EMF radiation exposure and investigated the aforementioned by utilizing the following databases in the systematic literature review (Webster & Watson, 2002), using content and scientific-technical analysis, (discussed in Chapter 4):

1. Oceania Radiofrequency Scientific Advisor Association (ORSAA) database (2016);
2. WHO's (2016) recommended EMF project research database, the EMF-portal (2016);
3. Google Scholar;
4. Google web search;
5. Government websites;
6. Press news sites; and
7. Activist websites and social media.

The research process of content analysis, followed by scientific-technical analysis, enables the extraction of parameters and data needed as inputs for the STEP and LTCEP models in the construction of an EMF radiation HYGEIA model (presented in Chapter 6) in fulfilment of RQ_4.

Systematic content analysis of judicial opinions is the establishment and confirmation of a public interest. A public interest, in this study, is established by using a combination of systematic content analysis of judicial opinions on case law and consultations with practitioners per the MIMES framework, as discussed, in Chapter 4 (Hall & Wright, 2008; Boumans et al., 2015).

Therefore, practitioners (includes model dataset sources and regulators) consulted are incorporated as preliminary data to strengthen the development and understanding of literature. This is inline with how problem issues typically develop in inductive research and how deductive reasoning and inductive reasoning can be used to strengthen the development of an argument and understanding of a problem issue (Krauss, 2014). The review of literature, therefore, occurred in response to or in parallel with lessons learnt from reviewing legislation, case law and consulting with practitioners (Becker, 1993; Thomas, 2000; Wilkinson, 2000; Krauss, 2014). This allowed the researcher to approach the social phenomena mostly inductively and with openness rather than trying to identify an appropriate theoretical lens or systematic 'stepping stones' from literature before consulting data sources, practitioners, and constructing the model in Chapter 6. Literature analysis thus entails a juggling of induction, i.e., interpreting the data using situated and subjective knowledge (community and scientific paradigms), and deduction (case law), i.e., applying objectified methods, frameworks, and theories to the data (Krauss, 2017).

As discussed in the previous chapter, the data input for risk threshold values of a community can be found and interpreted in legislation and case law. SA's common law is composed of the foundational Roman-Dutch legal principles, as modified and interpreted by judicial precedent (DoJCD, 2015). Understanding legal principles and judicial precedent will aid in future studies and may contribute to influencing government policy (Wilkinson, 2000; Hall & Wright, 2008; Hsieh, 2012). In a common law system cases play a vital role in interpreting statutes, building arguments, organizing analyses, and conveying points of view. Legal research often begins with statutes or regulations, the primary law passed by the legislature or regulatory agency in the relevant jurisdiction. Cases, in turn, interpret those statutes and regulations (Hsieh, 2012).

Systematic content analysis of judicial opinions, as demonstrated in this chapter and the next, is the application of basic social science methods to subjects of legal interest (Hall & Wright, 2008). Using this method, the researcher collects legislation and judicial opinions on a subject; systematically reads them, recording features of each and drawing inferences about their use and meaning (Hall & Wright, 2008). The findings are then collated into a data matrix that could be modelled by using software.

Content analysis is not a true legal science as it is incapable of scientifically analysing legal principles and precedent on a level that is relevant to traditional practitioners (Hall & Wright, 2008). This is a problem discussed in this chapter and experienced by the researcher when consulting with practitioners. The researcher employed the methodology of scientific-technical analysis to the problem space (discussed in Chapter 3) to overcome the scientific methodological weakness of content analysis. The merging of the two methodologies resulted in a framework (discussed in Chapter 5) which enabled the extraction of data inputs for the proposed model (discussed in chapter 6). The STEP and LTCEP EMF radiation dosimetry models related to literature, case studies, and legal policies were examined for metrics that can be extracted for geospatially propagation modelling (Chapter 7) potential public health interests in a GIS (Chapters 8 and 9).

To prepare the reader to understand challenges in the review of literature related to EMF radiation exposure and applicable public interest, the remainder of this section establishes the intentions of the STEP and LTCEP EMF radiation models of this study and where the problem statement was investigated. It is necessary to briefly identify and clarify the meaning of key principles used in this study.

In establishing RQ_1 the researcher discovered that scientists globally express different views regarding radiation exposure and tolerance of acceptable risk. These views consist of "science-based" approaches which reflect major differences in social, economic, cultural and philosophical approaches (Foster, 2001, Vitale, 2005; WHO, 2006a; EMFscientist.org, 2015; EDA, 2016). These differences were most apparent between EMF radiation exposure reference levels and limits driven by social accounting or market driven for many years (WHO, 1999; Foster, 2001; WHO, 2006a; Mazar, 2009).

The social accounting driven LTCEP model originated in the days of the Soviet Union and the Warsaw Pact (Foster, 2001; WHO, 2009) and was founded by Russia, China and most of Eastern Europe, known as the Russian National Committee on Non-Ionizing Radiation Protection (RNCNIRP) (Foster, 2001; WHO, 2009). The LTCEP model was thereafter adopted by Switzerland, Italy and other social accounting driven countries. Today, over half the world's population countries endorse the LTCEP model, with STEP model countries increasingly switching to the LTCEP model following High Court deliberations (Government of Italy, 1998; Foster, 2001; Perov et al., 2009; Kumar, 2010; Van Leeuwenhoeklaan, 2011; Government of India, 2012; Rajasthan, 2012; WHO, 2015a; BfS, 2016; WHO, 2016a; WHO, 2016c). Appendix, Section 2.6 (STEP and LTCEP model endorsement by country population vs GDP) can be consulted for supportive charts and figures. While a considerable proportion of the countries in the world endorse the LTCEP model, there are significant differences in the principles, methods and science base used for establishing EMF exposure standards in these countries.

The market driven STEP model likewise originated in the days of the cold war era (Warsaw Pact). The STEP model was initially founded by the Institute of Electrical and Electronics Engineers (IEEE) which was adopted in the United States and Western Europe. The USA IEEE STEP Model developer later founded in Europe as the International Commission on

Non-Ionizing Radiation Protection (ICNIRP) (Foster, 2001; Perov et al., 2009). The STEP model endorsing countries currently have the highest combined GDP, but this is changing, as discussed in the previous paragraph (BfS, 2016; WHO, 2016a).

Large differences in perceptions regarding science and health protection are underlying to the STEP and LTCEP models (WHO, 1999; Foster, 2001; WHO, 2004b; WHO, 2006a). The STEP model EMF radiation guideline reference levels are set to protect against direct effects, such as electric shock and body tissue heating, based on acute, single exposures for less than 6 minutes on a specific point on the human body, referred to as the specific absorption rate (SAR) (Perov et al., 2009; Kumar, 2010). Appendix, Section 2.8 (SAR thermal heating example) can be consulted for an example of how RF-EMF causes thermal heating in organic tissue.

The STEP model endorser (ICNIRP), however, do not consider that the available scientific evidence regarding reported adverse health effects at lower LTCEP model exposure levels justifies a more precautionary attitude (Foster, 2001; WHO, 2001). The STEP model guidelines are more tolerant of EMF radiation health risks whilst the EMF radiation guidelines have been influenced by market driven forces (forces of demand and supply representing the aggregate influence of self-interested buyers and sellers) (World Health Organization [WHO], 1999; Foster, 2001; Israel Ministry of Communications, 2009).

The LTCEP model's EMF radiation guidelines and limits are driven by the state in the interest of social well-being (WHO, 1999). The LTCEP EMF radiation limits are scoped to low-intensity biological effects and cumulative exposure recommending an EMF radiation guideline power density level of exposure between 1/10th and 1/10 000th in magnitude compared to the STEP model *reference levels* (Foster, 2001; Perov et al., 2009).

A breakdown of the STEP model reference levels and LTCEP model limits is available in Appendix, Section 2.1 (International RF-EMF radiation power flux density limits for GSM1800).

Both the World Health Organization (WHO) and South Africa's (SA) Department of Health (DHSA) confirm there that are *no* national standards in SA for EMF radiation exposure for static, extremely low frequency (ELF) and radio frequency (RF) fields (City of Cape Town Municipality [CCPTM], 2015; DHSA, 2016c; WHO, 2016a). The DHSA recommends adopting the STEP model's ICNIRP 1998 EMF radiation guideline for radio frequency (RF) EMF *only*. However, the DHSA does neither prescribe nor enforce any mandatory exposure limits for EMF radiation guidelines but merely recommends voluntary compliance by industry and government bodies on the STEP model's ICRINP 1998 EMF radiation guidelines (CCPTM, 2015).

Industry has advertised the adoption of the DHSA recommended STEP model as a signed 'honour code' in SA (Telkom annual report 2012:104; CCPTM, 2015; EMFDS3, 2016; Regulator4, 2016). However, there is no survey, database, enforcement or monitoring system of any kind by a statutory body that can indicate the specific levels of EMF radiation emitted by EMF radiation infrastructure that the public would be exposed to when it is in operation (CCPTM, 2015:47; Regulator9, 2015; Regulator8, 2016a; Regulator8, 2016b).

The STEP model ICNIRP EMF radiation guideline clearly states that, for simultaneous exposure to multiple frequency fields, the sum of all the EMF radiation must be taken into consideration. The STEP model's EMF radiation safety protocol in SA has only applied STEP model guideline reference levels to individual carriers; potentially resulting in the EMF radiation level exposures being exceeded exponentially in comparison to those proposed in the STEP model guideline (Kumar, 2010; Rajasthan, 2012; Practitioner5, 2016).

The STEP model's ICNIRP guideline stipulated that different groups in a population may have different abilities to tolerate a particular EMF radiation exposure (ICNIRP, 2002). ICNIRP (2002) warns that children, the elderly, and some chronically ill people might have a lower tolerance for one or more forms of EMF radiation exposure than the rest of the population and that, under such circumstances, it may be necessary to develop separate STEP model reference levels for different groups within the general population (ICNIRP, 2002). Alternatively, it may be more effective to adjust the STEP model for the general population to include such groups (ICNIRP, 2002). This is not the current practice in SA and it is officially discouraged by the DHSA (CCPTM, 2015; DHSA, 2016c).

The next sub-section will focus on introducing a review on the kind of biological effects (toxicology, subclinical, epidemiology), classification by authoritative bodies and knowledge gaps. The author is not a medical expert and therefore further investigation study would be needed.

2.2.1 What kind of biological effects have been shown and details of studies

Electrosensitivity is defined as the degree to which a system will respond to a change in the EMF environmental conditions (GRID-Arendal, 1995; ICNIRP, 2002:546). Thereby, anyone who has any biological response to exposure to EMF, including natural occurring EMF, i.e., solar EMF (WHO, 2004; Redmayne, 2017). Most of these responses are subclinical and cannot be appreciated by the individual. Nevertheless, according to the WHO (2004), electrosensitivity in the sense of subclinical responses is widespread and have the potential to influence downstream health-related endpoints. Dependent on time and duration of exposure to low levels of ELF-EMF, published reviews by the Council of Europe Parliamentary Assembly (2001), WHO (2004; 2016c; 2017), European Parliament Scientific and Technological Options Assessment (2001), and the European Environment Agency (2009) confirmed the capacity for biological effects and thus also the potential to cause a health hazard. This subsection will discuss the classification of EMF radiation as biologically active derived from results of available laboratory investigations, animal and human experiments and is no longer seriously disputed by any scientific institution.

ELF-EMFs, when used therapeutically have been shown to be beneficial for patients suffering from neurological disorders, including the promotion of recovery in poststroke patients (Cichoń et al., 2017a; Cichoń et al., 2017b). Experimental evidence suggests that it may also enhance the performance of certain drugs due to its disruptions in biological functions such as redox regulation (Akbarnejad et al., 2017).

On the other hand, RF and ELF-EMFs that permeates our environment from infrastructure and personal electronic devices has an environmentally negative effect on humans' health and behaviour and is increasingly been recognized as an environmental pollutant (WHO, 2007). The molecular mechanism through which ELF-EMFs influence cellular behaviour is unclear (WHO, 2007; Vatansever & Hamblin, 2012; Leszczynski, 2017; Bürgi et al., 2017). An association has been made between ELF-EMF exposure and changes in the expression of genes involved in aging, cell proliferation and death (Yan et al., 2010; Fathi et al., 2017; Rezaie-Tavirani etl a., 2017). Because many factors affect these systems including hereditary genetics, state of health, age and environmental factors, the negative impact of ELF-EMF exposure on humans' health is predicted to vary.

Data suggests that ELF-EMFs could perturb chemical reactions involving free radical production (WHO, 2007:4; Fathi et al., 2017). Cells maintain their redox balance through the production of ROS/RNS and antioxidant molecules. A disruption of this system has been linked to pathological conditions such as cancer, aging and neurodegenerative diseases (Patruno et al., 2015). Short-term ELF-EMF exposure has also been linked to the development of anxiety like behaviour in rats mediated by inducing oxidative stress and increased nitric oxide (NO) concentrations in the rat hypothalamus (Djordjevic et al., 2017).

A human study by Zhang et al., (2017) involving male workers with occupational exposure to high-voltage electrical power-lines exhibited elevated urinary levels of 8-hydroxy-2-deoxy-guanosine (8-OHdG) and F2-isoprostane and lower plasma nuclear factor kappa B (NF-κB) and interleukin (IL)-6 in exposed workers compared to the reference group. This indicates that ELF-EMF has an adverse effect on oxidative stress and immune response and poses a DNA damage risk (Zhang et al., 2017).

It is predicted that the effect of ELF-EMFs on the general public who have a lower dose exposure would therefore vary based on their distance from EMF infrastructure and daily personal electrical appliance exposure, but it is important to note that the deleterious effects although undetected at first may prove to be additive and dependent on humans age and state of health as has been shown with other environmental pollutants.

2.2.2 Toxicological evidence

The contradicting reviews of the effect of EMF exposure on human health is complicated by two issues. Firstly, the conflict of interest in science and politics, discussed Section 1.1. And secondly, that low intensity ELF-EMF may be disrupting multiple molecular pathways depending on the signals emitted. These signals may be manipulated to induce a therapeutic effect or in the absence of controlled exposure (i.e. EMF frequency ranges, duration and intensity) they may act as co-carcinogens and/or inducer of different disease states depending on the individuals genetics and physiology (WHO, 2007; De Luca et al., 2014; Leszczynski, 2017). For example, DNA appears to hold two (2) structural characteristics of fractal antennas, self-symmetry and electronic conduction (Blank & Goodman, 2011). These reactive characteristics contribute to greater reactivity of DNA to the wide frequency EMF range in the environment (STOA, 2001; Blank & Goodman, 2011). For example, phantoms representing humans, under the height of 1.3 meters (approximately children under 8), displayed an up to 40% greater whole body specific absorption rate (EMF thermal specific absorption rate (SAR)) over adults (Kumar, 2010; Dimbylow et al., 2007; Kos et al., 2011; Yahya & Khalil, 2015). SAR provides a valid measure of energy absorption, but is not a quantity indicator for estimating biological effects (WHO, 2003:69). The use of linear perception (SAR) as a procrustean[9] scientific approach to assessing the thermal effects of human exposure to EMF is adequate (STOA, 2001), but is inappropriate for realistic consideration of the non-thermal, frequency specific vulnerability living organisms to

[9] A framework or system, enforcing uniformity or conformity without regard to natural variation or individuality. A Ruthless disregard of individual differences or special circumstances.

coherent EMFs, thereby requiring a nonlinear analysis (STOA, 2001; WHO, 2003:69, Parsaei et al., 2017; Marino et al., 2000). The non-thermal influence of EMFs when exposed is dependant on the state of the organism. In the real world this varies not only between different vulnerable population categories (non-procrustean), but also for the same exposed individual, depending on his/her condition at the time of exposure, as such, EMF adaptive compensation influences are inherently nonlinear in nature (GRID-Arendal, 1995; Marino et al., 2000; WHO 2003:69; WHO, 2007:15). Commonly, when EMF experiments are conducted linearly difficulties in independently replicating the experiments tends to lead to their dismissal (Donald Rumsfeld knowledge category 2 – 'unknown', discussed in Section 1.1). Final example, functional MRI (fMRI) scans by Heuser & Heuser (2017) reported abnormal fMRI for vulnerable population categories who reported an intolerance to low dose EMF radiation exposure. The patients had a medical history of either a head injury, exposure to potentially neurotoxic chemicals, especially mould. The study verified the EMF to act as an inducer/co-promoter of different disease states dependent on the individuals evolved genetics and physiology.

What distinguishes consumer technological EMF emissions to most naturally occurring ones is their considerably higher degree of coherence. Giving rise to increased biological potency, and risk of frequency-specific, nonthermal influences of various kinds (subclinical symptoms) (STOA, 2001). A human subclinical example of low intensity frequency-specific EMF is light flashing at a certain rate to trigger seizures in people suffering from photosensitive epilepsy (STOA, 2001; WHO, 2007:5). It is not the intensity of the EMF, but rather to the frequency of the EMF similar to the frequency of the EMF brain activity involved in epileptic seizures, that triggers the occurrence.

The EMF exposure phenomenon is not directly the cause for the seizure but rather an EMF frequency-specific effect of information transfer from the light (EMF) to the brain. The brain producing a biological response to the 'recognised' light (EMF) by the rate (frequency) at which it flashes. People predisposed to epilepsy are likely to be more susceptible to induced ELF electric fields in the central nervous system (CNS) (WHO, 2007). In contrast different ELF-EMF pulsed biogenic frequencies are used in medical devices influencing the body's ability to contribute in alleviating conditions and support the body's own self-healing regenerative process (Vatansever & Hamblin, 2012; BEME, 2016).

A review by Wang and Zhang (2017) on multiple studies for ELF-EMF effects on ROS, for humans and animals, mostly found that ELF-EMF could increase ROS levels, but there were was also evidences indicating alternative results. The review into in vitro and in vivo discovered the effects of ELF-EMFs on ROS levels being dependent on multiple factors, i.e. ELF-EMF intensity, frequency, duration of exposure, cell lines, or tissues of animal models. Thereby, any parameters alterations could potentially cause changing experimental results (Wang & Zhang, 2017). Therefore, all detailed information, especially radiation dosimetry, should be carefully recorded for EMF-related studies.

Low-intensity ELF and RF-EMF radiation technological emissions can cause biological effects having a dose-dependent increase in DNA strand breaks, resulting in the incidence of tumours (Lai & Singh, 1995; Lai & Singh, 1997; Adlkofer, 2006; Lerchl et al., 2015; Soffritti et al., 2016; Yakymenko & Tsybulin, 2017). With EMF as a co-promoter to DNA strand breaks may affect cellular functions, leading to carcinogenesis and cell death, and be related to onset of neurodegenerative diseases (Lai & Singh, 1997; Leszczynski, 2017).

A large animal study (Adlkofer, 2006) pooled data carried out by twelve (12) research groups. A mixed but intriguing pattern emerged from their analyses (Adlkofer, 2006). Intermittent exposure to ELF-EMF at 50Hz had genotoxic effects on human fibroblasts, human melanocytes and some animal cells. Lymphocytes and other cell lines, meanwhile, remained unaffected. In fibroblasts, they discovered a direct correspondence between the intensity and duration of ELF-EMF exposure and the number of DNA breakages or micronuclei, both markers of genotoxicity. Questions arose around the replicability of the Adlekofer (2006) study but Soffritti et al., (2016), the largest animal exposure study ever done on ELF-EMF, found significant carcinogenic effects for the mammary gland in rats (male & female), and a significant increased incidence of malignant schwannomas of the heart as well as increased incidence of lymphomas/leukemias in males.

2.2.3 Subclinical outcomes in humans

For example, in a double-blind sleep study (Mueller & Schierz, 2004) participants soundness of sleep and behavioural effects were monitored. Periodically, they were randomly exposed to 50 Hz ELF-EMF measuring an electric (80-160 V/m) and magnetic (20-60 mG) fields provocation in their beds. When exposed, there was a significant correlation of movement to the opposite edge of the bed away from the ELF EMF source and an effect on human subject’s well-being in the morning. Cross-sectional sleep studies evaluation of occupational and residential ELF-EMF exposures found increased risk of oxidative stress and sleep insufficiency (Altpeter et al., 2006; El-helaly & Abu-hashem, 2010; Liu et al., 2014). The reviewed studies showed that daily occupational and residential ELF-EMF exposure was positively associated with poor sleep quality but not duration of sleep. The WHO International Agency for Research on Cancer (IARC) (2010) classified white/blue light as a probable carcinogen (Group 2A) due to melatonin disruption. An experimental study (Liburdy et al., 1993) found at the cellular level an increased breast cancer cell proliferation at occupational and residential hazard conditions ELF-EMF exposure levels. The studies (Altpeter et al., 2006; El-helaly & Abu-hashem, 2010; Liu et al., 2014) found ELF-EMF inhibiting melatonin's natural oncostatic action through lowered lower plasma melatonin levels (melatonin disruption) and higher malondialdehyde levels (Liburdy et al., 1993) when exposed. Recommendations to ameliorate the oxidative effect of ELF-EMF on humans require reduced daily cumulative EMF exposure (Yu, 1998; El-helaly & Abu-hashem, 2010), and taking antioxidant vitamins (Belyaev et al., 2016; El-helaly & Abu-hashem, 2010; Belpomme et al., 2015). An evaluation of previous epidemiologic studies, have suggested that sleep disorder plays an important role in overall human health and diseases including depression and anxiety, obesity, metabolic syndrome, diabetes, and immune function (Soffritti et al., 2016).

The list of potential confounders historically raised potential doubt in epidemiological studies. This was compounded by many studies not demonstrating a dose-response relationship. The next subsection will discuss continued studies addressing the issue of potential residual confounding.

2.2.4 Epidemiological evidence

The first English-based ELF-EMF epidemiological study dates to 1907 in an assessment of telegraph line installers and the telephone switchboard operators (Toronto Telephone Commissions, 1907). The reported exposure symptoms of illness included neurasthenia (nerve disorders), depression, extreme anxiety, exhaustion, convulsions, unconsciousness, rashes, and a whole host of other malaise.

However, it was only in 1979 when Wertheimer and Leeper (1979) published their study about the statistical relationship between proximity of homes to electrical power lines and the incidence of childhood leukemia and brain tumors that EMF radiation and public health received attention in the US. The study initiated a new era and was the epicentre for studying health-relevant effects from exposures to EMF radiation (Belyaev et al., 2017). Arguments erupted on the quality of the Wertheimer and Leeper (1979) study and subsequent studies (Kheifets, 2012). Taken as a whole, epidemiological powerline proximity studies results provide little evidence for an association between magnetic field exposure and childhood brain tumours (Kheifets, 2012).

Majority of EMF studies are useless for estimating human health exposure risk and therefore not useful for setting up human health exposure protection policies (Leszczynski, 2017). There are no 'real' EMF radiation exposure data, and there is a variety of bias unaccounted for (Leszczynski, 2017). There is a great lack of dosimetry and biomarker recorded studies examining responses of human physiology to exposure, and a lack of studies on chronic exposures. Majority of studies examined only acute responses (WHO, 2007:12; Leszczynski, 2017). Many studies presented a low scientific standard (limited radiation measurement), therefore the majority of information is useless and we still do not have much information. Most human exposure information is based on animal, vitro and epidemiological studies (which is indirect information in many cases) (Leszczynski, 2017).

Results seemed inconsistent until in 2000 when two (2) pooled analyses (Ahlbom et al., 2000; Greenland et al., 2000) providing no clear support for other explanations or inconsistency, demonstrated an increased leukaemia risk (Kheifets, 2012; Belyaev et al., 2016). Increasing ambient ELF-EMF exposure levels were deemed statistically significant for levels above 3-4 mG relative to averages below 1 mG but without indication of a threshold. Since 1979, more than thirty epidemiological studies have scrutinized the association between ELF-EMF and childhood cancer (Bürgi et al., 2017).

Pooled analysis to date output a consistent association between ELF-EMF and childhood leukaemia (Kheifets, 2012; Belyaev et al., 2016). There is sufficient evidence from reviewed epidemiological studies of an increased risk for childhood leukemia from exposure to ELF-EMF that cannot be attributed to chance, bias or confounding (STOA, 2001; Kheifets, 2012; Kundi, 2012; Kundi & Hutter, 2014; Belyaev et al., 2016). The reviewed studies categorizing children and the chronically-ill as a vulnerable population category was solidified in (Yang et al., 2008).

The study (Yang et al., 2008) evaluated the gene-environment interaction in relation to ELF-EMF flux densities with a mean of 1.4 – 1.8 mG from electric transformers and power lines within 100 meters. The results showed a significant effect enhancement in children with a polymorphism in a DNA-repair gene. The study was significant because it applied an unconditional logistic regression analysis adjusting for age, gender, parental education and occupation, indoor and outdoor pesticides use, presence of television sets, refrigerators and microwave ovens in children's rooms and the presence of chemical factories or telecommunication transmitters within 500 meters of the houses (Yang et al., 2008). Kheifets (2012) found ELF-EMF effects in children arise primarily from a genetically susceptible subpopulation, and the increased mitotic activity in the cells (STOA, 2001) of developing children makes them more susceptible to genetic damage. The identification of genetic susceptibility was also found outside the assessment of children (De Luca et al., 2014). In De Luca et al., (2014), the objective was a metabolic and genetic screening to EMF intolerance for different population demographics. The biomarker assessment involved pro-oxidant / pro-inflammatory tests for alterations in blood, and selected genetic tests. The results showed:

- Distinctively increased plasma coenzyme-Q10 oxidation ratio;
- Significantly altered distribution-versus-control of the CYP2C19*1/*2SNP variants;
- Combined presence of genotype. Genotype (null)GSTT1 + (null)GSTM1 variants and;
- Confers 9.7 times higher risk of EMF intolerance that other GSTM1 GSTT1 combinations.

The vulnerable population categorization for the elderly and chronically-ill was demonstrated in studies (Hug et al., 2006; Huss et al., 2009). In Huss et al., (2009), a longitudinal study on the population evaluated residence near power lines and mortality from neurodegenerative diseases. The results showed a dose-response relationship to Alzheimer's disease and senile dementia for person's living a minimum of five years within 50 meters of a 220-380 kV overhead power line. There was little evidence for increased risk of amyotrophic lateral sclerosis, Parkinson's disease, or multiple sclerosis. Alzheimer's disease has demonstrated the biggest economic burden to the state over other disease (Belpomme et al., 2015). Weaknesses in the Huss et al., (2009) study include only relying on death certificates and not clinical examination. Huss et al., (2009) disclaimed if clinical examinations diagnosis were included it may have resulted in a two to eight (2 – 8) fold higher rate for Alzheimer's disease. Secondly, the Yang et al. (2008) study did not include underground cables and only relied on spatial proximity to overhead cables and did not include field or simulated measurements. Yang et al. (2008) reported the assumption from industry for levels to be above the WHO IARC (2002) hazard condition classification of above 3-4 mG within the 50meters proximity. In Contrast, measurements found in Takemoto-Hambleton et al., (1996), and Kelfkens et al., (2002) demonstrated a much larger percentage of the population to be exposed then estimated in Huss et al., (2009) and the proximity distance to reach EMF levels below 3-4 mG may be extended to 250 – 500 meters, dependent on infrastructure installation arrangements.

The vulnerable population categorization for pregnant mothers and newborns was found in a thirteen (13) years prospective cohort Li et al., (2011) study, after adjustment for potential confounders, found a statistically significant linear dose-response relationship between increasing maternal median daily ELF-EMF exposure level in pregnancy and an increased risk of asthma in offspring. Children whose mothers had a high ELF EMF level (>2.0 mG) had more than a 3.5-fold increased rate of asthma.

The next subsection will discuss the predominant authoritative review bodies on EMF exposure and possible biological effects.

2.2.5 Classification by authoritative bodies

Discussed in Section 1.1, conflicting publications arise because of two very different scientific paradigms toward EMF radiation assessment. Major differences regard the importance of the observed biological effects in relation to disease development (ICNRIP, 2002; Li et al., 2011). Discussed in Section 2.2, the STEP paradigm (opinion) is applied engineering science, focused on technological performance, only considering a biological effect as a thermal effect, with risk thresholds being market driven. Criticism arises on the studies being 'weighted' (bias) (discussed in Section 2.6) because research is funded by industry using linear equations not suitable to assess biological effects outside the thermal scope (SAR). The industry funded organisation lobbying the engineering paradigm is the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and ICNRIP WHO EMF Project. Both the ICNRIP Chairman & head of ICNRIP WHO EMF presented doubts about the reliability of the evaluation of science by ICNIRP on EMF radiation (Vecchia, 2008; Leszczynski et al., 2017). Neither of them said that ICNIRP evaluation of science is reliable and the International EMF Scientist Appeal of over 220 scientist's opinion is unreliable (LTCEP paradigm) (Leszczynski et al., 2017).

The EMF Scientist Appeal (LCTEP paradigm) is applied biological and environmental science, focused on biological performance, with risk thresholds prioritizing social accounting (discussed in Section 2.2).

In reviews by authoritative bodies, a problem arises when all scientists on the evaluating team follow the same exposition and or paradigm, resulting in there to be no real scientific debate. Therefore, there is a clear bias on the evaluation of science depending on who is the feeding publishing organization.

The exception was in 2002, the association between exposure to ELF-EMF and resulting incidence of diseases led to the classification of ELF-EMF by the WHO IARC (2002) as a "possible human carcinogen" (Group 2B). The same resolution was established for RF-EMF by the WHO IARC (2013) in 2011. The WHO IARC (2002) working group decision was based on two pooled analyses (Ahlbom et al., 2000; Greenland et al., 2000) of childhood leukemia. Ahlbom et al., (2000) evaluated nine (9) studies that fulfilled the strict inclusion criteria of a defined population base for case validation, control selection, historical ELF-EMF field calculations and or measurements for exposure assessment, while Greenland et al., (2000) also included wire codes. Both pooled analyses (Ahlbom et al., 2000; Greenland et al., 2000) and further pooled analyses (Kheifets et al., 2010; Zhang et al., 2016) concluded a monotonously increased risk with increasing ELF-EMF (50Hz/60Hz) emissions levels.

Recent science-based studies demonstrate grounds for a reclassification to "probable human carcinogen" (Group 2A) (Hardell et al., 2007; Coureau et al., 2014; Lerchl et al., 2015; Belyaev et al., 2016; Soffritti et al., 2016; NTP, 2016; Ostrom et al., 2016; Zhang et al., 2016; Leszczynski, 2017). Review of mobile devices (micro sources) (Hardell et al., 2007; Coureau et al., 2014; Ostrom et al., 2016) were included in this assessment because the personal devices can emit an ELF-EMF of up to 1000mG (similar to animal studies in Wang & Zhang, (2017)) when in operation (Sage et al., 2007). This classification is regarded as the critical threshold for risk assessment and regulation. Exposure to long term low intensity EMF radiation emissions has been described in several studies and published organization reports reviewed above, as a risk factor for affecting multiple biological functions, and having implications on public health, economy and social accounting. The public health and economic implications shall be discussed in Chapter 4, and discuss why EMF research is important for public health.

The reader should now understand the context and aim of the study defined by the preliminary literature review above and thus be prepared to proceed to the next section that discusses the requirements for the construction of a public interest in fulfilment of RQ_1 and RQ_2.

2.3 Construction of a public interest

In partial fulfilment of RQ_1 the study's first framework entity is the investigation and establishment of a public interest. Public interest is a common concern amongst citizens and significant segments in the management and affairs of local, provincial and national government (West's Encyclopaedia of American Law [WEAL], 2008; Connor, 2013: 6) and is rooted in the SA constitutional human rights (1996) as a promotion of social accountability. Private companies that provide a public utility requiring regulation are included, because private individuals rely on such a private company for vital services (Public Interest Law Society TWEN, 2008; WEAL, 2008). Public interest in SA includes the systemic threat or violation of human rights and/or may include upholding the law as well as public awareness of public safety or environmental risks (De Lange and another v Eskom Holdings Limited [DvE], 2012:57, Practitioner9, 2016).

The measurement of public interest for public safety or environmental risks is traditionally not a well-defined metric. The Institute of Chartered Accountants in England and Wales [ICAEW] (2012) argued that applying a detailed definition is likely to result in unintended consequences. The vague and broad measurement system in determining public interest requires each circumstance to be assessed, based on criteria of the relevant public wants and constraints and the balancing of competing interests.

In SA, after the establishment of PAIA (2000), in The Centre for Social Accountability versus the Secretary of Parliament and others (2010), the Eastern Cape High Court defined the metric thresholds that must be met to establish that the record reveals evidence of either a substantial contravention of, or failure to comply with, the law, or an imminent and serious public safety or environmental risk (Connor, 2013). The ruling found that the applicant must show 'on the balance of probabilities' that the disclosure of the record would reveal the required contravention, failure or *risk*. This means that all interested parties have to be granted access and opportunity to submit their cases to 'the balance of probabilities' test before any decision is made (Odeku, 2014). If the application on merit is successful, the public interest becomes public disclosure, making information or data readily accessible and available to all interested individuals and institutions.

Exposure to EMF radiation is a globally recognised public interest cause of concern for many people and governments (Stewart, 2000:115). The review of literature and EMF radiation related policies identified publishing organizations to espouse different EMF radiation model paradigms (Foster, 2001; Vitale, 2005; WHO, 2006a; EDA, 2016; Hardell, 2017). Debates and differing paradigms will likely remain on the scientific and political agenda for the foreseeable future. This is mainly as a result of the characteristics and levels of EMF radiation emissions continually varying due to new infrastructure deployments, smart environments and novel wireless devices that dominate social currency (Young, 2004; Dürrenberger et al., 2014; Fisher et al., 2016).

Systematic and coordinated efforts to monitor EMF radiation exposure were rare before 2009. Due to public concerns and identified EMF radiation exposure violations by industry and government agencies, countries have increasingly started implementing national EMF continuous radiation monitoring services (Government of India, 2010; WHO, 2011; Dürrenberger et al., 2014; WHO, 2016b). Unfortunately, little is known about personal EMF radiation exposure levels in the real world. This lack of knowledge has been identified as detrimental to any evidence-based risk, exposure and health policy, management and communication (Independent Expert Group on Mobile Phones, 2000; Vitale, 2005; Dürrenberger et al., 2014; Boumans et al, 2015; EDA, 2016).

As discussed in Section 1.1, there is no longer an EMF radiation exposure protection standard in SA because of intervention by industries (DHSA, 2005; DHSA, 2016c; Regulator 8). Authorities engaged by the researcher expressed a need for a dynamic and accurate model output to define the broad EMF radiation implications expressed in models findings in the public interest for the development of EMF radiation protection regulations in SA (WHO, 2009; Lerchl et al., 2015; HHS NTP, 2016; Soffritti et al., 2016).

The systematic literature review included reviewing legislature, court cases and or tribunal rulings (case law) in an effort to establish EMF radiation dose-relationship metrics related to legislature policies in preparation for the input of data to the proposed public interest EMF radiation HYGEIA model.

Case law is a great source of information because the courts and/or tribunals are approached in the applied theory of judicial interpretation (Walker, 1980). Judicial interpretation is the general approach that the judiciary uses to interpret the law; particularly constitutional documents and legislation. Highest courts have the power to overturn laws made by the legislature in a process called judicial review (Walker, 1980). The manner in which justices interpret the constitution and the ways in which they approach this task thus has a political aspect.

Judicial hearings have the potential of bringing together parties and experts from different disciplines in the interest of EMF radiation exposure guidelines and standards. These parties' counter arguments and supporting evidence are placed into a metric and weighed in interpretation by the country's constitution. The judicial review process enables further practical debate between both parties, leading to a further definition and external review of a policy associated with EMF radiation public safety (Government of Italy, 2008; Government of India, 2010; Government of India, 2012; Rajasthan, 2012; WHO, 2015a, WHO, 2016c).

The investigation of evidence and support in the construction of a public interest can be attained through a historical review and/or recording of a systemic threat or violation of human rights. The sections below are a discussion of the reviewed literature findings in support of the construction of an EMF radiation exposure public interest:

- Section 2.4: A summary review of regulation and practice in SA between the STEP and LTCEP EMF radiation models;
- Section 2.5: Legal accountability discussion between guidelines and standards; and
- Section 2.6: The construction, promotion and marketing of weighted studies aimed at misinforming the public about potential EMF radiation hazard conditions.
- Section 2.6.1: Evidence of the DHSA only publishing EMF radiation weighted studies and misleading public awareness safety campaigns.

2.4 A summary review of regulation and practice in SA: STEP versus LTCEP EMF radiation models

The recommendations and guidelines regarding the exposition for EMF radiation in SA by regulatory bodies vary substantially depending on the organization and or manufacturer which publishes it (Vitale, 2005; EDA, 2016). In Table 2.1, a side-by-side comparison of the STEP versus LTCEP models, supporting case precedent and policy views in SA, is displayed. The STEP model rationale statement by the DHSA is on the left and the responsive LTCEP model counter statement is on the right.

Table 2.1 Comparison table of STEP versus LTCEP models in SA

STEP model	LTCEP model
(1) Scientific evidence of a dose-relationship	
DHSA (CCPTM, 2015; Regulator8, 2016b): there is no scientific evidence that RF-EMF radiation from cell towers in SA will cause adverse health effects to the general population. General population means *everybody*.	Science-based studies reveal that adverse health effects may occur with exposure to EMF radiation. The case of EMF radiation potentially affecting the population has been investigated and ruled by: Advertising Standards Authority of SA [ASA] (2004), Nelson Mandela Bay Municipality [NMBM] (2011), KwaDukuza Municipality [KM]

	(2012), South African Human Rights Commission [SAHRC] (2015), Western Cape Government Ministry of Social Development [WCSD] (2012): Previous STEP model chairman stated that the STEP model is "not to be a mandatory prescription for safety", "not a defensive wall for industry and others", "one scientific input into the formulation of societal policies" (Vecchia, 2008:28). The STEP model confirms that it is not a protection guideline for the general population (ICNIRP, 2002). STEP model safety reference levels were defined only for *one very specific* population category (WHO, 2009).
(2) Number of supporting credible endorsers	
DHSA (2016c): Only activists speculate about adverse health effects of EMF radiation.	Over fifty percent (50%) of the world's population endorse the science-based LTCEP model (BfS, 2016; WHO, 2016a).
(3) Are reported health complaints imaginary or real?	
DHSA (Regulator8, 2016b; CCPTM, 2015) complaints of EMF radiation are idiopathic and indicative of a psychiatric problem and therefore health effects are non-existent.	Science-based LTCEP standards confirm that EMF radiation has the potential to affect neurological behaviour and cognitive function (ASA, 2004; Daniels et al., 2009; NMBM, 2011; KM, 2012; WCSD, 2012; SAHRC, 2015). The South African Society of Psychiatrists (2013) case review investigation revealed that EMF related complaints do not fall within the psychiatric framework. The case report ruling by SAHRC (2015) confirmed EMF radiation related health effect complaints not to be a psychiatric cause. The state thereby confirmed a genuine somatic pathological entity (SAHRC, 2015; Belyaev et al., 2016).

(4) Medical diagnostic testing	
DHSA (Regulator8, 2016b; CCPTM, 2015): no medical tests exist to confirm a reaction of adverse health effects from EMF radiation	Science-based LTCEP model standards confirm medical testing in the establishment of EMF limits. Medical biomarker tests have been established in humans (Austrian Medical Association, 2012; Eskander et al., 2012; Tuengler & Von Klitzing, 2013; De Luca et al., 2014; Gharib, 2014; Belpomme et al., 2015; Belyaev et al., 2016; Heuser & Heuser, 2017; Zothansiama et al., 2017). Medical tests and literature were reviewed and verified by ASA (2004), WCSD (2012) and SAHRC (2015).
(5) Municipal spatial planning	
DHSA (CCPTM, 2015:47): "local and other authorities, in considering the environmental impact of any particular base station, *do not need* to and *should not attempt*, from a public health point of view, to set *any restrictions* with respect to parameters such as distance to the mast, duration of exposure, height of the mast, etc."	WHO (2007:14) instructs that government and industry should improve planning of EMF emitting facilities, including better consultation between industry, local government, and citizens when citing macro EMF infrastructure sources. The science-based LTCEP model requires spatial planning to protect the public. KM (2012) and NMBM (2011) wrote spatial planning restrictions into their policies in accordance with the National Environmental Management Act (NEMA) (1998), the Local Government Municipal Systems Act (2000) and Schedule 4 of the SA (1996) Constitution.
(6) Weighted science-based studies	
DHSA (CCPTM, 2015) and CCPTM (2015): only literature that falls within STEP model rationale parameters is reviewed in determining public health protection policies.	NMBM (2011), KM (2012), WCSD (2012), SAHRC (2015) and ASA (2004): literature and case studies that falls within STEP and LTCEP models' rationale parameters were reviewed in determining public health

	protection policies.

It could be argued that SA may be developing the potential to becoming an LTCEP model endorser, given long-term SA economic and scientific education trends. On an educational and scientific front, SA signed a memorandum agreement to send two hundred (200) South Africans to Russia to train as nuclear engineers (Fripp, 2015). It is possible that the SA scientists will be trained in Russian LTCEP model curriculum and that they may continue to follow the EMF radiation Russian Sanitary Norms and Regulations 2.2.4/2.1.8.055-96 in the implementation of domestic projects upon their return to SA.

The next section discusses the legal accountability differences between an EMF radiation guideline and standard.

2.5 Guidelines versus standards

This section discusses the strategy of creating a false sense of public safety through the mixed and inappropriate use of words guidelines and standards. A pattern of the CCPTM, the DHSA and SA industries inter-changing the definition of guidelines and standards, with respect to EMF radiation protection measures, was identified in the literature review (Telkom annual report 2012:104; CCPTM, 2015; EMFDS3, 2016; Regulator4, 2016). The WHO (2006a) explains how the use of the words guidelines and standards has substantially different implications for public health and EMF radiation protection enforcement.

(1) Guidelines are voluntary instruments of instructions and recommendations that are not legally mandated and therefore have no legal standing (WHO, 2006a).
(2) Standards are the mandatory, compulsory and legally binding instruments, i.e., laws, acts, regulations, ordinances and decrees. They require procedures and systems to exist in order to ensure compliance of mandatory standards, i.e., an agency is mandated to check compliance through calculations and measurements in the workplace, residence and other vulnerable areas (WHO, 2006a).

WHO (2006a) states there is to be *no* international mandated EMF radiation standard but recommends that countries adopt their health-based EMF radiation standard from the large selection of international guidelines published, based on their tolerance of *risk value* toward accrued benefits to health.

It could be argued that EMF radiation protection and interpretation would fall into existing legislation in SA with there being *no* national EMF radiation exposure safety standard (DHSA, 2017) in the country. The argument is based on the false sense of safety associated with lack of a standard and consequently lack of surveillance of EMF exposure to the public. Because it cannot be denied that there is potential of harm from exposure to EMF radiation, legally binding exposure standards have been established in many countries worldwide. The (1996) Constitution, National Environmental Management Act (NEMA) (1998), Promotion of Administrative Justice Act 3 of 2000 (PAJA), Promotion of Equality and the Prevention of Unfair Discrimination Act 4 of 2000 (PEPUDA) and case precedents of ASA (2004), WCSD (2012) and SAHRC (2015) require that protection measures toward EMF radiation adopt the LTCEP model and that EMF radiation emissions are made accessible to the public as a public interest (Stewart report, 2000).

The next section discusses another conservative with the truth: public safety strategy with regard to EMF radiation exposure, termed weighted studies.

2.6 Weighted studies

The classification of EMF radiation as biologically active is derived from results of available laboratory investigations and animal experiments and is no longer seriously disputed by any scientific institution (European Parliament Scientific & Technological Options Assessment, 2001; WHO, 2006a; Adlkofer et al., 2009; European Environment Agency, 2009; Ramazzini Institute, 2010; Lai, 2010; Herbert et al., 2012; Belpomme et al, 2015; Lerchl et al., 2015; NTP, 2016; Soffritti et al., 2016; Heuser & Heuser, 2017). Major differences are merely opinions concerned only with the importance of the observed biological effects in relation to disease development (Foster, 2001; Vitale, 2005; WHO, 2006a; EDA, 2016).

Both the science-based EMF radiation STEP and LTCEP models have extensive literature in support. Independent authorities warn that recommendations and guidelines regarding the exposition for EMF radiation are very different depending on the (STEP or LTCEP) model endorsed by the organization and or manufacturer which publishes it (Vitale, 2005; EDA, 2016; Hardell, 2017). For example: the science-based LTCEP endorser review article by Genuis (1998) surveyed 112 peer-reviewed studies and described vested industrial interests that biased scientific research and promoted doubt and uncertainty to minimize the potential harm of EMF radiation. Genuis's (1998) argument of RF-EMF radiation weighted studies documented "an effect" or "no effect" attributed to the funding source and is supported in studies a decade later by Lai (2010) and Huss et al. (2008). This trend still aggressively continues (Starkey, 2016).

Figure 2.1 on the next page shows an analysis by Lai (2010) of a weighted studies comparison of RF-EMF research funding source. Lai's (2010) analysis showed that thirty-two percent (32%) of industry-funded research and seventy percent (70%) of non-industry funded research documented RF-EMF radiation biological effects. One hundred and twenty three (123) studies showed biological effects from RF-EMF radiation. From an LTCEP model perspective, Lai's (2010) weight-of-evidence for non-industry funded studies revealed that RF-EMF radiation is biologically active. Lai's (2010) applied chi squared analysis documented a difference in results based on the funding source to be statistically significant at a level of ninety-nine point nine percent (99.9%).

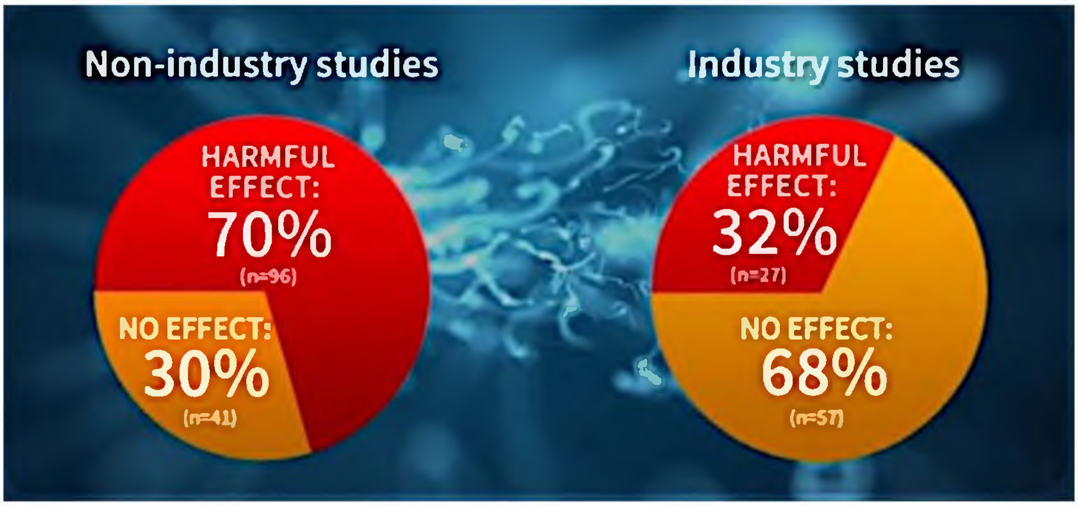


Figure 2.1 Weighted studies comparison of RF-EMF research: Does funding matter? (Lai, 2010)

Recently, twenty (20) year old studies were replicated by STEP model endorsers confirming that *low-intensity* ELF and RF-EMF radiation can cause biological effects having a dose-dependent increase in DNA strand breaks (Lai & Singh, 1995; Lai & Singh, 1997; Leszczynski et al., 2002; SWISS-COM AG, 2004; WHO, 2006b; WHO, 2006b; European Environment Agency, 2009; Levitt &; Lai, 2010; Lerchl et al., 2015; NTP, 2016; Soffritti et al., 2016; Yakymenko et al., 2016; WHO, 2016e).

A list of 56 science-based studies showing biological/health effects of low-intensity RF-EMF radiation is available in the Appendix, Section 4.5 (Science-based studies demonstrating biological/health effects of low-intensity RF-EMF radiation).

Levitt & Lai (2010) reported that, in human studies, the RF-EMF radiation mean and median power densities (W/m^2) / field intensity (V/m) that have been reported to cause biological/health effects are:

> Mean = 0.028 W/m^2 (3.2 V/m), median = 0.005 W/m^2 (1.3 V/m), range: 0.1W/m^2 - 0.00005W/m^2 (6.1 – 0.13 V/m).

These are the intensities that one would potentially be exposed to within a cell mast range of 63m (0.1 W/m^2 or 6.1 V/m) to 900m (0.00005 W/m^2 or 0.13 V/m). An explanation of the environmental EMF radiation calculation is available in the Appendix, Section 4.10 (Far-field power density evaluation calculation for RF-EMF radiation exposures) and Section 7.2 (Far-field power density evaluation).

The researcher needed to evaluate epidemiological studies of both STEP and LTCEP model endorsers and had to extract the defined metrics for EMF radiation biological reactions to be used in a proposed public interest EMF radiation HYGEIA model as a result of a review of the EDA's (2016) public interest warning on the exposition of EMF radiation reference levels and limits being dependent on the publishing source organisation and or manufacturer, combined with the findings of weighted-studies above (Vitale, 2005; Lai, 2010).

Genuis's (2008) review, for example, surveyed one hundred and twelve (112) peer-reviewed studies and concluded that, from an LTCEP model perspective, there is compelling epidemiological evidence of considerable potential for injury and affliction as a result of EMF radiation exposure (WHO, 2006b; Belyaev et al., 2016). Conducting a literature review on literature reviews is not a practical scientific approach for this public interest research, because the proposed public interest EMF radiation HYGEIA model simulations require public health metrics to be associated with respective EMF radiation levels. The study of Edger and Jahn (2010) and the German mobile phone programme (DMF) QUEBEB (2007) study are examples of examining literature in the scope of this section's argument.

The two studies set out to investigate the existence of a dose-response relationship between alleged EMF radiation-related health symptoms within proximity distances to newly erected cell phone towers. Both studies investigated large sample groups of the population. In assessing the weighted-studies parameters, it must be noted that the Edgar & Jahn (2010) study was conducted without outside funds and that the QUEBEB (2007) study was funded by the DMF. From a science-based approach, both studies followed a research protocol involving physicians and the municipality.

The QUEBEB (2007) study found no statistical significance related to a dose-response relationship of symptoms, but Edgar and Jahn (2010) found a significant dose-response relationship between mean EMF radiation exposure levels of the study participants and reported health symptoms. To put the findings in perspective: the STEP model field intensity reference level is approximately 60 V/m and the LTCEP model limit can range between 19 and 0.58 V/m, depending on the country and context.

The highest EMF radiation exposure group recorded a mean RF-EMF radiation exposure field intensity of 1.2 V/m in Edgar and Jahn (2010). They did record, similar to QUEBEB (2007), ambient RF-EMF radiation levels from micro sources concerning the use of DECT phones (domestic cordless phone). Measurements revealed an additional background RF-EMF radiation exposure level in the homes in all participating households.

Edgar & Jahn (2010)'s results showed a clear trend for decreasing symptom scores with decreasing mean RF-EMF radiation exposure levels caused by RF-EMF radiation cellular tower transmitter emissions. The QUEBEB (2007) study showed no significant dose-relationships, because the highest RF-EMF radiation measurement recorded given was 1 V/m, whereby the remaining ninety-nine percent (99%) of the measurements were below 0.34 V/m. The mean exposure level was at 0.07 V/m with a 95% percentile at 0.17 V/m. A similar recent 'no effect' for RF-EMF radiation on children in Switzerland was published with the highest recorded mean field intensity of 0.38 V/m (Schoeni et al., 2016). A possible explanation for the 'no effect' in the Swiss study results may be due to the existing strict LTCEP model standard utilized. In Switzerland the field intensity limit for LTE cellular is under 6 V/m, versus the 60 V/m investigated region reference level in the QUEBEB (2007) study. The health exposure functions for an EMF radiation HYGEIA model would receive Framework EMF radiation policy inputs. The model would need to correlate the EMF radiation exposure level range for potential health effects into both high and low exposure.

The Edgar & Jahn (2010) and QUEBEB (2007) studies can, for example, be divided into two EMF radiation hazard conditions evaluation groups, namely a high and low exposure group. 82 out of the 251 study participants in the Edgar & Jahn (2010) study fell into a high exposure group above 0.7 V/m (32.7% of the study participants), in contrast with less than 1% of the participants of the QUEBEB (2007) study being exposed to above 0.34 V/m.

In a study by Abdel-Rassoul et al. (2007) high exposure groups measured an RF-EMF radiation field intensity of 3 V/m, and a more recent survey across Europe measured above 6 V/m and 20 V/m within the population (Gajšek et al., 2015; WHO, 2015b). Gajšek et al.,

(2015) created three (3) population exposure categories, one (1) intermittent variable partial body exposure, two (2) intermittent variable low-level whole-body (WB) exposures and three (3) continuous low-level WB exposures for risk assessment studies.

High EMF radiation exposure groups identified in Edgar & Jahn (2010) were relatively minimal in the study samples of QUEBEB (2007). In QUEBEB (2007) the methodology approach of random sampling led to a systematic underestimation of the risk for population groups with higher exposures identified in Edgar and Jahn (2010). The latter explained that the methodology reasoning in the QUEBEB (2007) study had found no dose-relationship correlation, because it only applied its methodology to low-exposure groups and is, therefore, unable to contradict the findings in Edgar & Jahn (2010). Further studies by Eskander et al., (2012) and Zothansiama et al., (2017) were able to demonstrate a dose-response relationship to residents RF-EMF base stations using a combination of both spatial proximity and biomarker testing.

Gathering detailed data in fulfilment of RQ_4 and RQ_5 of this dissertation will aid in the development of a proposed public interest EMF radiation HYGEIA model in accordance with the modeling methodology of EMF radiation high exposure groups, as demonstrated by Edgar & Jahn (2010). Securitization of EMF radiation behaviour also needs to be examined by publishing government agencies and academic research institutes and the findings should be critically compared. Review of the simulation model projected and site EMF radiation levels by international government agencies themselves, compared to those by academic institutions, revealed measurements to be many folds different (Takemoto-Hambleton et al., 1996; FCC, 1997; Mann et al., 2000; Kelfkens et al., 2002; Vitale, 2005; Hondou et al. 2006; Kos et al., 2011; Yahya & Khalil, 2015; EMFs.info, 2016).

2.6.1 DHSA weighted published findings and misleading public awareness campaigns

A possible pattern of selective published EMF radiation research and misleading public awareness campaigns by the DHSA were identified by this study (DHSA, 2008; Telkom's annual report, 2012:104; DHSA, 2013; Practitioner18, 2016; Starkey, 2016). An examination of the DHSA's historical EMF activities reports and references to the DHSA in other public bodies and industry reports, revealed the following:

(1) Misleading EMF radiation monitoring: The DHSA reports RF-EMF radiation measurements conducted for over six thousand cellular ARD base stations over a number of years. The base stations were reported to be within STEP model reference

levels and it was stated that the data is available. The researcher requested the data from the Regulator8 (2016b). Regulator8 (2016b) responded that the data has never been reviewed or audited by the DHSA and that industry provided only the summary notification to the DHSA. The researcher requested the data from the data source referenced in the DHSA reports, but the source declined to share the data, even for public interest academic research purposes (Practitioner18, 2016).

(2) The DHSA selectively publishes reports on domestic EMF radiation and public health research studies that are supportive of the STEP model and that demonstrate no negative link between EMF radiation and public health. For example: in DHSA (2008), the report presented the South African Falzone et al. (2008) study for cellular RF-EMF on sperm to have no effect. However, the same authors later republication in Falzone et al. (2011), re-assessed and concluded that the original study results could indicate a significant effect of RF-EMF on sperm fertilization potential but found no occurrence of heat shock proteins (Hsp27). However, other studies review cited a Hsp27 association (Leszczynski, 2017). A heat shock protein response (Hsp27) suggests that cells mount a vigorous response to RF-EMF stress during short-term exposure (STEP model) (Leszczynski, 2017). Studies supportive of the LTCEP model not published in the DHSA national WHO reports are Vermeeren et al., (2010), Daniels et al. (2009), CANSA (2011) and this current study. The DHSA stipulates its' primary source of information and guidance to the public being based on the STEP model (DHSA, 2017); and strongly advises the public to ignore the LTCEP model (DHSA, 2016c; DHSA, 2017). The DHSA classifies endorsers of the LTCEP model in SA as activists seeking to "exploit the general public's ignorance about and the fear of electromagnetic fields for their own purposes" (CCPTM, 2015; DHSA, 2016c:1; DHSA, 2017).

(3) The DHSA is represented to industries and regulatory bodies as the responsible body for the regulating, maintaining and investigating of EMF radiation standards in SA (Telkom's annual report, 2012:104; CCPTM, 2015; Regulator4, 2016). However, the DHSA stipulates in CCPTM (2015:47) that the STEP model reference levels are voluntary and that there has been *no* national EMF radiation standard since 2003, because of industries objections (DHSA, 2005; DHSA, 2016c).

(4) The DHSA does not mandate the ICNIRP 1998 STEP model but recommends its adoption to government bodies and industry as the only suitable EMF radiation protection guideline (CCPTM, 2015; DHSA, 2016c). The DHSA and SA industries STEP model recommendations are contradicted by the ICNIRP STEP model chairman (2004 to 2012) Professor Paolo Vecchia. Professor Vecchia described the ICNIRP

STEP model as (1) "*not* mandatory prescriptions for *safety";* (2) "not the 'last word' on the issue"; and (3) "they are *not defensive* walls for industry or others" (Vecchia, 2008:28). Vecchia's (2008) statement was supported in a German High Court ruling recently. The High Court deliberations rejected the defence's government expert opinion that relied on selective ICNRIP and the WHO (economic division) claim that there is no proof of biological harms (Federal Administrative Court, 2012; Weatherall, 2013).

The DHSA and industries' potentially misleading public awareness campaigns are in conflict with SA operating on a 'reactive system' (Hardell, 2017). Such system requires members of the public to lodge complaints with regulatory bodies, to highlight weaknesses in current policies and to make recommendations to enable the judicial review process to produce new and/or updated national protection standards to be implemented in the interest of public safety and awareness (Regulator1, 2016; Regulator3, 2016; Government Gazette, 2016).

A further elaboration on misleading DHSA campaigns is available in the Appendix, Section 2.3 (DHSA weighted publishing findings and misleading public awareness campaigns).

2.7 SA legislation supportive of EMF radiation protection

As discussed in Section 1.1, there is no national EMF radiation protection standard in SA. A literature review therefore needs to determine whether completely new EMF radiation legislation needs to be established or whether there is existing legislation that can be used to invoke EMF radiation exposure protection for the public. A discussion of the literature reviewed is categorized into the following sub-sections:

- Section 2.7.1: EMF radiation responsivities by organs of the state.
- Section 2.7.2: Suspended national EMF radiation protection standards in SA.
- Section 2.7.3: SA municipal bylaws supportive of EMF radiation protection.
- Section 2.8: International EMF radiation protection legislation.

2.7.1 EMF radiation responsibilities by organs of State

Odeku's (2014) study of SA environmental legislation revealed that several organs of the state are responsible for the administration of environmental legislation and that they are found in all spheres of government, except in the specific case of low-intensity EMF radiation in SA (CCPTM, 2015; WHO, 2016a).

Odeku (2014) expressed a major common concern that the responsibility to protect the environment has been placed in the hands of different organs with no centre that manages cohesion and synergy.

For example: the DHSA is marketed as being the managing body of EMF radiation policy in SA; with Regulator9 being responsible for RF-EMF spectrum licensing only; the Department of Environment merely limits EIA application height restrictions on RF-EMF transmission towers; whilst the Advertising Standards Authority (ASA) of SA regulates public awareness and protection of RF-EMF advertised devices (Regulator9, 2015; Regulator8, 2016b). Although the ASA is not an organ of state, its rulings often lead to development of national standards (Regulator1, 2016). The ASA is in the process of being formalized into the Consumer Protection Act, 2008, No. 68 of 2008 (Regulator1, 2016; Government Gazette, 2016).

Odeku (2014) expressed concern that the lack of environmental protection synergy is creating ineffective administrative implementation and tensions amongst the organs of state. Regulator4 (2016) stated, for example, that they have neither the power nor the mandate to act on potential EMF radiation concerns, because the matter must be handled by DHSA as per DHSA instruction. DHSA (CCPTM, 2015) counter stated that they have neither the power nor the mandate, because there are *no* mandatory national standards or system to survey and/or monitor the said RF-EMF radiation in SA (CCPTM, 2015; Regulator8, 2016a).

In 1998 NEMA was enacted to authorize the creation of a basic legal framework for environmental protection in SA by utilizing the obligations and entitlements afforded by the 1996 SA constitution (Strydom and King, 2009). SA has not yet evaluated a specific national EMF standard endorsement of the STEP or LTCEP model according to NEMA (1998), but does hold specific clauses that recognize EMF radiation exposure protection enacted by LTCEP model international treaties. They are the precautionary and polluter pays principles.

Precautionary principle: is a well-known principle in environmental law, that states there is a social responsibility to protect the public from exposure to harm, when scientific investigation has found a plausible risk. Such protections can be relaxed only if further scientific findings emerge that provide sound evidence that no harm will result (SCOI Report, 2017). In terms of Section 2(4)(a)(vii) of NEMA (1998), SA has mandated the preventative/precautionary model to all pollutants and does not exclude the environmental pollutant EMF radiation. Due to the continued contrasting views on environmental guidelines amongst scientists, industries, and governments, an agreement was concluded at the United

Nations Environment Program (UNEP) Rio Conference for countries (including South Africa) to follow the precautionary principle. Principle 15 of the Rio Declaration states: "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are potential threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation …" As a result, any short or long term environmental and public harm caused by exposure to this EMF radiation may go unchecked (UNEP, 1992; National Environmental Management Act (NEMA), 1998:s 2(4)(a)(vii); Commission on the European Communities, 2008; WHO, 2011).

As defined in Section 2(4)(a)(ii) of NEMA (1998), the preventative principle requires the process of a pollutant affecting the ecology to be avoided and, where it cannot, the ALARA (as low as reasonably achievable) principle is enacted and those environmental remedies are to be actioned. For example, electric power brings health, social and economic benefits, and precautionary approaches should not compromise these benefits (WHO, 2007:13). But all mitigation options must be explored seeking long term benefit solutions. For example, solar power is an alternative fuel source to coal. Germany's recent legislation required that the installation of electrical power infrastructure must not be compromised, but instead, planning and research efforts must be employed into technology advancement and equipment configuration to enable lower ELF-EMF emissions, thereby maintaining a closer proximity to the public (WHO, 2016c). When changes to existing EMF sources are contemplated, the EMF reduction should be considered alongside safety, reliability and economic aspects (Von Winterfeldt et al., 2004; WHO, 2007:13;).

Polluter pays principle: Section 2(4)(a)(ii) of NEMA (1998) was applied in the ASA (2004) ruling prohibiting the advertising of RF-EMF radiation devices to persons under the age of sixteen (16) for use in non-essential purposes (ASA, 2004; Regulator1, 2016). The ASA (2014) rationale for the ruling was based upon science-based reviews presented by the ASA (2004) complainant and evaluated by the ASA investigation panel. ASA (2004) revealed that RF-EMF radiation has the potential to cause adverse health effects.

In SA the ASA's rulings invoked both the precautionary and polluter pays principle for EMF radiation exposure protection (ASA, 2004; Regulator1, 2016). ASA's impending empowerment under the Consumer Protection Act (2008) may bring about additional RF-EMF legislation (Government Gazette, 2016). In 1998 the Cwmbran Magistrates Court, South Wales, for example, issued a summons under section 10 of the UK Consumer

Protection Act, 1987 for Dr. Roger Coghill to bring a private criminal action against the Telephone Shop UK Ltd., a retail distributor of Orange and Motorola mobile phones (Woodley, 2000). A similar instance was deliberated in CTIA *v* City of Berkeley (2017). Dr. Coghill's action claimed that the distributors failed to affix labels, warning against possible RF-EMF radiation-related health risks to users from prolonged use, to their handsets (CTIA *v* City of Berkeley, 2017). Similar to the ASA (2004) ruling based in part on UK legislature, Dr. Coghill presented science-based evidence of potential adverse health risks with RF-EMF radiation devices.

2.7.2 Suspended national EMF radiation standards in SA

The DHSA's (2005) annual national EMF radiation report stipulated that the Hazardous Substances Act, 1973, Act No. 15 of 1973 was implemented as a national EMF radiation protection standard in SA, but it has been retracted by industry objections and has been continuously blocked since 2003 (DHSA, 2016c).

The current version of the Hazardous Substances Act (1973) provides a very broadly defined metric to low-intensity EMF radiation. The only references to EMF radiation contained in the Hazardous Substances Act (1973) are held in section 1, "electronic product radiation" and "electronic product". The Hazardous Substances Act (1973) definitions recognize a manufactured product that, when in operation, has the capacity to emit EMF radiation and EMF radiation having the capacity to potentially cause harm in the form of electrical, biological and excessive temperatures, which may cause injury, ill-health or death to human beings.

The DHSA's (2016c) recent excuse for the delay in implementing a national EMF radiation standard is the long awaited publication by the WHO health risk assessment panel of RF-EMF radiation guidelines. The DHSA (2016c) reported that it would most likely adopt the latest WHO RF-EMF guidelines as a national EMF radiation standard. DHSA's (2016c) reasoning for a delayed national EMF radiation standard is contradicted by WHO's (2006a) framework for developing health-based EMF standards. WHO's (2006a) framework publication stipulated that, based on their values risk threshold limits (defined in Section 1.5 from the previous chapter), there is a large array of EMF radiation guidelines and adopted standards around the world available for SA to implement.

Furthermore, DHSA (2016c) further contradicted itself by stipulating that the South African Bureau of Standards (SABS) Technical Committee 73 considered the development and adoption of standards related to the measurement and calculation of human exposure to time-varying EMF radiation in that the DHSA (2016c:1) reported that the EMF radiation standards developed in this regard are by "IEC TC106 and CENELEC TC106X and will likely be adopted and underwritten as SA national EMF radiation standards, *as and when appropriate"*. In contrast thereto the lack of an investigated national EMF radiation standard by the SABS has repeatedly been reported by the DHSA (2005) for *over a decade*.

2.7.3 SA municipal bylaws supportive of EMF radiation protection

A review of SA legislation and organs of the state revealed a base principle for EMF radiation protection and enforcement. In the administration and management of the environment, the SA government uses NEMA (1998) that explicitly provides for co-operative environmental governance (Odeku, 2014). Like other climate change pollutant issues, EMF radiation responsibilities by organs of the state lack cohesion and synergy (ASA, 2004; DHSA, 2005; Odeku, 2014; Regulator1, 2016). Legislation depends on enforcement and implementation by the state for its effectiveness (Odeku, 2014).

Concurrent competencies are articulated in Schedule 4 in the Constitution of the Federal Republic of SA (1996), Act 108 of 1998. Schedule 4 enables a provincial legislature or municipality to promulgate and administer by-laws, provided that they do not decrease the level or the standard or protection of the national policy (Strydom & King, 2009). Some municipalities in SA have taken it upon themselves to develop RF-EMF radiation protection policies advertised as bylaws, empowered by Schedule 4, due to the lack of a synergized national EMF radiation protection standard (Nelson Mandela Bay Municipality [NMBM], 2011; KwaDukuza Municipality [KM], 2012; CCPTM, 2015).

The policies of Nelson Mandela Bay Municipality (NMBM) (2011) of the Eastern Cape, KwaDukuza Municipality (KM) (2012) of KwaZulu-Natal, and the City of Cape Town Municipality (CCPTM) of the Western Cape (2015) were developed with different interpretations and definitions regarding metrics and public safety values risk threshold limits with respect to RF-EMF radiation from cellular transmitters (WHO, 2006a). Note the above mentioned municipalities only have a telecommunication policy and not a bylaw. A policy is a voluntary instrument like a guideline however, a bylaw, like a standard has mandatory and legally binding instruments, monitoring and enforcement systems.

The summarised RF-EMF radiation rationale comparisons between the three SA municipal policies are:

1. Both NMBM (2011) and KM (2012) place RF-EMF public health concerns as a primary priority while CCPTM (2015) sets RF-EMF public health concerns as a secondary priority;
2. Both NMBM (2011) and KM (2012) acknowledge investigating the STEP and LTCEP models in its RF-EMF radiation safety reference levels and limits rationale but CCPTM (2015) only provides evidence of reviewing the STEP model;
3. Finally, and in line with international practices, i.e., Poland, France, Australia, Israel and Spain, both NMBM (2011) and KM (2012) acknowledge and incorporate the Local Government Municipal Systems Act (2000) and Schedule 4 of the SA (1996) Constitution. CCPTM (2015), on the other hand, removed the corresponding NMBM (2011) and KM (2012) clauses of legislature from its 2011 draft policy under the heading "Mandate: Responsibilities and Powers of Council". The removed clauses of accountability contained important municipal mandate parameters and these parameters required the safety and welfare of its community above 'market driven' economic well-being (LTCEP model). The CCPTM (2015) has a primary responsibility to apply its mind set and define its policies.

For a detailed narrative breakdown comparison of the NMBM (2011), KM (2012) and CCPTM (2015) policies see Appendix, Section 2.4 (SA municipal bylaws supportive of EMF radiation protection).

2.8 International EMF radiation protection legislation

There is a broad distinction between the STEP and LTCEP model endorsers globally (van Leeuwenhoeklaan, 2011; WHO, 2006a; BfS, 2016). Individual STEP and LTCEP endorsing countries, however, have different evolved and specified EMF radiation protection standards and exposure limits (van Leeuwenhoeklaan, 2011; BfS, 2016). The evolution of an EMF radiation protection standard within a country is influenced by the endorsed publishing agency paradigm, coupled with the political ruling party's economic accounting scope, i.e. market driven or social accounting.

Within the EU and North America, for example, there is a strong difference of opinion on acceptable EMF radiation exposure levels. The STEP model is endorsed by the EU and USA economic forum (van Leeuwenhoeklaan, 2011), but public interest investigation and studies carried out by the European Parliament Scientific & Technological Options Assessment (STOA) (2001) recommended a science-based LTCEP model value 1/10 000th of the STEP model safety reference levels (Council of Europe Parliamentary Assembly, 2011). In the

USA a similar LTCEP model investigation and endorsement was carried out by the USA National Institute of Health Sciences and the Department of Health and Human Services (HHS) NTP (Giuliani, 2002; NTP, 2016).

EMF radiation exposure limits are further complicated by countries employing the LTCEP model for ELF EMF radiation but the STEP model for RF-EMF radiation. The same pattern is legislated in STEP model endorsing countries that employ the LTCEP model in selective instances or communities. Additionally, some countries include mitigation strategies in legislation in order to accommodate both STEP and LTECP model parameters.

Germany, for example, included the mitigation option for improved technologies and quality parameters in legislation, thereby decreasing adverse EMF radiation capabilities toward public health. The mitigation option creates closer proximity between the public and EMF radiation infrastructure sources and enables economic prosperity (WHO, 2016c).

The Council of Europe Parliamentary Assembly (CEPA) (2011) passed a final resolution 1815(2011) recommending that EU members endorse the LTCEP model approach to EMF radiation rather than the STEP model and that they should apply the ALARA (as low as reasonably achievable) principle in an effort to reduce EMF radiation exposure to the science-based STOA (2001) level of 0.0001 W/m2 (1/10 000th of the STEP model safety reference levels). The STOA (2001) EMF radiation power density level was based on the social accounting context of growing exposure of the population. In respect of vulnerable groups, such as young people and children in particular, there could be extremely high human and economic costs if early warnings are neglected (European Environment Agency, 2009; Ramazzini Institute, 2010; Council of Europe Parliamentary Assembly, 2011:1; California Department of Public Health, 2014).

In support of the ALARA principle rollout, the CEPA (2011) recommended that an increase in EMF radiation awareness safety campaigns should be rolled out within different ministries (education, environment and health) and that warning labels should be placed on RF-EMF devices. EMF municipal infrastructure spatial planning and approval are not solely determined by the telecommunication operators' economic interests but should take place in consultation with local and regional government authorities, residents and associations of concerned citizens (public interest). CEPA's (2011) resolution is concurred in High Court orders in several international countries (WHO, 2009; Government of India, 2010; WHO, 2015a)

For a detailed narrative comparison and breakdown of international EMF radiation protection legislation in the EU see Appendix, Section 2.5 (The debate of EMF radiation protection implementation within the EU).

The foreseeable future debates and differing paradigms will likely remain on the scientific and political agenda. This is mainly due to EMF radiation emissions continually altering in characteristics and levels due to new infrastructure deployments, smart environments and novel wireless devices that dominate social currency (Young, 2004; Dürrenberger et al., 2014; Fisher et al., 2016).

2.9 Domestic case precedents for EMF radiation protection

According to case precedent there are two approaches that can contribute to the formulation of public EMF radiation exposure protection, namely a 'bottom-up' and 'top-down' approach.

Bottom-up approach: This approach involves participation and discussion at the lowest level of the hierarchy, working up to the top. Legislative and regulatory practitioners in SA are bound to act only in a 'reactive system'. A 'reactive system' strategy requires repeated successful complaints to a tribunal body or regulator, such as the ASA, Commission for Conciliation, Mediation and Arbitration (CCMA), Ombudsman or Consumer Protector, until a national body, like the Department of Trade and Industry (DTI), implements a national protection EMF radiation protection policy (Regulator1, 2016; Government Gazette, 2016); Alternatively, in accordance with international practices, a request for judicial review can be submitted to the High Court (Government of India, 2012; Rajasthan, 2012; WHO, 2015a; WHO, 2016c).

The earliest EMF radiation judicial review in SA was the ASA (2004) ruling prohibiting advertising regarding the use of cellular RF-EMF radiation devices for non-essential purposes to be targeted at children under the age of sixteen (16) .

The second step was the recognition that EMF radiation has the capacity to render a state of functional impairment (morbidity) on SA citizens (WCSD, 2012; SAHRC, 2015). The WCSD (2012) classification underwent judicial review in the Magistrate and High Court with the outcome confirming the WCSD population categorization (2012) that SA citizens can have a vulnerability to EMF radiation and are discriminated against per PEPUDA (2000) (SAHRC, 2015).

The third step resulted from the consultation with the Regulator2 (2016) and determined that a residents' association may carry out a vote in the implementation of an EMF radiation bylaw. If a municipal ward representative quorum is reached, the bylaw may be carried forward to the municipal council by the ward council representative. The residents' association bylaw would act as a proxy for public participation in the municipal ward area, thereby dismissing the granting of future permit applications for EMF radiation related infrastructures and/or removal of existing structures (Regulator2, 2016). An increase in municipal ward submissions would lead to the creation and/or modification of existing EMF radiation municipal bylaws (CCPTM, 2015).

A 'bottom-up' approach review of literature provides information for the public to organically (a lengthy process) contribute to the development of formalized EMF radiation protection policies in SA.

Top-down approach: This approach is an autocratic process of upper leadership reaching independent conclusions that change or improve the specified system. In SA a 'top-down' approach could comprise a combination of regulatory bodies using a combination of the 'reactive system' and EMF radiation HYGEIA model's exposure functions (Chapter 6) to formulate a national EMF radiation exposure protection standard. The construction of an EMF radiation HYGEIA model may aid policy makers to develop a regulatory EMF radiation exposure standard that balances public health concerns with controlling the levels of exposure, while remaining a digital economy.

2.10 International case precedents for evolved EMF radiation protection

Non-biased judicial deliberations are valued because the court is assigned to objectively referee scientific debates based on the community's value risk threshold limits (social and cultural values). Internationally and in SA, in theory, the law and application of science seeking the best interest of the community is to be applied and practiced (Practitioner19). However, due to political intervention and COI practice what is considered as 'right' is not actioned. Therefore, members of the public and knowledge disruptive scientists are required to approach the senior courts to review the matter and provide a judicial ruling if a PIO is demonstrated (Practitioner19). In-line with multinational High Court deliberations, an Italian High Court ruling confirmed the association of a tumor and excessive (hazard condition) cellular RF-EMF radiation exposure (Barry, 2017). Micro EMF sources are out of the scope of this study but are dependent on infrastructure (macro). As discussed in Section 2.6 (Weighted studies), the court expert's submitted evidence of reviewed studies was dismissed studies because they were funded by the telecom industry (weighted studies). What is interesting is that excessive (hazard condition) was labeled at one (1) hour per day but the practical context was averaged at around three (3) hours per day in this case. The complainant sued the State for failing to regulate the public awareness and exposure around the potential EMF dangers (Barry, 2017).

The researcher chose to model the Rajasthan (2012) State of India for this public interest research due to literature review limitations imposed by a multi-lingual barrier limiting access to documentation and sourcing case precedents similarities to the SA (1996) Constitution.

Rajasthan (2012) was selected on the merits of India (like many EU member states and Israel) recently transitioning to lower EMF radiation power flux density levels to a minimum 1/10th the value of the STEP model and to a LTCEP model.

India's migration from the STEP to the LTCEP model followed deliberations from an in-depth inter-ministerial committee investigation comprised of India's Department of Telecommunications, Biotechnology Council of Medical Research, Ministry of Health, Ministry of Environment and Forest and Ministry of Communications & Information Technology (Government of India, 2010).

India historically followed similar EMF radiation exposure practices to SA (Regulator9, 2015; CCPTM, 2015:47). The inter-ministerial report of the government of India (2010) identified a public interest because of a systemic violation of human rights with 'substances released into the environment' and a 'public safety or environmental risk' (Kgomo, 2012; Practitioner9, 2016).

Like SA the government of India (2010) cited there was "no restriction on the location of cellular towers in India leading to a situation of jumble of towers/antennas all throughout; a 'mushroom growth' of mobile tower infrastructure seen which is contrary to the practice in developed countries" (Rajasthan, 2012:59). The inter-ministerial report of the government of India (2010) found that the STEP model does not address LTCEP model science-based reports of biological effects and concluded that the STEP model reference levels "are insufficiently protective of public health" (Government of India, 2010:29).

As discussed in Section 2.7.3 the CCPTM (2015) policy does not permit a cellular RF-EMF radiation transmitter within 50 meters line-of-sight of a habitable building. A recent Supreme Court ruling in India could present potential implications if the CCPTM (2015) policy is violated. In the Supreme Court ruling invoking the precautionary principle, a 42 year old domestic worker was successfully granted the removal of an illegal cell phone tower following him getting cancer, and classified in the vulnerable population category (Government of India, 2017; Mahapatral, 2017). The residence of employment was within 50 meters of an illegal transmitter. India only recently converted to the LTCEP model, as discussed in Section 2.8. Judicial deliberations are currently underway for civil damages but have not been concluded at the time of this study. The correlation between harmful EMF radiation from the cell phone tower and the complainant's cancer is yet to be proved conclusively; but the court apparently thought that the company's cellular transmitter had so far failed to prove that its EMF radiation is safe, or could not have caused the complainant's cancer, as the burden is upon the cellular to show proof under the precautionary principle (SCOI, 2017).

A more detailed narrative on India's judicial review on EMF radiation protection is contained in Appendix, Section 2.7 (International case precedents for evolved EMF radiation protection in India).

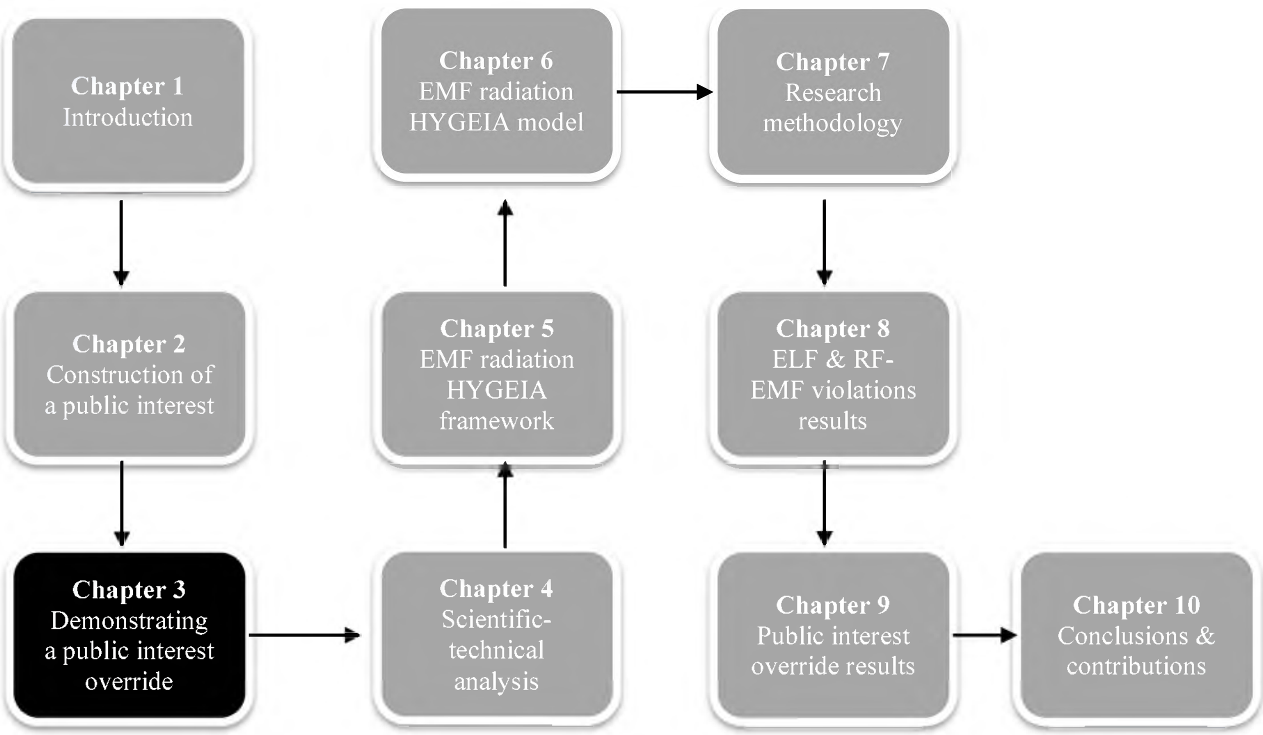
Countries are increasingly and extensively deliberating the *latest* science-based research and the EMF radiation public interest debate globally. Similar to India, High Court orders in Israel and Germany have recently promulgated legislation to enforce the change from the STEP model to the mandate of the LTCEP model as a national EMF radiation protection standard (Government of Italy, 1998; Federal Administrative Court, 2012; Government of India, 2012; Rajasthan, 2012; Weatherall, 2013; French National Assembly, 2015; WHO, 2015a; WHO, 2016c).

For charts and figures see Appendix, Section 2.6 (STEP and LTCEP model endorsement by country population vs GDP).

2.11 Conclusion

This chapter provided an overview of the EMF radiation exposure literature and the construction and deliberation of a public interest, both in SA and internationally. The aim was to identify the need to explore, demonstrate and validate a public interest in respect of EMF radiation exposure in SA (RQ_5). The chapter also looked at the different strategies employed in providing a false sense of safety regarding EMF radiation exposure in an unregulated environment. International High Court deliberations are increasingly ruling in favour of EMF radiation exposure being a public interest and are confirming the recommendation of the LTCEP model as a national standard. The next chapter discusses the SA requirements in demonstrating a PIO in order for this study to potentially influence government policy as part of the practitioner research methodological output.

CHAPTER 3: DEMONSTRATING A PUBLIC INTEREST OVERRIDE REVIEW OF LITERATURE



3.1 Introduction

3.2 Promotion of Access to Information Act of 2000 – Public interest

3.3 When to use PAIA (2000) in gaining access to data for academic research

3.4 PAIA – public interest override function

3.5 PAIA (2000) case precedents

3.6 Application for detailed facts and data needed to accurately model public interest

3.7 Public interest override function checklist

3.8 Conclusion

CHAPTER 3
Demonstrating a public interest override review of literature

3.1 Introduction

The previous chapter discussed the investigation, analysis and construction of a public interest. Access to data is needed, however, to monitor, investigate and regulate EMF radiation exposure. As discussed in Section 1.1 the needed data is denied by industries in SA. This chapter discusses the second proposed framework entity for the study, namely the demonstration of a public interest override (PIO). PIO is a provision in legislation that obligates a private or public body to disclose, without delay, any information about a risk of significant harm to the environment or to the health or safety of the public, a group of people, or a person or if for any other reason, disclosure is clearly in the public interest (NAIT, 2017). Following a favourable PAIA judicial review, academics and practitioners would be granted access to the data needed to monitor and to regulate EMF radiation exposure in SA. The outputs from this chapter are sought to answer the first, third and fifth sub-questions. The first, third and fifth sub-questions were presented in Chapter 1 as follows:

> RQ_1: What should a multidisciplinary entities framework encapsulate to enable modeling of macro EMF radiation sources, considering domestic and international legislation and scientific opinions?

> RQ_3: How should a legislative PIO function be formulated into a quantitative checklist or index to be used in a simulation model?

> RQ_5: How does the model demonstration runs identify potential EMF radiation violations that can be used to substantiate a PIO claim?

The literature review process that is used in this chapter to answer these research questions is presented in various sections in this chapter. Section 3.2 introduces the SA legislation that enables a PIO, Section 3.3 discusses when to use legislation to demonstrate a public interest, Sections 3.4 to 3.5.2 discuss the PIO function and case precedents, Section 3.6 demonstrates why SA public interest legislature is needed to fulfil this study and, finally, Section 3.7 presents the constructed PIO function checklist derived from the literature review in this chapter.

The next section discusses the primary legislation used in the research design for this study in fulfilment of RQ_5.

3.2 Promotion of Access to Information Act of 2000

Promotion of Access to Information (PAIA) is known in practice as the Promotion of Access to Records (Practitioner19). According to the introduction of the SAHRC (2014) PAIA handbook, the purpose of PAIA (2000) is to promote the right of access to information/records to foster a culture of *transparency* and *accountability* in SA. PAIA (2000) is furthermore aimed at encouraging an open democracy where individuals from all walks of life are empowered to engage with government and to participate in decisions that *affect their lives* (SAHRC, 2014). The preamble of the PAIA Act specifically references empowerment by section 32(1) of the SA (1996) Constitution provides that *everyone* has the right of access *to any information* (record) *held by the state*. The italicized parts of the sentence are emphasized by the DoJCD in government training programs on the practice of PAIA (Practitioner19).

The Promotion of Access to Information Act 2 of 2000 (PAIA) is one of the three basic human rights acts in SA. The other are the Promotion of Administrative Justice Act 3 of 2000 (PAJA) and the Promotion of Equality and Prevention of Unfair Discrimination Act 4 of 2000 (PEPUDA).

Section 32 of PAIA (2000) “gives everyone effect to the constitutional right of access to any information held by the State and any information that is held by another person and that is required for the exercise or protection of any rights” and instructs that national legislation must be enacted to give effect to this right (South African Institute of Charted Accountants [SAICA], 2016:1; Practitioner8, 2016).

In basic terms: a citizen is encouraged to exercise that right by applying for information in accordance with PAIA (2000). The chief purpose of PAIA (2000) is to give effect to “the right of access to any information held by a public or private body and bearing in mind that this right may be limited to the extent that the limitations are reasonable and justifiable in an open and democratic society” (Practitioner8, 2016).

A government body or private company is legally obligated to comply with PAIA (2000) in providing the requested information per PAIA’s (2000) procedures and requirements. Mr. Mushwana, the chairperson of the South African Human Rights Commission (SAHRC), explained that “the right of access to information forms an important part of the realization and protection of our SA (1996) Constitutional human rights as well as the promotion of social accountability. This makes it possible to recognize the right to information as a *resource* for everyone rather than for a few privileged who have the *luxury to assert* their rights" (Connor, 2013: 6).

Section 1 of PEPUDA (2000) refers to unfair discrimination by age, especially advanced age, while Section 6 discusses the prevention and general prohibition of unfair discrimination. As discussed in the previous chapter, recent international High Court rulings and other legislative bodies deliberated extensively on inter-ministerial reports and the most current science-based research. The STEP model recognizes thermal heating as a health concern for only a *single category member* of the population. The STEP model EMF radiation reference level was based on the anthropometric measurements of a *single healthy* normal-build *adult* male (phantom) and *normal* temperature regulation capacities to *represent* the general public in free space (non-real world conditions) (Giuliani, 2002). The conclusion was that the STEP model does not guarantee adequate protection against long-term EMF radiation exposure. The STEP model *does not* mandate safety measures by *age, health or intolerance* to EMF radiation. For example, children are more vulnerable than adults, and those with neuro-developmental disabilities are even more so (ASA, 2004; Dimbylow & Bolch, 2007; WHO, 2009; RNCNIRP, 2011; Herbert et al., 2012; Nikolopoulos et al., 2015). The public interest of health for all members of the population (equality) overrides industries' strategic economic interests. As a result of the rulings, certain countries disbanded the STEP model and adopted the LTCEP model for EMF radiation exposure protection (discussed in Section 2.10).

PAIA (2000) can be an extremely useful tool in gaining access to information with the goal of identifying a public interest and/or to monitor whether public or private bodies that provide products or services to the public are conducted within the public's best interest. Below is a review of how PAIA (2000) can be utilized in accomplishing this research's goals:

- Section 3.3: When to use PAIA (2000) in gaining access to data for academic research;
- Section 3.4: The PAIA (2000) PIO function;
- Section 3.5: PAIA (2000) case precedents;
- Section 3.6: Why PAIA (2000) is needed for this research and how it is applied internationally;
- Section 3.7: Construction of a PAIA (2000) PIO checklist.

3.3 When to use PAIA (2000) in gaining access to data for academic research

In terms of PAIA (2000) per the Department of Justice and Constitutional Development (DJCD) (2016):

- Section 5: Application of other legislation prohibiting or restricting disclosure.
  - PAIA applies to the exclusion of any provision of other legislation that prohibits or restricts the disclosure of a record of a public body or private body and is materially inconsistent with an object, or a specific provision, of PAIA.
- Section 6: Application of other legislation providing for access.
  - Nothing in PAIA prevents the giving of access to a record of
    - (a) A public body; or
    - (b) A private body in terms of any legislation referred to in Parts 1 or 2 of the schedule.

According to the Practitioner8 (2016), PAIA (2000) is to/will be used as and when necessary and when requests for access via other channels fails. In other words, when the academic researcher requests access to the public interest research data from company 'A', company 'A' may comply by giving access, or they may refuse. In the event of company 'A' refusing, the researcher would lodge a PAIA (2000) request to company 'A'. The request must include a full motivation and must also state which right it is that the researcher wishes to protect or exercise. If still refused, the researcher may lodge an application to the court for relief. The same principle similarly applies to public bodies, except that the researcher need not submit reasons why he/she wishes to have access to the record(s) (Connor, 2013).

Practitioner8 (2016) disclaimed that access to records is not an absolute right but merely a relative right and that the researcher may be refused access to the records requested in accordance with the grounds for refusal as set out in Chapter 4 of the PAIA (2000).

3.4 PAIA – PIO function

Section 46 (public bodies) and section 70 (private bodies) of PAIA (2000) explained in De Lange and another v Eskom Holdings Limited (2012:54), "has been promulgated specifically to serve or act as a mandatory PIO provision where one or more grounds of refusal have been established. The section's requirements are mandatory: where access to a record is denied under section 36(1)(b) or (c) or section 37(1)(a), an information officer must nonetheless grant access to the record if it is in the public interest to do so". PAIA (2000) is about weighing the respective rights of the individual, company and SA (1996) Constitution.

The information holder may refuse to provide the required information but then needs to display supported warrants by providing simulated model outcomes (RQ_4) and evidence on how sharing the information may harm their commercial interests (RQ_5) in outweighing the PIO function from the requestor.

In an EMF radiation public interest model (RQ_4), the requested information is synthesized within a systems model to forecast ecosystem services and human-use dynamics under alternative scenarios (RQ_5) (Boumans et al, 2015). The public interest model could be calculated for both parties. Below are a review of PAIA's (2000) PIO function criteria test and a means of gaining pertinent information for further studies based on this dissertation (RQ_5).

Connor (2013:41) and Kgomo (2012) in De Lange and another v Eskom Holdings Limited (2012) explain that PAIA (2000) provides that, even where grounds for refusing access to a record exist, the public interest is paramount in certain information. Accordingly, where the PIO test, concerning PAIA (2000), is satisfied, the record must be released, irrespective of an applicable mandatory or discretionary ground for refusal. The test has two parts. Firstly, it needs to be established that the disclosure of the record would reveal evidence of either:

1. A substantial contravention of, or failure to comply with the law (for example, regulations not being implemented, corruption); or
2. An imminent and serious public safety or environmental risk (for example, EMF radiation exposure hazard conditions that may go unchecked).

A 'public safety or environmental risk' is defined to mean harm or risk to the environment or the public (including individuals in their workplace) associated with:

3. A product or service which is available to the public;
4. A substance released into the environment, including the workplace;
5. A substance intended for human or animal consumption;
6. A means of public transport; or
7. An installation or manufacturing process or substance which is used in that installation or process.

Secondly, after establishing that the records contain one of those two categories of information, it must be established that the public interest in the disclosure of the record clearly outweighs the harm contemplated in the relevant ground for refusal (RQ_5).

In The Centre for Social Accountability versus the Secretary of Parliament and others [CfSAvSPo], the Eastern Cape High Court defined the metric thresholds (RQ_5) that must be met in establishing that the record would reveal evidence of either a substantial contravention of, or failure to comply with, the law or an imminent and serious public safety or environmental risk (Connor, 2013). In the CfSAvSPo matter, failure to observe the code of conduct required from members of parliament, on a 'balance of probability' constitute a substantial contravention of, or failure to comply with, the law (CfSAvSPo, 2010). Interestingly in CfSAvSPo (2010) it was ruled the words 'substantial' and 'would' in section 46 (a) do not require any heavier onus than the accepted standards of civil procedure. Thereby, a contravention or failure can be either a minor or substantial breach. Therefore, it is simplified to a contravention or failure.

The CfSAvSPo (2010) ruling held that the applicant must show 'on the balance of probabilities' that the disclosure of the record would reveal the required contravention, failure or *risk* (RQ_5). This means that all interested parties have to be given access and opportunity to submit their cases to 'the balance of probabilities' test before any decision is made (Odeku, 2014). For example: EMFDS12 (2012), EMFDS14 (2012), EMFDS13 (2012), EMFDS4 (2012) and EMFDS3 (2012) refused to provide any information regarding the location of their transmission sites as there is, from their perspective, no violation of PIO per the STEP model. However, as discussed in Section 2.4, the STEP model disclaimed "not to be a mandatory prescription for safety" and "not a defensive wall for industry and others" (Vecchia, 2008:28). CfSAvSPo (2010) affirmed requested information cannot be in the public interest unless the information embraces the legitimate expectations of society. Thereby, if society expects a regulated EMF emissions environment, and to be safe from potential EMF radiation biological effects classified in the LTCEP model, then EMF radiation emissions levels are a public interest. Therefore, the public interest which triggers the PIO in section 46 (b) should therefore be interpreted to accord with the test of society's legitimate expectation as to when and under what circumstances private information protected by the right to privacy loses its constitutional protection under section 14 of the SA (1996) Constitution (CfSAvSPo, 2010). The public interest legitimate expectation test, embrace all those interests necessary for a structured and orderly society. Therefore, the public interest test is to be assessed in accordance with the principle of legitimate expectation (CfSAvSPo, 2010).

This dissertation needed to review the literature and research methodology in identifying potential public interest violations in terms of the STEP and LTCEP models in gaining access to the required data for this dissertation to address the private telecommunications companies' claims and model different expectations of societies within SA.

The researcher chose to review and model this dissertation's (RQ_3) on De Lange and another v Eskom Holdings Limited (2012) in its PIO qualification, because this case precedent held merits similar to those identified for the needs of the study.

3.5 PAIA (2000) case precedents

The purpose of the next two subsections is to demonstrate to the reader examples of domestic PAIA case law used to guide the construction of the framework in Chapter 5. Additionally, the case law has implications to this study.

3.5.1 De Lange and another v Eskom Holdings Limited

In Judge Kgomo's (2012) ruling in De Lange and another v Eskom Holdings Limited and others (2012), the South Gauteng High Court granted access to records revealing contracts for the supply of electricity between Eskom and BHP Billiton that it found would otherwise have been exempted under PAIA (2000) Section 36(1)(c) (commercial information) based on the PIO function.

The High Court found that the records would reveal evidence of an imminent and serious public safety or environmental risk, because the unavailability of an electricity supply would lead to the use of unhealthy power supplies, such as coal-fired stoves or braziers in households, with obvious environmental and health dangers that may result in death from smoke or gas fumes or lung diseases that will increase pressure on health care facilities (Connor, 2013).

Kgomo (2012) indirectly invoked the precautionary principle (NEMA, 1998) to avoid potential broad public health and economic implications. The precautionary principle brings foresight and transparency to situations with high stakes (Ramazzini Institute, 2010). It re-invigorates the public health tradition requiring that we do no harm (Section 2.7). While precautionary actions can be reversible, failure to take precautionary action may cause irreversible harm (Ramazzini Institute, 2010).

The court held that the information in the records, therefore, fell into the category of 'substances released into the environment' within the definition of 'public safety or environmental risk'. The court further held that a short supply of electricity may incapacitate rail or commuter services resulting in harm to the economy, job losses and strike action, all of which may lead to serious public safety or environmental risks that were relatively imminent (Connor, 2013: 41).

In reviewing the above criteria examined in Kgomo's (2012) ruling, it appears that SA includes social accounting in its environmental economic policies, thus being in line with the LTCEP model.

3.5.2 Academic public interest override

The Stellenbosch University (SU) ethics handbook explains PAIA (2000) as the exercised right in gaining access to "information that is considered to be in the public's best interest or in the interest of the 'common good" (Horn et al., 2015:19).

Referenced in Horn et al., (2015:20), for example, is the case precedent of SU researchers in 2013 that "published the results of DNA analysis research indicating that meat products bought at various supermarkets in South Africa contained products and meat from animals (e.g. horse, water buffalo) that were not declared on the label."

A consumer protection organization launched a formal petition requiring that SU discloses the identities of the stores where the meat samples had been purchased so that these stores could be publicly named. In accordance with PAIA (2000), SU was compelled to comply with this request.

3.6 Application for detailed facts and data needed to accurately model public interest

The formulation of a public interest model requires that decisions and communication activities must be based on *facts* and *data* (European Environment Agency, 2009; Ramazzini Institute, 2010; Boumans et al., 2011; Boumans et al., 2015). Public interest represented in a model is not a series of assignment and control statements, but rather a set of facts that are true regarding the subject of the model (Boumans and McNally, 2011).

The reported biological effects of EMF radiation are based on very specific data and facts. Although individual variability was observed, for example, biological effects from RF-EMF radiation from mobile phones is strongly dependent on the frequency and communication channel (Belyaev et al., 2016). EMF radiation provocation studies found consistently lower DNA repair at the 905 MHz GMS channel 74 to 915 MHz GMS channel 124, whilst stronger effects of RF-EMF radiation exposure were found at the 1946.4 MHz UMTS channel. The evidence from provocation studies revealed that detailed data required on EMF radiation exposure from different types of technology sources is to be modelled separately and should then be combined in conducting demonstration runs of hazard condition scenarios (Boumans et al., 2015; Belyaev et al., 2016).

In Odeku's (2014) review, there are three branches in the access to information:

1. The SA (1996) Constitution allows unhindered access to government and government agency's information;
2. PAIA (2000) promotes unhindered access to information for purposes of knowing what is right and what is wrong;
3. NEMA (1998) is closely linked to PAIA (2000) regarding ample access to information within a demonstrated public interest of "substances released into the environment".

In Brits et al. (2014), for example, NEMA (1998) categorizes information on pollution and waste products from industry to be public, never private, information and, under PAIA (2000), a company cannot refuse to provide information unless it would harm the alleged polluter's commercial interests (Odeku, 2014).

International trends reveal that the release of the location and technical specification of cellular ARD transmitters to the public domain did not jeopardize the commercial interests of private telecommunications in meeting the public interest (Stewart, 2000:115; Deloitte and GSMA, 2012; Belyaev et al., 2016; GSMA, 2016; CTIA v City of Berkeley, 2017).

Gaining access to EMF radiation infrastructures' technical specifications and operation log files is essential to addressing EMF radiation regulatory concerns in SA. SA regulatory bodies report being faced with alleged resource constraints and input data requirements for computer-simulated modelling for the mapping of potential EMF radiation high-exposure groups (WHO, 2011; Regulator8, 2016b; Regulator4, 2016). Access to technical specifications and emissions data can enable monitoring and the enforcement of either short or long term environmental and public harm caused by exposure to this EMF radiation that may otherwise go unchecked (Commission on the European Communities, 2008; Government of India, 2010; WHO, 2011). For example, Bürgi et al. (2017) developed a valid reliable and cost-effective 3D modelling ELF-EMF exposure assessment system. The system has been verified and approved by the Swiss government (Bürgi et al., 2017).

As result of a study conducted by the Independent Expert Group on Mobile Phones (Great Britain) and Stewart (2000), also known as the Stewart Report, access to cellular RF-EMF infrastructure data was set up through a UK National Registry of base stations as a first requirement for reliable and openly available information regarding the location and operating characteristics of base stations. The Stewart Report (2000) furthermore motivated that public access to data would be useful when applications for new cellular ARD transmitters were being considered and would also be of value in potential epidemiological studies. USA, Australia, Greece, Belgium, India, France, Israel, UK, New Zealand and Germany (WHO, 2012; WHO, 2014; WHO, 2015a) are examples of countries that have headed the Stewart Report (2000) advisement.

The Stewart Report (2000:115) made the following recommendations in establishing a national RF-EMF database set up by the government, providing details of all base stations and their emissions, namely: each site should list the name of the operating company; the grid reference; the height of the antenna above ground level; the date that transmission started; the frequency range and signal characteristics of transmission; the transmitter power and the maximum power output under the respective Telecommunications Act. Moreover, this information should be accessible readily to the public and should be held in such a form that it would be easy to identify, for example, all base stations within a defined geographical area and those belonging to a specified operator.

In SA, under the Telecommunications Act (2000), the setting up of a national database registry should be feasible, given that the Telecommunications Act (2000) mandates license applicants to submit their technical specifications per site in detail to the national regulator Regulator9. Regulator9 (2015), however, confirms public interest failure (CfSAvSPo, 2010) by not having the detailed RF-EMF radiation infrastructure technical specifications mandated by the Telecommunications Act (2000) and has *only* the GPS coordinates of cellular ARD transmitter sites, but are unwilling to display it to the public due to confidentiality agreements with particular private telecommunication companies.

A potential reason for the lack of compliance identified in Regulator9 (2015), as explained by Regulator10 (2016), Regulator7 (2016), Regulator4 (2016), Regulator2 (2016), CCPTM PDM (2014, 2016a, 2016b) from the EMFDS9, may be that telecommunications companies *refuse* to provide the technical specification and EMF radiation emissions information for their sites.

Another potential means of gaining access to data is through public participation. In studies by Maret (2015) and Sagar et al., (2016) placed an EMF radiation spectrum analyser dosimeter on a person. This method is valuable in analysis studies to measure and monitor real world scenarios and cumulative EMF radiation exposures, from both macro and micro sources, for a single person in his/her daily life. The Maret (2015) LTCEP model endorsing study identified findings that are different to public safety perceptions:

1. RF-EMF radiation measurements of Wi-Fi in the school investigated displayed substantially higher RF-EMF radiation exposure levels than in a public Wi-Fi coffee shop. Sagar et al., (2016) also found high variability between different microenvironments from the same activity type.
2. The cumulative RF-EMF radiation exposure levels in the school exceed daily EMF radiation exposure safety recommendations, according to benchmarked LTCEP model referenced in the study.

After reviewing the different approaches, the study identified Israel's WHO (2013) approach of using a continuous EMF radiation monitoring system as the most accurate and resource feasible solution to EMF radiation monitoring. The continuous EMF radiation monitoring system receives the technical installation specifications and live-log operational files of EMF radiation infrastructures, identifying violations and emissions levels. With the development of advanced 3D GIS analysis and the availability of anthroposphere data models, reliable simulation models can be carried out in tracking EMF radiation propagation, re-radiation and localized hotspots.

3.7 Public interest override function checklist

The defining parameters for public interest of 'substances released into the environment' and 'public safety' or 'environmental risk' as per PAIA (2000) judicial review rulings were extracted and compiled into a checklist (RQ_3) available in the Appendix, Section 3.1 (PAIA (2000) PIO checklist). The application of the constructed checklist is demonstrated in Chapter 9.

A key deliverable for this public interest research (RQ_5) is that the literature review and research findings demonstrate a PIO on the 'balance of probabilities'.

The 'balance of probabilities' in PAIA (2000) operates on a social accounting and not market driven scale (WHO, 1999; Dämvik & Johansson, 2010; Kgomo, 2010). According to NEMA (1998) Section 2(4)(a)(ii) case law it is a necessary condition, even in the case of scientific conflict/debate, for this section to be invoked (Dämvik & Johansson, 2010). Therefore, no high levels of proof are demanded by NEMA (1998) Section 2(4)(a)(ii) for a risk indicator to justify extensive measures (Dämvik & Johansson, 2010). Even in a very high level of scientific uncertainty, a risk assessment can be based on a result of a theoretical hypothesis as a minimum 'balance of probabilities' requirement (Dämvik & Johansson, 2010; CfSAvSPo, 2010; Horn et al., 2015:19).

Case law provides examples of the minimum set requirement (metric) of scientific evidence that leads to the application of NEMA (1998) Section 2(4)(a)(ii). Additionally, case law provides guidance on how far the scientific risk assessment must be maintained in cases in which the scientific uncertainty is substantial.

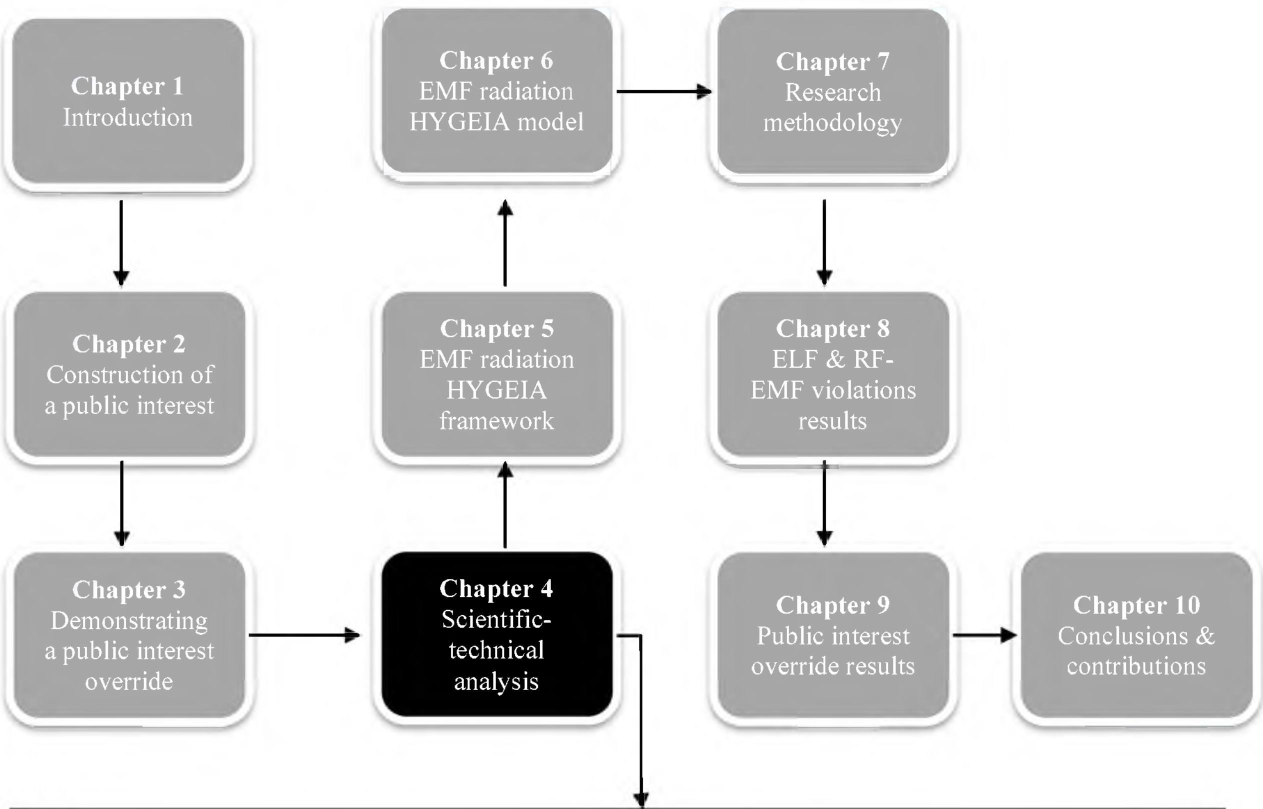
The Pfizer case indicated that the findings in a single study may be sufficient proof. An observation that concerns only one individual was regarded as a sufficient indication of risk, thereby supporting the invoked application of the NEMA (1998) Section 2(4)(a)(ii) measures (Dämvik & Johansson, 2010). The observed concerns of a single individual are recognized within different regulatory departments of the CCPTM (Regulator4, 2016; Regulator6, 2016; Regulator5, 2016; Regulator2, 2016).

A fulfilled PIO function checklist may enable a successful outcome in a judicial review process to attain EMF radiation data for public interest modelling. This literature review has identified potential EMF radiation protection violations per PAIA (2000) PIO function. The identified potential violations will remain potential until they are presented in a SA court of appropriate jurisdiction where the reported violations can be examined and confirmed, or discarded, through a judicial review process.

3.8 Conclusion

This chapter provided an overview of SA legislation that enables the argument for and demonstration of a PIO. The demonstration of a PIO following judicial review enables unrestricted access to data needed for future related studies. The chapter constructed and presented a PIO Checklist (Appendix, Section 3.1) to be used and demonstrated in Chapter 9 (fused findings). The inherent issue with PAIA (2000) in demonstrating a PIO, however, is the empirical and subjective context required in its deliberation during a judicial review process. The next chapter discusses the application of scientific-technical analysis as a means of addressing the inherent weakness discussed in this chapter and to enable the scientific modelling of an EMF radiation public interest case for this study.

CHAPTER 4: SCIENTIFIC-TECHNICAL ANALYSIS REVIEW OF LITERATURE



4.1 Introduction
4.2 Climate change framework
4.3 MIMES framework
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CHAPTER 4
Scientific-technical analysis review of literature

4.1 Introduction

This is the final chapter of the literature review in this study. The previous chapter discussed and presented the construction of a PIO checklist in partial fulfilment of RQ_3. The constructed checklist in the previous chapter inherited an empirical issue in using the systematic content analysis methodology; thereby lacking scientific metrics in adding credibility. Enhancing the checklist from the previous chapter, using the scientific-technical analysis, may enhance the demonstration of a public interest as discussed in Chapter 2. Introducing quantitative scientific metrics, instead of relying on the subjective interpretation of the judicial reviewer, may add objective credibility to this study.

The demonstration of a PIO is dependent on a subjective view point on the 'balance of probabilities' as discussed in the previous chapter. Outputs from the literature review in the previous two (2) chapters, in conjunction with practitioners (Chapter 7), indicate that a subjective view to a problem space in judicial deliberations could result in a weighted outcome and thereby be detrimental to the public as a result of practitioner social practices (discussed in Chapter 2).

The establishment of accurate exposure estimates for the investigated areas in SA is critical in demonstrating a PIO on the 'balance of probabilities', as discussed in Chapter 3 (RQ5). The application of scientific-technical analysis to the 'balance of probabilities' is necessary to address accusations by either STEP, or LTCEP model endorsers, spreading speculative public health concerns toward EMF radiation exposure (DHSA, 2016c). Dürrenberger et al. (2014) identified that the lack of EMF radiation monitoring data creates, even among experts, quite unrealistic perceptions about the EMF radiation exposure of the population.

The 'balance of probabilities' requires weighing the benefits and losses from both parties' arguments. The application of a scientific-technical analysis could provide a more reliable quantitative metric to arguments and to the evaluation of a PIO function, as discussed in the previous chapter. A scientific-technical analysis uses instruments to enable the forecast modelling of potential scenarios based on facts and data that may aid policy makers in judicial deliberation. In fulfilment of RQ_4, EMF radiation exposure modelling forecast scenarios may aid policy makers to develop a regulatory EMF radiation exposure standard that will balance public health concerns with controlling levels of exposure, while remaining a digital economy.

The purpose of this section is to prepare the reader to understand the intentions in this chapter and the problem statement. It is therefore necessary to briefly identify and clarify the meaning of key concepts, contexts and framework entities used in the current and following chapters.

Technical analysis is a methodology for forecasting the direction of a social/market influential variable through the study of past environmental data. This is done primarily with a few other selective ecosystem service variables that influence change in the domain of interest (Kirkpatrick & Dahlquist, 2006:3). One of the problems with conventional technical analysis has been the difficulty in specifying patterns in a manner that permits objective testing (Caginalp & Balevonich, 2003). The difficulty in objective testing arises because technical analysis lends to a random order; hence the need for non-linear statistical analysis. Scientific-technical analysis, on the other hand, uses a system theory asset-flow of a differential equations model to show that the major patterns of technical analysis could be generated with some basic assumptions (Caginalp & Balevonich, 2003). Some of the patterns, such as a triangle continuation or reversal pattern, can be generated with the assumption of two distinct scientific groups of paradigms (STEP and LTECP) with different assessments of valuation on the values risk threshold limits to EMF radiation exposure (Caginalp & Balevonich, 2003). The goal of scientific-technical analysis is to establish a principled classification of the possible patterns characterizing the deviation or defects from the random occurrence in the real world and its time translational invariant properties (UNEP, 1995; Anderson et al., 2000; Caginalp & Balevonich, 2003; Kirkpatrick & Dahlquist, 2006:3).

A scientific-technical analysis in this research is scoped to the impacts, adaptations and adaptation/mitigation of EMF radiation exposure. The goal of this chapter is to review the state of knowledge concerning the effects of EMF radiation exposure as a climate change variable on physical and ecological systems, human health and socio-economic sectors (Intergovernmental Panel on Climate Change [IPCC], 1995).

As discussed in Chapter 1, both the magnitude and the rate of the EMF radiation as a climate change variable are important in determining the sensitivity, adaptability and vulnerability of population groups within a system (GRID-Arendal, 1995). Although much progress has been made, there are large uncertainties in predicting regional EMF radiation health impact changes, future conditions in the absence of regulation and to what degree unregulated EMF radiation exposure will become more variable. All these factors are important in predicting the potential impact of unregulated EMF radiation exposure on the population (GRID-Arendal, 1995).

The scientific-technical analysis methodology requires reviewing available information on the technical and economic feasibility of a range of potential adaptation and mitigation strategies related to the problem space on unregulated EMF radiation exposure in SA. In fulfilment of RQ_4 and RQ_5, this assessment provides scientific, technical and economic information that can be used, inter alia, in evaluating whether the projected range of plausible effects constitutes "dangerous anthropogenic interference with the climate system…" as referred to in Article 2 of the United Nations Framework Convention on Climate Change (UNFCCC), and in evaluating adaptation and mitigation options that could be used in progressing towards the ultimate objective of the UNFCCC (IPCC, 1995:1).

Human health, terrestrial and aquatic ecological systems as well as socio-economic systems, are all vital to human development and wellbeing and are all sensitive to changes in the anthroposphere emissions' variable EMF radiation. Whilst regions with unregulated EMF radiation exposure are likely to experience the adverse biological effects of EMF radiation exposure - some of which are potentially irreversible - some effects of regulated EMF radiation infrastructure expansion are likely to be beneficial. Hence, different segments of society can expect to confront a variety of changes and will need to adapt thereto (IPCC, 1995; Rajasthan, 2012).

Policymakers are faced with responding to the risks posed by anthropogenic emissions of EMF radiation in the face of significant argumentative scientific uncertainties between STEP and LTCEP model endorsers. Delaying action in an unregulated EMF radiation environment might reduce the overall costs of mitigation because of potential technological advances, but could increase both the rate and the eventual magnitude of climate change (RQ_4), hence the adaptation and damage costs (IPCC, 1995; Boumans et al., 2015; NTP, 2016).

Policymakers will have to decide to what degree they want to take measures by mitigating and regulating EMF radiation emissions and by enhancing the resilience of vulnerable population groups by means of adaptation (RQ_5). Uncertainty does not mean that a nation, or the world community, cannot position itself better to cope with the broad range of possible EMF radiation exposure scenarios or to protect itself against potentially costly future outcomes (IPCC, 1995; Boumans et al., 2015; NTP, 2016). To delay such measures may leave a nation poorly prepared to deal with adverse changes and may increase the possibility of irreversible or very costly consequences (Government of India, 2010; IPCC, 2015; NTP, 2016). Options for adapting to change or for mitigating change that can be justified for other reasons (e.g., abatement of air and water pollution) and that can make society more flexible or resilient to anticipated adverse effects of EMF radiation exposure, appear particularly desirable (RQ_5).

A review of the literature from multiple disciplines was used in the development of an EMF radiation HYGEIA framework, and model. The EMF radiation HYGEIA model may aid policy makers to develop and decide on the type and definition of restrictions in regulating EMF radiation exposure for SA.

Answers to the first, second and forth sub-questions will be sought in this chapter. The first, second and forth sub-questions were presented in Chapter 1 as follows:

> RQ_1: What should a multidisciplinary entities framework encapsulate to enable modeling of macro EMF radiation sources, considering domestic and international legislation and scientific opinions?
>
> RQ_2: How should a proposed framework construct a public interest EMF radiation model and can it be used to construct public health forecast simulations in a designated area?
>
> RQ_4: What are the simulation outputs when using the EMF radiation model?

The literature review process used in this chapter to answer these research questions is presented in various sections in this chapter. In Section 4.2 the revered climate change framework is presented; in Section 4.3 the MIMES framework, an IS capable of encapsulating model libraries from multiple disciplines for public interest research and in Section 4.5 the HYGEIA model, a public health model that focuses on prevention in the context of public interest, are presented. Sections 4.6 to 4.14.4 explore the EMF radiation exposure domain and the manners in which it could be encapsulated into a public interest framework and health forecast model.

This is the longest chapter of the three (3) because the problem space of EMF radiation exposure is a multidisciplinary issue and therefore requires drawing on tools and literature from multiple domains to prepare the reader for the rest of the study. The next section discusses the climate change framework.

4.2 Climate change framework

The potential impact of climate change on the environment and socio-economic systems, as introduced in the previous section and defined by the United Nations Environmental Program (UNEP), can be understood using scientific-technical analysis in terms of sensitivity, adaptability and vulnerability of the system (GRID-Arendal, 1995; IPCC, 1995). A scientific-technical analysis categorises EMF radiation as an air pollutant (Singh, 2017).

Article 2 of the UNFCCC explicitly acknowledges the importance of natural ecosystems, food production and sustainable economic development (IPCC, 1995). This section addresses the potential sensitivity, adaptability and vulnerability of ecological human health and socio-economic systems in respect of EMF radiation emissions from infrastructure sources.

The climate change framework is revered as a science-based modeling and implementation framework increasingly implemented by domestic and international authorities (United Nations Framework Convention on Climate Change [UNFCC], 2014). Climate change is the study of the effects of the anthroposphere on ecosystem services (Boumans et al., 2015). Ecosystem services are divided into four (4) broad categories:

1. Provisioning, such as the production of food and water;
2. Regulating, such as the control of climate and disease;
3. Supporting, such as nutrient cycles and crop pollination; and
4. Cultural, such as spiritual and recreational benefits assessment (Boumans et al., 2015).

Ecosystem services are assigned economic values to assist decision makers in the design and implementation of appropriate environmental and population development policies (RQ_4) (Boumans et al., 2015).

With reference to Chapter 2, case law precedent in both STEP and LTCEP endorsing countries has enabled the youth and citizens in taking legislative action against and in suing the national president, industry, and other government agencies violating their constitutional rights by declining to act against climate change impactors (RQ_5) (Griggs, 2015; Emerson, 2016).

The study sought what model outputs are needed from RQ_4, based on health exposure functions for climate change and health agencies, in fulfilment of RQ_5. This study uses the climate change framework scientific-technical analysis, sourced from climate change case law in Chapter 2, in classifying potential EMF radiation exposure vulnerable areas in public health modeling. From a health agency example, the WHO defines an EMF radiation-related health hazard as a biological effect that has health consequences outside the compensation mechanisms of the human body and that is detrimental to health or well-being (WHO, 2006a). The climate change framework scientific-technical analysis for compensation mechanisms is defined as follows:

1. Sensitivity: the degree to which a system will respond to a change in climate variable condition, including the extent of change in ecosystem composition, structure and functioning.
2. Adaptability: the degree to which adjustments are possible in practices, processes, or structures of systems to projected or actual changes of climate. Adaptation can be spontaneous or planned and can be carried out in response to or in anticipation of changes.
3. Vulnerability: the extent to which climate change may damage or harm a system. This depends on a system's sensitivity and ability to *adapt* to new climatic conditions.

Both the magnitude and the rate of EMF radiation exposure are important in determining the sensitivity, adaptability and vulnerability of a system (GRID-Arendal, 1996; OCCRI, 2010; Boumans et al., 2015).

The most vulnerable systems are those with the greatest sensitivity to climate changes and the least adaptability (IPCC, 1995). Classifications of the population that exhibit sensitivity to EMF radiation, for example, have a level of biological organization that is less efficient to compensatory reaction (adaptability) (Belyaev et al., 2016). Prolonged duration, intensity of sensitivity and inefficient adaptability lead to a classification of vulnerability (Yu, 1998; Foster, 2001). For example, everyone is electrosensitive. Electrosensitive is anyone who has any biological response to exposure to EMF, including natural occurring EMF, i.e., solar EMF (Redmayne, 2017). Depending on exposure and adaptability, each population category has a different vulnerability threshold (Perov et al., 2009).

Climate change concerns have become of particular public interest with the rising pollutant emissions resulting from the ubiquity of ELF and RF-EMF radiation sources (Yu, 1998; Suzuki, 2014; Hedendahl et al., 2015, WHO, 2016c). Wireless RF-EMF radiation related communication technologies can result in near-constant exposure to low/high levels and localized hotspots of EMF radiation close to the source (NMBM, 2011; KM, 2012; Suzuki, 2014; DHSA, 2016c; Belyaev et al., 2016; Regulator4, 2016). A survey of RF-EMF radiation measurement campaigns demonstrated that the EMF radiation exposure level in the anthroposhere is continuously increasing (Gajšek et al., 2015; WHO, 2015b; Schoeni et al., 2016).

Associated speculations are that EMF radiation can act as a promoter or co-promotor of adverse health effects such as neurodegenerative diseases and cancer (Wrensch et al., 1993; Holmberg, 1995; Gherardini et al., 2014). Expressed EMF radiation concerns by the public and scientists endorsing the LTCEP model are based on the premise that low-intensity EMF radiation is initially tolerable and manageable, but that the cumulative effect of radiation exposure and the friction of adaptability of the human system in a life-long term, could be destructive (Yu, 1998; Foster, 2001; WHO, 2006a; Levvit & Lai, 2010). Scientists have been developing modeling tools to help track and forecast the degree of climate change in accordance with the different climate change framework scientific-technical analysis for decades (GRID-Arendal, 1996; UNFCC, 2014).

The next section discusses the MIMES framework; a framework and tool contained within the climate change framework that have been used by academics and practitioners. One of the contributions in this study is the foundation of a practitioner research methodological output as discussed in Section 1.3. Employing the MIMES framework in this study has value to achieving its aim.

4.3 MIMES (multi scale integrated models of ecosystem services) framework

The MIMES framework and model libraries are rooted in systems theory and are the applications of the interdisciplinary science of coupled human and natural systems (CHANS). CHANS science seeks to understand the connections, feedbacks, and trajectories that occur as a result of the natural and human system processes and exchanges, shown in Figure 4.1. An important goal of CHANS science is to uncover the current and future limits of natural system functions to support human wellbeing needs (food, freshwater, economic opportunities) and to explore the tradeoffs (benefits and losses) associated with alternative futures (Gopal et al, 2016).

The MIMES framework illuminates not only market values but also functional and social values (RQ_4 & RQ_5) (Boumans and McNally, 2011; Boumans et al., 2015).

The MIMES framework is an IS application chosen for three critical features, useful for addressing ecosystem services at multiple scales:

(1) The MIMES framework approach can engage a wide diversity of collaborators and experts (practitioners listed in Section 1.4) across multiple disciplines, including those more knowledgeable in disciplines of ecology, economics, mathematics, biostatistics, medicine, physics and modelling;
(2) Online resources allow EMF radiation investigators from around the world to work collaboratively within the MIMES framework application;
(3) Boumans et al. (2015) reports how expert groups have achieved to work on related problem rationales to account for knowledge and policy developments within the different discipline domains.

The primary MIMES framework structure includes the percentage of the earth's surface at each location that is in each of eleven basic surface-use types, shown in Figure 4.1 (Boumans et al., 2015). Multiple interconnected locations arranged as either a regular grid, or polygons within a GIS, represent spatial patterns of the system under investigation.

The ecosystem service of the anthroposphere (red block in Figure 4.1) was scoped as the focus for the study. The spatial resolution of the MIMES framework IS application can be varied for specific analysis of EMF radiation modeling applications in both macro (EMF infrastructures) and micro (personal use and close-quarters) environments (Boumans et al., 2011; Boumans et al., 2015).

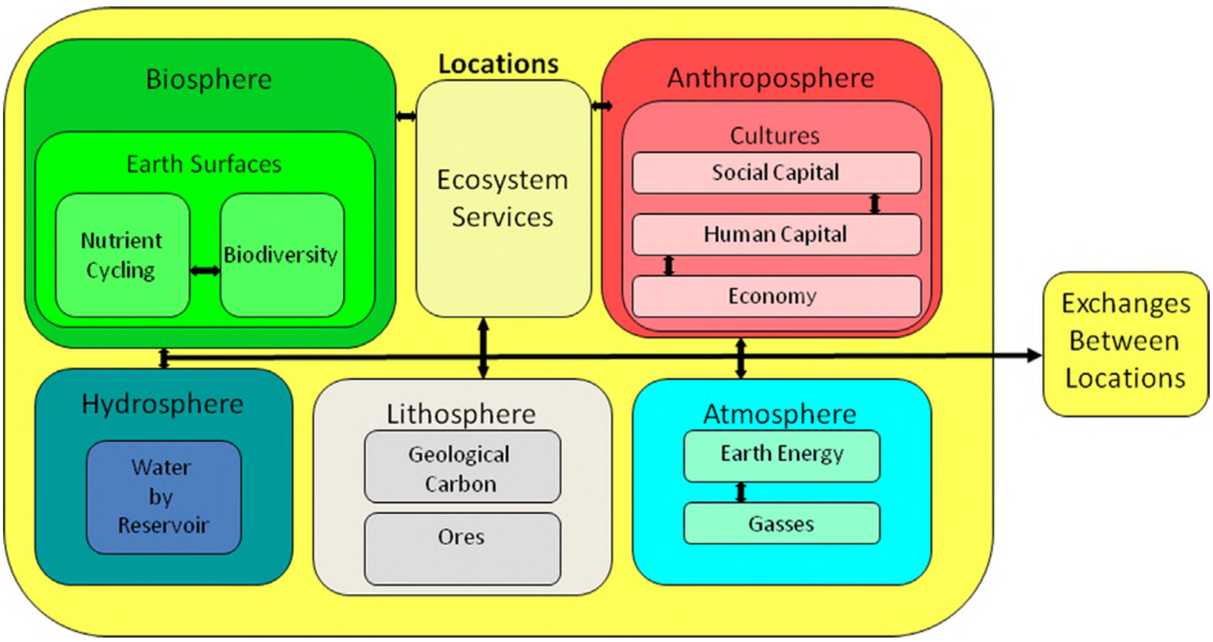


Figure 4.1 MIMES 11 basic surface types (Boumans et al., 2015)

The analysis depth and scope of the MIMES framework toward a public interest model, shown in Table 4.1, is categorised into four (4) tiers. The data to be collected and assessed in the study is only limited to spatial related data (Tier 1) and some time series (temporal) data in Tier 2. Tiers 3-4 in Table 4.1 are out of the scope of the study (highlighted in red).

Table 4.1 MIMES 4 tiers of analysis (Boumans and McNally, 2011)

Tier	Tool	Methods & data	Space/Time	Application	Decision maker?
1	ESV (ecosystem service valuation)	GIS data; benefit transfer	Space	EE valuations	NGOs; consultants
2	Land use change simulations + ESV	GIS data; time series; benefit transfer	Space + time	World model	NGOs, municipalities; spatial planners; resource managers
3	Land use change ecosystem production functions + ESV	GIS data; biophysical models	Space + time	MOP	Industry; resource managers; national agencies.
4	Future steps	GIS data; biophysical models Input-Output economic models	Space + time	Complete accounting	national level of govt;

The MIMES framework utilizes 'declarative modeling' (algorithm development) because it represents a model, not a series of assignment and control statements, but a set of facts that are true regarding the subject of the model (Boumans & McNally, 2011).

An advantage of the 'declarative modeling' approach is that it requires the researcher to focus on the context of the public interest research and data, instead of getting caught up in the software and procedural line programming issues. Boumans & McNally (2011) recommend using the information system modelling software SIMILE (system dynamics and object-based modelling and simulation software) for all four (4) tiers of MIMES modelling because it can handle multi-dimensional arrays of time and space, (X, Y, Z, M co-coordinates in a GIS attribute map) data and data coupling.

For Tier 1 of the MIMES framework, the researcher elected to use a commercial GIS package that can be incorporated into SIMILE in potential future studies.

The next section discusses the anthroposphere; the prominent MIMES surface type with regard to the production of EMF radiation emissions and the potential effect it may have on the public. It is also the domain in which EMF radiation exposure propagation variables can alter to reduce or increase the hazard conditions to EMF radiation exposure for biological effects.

4.3.1 Anthroposphere

The MIMES framework handles multi-dimensional arrays carried out within a GIS location grid (GIS attribute map) under investigation. Each GIS location grid, shown in Figure 4.2, can have multiple cultures that have their own social and human capital and run their economy.

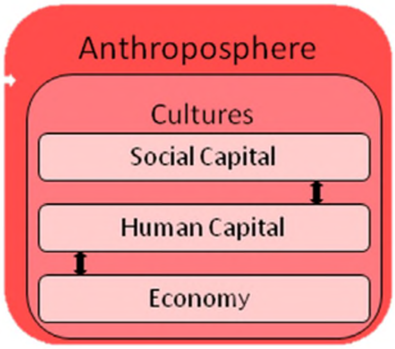


Figure 4.2 Basic MIMES structure view on anthroposphere modelling (Boumans et al., 2015)

'Capital' in Figure 4.2, within the MIMES framework, is defined by the elements of the system contributing to services and goods that have an effect on *human wellbeing*. Interpreting the STEP and LTCEP models in terms of the 'capital' classification in the literature review and EMF radiation epidemiological studies may contribute to fulfilling (RQ_5), under the PAIA PIO question heading 'substances released into the environment' and 'public safety or environmental risk' discussed in the previous chapter.

The MIMES framework 'capital' recognizes four (4) types of capital, namely: built capital (physical construction and infrastructure), human capital (knowledge and education), social capital (social institutions i.e. families and neighbourhoods) and natural capital (natural entities, structures and processes that contribute to human wellbeing) (Boumans et al., 2015). The first three (3) capitals are associated with the human system, taking the form of physical construction and infrastructure (built capital).

The STEP and LTCEP models will each be constructed as an anthroposphere model (Figure 4.2), with each model providing anthroposphere model outputs (RQ_4). Additionally, coupled MIMES model outputs (RQ_4) (Figure 4.1) would enable a visual declarative model analysis of the human and social capital interactions with the ecosystem services over space and time (biosphere model, Tier 2 of the MIMES framework). Separate MIMES models, serving as 'impact predictors', will use the 'limitation' tool calibrated by the scientific-technical analysis. Simulation models are run in the GIS location grid under investigation for the different identified human and social capital groups found within the anthroposphere, for example: facilities predominantly occupied by the youth, elderly and chronically ill (ICNIRP, 2002). The complex narrative above is expanded and visually simplified in the next two chapters.

The next section discusses the scientific-technical analysis of identifying and assigning metrics for EMF radiation exposure affected population groups used in this study and known as impact predictors.

4.4 Impact predictors

The concept of vulnerability, or the potential for harm, encapsulated within the climate change framework, has a long history in the development and application of understanding the impact of environmental hazards on humans, as highlighted in Chapter 2 (Boumans et al., 2011).

Real-time EMF radiation exposure impact is difficult to quantify and existing studies are limited in scope (IPCC, 1995; Foster, 2001). Although knowledge has increased significantly during the last decade and qualitative estimates have been replicated, quantitative projections of the impact of EMF radiation exposure on any particular system at any particular location are difficult, because regional scale EMF radiation exposure predictions are uncertain; our current understanding of many critical processes is limited and systems are subject to multiple variable related climatic and non- climatic stresses, the interactions of which are not always linear or additive (IPCC, 1995; Marino et al., 2000; Chiang, 2009).

The STEP and LTCEP models have developed indices of vulnerability which use a wide variety of social, demographic, health, and environmental variables in their formulation. Major differences in vulnerability indices between the STEP and LTCEP models only concern the importance of the observed biological effects in relation to disease development (WHO, 2006a; Adlkofer et al., 2009).

STEP and LTCEP models' indices characterizing the relative vulnerability of the residents in different census units in the study area (anthroposphere) within a MIMES framework public interest model, would be forecast as sub-models as a GIS dataset layer. Census block variables for age, ethnicity, population density, social isolation, impervious surfaces and remotely sensed EMF radiation levels would need to be constructed for the investigated area. These spatial patterns can then be overlaid with the geospatial propagation model (Chapter 7) variations in high EMF radiation exposure to identify the areas of highest concern in fulfilment of RQ_4 (Boumans et al., 2011).

The use of a social vulnerability index (SoVI) would need to be applied when implementing Tiers 2 to 4 of the MIMES framework (Table 4.1) outside the scope of this study. This SoVI index, generalized for natural hazard vulnerability, is calculated by summing factors derived from several demographic, socio-economic, and built environment variables (Boumans et al., 2011).

This section discussed the framework entity impact predictors. The next section discusses the HYGEIA model and how impact predictors are used in forecasting different demonstration run outputs per population group (RQ_4).

4.5 HYGEIA model

The goal of this study, as discussed in Chapters 2 and 3, is to construct a framework and model to identify and demonstrate a PIO (RQ_5). This section discusses the tool development regarding the how and why of the MIMES framework goal, namely to create a public interest modelling tool that can incorporate stakeholder input and biophysical datasets for valuation of ecosystem services to enable informed decision-making by simulating ecosystems and socio-economic systems in space and over time, in addition to the interactions between ecosystems and socio-economic systems through coupling (Boumans & McNally, 2011).

HYGEIA (see Chapter 1) originated from the Hippocratic Oath representing a public health model that focuses on prevention in the context of public interest (Boumans et al., 2011). The HYGEIA model was chosen as it has been successfully applied to address the particular issue of environmental change case studies within the climate change framework (Boumans et al., 2011; Boumans et al., 2015).

The HYGEIA model makes use of the MIMES framework and model libraries. It is a model used in forecasting the effects of environmental change on human health and health environment interactions. It is also a dynamic GIS, designed to address the magnitude, dynamics, and spatial patterns of ecosystem service values (Boumans et al., 2011). It is employed, in fulfilment of RQ_4, to visually identify EMF radiation islands occurring in cityscapes and to design appropriate mitigation strategies. HYGEIA also predicts outcomes for a variety of demographic conditions, i.e., age, race and income level and was designed to be applied to any area in the country that has the requisite and standardized data input layers. These may include land cover, environmental scenarios and block census data (Boumans et al., 2011).

A baseline must be established before forecast simulation scenarios can be performed in a HYGEIA model. A scientific-technical analysis may, however, be influenced by community values as a result of the occurrence of the shifting baseline syndrome, which, in turn, may offset tracking a model forecast for adaptability. Shifting baseline syndrome is a drift away from true natural conditions and, as a consequence, a change in perception of ecological change varying from generation to generation (Papworth et al., 2009). It describes the way that a high EMF radiation exposure area is evaluated by experts who use the state of the ambient EMF radiation levels at the start of their investigation as the baseline, rather than the ambient levels in its untouched state (Pauly, 1995)

A collage of screenshots from the HYGEIA model, superimposed upon the model diagram in Boumans et al. (2014a), is shown in Figure 4.3 on the next page,. The model's output from the MIMES framework applications is multiple, complex and a representation of the real world. The execution of different types of scenarios, even those unanticipated during the development of the model, is a key representative benefit of the complex ecosystem simulation model.

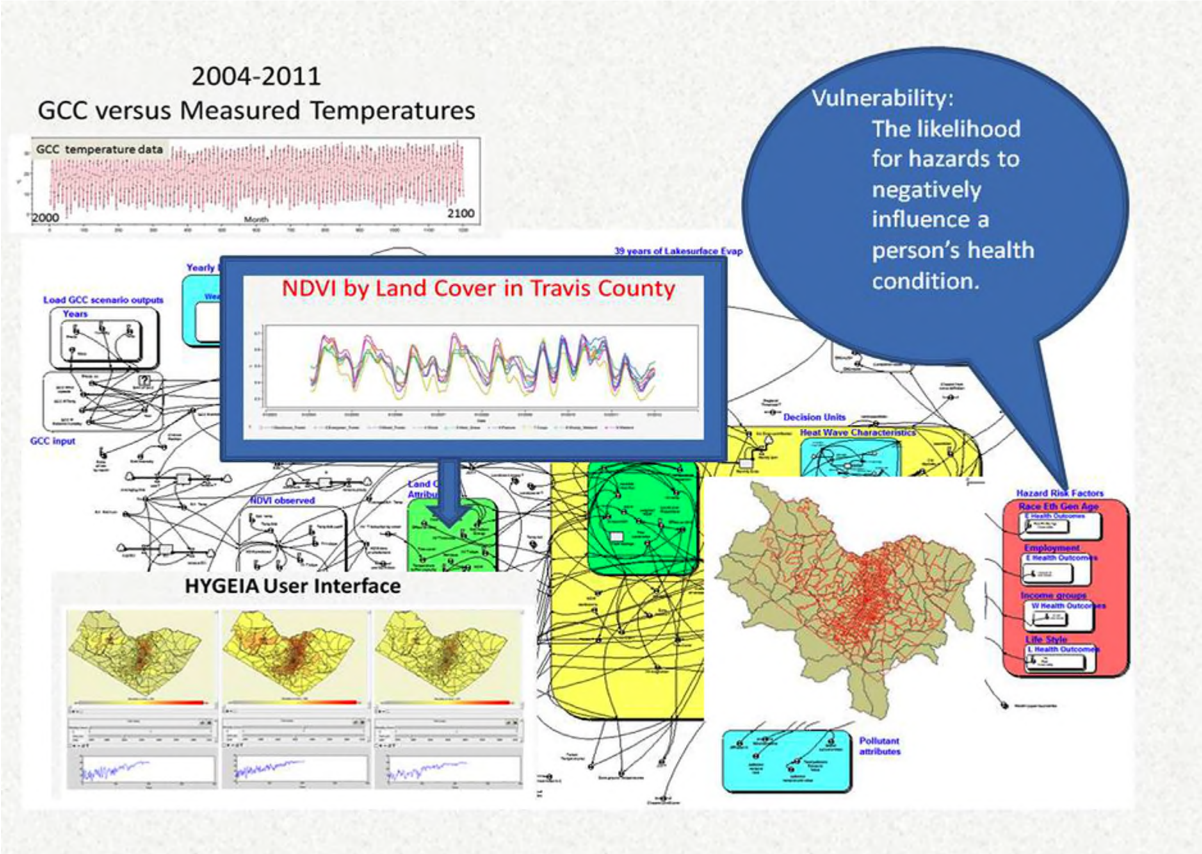


Figure 4.3 SIMILE screenshots capture of the MIMES IS framework HYGEIA model (Boumans et al., 2014a)

The HYGEIA model was chosen to help fulfil RQ_5, because it has a successful track record in highlighting human health over economic outcomes (Boumans et al., 2014a). The US Environmental Protection Agency (EPA) utilized and applied the HYGEIA model as a broadly applicable modeling and decision support IS platform that considered direct and indirect climate change variable effects on human health (social systems) and the effectiveness of mitigation options from increased ecosystem services (Phillips et al., 2014).

The HYGEIA model's application in the EPA (Phillips et al. (2014) study inspired the chosen MIMES framework for this dissertation because of its ability to examine the manner in which variable solar EMF induce heat stress and how it could affect morbidity and mortality in Travis County, Texas, USA. HYGEIA modeling, in the EPA's application of the MIMES framework, enabled the application of a human planning policy and the implementation thereof in various ways, as it could quantitatively mitigate solar EMF heat stress effects. The mitigation strategy, proposed in Phillips et al. (2014) for the EPA, achieved this by modeling the various scenarios by manipulating the placement of trees within the study area to absorb the solar EMF and to thus alter the micro-climate. The outcome was a reduction in both social and economic risks, as well as costs (RQ_4 & RQ_5) (Phillips et al., 2014).

According to Boumans et al. (2014b) the following desired characteristics of the platform were revealed when investigating publications regarding the incorporation of the HYGEIA model into the applied MIMES IS:

(1) Capable of addressing multi-stressor effects on human populations, for example: solar EMF heat stress, flooding, disease and changes in allergens;
(2) Temporally and spatially explicit, thereby producing static and dynamic map outputs;
(3) Scalable in having the capacity to consider local and regional interactions;
(4) Credible in assessing tradeoffs among mitigation and adaptation scenarios;
(5) Easily used and interactive through declarative programming;
(6) Transportable in that data from one community may be modelled to another and adaptability may be provided to new data and information.

The HYGEIA model may provide realistic scenarios of the future under different combinations of development activity and market decisions (Boumans and McNally, 2011). HYGEIA modelling within the MIMES framework can potentially encounter mistakes being made when utilizing *accurate* accounting data for *reliable* scenarios, because of in-depth experience needed in tuning data, algorithms and model structure to specific concerns (Boumans et al., 2015).

The remaining sections of this chapter discuss the different technical, methodological and paradigm elements of EMF radiation exposure and dosimetry, as well as the outstanding framework entities in fulfilment of RQ_1 and the required data inputs and processes needed in fulfilment of RQ_2. The sections are explained as a high level overview with references to further detailed explanations in the Appendix. EMF radiation exposure studies require a non-linear statistical analysis in line with a scientific-technical analysis. Therefore, traditional linear statistical hypothesis testing is not viable in this study. As a result, the study provides a narrative and visual comparison output between two (2) models, namely the STEP and LTCEP EMF radiation dosimetry models, instead.

4.6 EMF radiation dosimetry

Dosimetry is the quantification of EMF radiation interacting with the exposed human body. EMF radiation should be appropriately and precisely characterized when considering its interaction with the human body (Taki et al., 2001). Engineering and physics play a vital role in the collaboration of the quality judgment of biological researchers (Taki et al., 2001; NTP, 2016). Improved engineering should reduce the uncertainties that exist in unresolved problems of the EMF radiation health issue (Taki et al., 2001; WHO, 2016c).

As discussed in Section 2.2, the assessment of the biological effects of EMF radiation is considerably different depending on the publishing organization's and or manufactuere's exposition (STEP or LTCEP model). The major differences in opinion only concern the importance of the observed biological effects in relation to disease development (Adlkofer et al., 2009). The literature review, using scientific-technical analysis, examined the STEP and LTCEP dosimetry models and output under thirteen (13) category headings, namely: legal accountability; scientific scope; exposure safety assessment; dosimetry assessment and units of measurement; fiduciary duty and economic mandate; funding source of weighted studies; municipal spatial planning accountability; social and cultural factors; methodology in establishing exposure safety levels; scenario scope for establishing exposure levels; selective attributes and quality metrics; periods of ongoing research, and scientific opinion. A side-by-side comparative analysis of the STEP and LTCEP models per the category headings listed above is available in the Appendix, Section 4.1 (EMF radiation dosimetry).

The exposition of EMF radiation, discussed in Section 2.8, varies considerably and is determined by the country's evolved economic and political paradigm toward EMF radiation exposure. The literature review identified that the STEP model dosimetry is not designed to model the biological effects identified by using the LTCEP model dosimetry.

4.7 EMF radiation dosimetry reference levels and limits

The LTCEP model limits, as discussed in Section 2.2, are clearly not principally designed to protect against thermal hazards defined in the STEP model (Foster, 2001). LTCEP model limits are between $1/10^{th}$ and $1/10\ 000^{th}$ of the level of STEP reference levels, with the LTECP model limit embodying the concept of *dose* and *cumulative exposure*.

A breakdown of the STEP and LTCEP model RF-EMF limits per endorsing agency and country is available in the Appendix, Section 2.1.

STEP model endorsers primarily use an engineering scientific approach to EMF radiation reference levels (WHO, 2006a) that is focused on prioritized technology performance metrics and narrowed biological scope (thermal heating on a *phantom* in free space), designed for favouring market-driven economic policies (stock exchange trading) (WHO, 1999; WHO, 2006a; Mazar, 2009).

LTCEP model endorsers utilize a biological scientific approach to EMF radiation focused on the performance effect on the human central nervous system (CNS) and the neurological effect scoped to all ages in the human population, based on experiential and human studies

(Kolodynski & Kolodynska, 1996; Loos, 2003; WHO, 2003a; Lathrop, 2003; Chiang, 2009; Bąk et al., 2010; Gandhi et al., 2015). The LTCEP model is designed to accommodate social accounting economic policies (WHO, 1999).

The range of LTCEP model limits set between $1/10^{th}$ and $1/10\ 000^{th}$ to the level of STEP model reference levels is set against a balance between economic and social costs calculated by the endorsing country (RQ_5) (Foster, 2001). The Swiss LTCEP model limits, for example, are set to the lowest levels regarded as technically and economically feasible. This is known as the ALARA (as low as reasonably achievable) principle. Generally speaking, the Swiss LTCEP model limits are 1/10th V/m (field strength) or 1/100th W/m^2 (power flux density) to the STEP model ICNIRP reference levels.

The international tracking of the implementation of LTCEP model limits as an implemented national standard is challenging, due to the technical distinctions of 'immissions' and 'emissions', spurious emissions, localized hotspots, polarization, identified sensitive/vulnerable areas, new and old installation phasing and RF-EMF spectrums, i.e., 3G, LTE, and 4G. The designated sensitive areas applied are mostly schools, hospitals and residential areas (Foster, 2001).

The LTCEP model utilizes the volts per meter (V/m) unit of measurement for varying RF-EMF radiation at non-thermal levels and evaluates peak RF-EMF radiation values from a source (Yu, 1998; Perov et al., 2009; Philips & Lamburn, 2016).

The STEP model utilizes the watts per meter squared (W/m^2) unit of measurement, known as power flux density (PFD), that is generally used in evaluating the localized tissue heating effect (Philips & Lamburn, 2016). PFD is achieved by averaging the recorded instantaneous RF-EMF radiation power readings over a time of 6 or 20 minutes.

Calculating the relevant RF-EMF radiation exposure values of devices and associated infrastructures in today's ubiquitous wireless technologies (cellular, tablets and SMART meters), can be extremely misleading (Suzuki, 2014; Belyaev et al., 2016; Philips & Lamburn, 2016).

Peak RF-EMF radiation power readings (V/m) from a TETRA base station, for example, are double the PFD (W/m^2) reading (average power). A DECT cordless phone base unit (domestic cordless phone), a micro version of a cellular base station within the home, measures an instantaneous peak RF-EMF radiation radiated power level up to hundred (100x) times (V/m) more than the PFD (W/m2) value (average power) (Philips & Lamburn, 2016).

RF-EMF devices that send out short high-intensity RF-EMF radiation pulses (V/m) trigger biological effects more powerfully, with PFD (W/m2) RF-EMF radiation measurement values, underestimating LTCEP model endorsers' concerns (Belyaev et al., 2016). As discussed in Section 4.2, population groups that have a sensitivity to EMF radiation have a less efficient compensatory mechanism (adaptability) to high intensity RF-EMF radiation pulses, thereby triggering a state of vulnerability (biological effects). A graphical comparison of misleading RF-EMF radiation exposure values between the STEP and LTCEP models is in the Appendix, Section 4.2 (STEP model reference levels and LTCEP model limits).

4.8 EMF radiation dosimetry rationale

As discussed in Section 2.2, a longstanding and documented issue in EMF radiation guidelines and standards is the significant difference in perspective between the STEP model reference levels and LTCEP model exposure limits (WHO, 1999; Foster, 2001; Vitale, 2005; WHO, 2006a; EDA, 2016).

Both the STEP and LTCEP models are science-based, meaning that both models were established based on expert evaluation of the scientific literature to identify potential adverse effects of exposure in terms of the defined EMF radiation exposure scope (Foster, 2001; WHO, 2006a; EDA, 2016). The resulting STEP model reference levels and LTCEP model limits are designed to exclude identified hazards with an appropriate margin of safety (Foster, 2001). The descriptive difference in narrative between the STEP and LTCEP models is mainly due to the STEP model having a narrow field of scope and a broad tolerance of risk of potential adverse health effects when compared to the LTCEP model that covers a larger biological domain and a tighter tolerance of acceptable risk (Mazar, 2009).

The STEP and LTCEP models have two different scientific rationalizations to EMF radiation dosimetry. The STEP model's RF-EMF radiation approach is based on the thermal measure or estimation of specific absorption rate (SAR), indicating the power absorbed per unit weight of an object. The LTCEP model's RF-EMF radiation dosimetry relies on the measure of the time integrated RF-EMF power density incident on an object (Perov et al., 2009). The LTCEP model originally did not include the SAR method (Foster, 2001).

There are three (3) prominent issues in relying on the SAR method for modelling human exposure functions in a HYGEIA model:

(1) The STEP model SAR EMF radiation reference level, formulated by the Institute of Electrical and Electronics Engineers (IEEE) in 1982, was based on the anthropometric

measurements of a normal-build adult male (phantom) and normal temperature regulation capacities to represent the general public in free space (non-real world conditions) (Mason et al., 2001; Giuliani, 2002). The SAR safety reference levels were established by technical centric engineers and not by doctors, physicists or biologists (Mason et al., 2001; Weigel, 2013). LTCEP model endorsers criticize the STEP model SAR assumption as it would not offer the same protection to more sensitive subjects or to those with limited capacity for temperature regulation (Giuliani, 2002). Additionally, the EMF radiation effects on cellular, atomic or sub-atomic level were not taken into consideration, since the STEP model SAR is unable to account for such measurements and, to do so, would be contrary to industries' strategic economic interests, as discussed in Section 1.1 (Mason et al., 2001; Panagopoulos et al., 2013; Weigel, 2013). LTCEP model endorsers also criticize the SAR reference level because of the unfair discrimination and inequality of setting safety exposure reference levels for a single group of the population (discussed in Section 3.2) (Dimbylow & Bolch, 2007; PEPUDA, 2000; Vermeeren et al., 2010).

(2) A study by Dimbylow & Bolch (2007) generated SAR phantom models to represent different categories of the population. The study found that, in the frequency range of body resonance (100 MHz) for bodies shorter than 1.3 meters in height, approximately children aged eight (8) years or younger, the induced SAR to the human body could be, even at the STEP model reference level, up to forty percent (40%) higher than the current STEP model safety reference levels for adults when exposed to RF-EMF radiation frequency range 1 to 4 GHz, used in Wi- Fi and cellular ARD transmitters (WHO, 2009; RNCNIRP, 2011; Nikolopoulos et al., 2015). Other studies found a similar pattern with ELF EMF from an induction cooker (Kos et al. 2011; Christ et al., 2012). In addition, the hazard condition exponentially increased ELF EMF arose when users typically did not follow strict operational instructions. The STEP model reference levels therefore do not satisfy the absorption limits for a realistic exposure scenario (WHO, 2009). A factor correction would thus need to be applied to EMF radiation dosimetry in a HYGEIA model and future studies when using the SAR STEP model as an input. The SAR dosimetry findings on children of Dimbylow & Bolch (2007) have resulted in the increase in countries implementing legislation prohibiting the advertisement of cellular RF-EMF radiation devices to children within the hazard condition parameters (ASA, 2004; RNCNIRP, 2011; Federal Public Service Health, Food Chain and Environment, 2014; California

Department of Public Health, 2014). This provides additional support to Chapter 2 and RQ_5.

(3) The method provides a valid measure of energy absorption, but is not a quantity indicator for estimating biological effects and is therefore not an appropriate EMF radiation exposure metric (Lathrop, 2003; Chiang, 2009; WHO, 2003a: 69; Belyaev et al., 2016). Field intensity (V/m) and/or power flux density (W/m2), in combination with EMF radiation exposure duration, should be used in safety models (spatial and temporal GIS inputs) instead (Boumans et al., 2015; Belyaev et al., 2016). China's national EMF radiation public health division rationale against using SAR in health modelling is the result of the various bio-effects that can be seen with continuous versus intermittent EMF radiation exposure, or modulated versus unmodulated signals at the same SAR level (Lathrop, 2003; WHO, 2003a: 69). The LTCEP model therefore questions the wisdom of using SAR to set a basic EMF radiation exposure restriction and does not include SAR as a primary method (WHO, 2003a: 69).

The pattern above narrates considerably different mathematical dosimetry and exposition between the STEP and LTCEP models as inputs for the HYGEIA model. A breakdown and technical explanation of the STEP and LTCEP models' dosimetry equations are available in the Appendix, Section 4.3 (STEP and LTCEP dosimetry model).

The differences between the two models' rationale regarding safety standards and guidelines are mediated by political, technological and economic interests. These differences have been a major obstacle in limiting the growth of international trade and the diffusion of wireless products (Perov et al., 2009). Selection of an appropriate EMF radiation dosimetry model, in the interest of public health and awareness, is not only a domestic concern, but an international debate as well (Stewart, 2000:115; Foster, 2001; WHO, 2006a; ASA, 2004; Commission on the European Communities, 2008; NMBM, 2011; KM, 2012).

A further elaboration and history of the STEP and LTCEP models' rationale are available in the Appendix, Section 4.4 (EMF radiation dosimetry rationale, continued).

The next two subsections discuss the STEP and LTCEP models as framework EMF radiation policy inputs into the HYGEIA model.

4.8.1 STEP model inputs

The major players in the STEP model's development are:

- FCC OET Bulletin 65 (FCC, 1997).
- IEEE C95.1- 1999 with some modifications (IEEE, 1999).
- ICNIRP (ICNIRP, 1996).

The rationale for these reference levels is defined and explained at length in the documentation accompanying the standards and guidelines listed above.

The STEP model is *one* scientific input into the formulation of societal policies (Vecchia, 2008). STEP model reference levels for these standards and guidelines are formulated based on an extensive review of the scientific peer-reviewed literature to identify potentially hazardous effects and their thresholds within the STEP model developers' *scope* of tolerable risk, discussed in Section 2.2.

The development of the IEEE C95.1 (1999) STEP model EMF radiation threshold reference levels, for example, are scoped to the very specific thermal biological threshold limit, namely "the most sensitive measures of potentially harmful biological effects were based on the disruption of ongoing behaviour associated with an *increase* in *body temperature* in the presence of electromagnetic fields."

STEP model endorsers criticize the LTCEP model because of the STEP model's scoped literature findings revealing a "paucity of reliable data on chronic exposures." The majority of literature scoped by STEP model endorsers was concerned with short-term (*hours or less*) exposure to EMF radiation (Foster, 2001).

Due to the selected hazard scope of the STEP model, the hazards that are identified in the documentation are, for the most part, reviewing thermal considerations only, averaging exposure times of 6 to 20 minutes that are criticized as short per the LTCEP model (Foster et al, 1998). The STEP model reference levels are considered as investigation levels, rather than levels to be observed and not exceeded, in terms of the LTCEP model (Giuliani, 2002).

The prominent countries/regions that endorse the STEP model are North America, parts of Western Europe, Japan and South Korea.

4.8.2 LTCEP model inputs

The major players in the LTCEP model's development are:

- Russian Sanitary Norms and Regulations 2.2.4/2.1.8.055-96 (Yu, 1998).
- China Ministry of Health Standard (1987) (WHO, 2004a).
- Precautionary Principle (UNEP, 1992; Council of Europe Parliamentary Assembly, 2011).
- ALARA Principle (Switzerland, Ordinance on Protection from Non-ionizing Radiation (NISV), 1999).

The Russian National Committee on Non-Ionizing Radiation Protection (RNCIRP), a LTCEP model founder, explained Russia's public interest (Chapter 2) for the establishment of EMF radiation standards, motivated by a steady increase in the climatic change variable (Gajšek et al., 2015; WHO, 2015b; Schoeni et al., 2016). Public interest required the regulation of EMF radiation levels to protect Russia's workforce and population from EMF radiation effects (RQ_5) (Yu, 1998). The LTECP model, in association with the precautionary principle, has its foundation in international law and holds widespread political support over the STEP model (Foster et al., 2000; Cameron & Abouchar, 2001).

The LTCEP model standard reflects the scientific-technical analysis. Humans have a pre-existing level of sensitivity to the EMF radiation, as chartered in Figure 4.4 on the next page (Yu, 1998; Grigoriev et al., 2003; WHO, 2004a; Redmayne, 2017). The level of adaptability (tolerance) to the EMF radiation diminishes over time until a state of vulnerability, with either reversible or irreversible adverse health effects, occurs (Sherwin, 1983; Yu, 1998; WHO, 2004b; WHO, 2006a; WHO, 2006b). The LTCEP model directive is the fundamental prevention and assurance of conditions that optimize the human being's vital activities, based on over half a century of EMF radiation research (Yu, 1998; RNCNIRP, 2011; O'Connor; 2012; Government of France, 2016).

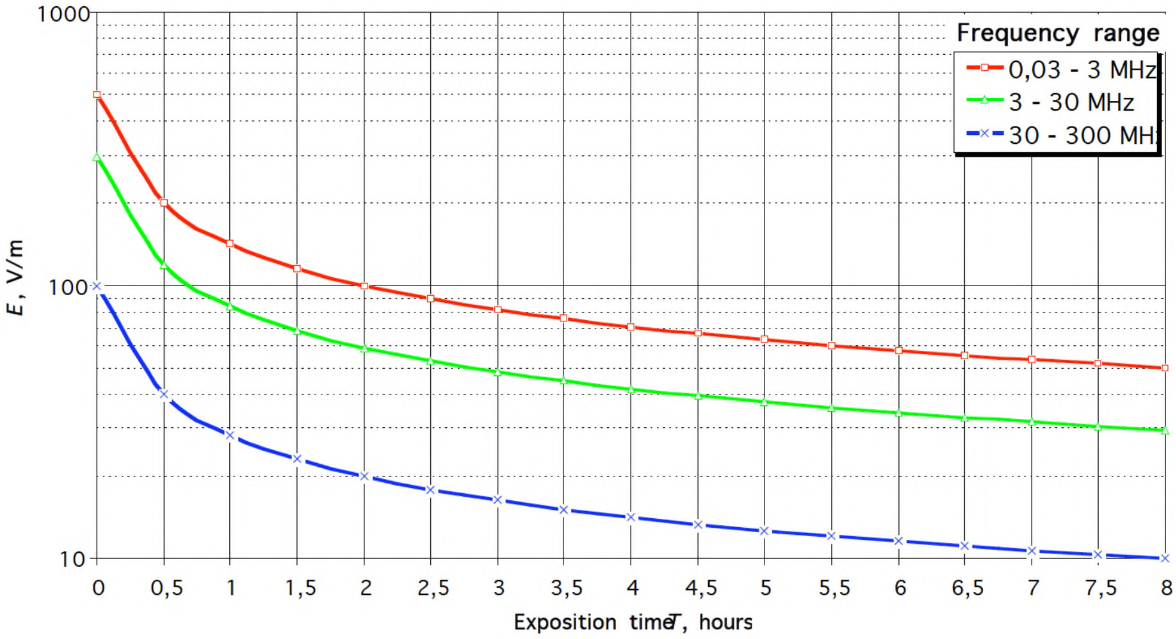


Figure 4.4 Limit values for electric field strength (in the workplace) per Russian Standard GOST 12.1.006-84 and SanPiN 2.2.4/2.1.8.055-96 (Yu, 1998)

Unlike the STEP model, the rationale of the historical Russian LTCEP model is not described in the standard itself (IEEE, 1999). The lack of clarity may be due to the LTCEP model being established over half a century ago, in the cold war era, resulting in a political lack of global cooperation and uniformity in comprehensive documentation by academia. This is in contrast with the STEP model being marketed as established by ICNIRP only three decades ago.

A literature review of commentary on the standards and bibliographies of scientists involved in the LTCEP model standards establishment was required to understand the historical rationale of the LTCEP model (Marha, 1971; McRee, 1997; Szmigielski, 1989; Sliney et al., 1985; Gajšek et al., 2002; Yu, 1998; Perov et al., 2009).

The LTCEP model dose is calculated by multiplying the incident of EMF radiation field intensity by time, rendering the LTCEP model *unrelated* to any conceivable thermal hazard nominated by the STEP model. The LTCEP model limits provide a clear conviction that long-term (*hours or more*) exposure, far below STEP model reference levels, results in adverse health effects, as discussed in Section 2.2 (Foster, 2001; Giuliani, 2002; WHO, 2003a; WHO, 2006a; WHO, 2006b; Belyaev et al., 2016; Government of France, 2016; NTP, 2016).

The prominent countries/regions that endorse the LTCEP model are Russia, China, India, Israel, Italy, France parts of South America, most of Eastern Europe and parts of Western Europe.

The next section discusses why an EMF radiation HYGEIA model needs to favour non-linear over linear statistical analysis when producing model outputs in fulfilment of RQ_4.

4.9 Non-linear statistical modelling

China, one of the LTCEP model founders during the cold war era, like Russia, is one of the few countries that conducted large scale EMF radiation studies on humans, ranging from nursery school children to adults. The multiple human experiments identified that chronic EMF radiation exposure is associated with a variety of non-specific symptoms (RQ_4 & RQ_5) (Chiang, 2009; Liu et al., 2014; Belyaev et al., 2016). One of the first initial LTCEP models was defined based on these test results (WHO, 2006b; Chiang, 2009).

STEP model endorsers criticize LTCEP model research findings to be inconsistent in replicability (Foster, 2001). LTCEP model endorsers respond that, unlike engineering systems, biological systems can exhibit stochastic outputs (Foster, 2001). STEP model endorsers' criticism of the LTCEP model is contradicted by Wiener (1966). During the establishing period of the initial STEP model Wiener (1966) confirmed a neurological effect, linked to EMF radiation, by using nonlinear interactions.

The application of adaptability, according to the scientific-technical analysis, varies regarding sensitivity and vulnerability depending on the biological system under investigation (GRID-Arendal, 1996; Tuengler & von Klitzing, 2013). Studies of the effects of EMF radiation on the immune and other body systems produced both positive and negative results and this pattern was usually interpreted to indicate the absence of real effects by STEP model endorsers (Marino et al., 2000; Foster, 2001; Tuengler & von Klitzing, 2013). However, if the biological effects of EMF radiation were governed by nonlinear laws, deterministic responses to fields could occur that were both real and inconsistent, thereby leading to both types of results (Marino et al., 2000; Tuengler & von Klitzing, 2013).

China's decades of research describe EMF radiation exposure effects on the body to have nonlinear characteristics, including frequency-dependent and power density dependent windows (WHO, 1995; Marino et al., 2000; WHO, 2003a; WHO, 2006b; Chiang, 2009).

In applied statistical analysis studies the results are dependent on the correctly applied statistical method through trial, error and experience (Boumans et al, 2015). LTCEP model EMF radiation biological studies indicated that the relationship between an applied EMF radiation and its associated biological effects were nonlinear in nature (Marino et al., 2000; Chiang, 2009; Belyaev et al., 2016). STEP model endorsers, however, assume that any response of a subject to EMF radiation would be governed by a linear law (engineering approach), and that inter-subject measurement differences were due solely to stochastic processes (Marino et al., 2000). LTCEP model endorsers found statistically significant changes with nonlinear laws.

The effect of EMF radiation on oxidative and nitrosative regulation capacity in affected individuals is one explanation for the nonlinear EMF radiation characteristics. The nonlinear characteristic may explain why the level of susceptibility to EMF radiation can change and why the range of symptoms is so large, rendering statistical mapping a more complex task (CAS-DSP, 2007; Belyaev et al., 2016). The MIMES Framework HYGEIA model was selected as a result of its capacity to enable non-linear characteristic modelling, based on the literature review findings.

Some of the properties of nonlinear dynamic systems, as explained by CAS-DSP (2007), are:

(1) They do not follow the principle of superposition (linearity and homogeneity);
(2) They may have multiple isolated equilibrium points, whilst linear systems can have only one;
(3) They may exhibit properties such as limit-cycle, bifurcation and chaos;
(4) They finitely escape time; the state of an unstable nonlinear system can go to infinity in finite time;
(5) The EMF radiation may contain many harmonics and sub-harmonics with various amplitudes and phase differences for a sinusoidal input, whilst a linear system's output will contain only the sinusoid at the output.

Due to resource constraints, this research is not scoped to run nonlinear EMF radiation characteristics models. Increased buffers were added into the EMF radiation spatial propagation evaluation method to keep the calculations simple (Chapter 7). The simpler calculation method results in a conservative geospatial propagation EMF radiation model in fulfilment of RQ_4 (Mann et al., 2000).

4.10 Knowledge bases – GIS dataset layers

Knowledge bases are used in impact functions (discussed in Section 4.4) to describe the effects that economic production have on the structure and functioning of ecosystems. These functions are the core concern for many organizations, i.e., the WHO, World Research Institute, US EPA and UNFCC (UNFCC, 2006; UNFCC, 2014; Boumans et al., 2015). Scenarios that incorporate best management practices (BMP), i.e. the STEP and LTCEP models' inputs, are typically parameterized through these impact functions. Although they can be project specific, impact functions can include general parameters, such as depletion rates, pollution levels and land cover changes (Boumans et al., 2015).

The impact table (GIS datasets) methodically characterizes human generated impacts and defines the impact levels caused by different types of human activities (anthroposphere) on system elements (hazard conditions) (Boumans et al., 2015). Land covers are assigned production profiles, while economic related sections (including households and pollutants) are assigned demand profiles (Boumans et al., 2015).

The model simulation outputs in RQ_4 are composed from multiple interconnected polygons (GIS dataset impact tables) intersected into a programmed resolution grid within a GIS to represent spatial patterns of the system under investigation, thereby revealing a spatial dynamic simulation of hazardous conditions for each specified resolution grid (Boumans et al., 2015). Each GIS dataset layer, for example, may have very distinct production and demand profiles, especially in the propagation of EMF radiation, resulting in potentially different extremes of EMF radiation hazard conditions (localized hot spots, intensity, frequency, magnetic field etc.).

The next sub-sections discuss the knowledge bases that serve as inputs in the proposed EMF radiation HYGEIA framework, and model in the following chapters.

4.10.1 EMF radiation pollutant sources

EMF radiation exposure can be categorised into macro and micro exposure. In many anthroposphere instances, there is a combination of both. EMF radiation micro sources are personal devices that incur a voluntary usage, i.e., cell phone, home Wi-Fi, tablet, 12 VDC transformers, domestic appliances and net currents on electric wiring, water pipes and other conductive materials (Belyaev et al., 2016).

EMF radiation macro sources are infrastructure that micro sources are dependent on for their designated functionality. EMF radiation exposure to macro EMF radiation sources is often involuntary and or continuous. A micro EMF radiation source can be considered macro when it is utilized in the public domain, i.e., public Wi-Fi, SMART meters and DAS (micro indoor cellular transmitters).

This research is limited in scope to macro EMF radiation sources. Macro EMF radiation sources pose the greatest systemic risk exposure to the public as they enable an increase in micro EMF radiation sources and exhibit higher emission intensities (Government of India, 2010; Rajasthan, 2012; French National Assembly, 2015) and, thereby, an increase in ambient radiation levels, re-radiation, EMF radiation environmental noise (interference) and hazard conditions (Boumans et al., 2011; Phillips et al., 2014; Boumans et al, 2015; Belyaev et al., 2016).

The forecasts from a public interest HYGEIA model are only as accurate as the data from the data source provider (Boumans et al, 2015). Detailed technical specifications and operation log files enable 3D simulation models with relative accuracy (EMFs.info, 2016).

As discussed in Chapter 1, resistance encountered in gaining access to technical specifications and operation log files from EMF radiation infrastructure data sources required data extrapolations from a literature review and generic simulation models. Construction of EMF radiation pollutant datasets, based on a literature review, uses a simpler geospatial propagation EMF radiation exposure calculation approach. The simpler the EMF radiation exposure calculation approach, the more conservative the outcome will be in RQ_4, resulting in greater compliance distances of framework EMF radiation policy inputs into the model (Mann et al, 2000).

The literature identified projections in EMF radiation levels to be considerably different depending on the organization and or manufacturer that publishes it (FCC, 1997; Kelfkens et al., 2002; Vitale, 2005; Dürrenberger et al., 2014; EMFs.info, 2016; EDA, 2016).

As discussed in Chapter 2, LTCEP model endorsers revealed STEP model endorsers to publish EMF radiation values of non-real world hazard condition scenarios, thereby providing potentially misleading EMF radiation public health awareness (Takemoto-Hambleton et al., 1996; Vitale, 2005; Vermeeren et al., 2010; Hondou et al., 2006; Dürrenberger et al., 2014; Maret, 2014; Yahya & Khalil, 2015; Philips & Lamburn, 2016).

An ELF EMF radiation example, namely the UK ELF EMF radiation government awareness information body, EMFs.info (2016), provided ELF EMF radiation measurements that were very conservative when compared to those of the Netherlands government (Kelfkens et al., 2002; EMFs.info, 2016). The Netherlands government illustrated real world scenarios that occupy a combination of HVAC infrastructure sources. The ELF EMF radiation exposure distances from the source, compared to the EMFs.info (2016) simulation measurement, were extended by another fifty percent (50%) (Takemoto-Hambleton et al., 1996; Kelfkens et al., 2002).

As an RF-EMF radiation example: the modeling and measurement exposition exposure to RF-EMF radiation hotspots were very different, depending on the endorsing agency. Mann et al. (2000), for the UK public health regulatory board, based their methodology on the US FCC (1997), a STEP model endorser. FCC (1997) and Mann et al. (2000) reported that hotspot EMF radiation measurements at a distance could only be double the field intensity (V/m) and/or quadruple the power density (W/m2). Simulation models, experiments and measurements by Reno & Beischer, (1973) and Hondou et al. (2006), however, provided different results. Hondou et al. (2006) demonstrated localized hotspot RF-EMF radiation measurements one thousand to two thousand times (1000-2000x) greater at the point identified by the FCC (1997) and Mann et al. (2000) studies, respectively. The FCC (1997) and Mann et al. (2000) were correct in their methodology within the STEP model, merely as a result of the use of specific context in their statements, selective measurement methodologies, language used and selective non-real world scenarios.

4.10.1.1ELF EMF radiation

Examples of macro ELF EMF radiation sources are HVAC power lines (including train lines), HVAC unshielded substations and public transport with electric hybrid technology (Hareuveny et al., 2015; WHO, 2015a).

Although outside this research scope, but supportive to Chapter 2 and RQ_5, the WHO (2015) performed ELF EMF radiation measurements in non-electrical train wagons on electricity produced by the diesel generators placed in the locomotives. The electricity supplied to the electric motors that operate the wagon's wheels resulted in ELF EMF radiation exposure in excess of 60 mG on the passengers' seats. ELF EMF radiation measurements in hybrid cars were recorded above 2 mG under certain conditions (Hareuveny et al., 2015)). The CCPTM has a progressive climate change policy that favours energy efficiency and carbon footprint reduction from fossil fuels. The encouragement and incentivizing of hybrid technologies are part of that strategy. In potential future studies an EMF radiation HYGEIA model should account for the emerging trend of hybrid technologies in demonstration runs.

This research is limited to scope HVAC power lines and unshielded substations of 11kV and greater (WHO, 2016c). Conflict arose in determining a base line estimate of exposed population to ELF EMF radiation hazard conditions as part of the risk analysis. Historical government studies reported that less than one percent (< 1%) of the population lives within the investigated epidemiological buffer zone of HVAC powerlines (Kelfkens et al., 2002; Kheifets et al, 2005; Huss et al, 2009). The Netherlands government, however, demonstrated that the projected estimation of encompassed residents is underestimated (Takemoto-Hambleton et al., 1996; Kelfkens et al., 2002). Exposure to ELF EMF radiation is a recognized concern with an increasingly growing exposure to ELF EMF radiation exposure sources, because of growing infrastructure demand requirements (WHO, 2015a; WHO, 2016c).

Weighted-studies by publishing organizations, for example, revealed different ELF-EMF radiation exposure levels. The literature review of Dürrenberger et al. (2014) revealed studies estimating that only about five percent (5%) of the European population is exposed to ELF EMF radiation levels above 1 mG. In contrast thereto, Dürrenberger et al. (2014) identified another study of thirty-nine (39) European experts who calculated that fifty percent (50%) of the population would be exposed to ELF EMF radiation above 1 mG and about five percent (5%) to above 2 mG.

Reviewed and replicated epidemiological studies demonstrated increased biological effects and subsequent health risks to vulnerable population classifications under ELF EMF radiation hazard conditions (Ahlbom et al., 2000; Greenland et al., 2000; Kheifets et al., 2010; Liu et al., 2014; Zhao et al., 2014). Significant ELF EMF radiation biological effects were defined in hazard conditions of average exposure levels above 3 mG or 4 mG, relative to averages below 1 mG. The peer-reviewed ELF EMF radiation hazard condition findings confirmed *no* attribution to chance, bias or confounding (Belyaev et al., 2016).

4.10.1.2 RF-EMF radiation

Macro RF-EMF radiation infrastructure sources are radio broadcast transmitters, public Wi-Fi, cellular transmitters and microwave line of sight transmitters. Microwave line of sight transmitters were not included in the scope of this public interest research.

4.10.2 EMF attributes and quality metrics

As discussed in Section 2.2, the STEP and LTCEP models have different and prioritized (reference levels in respect of STEP and dosimetry limits in respect of LTCEP) values to

EMF radiation pollutant attributes with respect to attributes and quality metrics. The regulatory EMF radiation pollutant attributes are (1) PFD (W/m^2), (2) magnetic field strength (A/m), (3) magnetic flux density (µT or mG), (4) field intensity (V/m), (5) localized hotspots, (6) re-radiation and (7) spurious emissions.

Points (1) to (4) are units of measurement for the instantaneous/peak and average values of the electric and magnetic components within EMF radiation. Points (5) to (7) are technological performances and/or biological hazard conditions. As discussed in Section 4.7, the STEP and LTCEP models' inputs each has its own dosimetry specified reference levels, limits, rationale and risk thresholds for points (1) to (7). An elaboration of points (5) to (7) is set out below.

4.10.2.1 Localized hotspots

A localized hotspot is the spatial fluctuation of the intensity of RF-EMF radiation and is attributable to the RF-EMF radiation wave nature of electromagnetism in terms of which the phases of RF-EMF radiation waves, coming from an infinite number of paths in a 3D space, interfere with each other (Vermeeren et al., 2010). The interference leads to an intensity distribution that is highly sensitive to an individual's position (Houndou et al., 2006; Vermeeren et al., 2010; WHO, 2016e).

The STEP model endorses and the DHSA (CCPTM, 2015:47) advocate that RF-EMF radiation from infrastructures is safe, because the inverse square law for RF-EMF radiation commands the exponential dissipation in RF-EMF radiation power density with distance (laboratory test environment) and, therefore, levels exceeding STEP model reference levels are unlikely to be encountered.

The STEP paradigm above is contradicted by decades of research studies. Reno & Beischer (1973) from the Naval Aerospace Medical Research Laboratory, Hondou et al. (2006) and Yahya & Khalil (2015), for example, demonstrated the naivety of the safety assumption of the STEP model in public areas (anthroposphere) (Sage et al., 2007). Based on the perspective law of mathematical physics electromagnetic waves, as described in Maxwell's set of partial differential equations, a fundamental element of RF-EMF radiation propagation is that a partial differential equation cannot be solved without specifying its boundary condition (Vermeeren et al., 2010; Hondou et al., 2006).

Reno & Beischer (1973) and Hondou et al. (2006) simulated, demonstrated and concluded that public exposure to RF-EMF ARDs can be enhanced by microwave propagation reflection, leading to passive RF-EMF radiation in public spaces, for example: elevators, cars, busses, airplanes, trains and many buildings (Paffi et al., 2015; WHO, 2015b; WHO, 2016e). An experiment by Hondou et al. (2006) demonstrated the occurrence of several localized hotspots arising within a real world environment. The RF-EMF radiation measurements for the localised hotspots at a prescribed distance were up to two thousand times (2000x) greater than predicted by the inverse square law advocated by STEP model endorsers. Detailed GIS dataset knowledge bases can enable the simulation and approximation of localized hotspots within the anthropophere under investigation (United States Naval Academy [USNA], 2016).

Another form of hot spot is constructive interference. Constructive interference, a resultant in the intensity of EMF to be generally stronger between multiple wireless devices, is another form of hotspot shown in Figure 4.5. As the number of sources increases, the amplification of the resultant field intensities at certain locations increases too, and for a large number of sources field intensities may become very sharp. This explains theoretically the detected hot spots from mobile telephony base stations in urban environments (Panagopoulos et al., 2015).

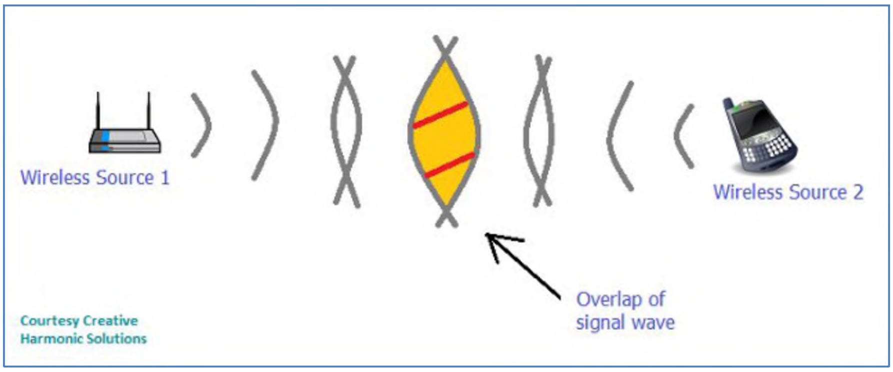


Figure 4.5 Constructive interference between multiple devices (EMR, 2017)

Constructive interference has the capacity of polarization in the biological activity of EMFs (Belyaev, 2015; Panagopoulos et al., 2015; Belyaev et al., 2016). Polarized EMF can have increased biological activity due to the ability to produce constructive interference effects and amplify their intensities at many locations. Secondly, the ability to force all charged molecules, and especially free ions within and around all living cells to oscillate on parallel planes and in phase with the applied polarized field (Panagopoulos et al., 2015). Such ionic forced-oscillations exert additive electrostatic forces and consequently disrupt a cell's electrochemical balance. These features render anthroposphere EMFs more bioactive than natural non-ionizing EMF radiation. This may explain the increasing number of biological effects discovered during the past century to be induced by anthroposphere EMFs, in contrast to natural EMFs in the terrestrial environment (ecosystem) which have always been present throughout evolution, although human exposure to the latter ones is normally of significantly higher intensities and cumulative durations (Suzuki, 2014; Panagopoulos et al., 2015; Belyaev et al., 2016). Thus, polarization seems to be a trigger that significantly increases the probability for the initiation of health effects in vulnerable population categories (Belyaev, 2015; Panagopoulos et al., 2015).

4.10.2.2 Re-radiation

Re-radiation is emitted as a consequence of a previous absorption of radiation. Examples of re-radiation are:

1. Localized hotspots;
2. Undesirable radiation of signals generated by a device that might cause interference, for example: near-field EMF radiation effects of a radio broadcast antennae may extend out three kilometers of or more. Cellular and microwave towers within this radius can reflect the radio broadcast signal out at a different EMF radiation frequency, resulting in interfering frequencies and/or biological effects (WHO, 2013; LBA Group, 2016);
3. EMF radiation, at the same or different wavelengths, received from an incident wave and coupled, for example: with EMF radiation from a cell transmitter (macro or micro) coupling onto a HVAC power line or metal piping into a residence. An example regarding SMART meters is contained in the next section.

4.10.2.3 Spurious emissions

Spurious emissions are unwanted EMF radiation transmissions on frequency, the level of which may be reduced without affecting the corresponding emission of information or energy (Mazar, 2009).

In ELF EMF radiation, spurious emissions are referred to as 'dirty electricity' (Belyaev et al., 2016). Dirty electricity is the electrical pollution consisting of high frequency voltage transients and harmonics riding along on the 50 or 60 Hz wave form and contaminating the electricity delivered to users (Milham, 2017). It is the result of voltage and/or current perturbations from micro or macro EMF radiation sources. The EMF radiation transients travel along the electric wiring and grounding systems and emit electric and/or magnetic fields into free space, resulting in exposure to humans in the immediate vicinity (Belyaev et al., 2016). The incidence of dirty electricity is increasing with the proliferation of SMART meters. SMART meters cause a significant amount of noise on the 50 or 60 Hz signal. Some of this electrical noise is due to the SMPS contained in the SMART meter, but it is also due to RF-EMF emissions being conducted along house wiring and being re-radiated into the home, as discussed in the previous section (Isotrope, 2013; Donahue, et.al, 2014; Anderson, 2017).

In following the STEP model, RF-EMF radiation spurious emissions are elementary components of regulation in that spurious emissions levels affect the suitable introductions of any new RF-EMF system. Adjacent licensed RF-EMF receivers may be interfered with as well (WHO, 2006a; Mazar, 2009). Mazar (2009) recommends spurious emissions to be a top priority to regulatory bodies, because lowered unwanted emissions reduce the uncertain risk of RF-EMF interference (environmental noise).

LTCEP model endorsers adopt an ALARA approach to spurious emissions as they potentially reduce adverse biological effects by releasing less erratic emissions to interfere with biological systems. Since healthy ELF and RF-EMF systems suffer less spurious emissions, they thus also ensure a longer product lifespan, avoidance of interference with other RF-EMF systems, reduced localized hotspot clusters, elevated RF-EMF transmission power levels and/or data signal repeaters (Mazar, 2009; WHO, 2016c).

A comparison of spurious emissions regulations between the USA, Japan and the EU is available in the Appendix, Section 4.6 (Spurious emissions continued).

4.11 EMF radiation GIS model formulas

Propagation is the study of how to get a data packet, or energy using EMF radiation, from Point A to Point B by establishing a 'hand-shake' protocol (USNA, 2016). Propagation calculations enable the calculation of EMF radiation dosimetry.

The engineering discipline of propagation is vast and complex and is divided into two categories of large and small scale propagation. This dissertation is scoped to utilize a high-level analysis of propagation to meet the GIS model calculation requirements for this research.

Product technical specifications and STEP model safety reference levels are based on free space propagation, since the real world is not devoid of terrain, mountains, buildings, ground and the atmosphere (USNA, 2016). 3D GIS software simulation models are used to forecast the complex engineering of EMF radiation propagation and for diagnosing technology performance interference issues, as well as potential hazard conditions (Boumans et al., 2015; ESRI, 2016; USNA, 2016) in order to address the real world inherent anthroposphere and topography limits on EMF radiation. A further elaboration on RF-EMF radiation propagation and calculation equations is available in the Appendix, Section 4.7 (Wireless RF-EMF radiation propagation).

Three different RF-EMF radiation geospatial propagation GIS model calculation approaches were investigated, namely: direct SAR, near-field and far-field.

Direct SAR and near-field provide the most accurate GIS model inputs for a MIMES framework public interest HYGEIA model (Mann et al., 2000; USNA, 2016). As discussed in Chapter 1, however, SA EMF radiation infrastructure data sources refuse to disclose (even to regulatory bodies and for academic public interest research) technical and operation log files needed to carry out accurate 3D GIS EMF radiation evaluation models. Further elaboration of the SAR and near-field approaches is available in the Appendix, Section 4.9 (Direct SAR and near-field evaluation). As discussed in Section 4.8, SAR is not an appropriate quantity indicator of biological effects and is therefore not an appropriate health exposure function metric (Lathrop, 2003; Chiang, 2009; WHO, 2003a: 69; Belyaev et al.).

Potential future studies would need to gain access to the necessary ELF and RF-EMF ARD technical specifications, required in modeling the direct SAR and near-field RF-EMF radiation power flux density and field intensities, in fulfilment of RQ_5

As discussed in Chapters 7 and 9, this study was denied access to detailed EMF radiation pollutant technical specifications and operation log files that restrict the use of GIS EMF radiation model formulas to free space propagation (known as far-field power density evaluation). The free space propagation equation in far-field has been altered to generic terrain conditions in a flat 2D geospatial analysis (RQ_4). Input into the geospatial propagation equations is data extracted from the literature, using the MIMES frameworks' benefit transfer method (BTM) (Boumans et al., 2015).

The simpler far-field calculation approach outputs a more conservative outcome (RQ_4), resulting in greater compliance distances of the framework (Chapter 5) EMF radiation policy inputs into the model in Chapter 6 (Mann et al., 2000). The next section discusses the far-field power density evaluation.

4.11.1 Far-field power density evaluation

A far-field power density evaluation is used when the total power fed into an ARD transmitter is known. This renders it possible for a single operator to calculate the power density in the boresight of the main beam by assuming inverse square law dependence upon distance in respect of all distances from the ARD transmitter. (Mann et al., 2000; USNA, 2016).

Further elaboration of the far-field approach and BTM values for multiple operator calculations extracted from the literature is available in the Appendix, Section 4.10 (Far-field power density evaluation calculation for cellular RF-EMF radiation exposures).

Generic far-field calculations do not represent real world modeling scenarios and are therefore unable to identify potential hazard conditions, such as localized hotspots. This is due to the inability of a generic far-field model to incorporate Maxwell's set of partial differential equations to account for reflection propagation (Mann et al., 2000; Houndou et al., 2006).

The far-field evaluation is reversible by using the Friis transmission equation (Kumar, 2010). This equation enables the conversion calculation from measured RF-EMF radiation to power density (W/m2), derived from the far-field evaluation. This is a theoretical measurement of the RF-EMF radiation power received at a distance by an ARD antenna (mobile device) and is used to receive the RF-EMF radiation at a specific spectrum / frequency modulation. The output is a rough approximation of the RF-EMF radiation exposure in the investigated area, using the mobile device (USNA, 2016).

A further elaboration on the Friis transmission equation utility to approximate RF-EMF radiation exposure, using a mobile device, is available in the Appendix, Sections 4.11 (Theoretical measurement for RF-EMF radiation received) and 4.11 (Conversion calculation for measured RF-EMF radiation to power density).

4.11.2 GIS modelling software

Three (3) prominent GIS applications were reviewed for this public interest research, namely: (1) QGIS (open source); (2) Google maps (freeware and commercial); (3) ArcMap (commercial).

(1) QGIS is the open source equivalent competitor to ArcMap. QGIS does offer a RF-EMF radiation propagation plug-in called Q-RAP.

(2) Google Maps is a powerful mapping engine technology with accessible APIs used through Google's 'Fusion Tables'. The licenses for the commercial platform were not available under the RU license agreement, however. Usage of the freeware license

would have placed the public interest research data into the public domain. This was not elected as a viable strategy, because some of the data from the service providers required the signing of a non-disclosure agreement preventing the placing of the data in the public domain.

(3) ArcMap was selected for this public interest research because of the available commercial license agreement with RU. In addition thereto, data service providers are using ArcMap for their commercial GIS needs, rendering ArcMap the best option for interoperability in this public interest research. Furthermore, third party plug-in commercial applications for RF-EMF propagation are available and utilized by private telecommunication companies in SA. In the event of technical specification data for ARD transmitters being received, gaining access to the same commercial 3rd party plug-ins would enable better interoperability.

The HYGEIA model in the MIMES framework information system allows for interoperability with any of the three GIS platforms listed above.

4.11.3 Land cover attributes

As discussed in Section 4.10, each GIS dataset land cover layer is assigned production and demand profiles and is assigned an index function. A review of the MIMES framework spells out the base land cover attributes required in a HYGEIA model (Boumans et al., 2011; Phillip et al., 2014; Boumans et al., 2015). The land covers attributes are census, demographics, topography, pollutant attributes and climatic data. Climatic data, however, is not scoped in the study.

4.11.3.1 Census and demographics

Census and demographics datasets are available from the EMFDS9, StatsSA and the Western Cape Department of Education.

EMF radiation exposure levels for each census/EMF radiation infrastructure polygon can be calculated as means weighted by the proportion of each cover class in the polygon (hazard condition health outcome) (Boumans et al, 2014). The selected census datasets represent the geospatial variation in EMF radiation exposure over the study area that can then be used to assess spatial relationships with vulnerable populations and for the computation of relative potential EMF radiation morbidity rates for the different areas (HYGEIA process model) (Boumans et al, 2014).

This study used the STEP and LTCEP models' indices of vulnerability (scientific-technical analysis) from the literature review to characterize the relative vulnerability of the residents in different census units (vulnerable facilities) in the study area. These spatial patterns can then be overlaid with the spatial variation in high EMF radiation exposure to identify the areas of highest concern (heat maps) (RQ_4 output). The EMF radiation vulnerability index (EMFVI) generated for this research incorporates variables related to demography and social situation, but is limited by excluding land cover, pre-existing health conditions and micro EMF radiation exposure usage patterns.

An examination of PAIA (2000) literature and case law enabled the construction of the PIO environmental risk vulnerability index, as discussed in Chapter 3 (PIOERVI).

A social vulnerability index (SoVI) measure is outside the scope of this research. The SoVI index for generalized natural hazard vulnerability may be calculated by summing factors derived from several demographic, socioeconomic, and built environment variables in potential future studies (Boumans et al., 2014).

4.11.4 Topography

Topography is the distribution of parts or features on the surface, or within ecosystem services, or the complex system as a whole (Boumans et al., 2015); an arrangement of the natural and artificial (anthroposphere) physical features of an area. A GIS manages, processes and intersects multiple dataset layers containing a detailed description or representation (X,Y, Z, M co-ordinates plane) of the natural and artificial features of an area on a map (ESRI, 2016).

The propagation of EMF radiation is bound by complex environmental characteristics (USNA, 2016). The EMF radiation characteristic variables, namely propagation, reflection, refraction, scattering, range, channel reuse, re-radiation, shadow zones and localized hotspots are all influenced by topography (Xia et al., 1993; Kumar, 2010; Hondou et al, 2006; Mitchel, 2016, USNA, 2016). A further elaboration on the influence that topography has on range and channel re-use is available in the Appendix, Section 4.13 (RF-EMF radiation range and channel re-use).

Access to detailed topographical data provides increased accuracy in forecasting EMF radiation hazard conditions within a MIMES framework HYGEIA model (Boumans et al., 2014, Phillips et al., 2014; Boumans et al., 2015). Examples of topographical data are the digital elevation model (DEM), tree cover, watersheds, 3D buildings, LIDAR (3D laser surface modelling), CAD (computer aided design) models and anthroposphere features (buildings, roads, etc.).

4.11.5 Vulnerable area facilities

Classification of vulnerable areas using scientific-technical analysis per the STEP and LTCEP models, is the long stay (hours) of the 'sensitive objects', where the policy applies within facilities. The latter is not limited to the building facility but also includes the garden (vacant space) as part of the sensitive object (GRID_Arendal, 1996; Government of Italy, 1998; ICNRIP, 2002; WHO, 2006a; Government of India, 2010; Rajasthan, 2012; EMFs.info, 2016b). Sensitive objects are categorized as the youth, pregnant mothers, chronically ill, the elderly and members of the population who express sensitivity.

Based on the literature review and context of the investigation area, the study scoped vulnerable area facilities as education facilities for children under the age of eighteen (18) and included libraries, clinics, hospitals, orphanages, hospices, juvenile prisons, fire stations and public facilities (sports grounds, tennis courts and swimming pools).

4.12 Hazard conditions

In fulfilment of RQ4 and the demonstration of a PIO in RQ5, the calibration of hazard conditions will determine the output of heat maps based on the framework EMF radiation policy inputs into the model. This section will discuss how the determination of hazard conditions by the STEP model inputs will considerably differ from that of the LTCEP model.

A hazard is a *subjective* concept of the circumstances under which ecosystem services intersect with and/or may influence the complex system, posing a level of threat to life, health or environment (Zaplatynskyi, 2013; Boumans et al., 2015; EDA, 2016). Hazards can be dormant or potential, with only a theoretical risk of harm (Zaplatynskyi, 2013). Hazard and possibility interact to create risk (Mazaar, 2009; Zaplatynskyi, 2013). Public interest modelling hazard conditions aim to achieve early prevention, instead of late correction (Sherwin, 1983; Boumans et al, 2011).

A scientific-technical analysis confirms that members of the population (when categorised by age and health) have different levels of vulnerability to low intensity electromagnetic field (EMF) radiation hazard conditions (Grid-Arendal, 1996; ICNIRP, 2002; Government of Italy, 1998; WHO, 2009; Government of India, 2010; WHO, 2014; Belyaev et al., 2016).

As discussed in Section 4.9, very specific EMF radiation exposure conditions may trigger biological responses in one individual, but not in others (Belyaev et al., 2016). Individual responsiveness or susceptibility, however, could expand over time and the intolerance to EMF radiation could extend over a broad range of exposure conditions or cumulative total body burden (RQ_5) (Belyaev et al., 2016). For example: a series of case reports indicated healthy adults developing intolerance to EMF radiation after a brief, high intensity RF-EMF radiation exposure hazard condition (Federal Administrative Court, 2012; Carpenter, 2015; Kundi, 2015; Belyaev et al., 2016).

It is challenging to define the value of health in EMF radiation related issues, as it is not an academic exercise, because there is *no clear line* between a normal state of health and sub-clinical diseases (Sherwin, 1983; Foster, 2001; WHO, 2006a; Mazar, 2009).

The WHO constitution of 1946 defined health as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (2006a:15). The broad definition of health by the WHO is parameterized by Sherwin (1983:1) as "homeostasis of the cellular ecology and a state where there has not been an inordinate loss, reversible or irreversible, of the structural and/or functional reserves of the body".

An adverse health effect is achieved, in line with scientific-technical analysis, when the "causation, promotion, facilitation and/or exacerbation of a structural and/or functional abnormality, with the implication that the *abnormality produced* has the *potential* of *lowering the quality of life*, contributing to a disabling illness, or leading to a premature death" occurs (Sherwin, 1983:1).

The WHO (2006a:11) disclaimed that STEP model guidelines are generally based on engineering considerations, i.e., "to minimize electromagnetic interference with other equipment and/or to optimize the efficiency of the device. While emission limits are aimed at ensuring, inter alia, compliance with exposure limits, they are *not explicitly based* on health considerations".

WHO (2006a) confirmed that the STEP model reference levels have the capacity for a biological effect and thus also the potential to cause a health hazard (WHO, 2004b). This was re-affirmed by the WHO International Agency for Research on Cancer (IARC) stating that "even small effects on radiation concentration could potentially affect multiple biological functions" (WHO IARC, 2013:103; Havas, 2016).

The WHO framework for developing health-based EMF standards (2006a) defines a biological effect as ‘any physiological response to EMF exposure’. Some effects may be subtle responses within a normal physiological range, or may result in pathological conditions, while others may have beneficial consequences for a person. Historically, the WHO (2006a) stated that “annoyance or discomforts caused by EMF radiation exposure may not be pathological per se but, if substantiated, can affect the physical and mental well-being of a person and the resultant effect may be considered as a health hazard” (WHO, 2006a:15).

WHO (2004b) recognized categories of the population to have an acute sensitivity and or intolerance to low intensity EMF radiation exposure (ICNIRP, 2002:546; WHO, 2007:12; Redmayne, 2017). (WHO, 2004b). The biological response manifests itself as a variety of severe dermatological, neurasthenic and/or vegetative symptoms which the person attributes to EMF exposure resulting in a functional impairment (WHO, 2004b). The biological response is ‘real’ signalled by noticeable biological responses. The symptoms are a biological defence reaction to a toxin or allergen, i.e. a functional impairment, which may be caused by an immune reaction to an environmental trigger (WHO, 2004b; Redmayne, 2017).

Half a decade later, reliable biomarker tests to establish a pathology to EMF radiation exposure and confirming a genuine somatic pathological entity were successfully developed (Leszczynski et al., 2002; Belpomme, 2011; Eskander et al., 2012; Austrian Medical Association, 2012; Tuengler & von Klitzing, 2013; De Luca et al., 2014; Gharib, 2014;; Belpomme et al; 2015; Belyaev et al., 2016; Yakymenko et al., 2016; Redmayne, 2017; Andrianome et al., 2017; Heuser & Heuser, 2017; Zothansiama et al., 2017). EMF radiation exposure pathology reports are supported by science-based studies, empirical observations and patient medical reports, clearly indicating interactions between EMF radiation exposure and health problems (Belyaev et al., 2016; Heuser & Heuser, 2017). Thereby, in accordance with the scientific-technical analysis, the WHO recognizes that an EMF radiation-related health hazard is thus defined as a biological effect that has health consequences outside the compensation mechanisms of the human body and that is detrimental (WHO, 2004b; WHO, 2006a; WHO IARC, 2013; WHO, 2016e).

LTCEP model experimental animal studies by Daniels et al. (2009) from the Department of Human Physiology, University of KwaZulu-Natal, HHS NTP (2016) and Soffritti et al. (2016) of the Ramazzini Institute, indicate that EMF radiation has the potential to cause serious adverse health effects and abnormal brain functioning through perturbations of the cellular ecology over long-term periods (Kolodynski & Kolodynska, 1996; IAFF, 2004;

WHO, 2006b; Fragopoulou et al, 2012; Herbert et al., 2012; Gherardini et al., 2014; WHO, 2015a; Belyaev et al., 2016; Djordjevic et al., 2017).

The parameters of morbidity range from the earliest or mildest symptoms of ill health to exacerbations of terminal illnesses of diverse kinds because of an external source (Sherwin, 1983). The range of categorization, as described by Sherwin (1983), is recognized for investigation and action by the Regulator4 (2016), Regulator5 (2016) and Regulator (2016), if, for example, the erection of a public Wi-Fi hotspot or cellular transmitter resulted in reported complaints of headaches from members of the public. These listed eventualities required by the CCPTM regulator departments above, however, confirm a lack of understanding of EMF radiation literature and rationale to take appropriate mandated action.

Hazard conditions forecasting morbidity and mortality health outcomes are implementable in a HYGEIA model and the implementation thereof will contribute to address the CCPTM departments' concerns and will provide a better understanding of EMF radiation (Phillips et al., 2014; Boumans et al., 2015). Hazards can affect various health outcomes, although health outcomes are not specific to a particular hazard (Boumans et al., 2011). If relevant data related to climate change is available, arrays of health effect values for incidence or mortality rates may be populated for other combinations and stratified by census variables such as age, for example.

Ecological knowledge (GIS datasets) about land covers, weather, ecosystem service patterns and pollutant behaviour informs a spatial dynamic simulation of hazard conditions at locations specified as polygons in a HYGEIA model. Dynamics in health outcomes under the simulated hazardous conditions are estimated when the location-specific nature of the social fabric (the race, ethnicity, gender, age, employment, income and gender distributions of the local population), is confronted with estimates on how social fabric elements are affected (discussed in Section 4.4) (Boumans et al., 2011). Modelled hazard conditions are identified through the intersection of GIS dataset layers.

Health effect scenarios, based on recent and projected extreme and changing environmental conditions, can assist in locating specific areas of vulnerability (Boumans et al., 2011). EMF radiation exposure-related morbidity complaints have been reported nationally in SA (ASA, 2004; DHSA, 2005; Daniels et al., 2009; NMBM, 2011; KM, 2012; EMRSA, 2014; SAHRC, 2015; DHSA, 2016c; Regulator5, 2016; Regulator4, 2016; Regulator6, 2016). As discussed in in Chapter 2 and Section 3.4, public interest is at stake when the structure of institutional democracy is threatened by a culture of 'secretive and unresponsive' government

(CfSAvSPo, 2010). Thereby, when no or limited action is taken on EMF radiation hazard condition complaints by regulators, there is a demonstrated PIO. However, the geographic and demographic scales of the EMF radiation exposure data have not been collected and are not sufficiently defined to address potential mitigation and adaptation responses on a local scale due to the threat on public interest discussed in the previous chapter (CfSAvSPo, 2010; National Institute of Environmental Health Sciences [NIEHS], 2010; Belpomme et al., 2015).

4.13 Mitigation options

The objective of the modelling of mitigation options is to create an overview of the various technologies and options that might be appropriate for mitigating EMF radiation exposure, as well as the types of legislative policies and measures that can promote the implementation of those options (UNFCC, 2006; Boumans et al., 2011; Phillips et al., 2014). Successful mitigation to enable EMF radiation adaptation is dependent on technological advances, institutional arrangements, availability of financing and information exchange (IPCC, 1995). Technological advances have generally increased adaptation options for managed systems (IPCC, 1995; WHO, 2016c). SA currently has limited access to these technologies and appropriate information, however (Regulator8, 2016b; Regulator4, 2016; Regulator5, 2016; Regulator2, 2016). The efficacy and cost effective use of adaptation strategies will depend on the availability of financial resources, technology transfer and cultural, educational, managerial, institutional, legal and regulatory practices, both domestic and international in scope (IPCC, 1995). The incorporation of EMF radiation exposure concerns into resource use and development decisions and plans for regularly scheduled investments in infrastructure will facilitate adaptation (IPCC, 1995).

A mitigation option/s would be executed in a demonstration run to forecast various public health interest model outcomes in a HYGEIA model.

There are five (5) mitigation category options that are implementable in policy in EMF radiation, namely: (1) intensity, (2) proximity, (3) duration, (4) shielding and/or absorption, (5) improved technology.

Not all EMF radiation sources are detrimental to public health. The spectrum of solar EMF radiation filtered through the earth's atmosphere is, for example, vital for life on earth. Chronic exposure (hazard conditions) to solar EMF radiation could, however, lead to detrimental health effects. The solar EMF radiation hazard conditions for each biological unit (human) are subjective, according to the climate change framework scientific-technical analysis. The solar EMF radiation exposure example highlights how the intersecting EMF radiation mitigation category parameters of (1-5) could create scenarios detrimental to human health.

Intensity, proximity and duration, in order of prominence, are the main EMF radiation mitigation options globally implemented per the STEP and LTCEP models' EMF radiation legislative policies, as shown in the Appendix, Section 2.1 (International RF-EMF radiation power flux density limits for GSM 1800). The mitigation options of the HYGEIA model demonstration runs in this dissertation are limited to intensity and proximity.

The common practice toward mitigating EMF radiation in vulnerable areas is to restrict the EMF radiation power flux densities (W/m^2) and/or field intensity (V/m) and the maximum exposure period and/or by imposing a geospatial buffer restriction around vulnerable area facilities. An additional mitigation option employs shielding technologies to protect inhabitants within a building from environmental RF-EMF radiation levels, for example: certain thermal insulating material, wire meshing and window UV coatings contain shielding properties that can reduce or reflect RF-EMF radiation. Such shielding installations are commonly found in computer server rooms containing sensitive data that needs to be protected from external hackers. Another mitigation option is the advancement in technology. For example, using Li-Fi or wiring of wireless devices in offices or classrooms (PureLiFi, 2014; OctoWired, 2016). The outcome is increased security, connection speed and mitigated hazard conditions.

In Boumans et al. (2014b), the HYGEIA model forecast mitigation strategy for reducing the induced solar EMF radiation heat effects on the population was achieved by the selective placement of trees. Kumar (2014) recommended the installation of dense, high tree lines in the wave of the ARD transmitter line of sight and reflection propagation path, surrounding vulnerable facility areas, when using trees as an RF-EMF radiation mitigation shielding/absorbing option. Kumar (2014) advises, however, that the referenced HYGEIA model mitigation strategy should include a feasibility analysis on the replacement of the trees because of the EMF radiation adaptability being dependent on the RF-EMF radiation levels (Bernatzky, 1996; Haggerty, 2010; Bhon, 2013; Waldmann-Selsam & Eger, 2013; Waldmann-Selsam et al., 2016; Halgamuge, 2017).

The study is limited to applying an EMF radiation HYGEIA model to humans only, but future studies should be extended to include other ecosystem services, such as vegetation, pollinators and sea life (Lázaro et al., 2016; Tomanova et al., 2016).

Alternative mitigation options reviewed for potential future studies are in the Appendix, Section 4.14 (ELF and RF-EMF radiation mitigation options).

4.14 Social fabric and economic attributes

Due to resource constraints, social fabric and economic attributes assumptions were based on STEP and LTCEP models' literature for the demonstration runs in Chapter 8. Accuracy is therefore limited, but could be increased in future studies by carrying out a computation of ecosystem services.

An elaboration on the structure for ecosystem services of 'economic costs', 'accounting costs' and dematerialization is available in the Appendix, Section 4.15 (Social fabric and economic attributes), for future studies. Another useful computational tool related to this section but outside the scope of this study, is discussed in the Appendix in Section 4.16 (Input-output analysis including social accounting matrices).

Discussed in Section 2.7, the precautionary principle uses the best available science as an input to public policy-making. However, sound policy depends not only on good science, but also on other values such as the moral imperative to preserve health, life and the environment (Ramazzini Institute, 2010). The assessment of social fabric and economic attributes in the anthroposphere, in fulfillment of RQ_4, contains a dynamic implementation of new technologies and economic growth through resource use. A thorough comprehension of the production of multiple, coupled ecosystem services, is a prerequisite for a desirable search for sustainable solutions (Boumans et al., 2015). On the next page, Figure 4.5 shows the comparative visual analysis for social and economic attributes from the model outputs in partial fulfilment of RQ_4. By comparing what is lost and what is gained among alternative mitigation decisions in RQ_5, an evaluation of tradeoffs and a better understanding of the consequences to human well-being are charted (STEP versus LTCEP model inputs) (WHO, 2006a; Boumans et al., 2015). Such tradeoffs can be estimated by a multitude of emergent properties in the social, economic, and environmental domains operating as one integrated system (Boumans et al., 2015).

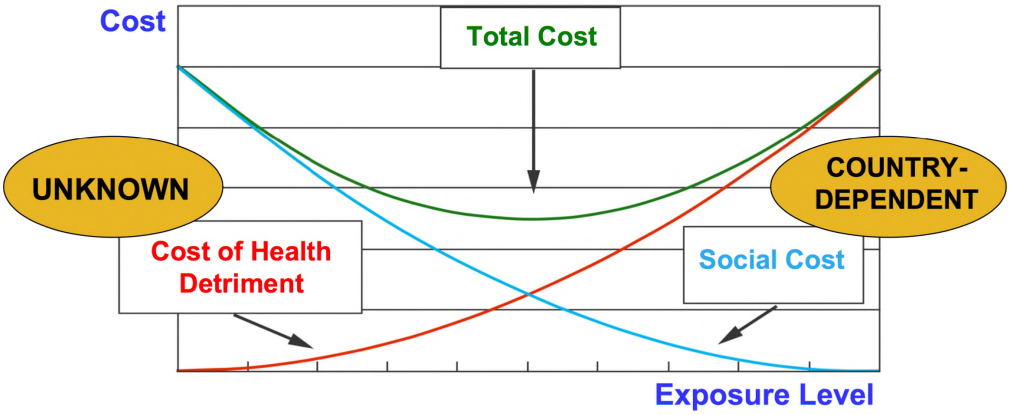


Figure 4.6 ALARA social accounting scope for EMF radiation scenario modeling (ICNIRP, 2008)

A literature review for extracting, calculating and processing social and economic attributes for a proposed public interest forecast simulation model revealed an array of tools and methods. The following tools and methods were chosen from the literature review and their usefulness to this research is discussed in the subsections below:

- Section 4.14.1: Evaluating minimum and maximum economic ecosystem service values.
- Section 4.14.2: The benefit transfer method for resource constrained research.
- Section 4.14.3: Evaluating economic risk threshold limits per investigated community.
- Section 4.14.4: Quantifying societal risk concerns and calculating risk threshold limits.

EMF radiation exposure to population groups' vulnerability increases as adaptive capacity decreases (IPCC, 1995; WHO 2007:5). The vulnerability of human health and socio-economic systems and, to a lesser extent, ecological systems, depends on economic circumstances and institutional infrastructure (IPCC, 1995). This implies that systems are typically more vulnerable in developing countries where economic and institutional circumstances are less favourable, resulting in an unregulated EMF radiation exposure environment (IPCC, 1995). As discussed in Section 2.2, population categories of the young, elderly and chronically ill are particularly vulnerable to unregulated EMF radiation exposure (IPCC, 1995; ICNRIP, 2002). Some regions have become more vulnerable to EMF radiation hazards conditions, such as localized hotspots and close proximity to EMF infrastructure sources, as a result of increasing population density in sensitive areas, such as schools, healthcare facilities and residential areas (Rajasthan, 2012). The broad potential implications for public health due to increasing ambient EMF radiation levels and hazard conditions' near term effects on human ecological and socioeconomic systems will, most likely, occur as a result of changes in the intensity, time and geographic distribution incidence of diseases resulting from exposure to EMF radiation (IPCC, 1995; NTP, 2016). Vulnerability can be reduced by strengthening adaptive capacity in most anthroposphere regions (IPCC, 1995; Boumans et al., 2015).

4.14.1 Minimum and maximum economic values: ecosystem service evaluation

The ecosystem service evaluation (ESV) tool within the MIMES framework is a spreadsheet-based tool for estimating the value of the ecosystem services of a landscape or sphere. ESV offers a standardized method to utilize the results of existing valuation studies in estimating the value of ecosystem services for a specific study area, using the benefit transfer method (BTM). The BTM approach applied to this public interest research is explained in the next section.

The ESV data requirements are land-use distributions and ecosystem health estimates by land-use classification (Boumans et al, 2015). A literature review of the STEP and LTCEP models provided the data extraction for an ESV table from the EMF radiation dosimetry rationale, environmental and EMF radiation related legislature, biological and epidemiological study findings and the tabulation of potential health estimates from EMF radiation exposure.

The inherent undefined metrics in public interest and health are, however, obstacles in completing an ESV table (Sherwin, 1983; WHO, 2006a; ICAEW, 2012). The MIMES framework contingency for defining undefined metrics is consultation with local and international experts in converting material into data for the MIMES framework public interest HYGEIA model (Boumans et al., 2015).

4.14.2 Benefit transfer method

The BTM is used to estimate economic values for ecosystem services by transferring available information obtained from case studies to another location and/or context (King and Mazzotta, 2000). Values for EMF radiation exposure levels and epidemiology studies in a municipality may, for example, be estimated by applying measures of EMF radiation values obtained from a study conducted in another municipality.

The basic goal of BTM thus is to estimate benefits for one context by adapting an estimate of benefits from some other context. King and Mazzotta (2000) recommended using the BTM when it is too expensive and/or when there is too little time available to conduct an original valuation study. Some measure of benefits is needed, however. The BTM is useful as a screening technique to determine whether a more detailed original valuation study should be conducted in the area, as identified in the scope of this public interest.

A further elaboration on the BTM and the steps involved in its execution is available in the Appendix, Section 4.17 (Benefit transfer method continued).

4.14.3 Economic risk threshold limits

Hazard conditions occur when hazard and possibility interact to create risk, as discussed in Section 4.12 (Zaplatynskyi, 2013). The first step in performing a risk assessment is the identification of hazard risks. A risk assessment is a conceptual framework for a structured review of information relevant to estimating health or environmental outcomes (WHO, 2007:11). A risk assessment is the operation that assigns an economic value to risk (Mazaar, 2009; Zaplatynskyi, 2013; Boumans et al, 2014). A health risk assessment reaches a decision on whether exposure requires any mitigation options and the associated economic, and social accounting outcomes (WHO, 2007:11). As discussed in Section 2.2, the STEP and LTCEP models have very different accounting scopes, accountability and risk threshold limits to EMF radiation exposure.

The LTCEP model is typically set as a national standard in countries that have a collectivized economic practice scope that includes social accounting (collectivized) (WHO, 1999; Foster, 2001; Mazaar, 2009).

The STEP model is market driven (individualized) in the interest of the individual by allowing the 'invisible hand' of the market to determine preferences in public interest, for example: the stock market (Foster, 2001; Mazaar, 2009). Whang et al. (2003) and Grant et al. (2010) expressed the significant potential risk in the individualized paradigm, because of the individual's potential aggressive pursuit of short-term reward that may engender their persistent behaviour, despite knowledge of the adverse consequences. STEP model agencies make the recommendation that countries must develop their STEP model guideline modifications, based on their *value system,* to defer EMF radiation exposure accountability (ICNIRP, 2002; WHO, 2006a; Vecchia, 2008).

The historical goal of natural resource management was to maximize the economic benefits harnessed from nature. There is a difference in systems approach paradigms between the STEP and LTEP models to provide the greatest goods for the greatest number and the longest run (Pinchot, 1910). A difference in a command-and-control vision of the world is presented in evaluating the economic rationale limits of the STEP and LTCEP models. Human and natural systems are largely separate and the outcomes of targeted human actions in the natural world can be calculated and executed for maximal gain (Boumans et al., 2015). The STEP and LTCEP models' economic paradigms limits are founded on the legacy models, but, with the continued growth of the human population and the contrasting belief values and risk tolerance metrics on a strained environment, potential forecasts represent different collapse models of anthroposphere ecosystem services (UNFCC, 2006; WHO, 2013; UNFCC, 2014; Boumans et al., 2015; NTP, 2016).

The collectivized rationality and the individualized approach provide different priorities and preferences of the public interest (Mazar, 2009). One of the STEP model's public interest rationale in RF-EMF radiation was expressed by the former chairman of the US FCC as follows: "full and complete consumer choice of wireless devices and services is the very meaning of the public interest" (Powell, 2002:6).

Mazar (2009) identified two different public interest rationale worldviews, namely the single top-down dictator and an anonymous bottom-up market populated by many well-behaved individuals.

The STEP and LTCEP models' public interest rationales bring about conflict between the collective utilitarianism and the individual rights (Mazar, 2009; Hardell, 2017). Mazar's (2003) research displayed most developing countries as "collectivists," whereas the developed West is displayed as "individualist". Individualism is the cosmological belief predominantly found in the West and is, in terms of Mazar's (2009) findings, what led the West to economic success through political decentralization and the application of the "inquisitive Greek spirit."

Bottom-up standards offer pluralism, competition and a spread of risks. The competition is seen as desirable, because it results in lowered prices and improved services (Mazar, 2009).

4.14.4 Quantifying societal and risk concerns and calculating risk thresholds

A panoramic view of vitro, animal and human experiments, and/or epidemiological studies, are required to quantify and assess the health risks of EMF radiation by the STEP and LTCEP models (Adlkofer et al., 2009; Belyaev et al., 2016).

As discussed in Section 4.2, the climate change framework is vetted in applying a multi-method, multidisciplinary approach to calculate climate change effects on health care. Both decisions of policy makers and a CHANS interdisciplinary approach are required to utilize the climate change and MIMES framework in public interest modelling in the uncertainty that damage will occur (Rayner & Malone, 1998; Gopal et. al., 2016). Climate change questions and EMF radiation public health concerns require policymakers to view the issue of climate change holistically, not merely as a problem of emissions reductions or placement (Boumans et al., 2015).

As discussed in 4.12, Sherwin (1998) defined health as a cellular ecology in that everything is connected to everything else. He also stated that the investigation into neurological and mental health promotion is a multidisciplinary endeavour, which works with people within their environment to investigate and treat the whole patient (Mazar, 2009; Pall, 2015; UN Human Rights Office of the High Commission, 2017). Public health protection and awareness regarding EMF radiation guidelines and standards both require prescriptive rules to achieve determined goals and can be better explored through philosophy and the understanding of prejudice and the application thereof in practice (Mazar, 2009).

No single discipline approach has all the answers in evaluating both the STEP and LTCEP models (Foster, 2001; Mazar, 2009; Perov et al., 2009). The CHANS interdisciplinary combinations of approaches, however, complement one another's strengths (Slovic 2000; Gopal et. al., 2016). As discussed in Section 2.7, leaving the EMF radiation public health problem space solely to scientists will not solve risk problems, as many risk conflicts have no technical solutions (Slovic 2000; Boumans et al., 2015). EMF radiation activists in SA have attempted to address risk controversies primarily with more science but, as shown by studies of Slovic (2000), this has led to exacerbating risk conflicts (DHSA, 2016c).

A combination of both science and knowledge gained from areas beyond science in choosing appropriate EMF radiation mitigation options in a MIMES framework HYGEIA model is required when reviewing the historical development of the LTCEP model. Trial and error case studies demonstrate society arriving at an essentially optimum balance between the risks and benefits associated with any activity, known as the 'revealed preference' approach, to 'how safe is safe enough' (Foster, 2001; Mazar, 2009)?

Calculating EMF radiation mitigation scenarios can be a challenge (Mazar, 2009; Boumans et al., 2009). The suitability of the MIMES framework outputs compared to the EMF radiation related public interest model problems, as identified above, were examined. The MIMES framework applications' output is multiple, complex and can be as baffling as the real world.

The benefits of the HYGEIA model, compared to this complex nature of EMF radiation, are that an implementation can be used to execute different kinds of scenarios (RQ_4), even those unanticipated during the development of the model (Boumans et al., 2015).

As discussed in Section 4.3, Tier 1 of the MIMES framework employs the ESV tool and BTM. In preparation of ascertaining the EMF radiation minimum and maximum social and health values for the BTM, the study reviewed Starr's laws and the *de minimis* risk thresholds.

Starr's laws are quantitative laws to analyze and model societal and risk concerns. The calculation of acceptable risk for a new technology is that the level of safety associated with ongoing activities must have a similar benefit to society (WHO, 1999; Slovic, 2000; WHO, 2006a; Mazar, 2009).

De minimis risk thresholds refer to a level of risk that is too small to be concerned with. The decision criteria of 'zero risk' as too stringent must be selected when defining the scope and level of risk for EMF radiation exposure that will be accepted (Mazar, 2009). The risk will not be allowed to exceed a specific level (LTCEP model), independent of the costs and benefits. This criterion is applied in the common law, such as nuisance and reckless endangerment (Morgan et al., 1992). The balance between the introduction of new technologies and the protection of existing services will determine the accepted level of EMF radiation related human hazards or interference (Mazar, 2009). The *de minimis* value is a favorable metric in determining the thresholds of EMF radiation infrastructure sources (Mazar, 2009).

Further elaboration on the application of Starr's Laws and *de minimis* risk thresholds to EMF radiation is available in the Appendix, Section 4.18 (Starr's law and *de minimis* risk thresholds).

4.15 Conclusion

This chapter investigated and discussed the remaining framework entities in fulfilment of RQ_1 as well as the required data inputs and processes needed in fulfilment of RQ_2. The sections have been explained as a high level overview with references to further detailed explanations in the Appendix. EMF radiation exposure studies require a non-linear statistical analysis in line with a scientific-technical analysis. Traditional linear statistical hypothesis testing is therefore not feasible in this study. As a result thereof, the study aims to provide a visual comparison between two (2) models, namely the STEP and LTCEP models, instead.

The study needs to present a comparative construction and evaluation of two models because, as discussed in Chapter 2, the public health safety concerns and recommendations regarding the exposition for EMF radiation exposure are considerably different depending on the model's endorsing publisher (RQ_5). The rationale for the EMF radiation dosimetry model safety reference levels and/or limits was placed into two models, namely the aforementioned STEP and LTCEP models, which represent public health views regarding EMF radiation.

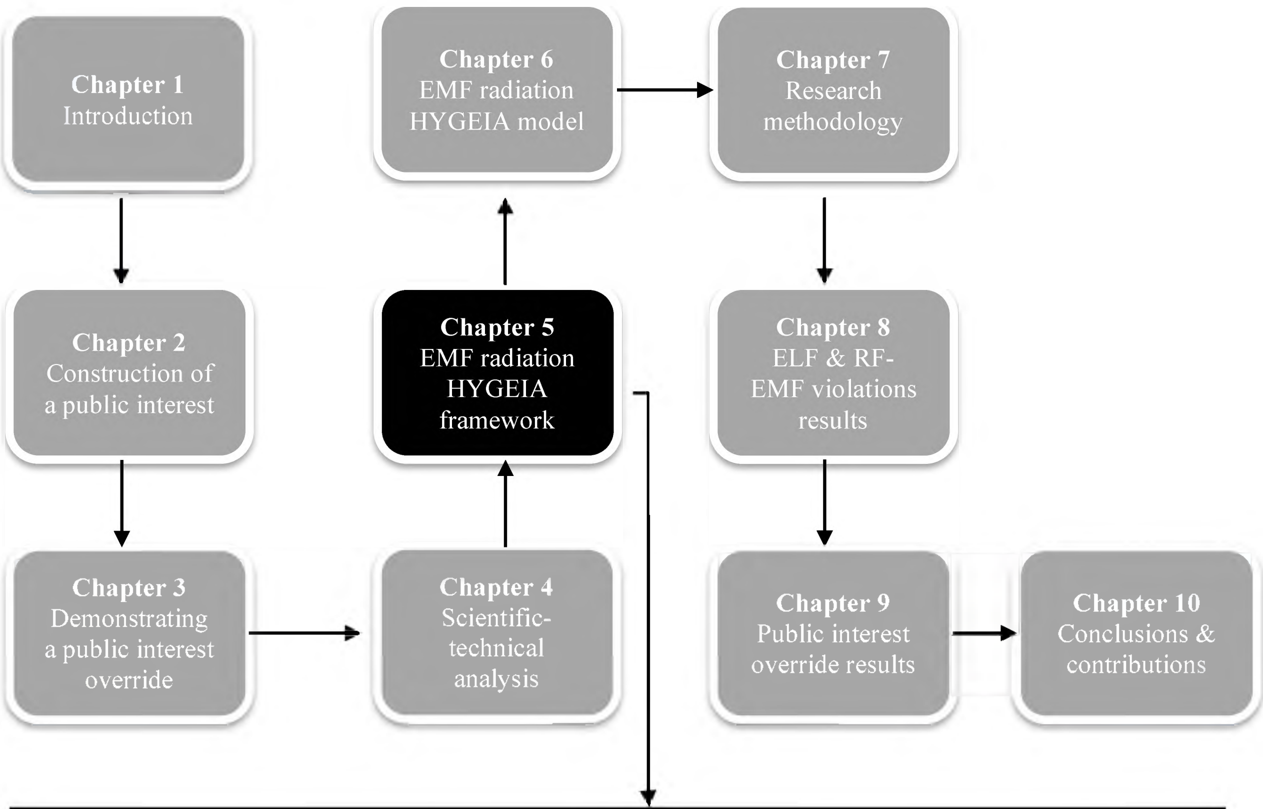
The investigation into the MIMES framework public interest, modelling EMF radiation per the STEP and LTCEP models, uncovered a multidisciplinary research process. The study needed the integration of multiple framework entities and modelling tools drawing input from multiple disciplines in fulfilment of RQ_1 and RQ_2. Despite the extensive efforts, limitations were imposed on this research due to the resource constraints discussed in Chapters 2 and 7.

The goal of MIMES framework in creating a HYGEIA modelling tool which can incorporate stakeholder input and biophysical datasets for valuation of ecosystem services to inform decision-making discussed in Section 4.5, is discussed in this chapter.

The aim of this study is to output a comparative visual geospatial analysis (RQ_4) that may aid policy makers to develop a regulatory EMF radiation exposure standard that balances between public health concerns and controlling the levels of exposure, while remaining a digital economy, by using the constructed EMF radiation HYGEIA modelling tool (Chapter 6).

A clear methodology for the data modelling exercise to be carried out in the research methodology (Chapter 7) is provided by a review of the scientific-technical analysis and MIMES framework. This data modelling preparation exercise and potential fulfilment of RQ_5 may enable potential future studies to carry out a more comprehensive EMF radiation HYGEIA model.

CHAPTER 5: EMF RADIATION HYGEIA FRAMEWORK



CHAPTER 5
EMF radiation HYGEIA framework

5.1 Introduction

A systematic literature review, using systematic content analysis and scientific-technical analysis, was conducted in this study. Chapter 2 discussed the requirements for the construction of a public interest and the different means in identifying one, whilst Chapter 3 described the means of demonstrating a public interest using SA legislation and constructed a PIO checklist to be used in this study in fulfilment of RQ_5. In addition thereto, the previous chapter reviewed the methodology of scientific-technical analysis in public interest frameworks that enable the construction of a public interest modelling tool needed in fulfilment of RQ_5 and thereby concluded the literature review requirements in this study.

Review of the literature and framework entities led to the construction of a proposed public interest EMF radiation HYGEIA framework - to be discussed in this chapter. The purpose of this section is to prepare the reader to understand the intentions of this chapter and to briefly identify and clarify the meaning of key concepts used in this chapter. The study describes the following terms:

Framework: A basic support underlying a system providing functionalities and/or solutions to the particular problem area.

Framework entities: An abstraction in which parts of multiple established frameworks can be extracted and selectively specialized by the researcher, thereby providing specific functionality to the particular problem area.

For example, The precautionary principle uses the best available science as an input to public policy-making. However, sound policy depends not only on good science, but also on other values such as the moral imperative to preserve health, life and the environment (Ramazzini Institute, 2010). The precautionary principle (discussed in Section 2.7) provides a framework using content analysis (Chapters 2 and 3) and scientific-technical analysis (Chapter 4) for achieving transparent, democratic processes that take these dimensions into consideration in developing policies (Ramazzini Institute, 2010).

The answer to the first sub-question will be presented in this chapter. The first sub-question was presented in Chapter 1 as follows:

RQ$_1$: What should a multidisciplinary entities framework encapsulate to enable modeling of macro EMF radiation sources, considering domestic and international legislation and scientific opinions?

RQ$_1$ was driven by the practitioner research methodological output to influence government policy by the demonstration of a PIO in RQ$_5$. The study first needs to construct a framework and model to perform test simulations against the PIO criteria in Chapter 3 to demonstrate a PIO in RQ$_5$.

This chapter will describe the process that was used to answer the research question and will present it in various sections of this chapter:

- Due to the high-level of complexity and detail in the proposed framework, Section 5.3 prepares the reader by providing a high-level analysis systems flowchart of the proposed EMF radiation HYGEIA framework in fulfilment of RQ$_1$;
- A second-tier, more detailed, analysis of the EMF radiation HYGEIA framework is presented in Section 5.4;
- The aforementioned is followed by a conclusion of the presented framework to be used in the construction of a model in fulfilment of RQ$_2$. The aim of the proposed model is to demonstrate the constructed framework in this chapter. The proposed model is discussed in the next chapter.

5.2 Proposed EMF radiation HYGEIA framework

In order to align with the broad objective of the study as discussed in Chapter 1, the study sought to create greater awareness regarding the problem space and attempted to present a scientific-technical analysis basis for further exploration of the fundamental nature or essence of the EMF radiation health issues. Since there is neither an agreed upon framework, nor regulation of EMF radiation exposure protecting the public, the research aims to contribute to academics and practitioners by providing a multidisciplinary public interest framework in this chapter. The framework offers a visual summary of what this public interest research seeks:

1. inputs and
2. means of processing paradigms, legislation, case law and risk values threshold limits
3. in order to enable outputs in the form of forecast simulation modelling, coupling and feedback mechanisms, as discussed in the previous chapter. The feedback mechanisms are vital to the system, because they enable the enhancement of the framework for the next iteration analysis cycle of the problem space.

The visual system process flow points (1-3) of the framework are required to aid policy makers in the development of a regulatory EMF radiation exposure standard that balances public health concerns and controls levels of exposure while remaining a digital economy.

The goal of this research is to contribute to the construction and demonstration of a proposed public interest framework that is broadly applicable to other regions, both in SA and internationally, with the possibility to incorporate other climate change pollutant variables in the future.

As discussed in the previous three (3) chapters, the proposed EMF radiation HYGEIA framework entities explored were the climate change framework, MIMES framework, HYGEIA modelling, EMF radiation dosimetry models, PAIA (2000) and other supportive SA legislature.

The constructed EMF radiation HYGEIA framework, shown in Figure 5.1 and Figure 5.2 in the next two (2) sections, is capable of processing outputs that would adjust the framework for the next model forecast scenario by feedback mechanisms. The real world is multiple, complex and sometimes messy, requiring a multidisciplinary application of CHANS science research (UNFCC, 2014; Boumans et al., 2015). CHANS science, as discussed in the previous chapter, is an interdisciplinary science of coupled human and natural systems. CHANS science seeks to understand the connections, feedbacks, and trajectories that occur as a result of the natural system and human system processes and exchanges, the goal being to uncover the current and future limits of EMF radiation exposure system functions to support human wellbeing needs and to explore the benefits and losses associated with alternative futures.

Figure 5.1, shown on the next page, visualizes the systems or systematic flow of key EMF radiation HYGEIA framework entities. The framework entities require inputs from multiple sources and feedback loops, resulting in the occurrence of another EMF radiation mitigation option scenario. The model and workflow allow for a nonlinear iterative systems approach as a result of demonstration runs executed on framework inputs.

The systems flow and detailed subsections for the proposed EMF radiation HYGEIA framework, shown in Figure 5.1 and Figure 5.2, are cross-referenced with the literature review in Chapters 2, 3 and 4.

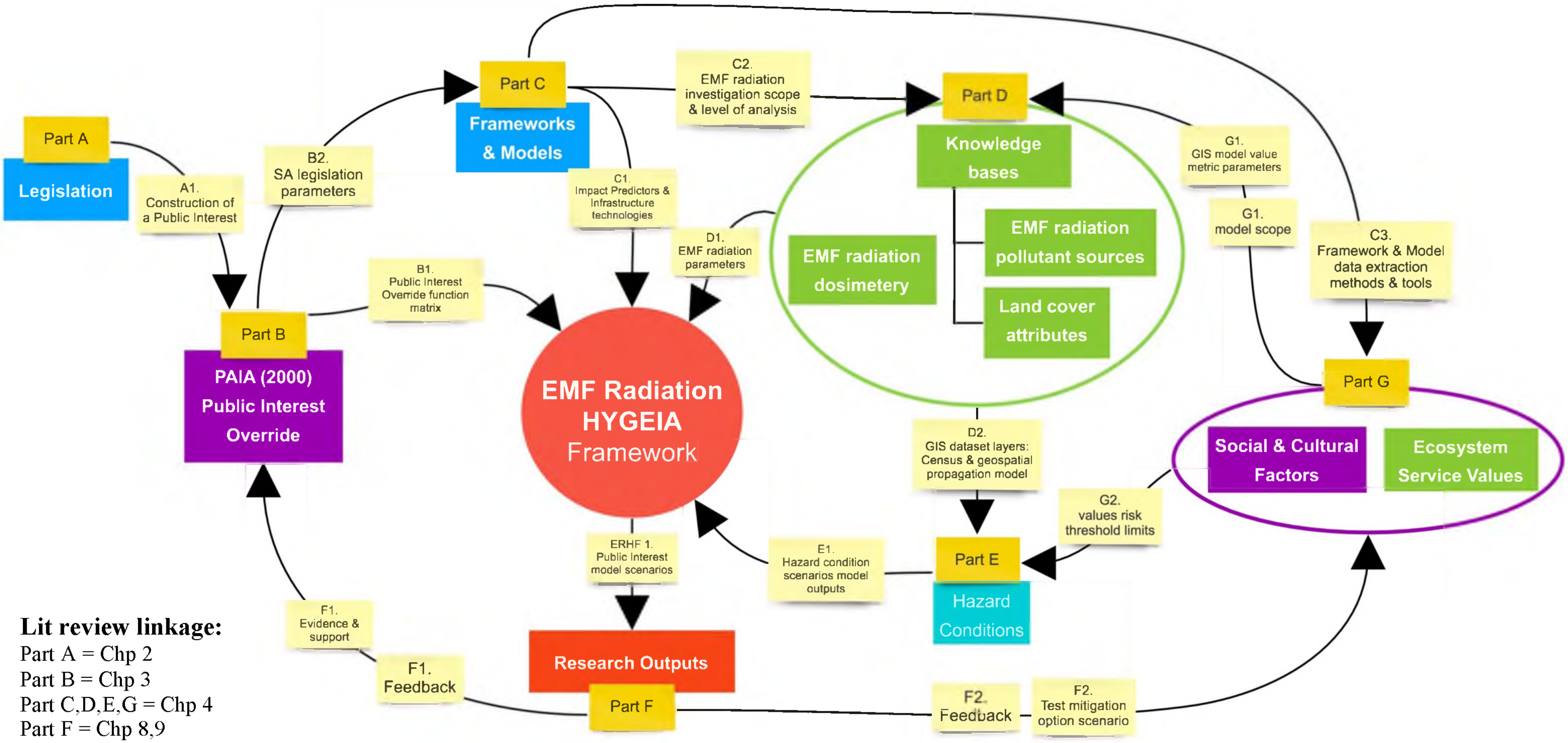
5.3 EMF radiation HYGEIA framework systems flow

The literature review of the previous three (3) chapters was lengthy and extensive, drawing knowledge and peer-reviewed opinions from multiple disciplines. As a result, the purpose of this section is to prepare the reader to understand the intentions of the constructed framework and the problem statement in this study. It is therefore necessary to briefly identify and clarify the meaning of key concepts used in the framework systems flowchart before introduction of the second-tier analysis of the framework in the next section.

This section presents a system flow of the constructed EMF radiation HYGEIA framework, as suggested by the research questions. This requires a systematic approach in the investigation and construction of this study. The purpose of the high-level EMF HYGEIA framework is a flowchart for a system that can deal with multidisciplinary issues, inputs and phenomena, as shown in Figure 5.1, on the next page. The system analysis cycle requires multiple inputs from multiple sources and feedback loops, resulting in the occurrence of another anticipated or undiscovered EMF radiation mitigation option scenario, known as systems iteration. The multiple cycle iterations are vital to an evolving system because:

(1) Policy makers need multiple forecast simulation demonstration runs;
(2) Legislation, technology and case law evolve with time; and
(3) The execution of the system iteration may uncover patterns that were not thought of during the study design phase, as discussed in the previous chapter. Using a systems flow chart may aid participating academics and practitioners to communicate with greater ease when the discussion involves a high level diagram.

The study used the methodologies of systematic content analysis, scientific-technical analysis, consultation with practitioners, ecosystem service valuation and the benefit transfer method as discussed in the previous three (3) chapters on the literature review. Minimum and maximum metric values are extracted from the methodological outputs of the different disciplines in Parts A to G. The system parts, namely inputs, processes and outputs are intersected and coupled using CHANS science, revealing different public interest forecast scenarios for the defined minimum and maximum values range per part. A high-level description for the systems flowchart is shown on the next page in Figure 5.1.



Lit review linkage:

Part A = Chp 2
Part B = Chp 3
Part C,D,E,G = Chp 4
Part F = Chp 8,9

Figure 5.1 EMF radiation HYGEIA framework systems flow

5.3.1 Part A: Legislation

Chapter 2 presented the case for an EMF radiation public interest in SA. As discussed in Chapter 1, a number of private, public, news and NGO sources needed to be consulted and/or reviewed in order to investigate the initial case for a public interest. The investigated problem space needs to present a systemic threat and/or violation of human rights. This framework entity's inputs, processes and outputs are summarized below.

1) Input:
   a) A literature review of international, domestic, national, provincial and municipal by-law legislation, case law, public awareness campaigns and occurrence of weighted studies;
   b) The literature review, evaluation of activist groups, NGOs and consultation with experts require the identification of a systemic threat or violation of human right(s) per the SA (1996) Constitution and legislation in order to warrant the construction of a public interest (Practitioner9, 2016).
2) Output: A1 - construction of a public interest argument into Part B.

5.3.2 Part B: Public interest override:

The constructed public interest of Chapter 2 is carried forward to the next framework entity, demonstrating a PIO. As discussed in Chapter 3, there are a number of ways to employ SA legislation for the demonstration of a PIO. The needs in demonstrating a PIO serve as a means of directing what the study requires as inputs, as well as what processed outputs are required in fulfilment of RQ_5. This framework entity's inputs, processes and outputs are summarized below.

1) Input:
   a) A1 - public interest argument (Part A) - output from first system iteration;
   b) F1 - feedback from the EMF radiation HYGEIA framework research outputs (Part F), output of *evidence and support* for a PIO function - output from second system iteration.
2) Process:
   a) Evaluation of PAIA (2000) sections and review of case rulings;
   b) PAIA (2000) applications to data sources. Output B2.

3) Outputs:
   a) B1 - construction of a PAIA (2000) PIO function matrix checklist of 'substances released into the environment' and 'public safety or environmental risk' into EMF radiation HYGEIA framework;
   b) B1 - construction of a PAIA (2000) PIO function matrix as a vulnerability index into the EMF radiation HYGEIA framework;
   c) B2 - SA legislation metric parameters on the 'balance of probabilities' into frameworks and models (Part C).

5.3.3 Part C: frameworks and models:

The previous chapter discussed the use of scientific-technical analysis as an applicable methodology in studying non-linear problem spaces, such as EMF radiation exposure effects, on the population. It is additionally used in this study to address the methodological inherent empirical weakness discussed in Chapters 2 and 3. This framework takes in empirical findings, reliant on subjective contextual interpretation, when under judicial review and processes quantitative metrics; thereby outputting findings. The framework entity findings aim to measure scientifically and to compare objectively, in an effort to influence government policy as part of this study's research practitioner methodological output, as discussed in Chapter 1. This framework entity's inputs, processes and outputs are summarized below:

1) Input: B2 - SA legislation parameters (Part B).
2) Process:
   a) Climate change framework scientific-technical analysis;
   b) MIMES framework tier scope analysis;
   c) Investigation and scope of the anthroposphere; and
   d) Identification of impact predictors (health outcome risk factors).
3) Outputs:
   a) C1 - selection of impact predictors, category of EMF radiation infrastructures technologies into EMF radiation HYGEIA framework. Impact predictors are model predictor variables that are statistically significant.

b) C2 - scope of EMF radiation investigation, i.e. macro, micro or specific infrastructure technologies or EMF radiation category (ELF, VLF, RF); incongruous flux densities; level of geospatial analysis, high overview or detailed defined area; application of which MIMES framework tier investigation level into knowledge bases and EMF radiation dosimetry (Part D).
c) C3 - selection of framework, models, methods and tools to be employed in data extraction and sourcing into social and cultural factors and ecosystem service values (Part G).

5.3.4 Part D: Knowledge bases and EMF radiation dosimetry

The previous chapter discussed two categories of EMF radiation exposure, namely ELF and RF. ELF is typically associated with magnetic fields sourced from HVAC powerlines, transformers and motors. RF is associated with wireless telecommunication that has an array of technology categories. Then there is the combination of the two with RF associated technologies emitting simultaneously EMF in the forms of VLF, ELF and RF. The framework directs the sourcing of interested EMF radiation exposure sources, technology categories, and interaction with organic matter, followed by parameters of the antroposphere that affect EMF radiation propagation. This framework entity's inputs, processes and outputs are summarized below:

1) Inputs:
   a) C2 - EMF radiation investigation scope and level of analysis (Part C); and
   b) G1 - model scope and GIS model value metric parameters output (Part G).
2) Process:
   a) Sourcing and constructing GIS data sets knowledge bases per scope of Part C2 inputs; and
   b) Construction of STEP and LTCEP EMF radiation dosimetry geospatial propagation model instances.
3) Outputs:
   a) D1 - EMF radiation parameters (context), i.e. GIS model formulas, STEP and LTCEP models, dosimetry rationale and limits into the EMF radiation HYGEIA framework.

b) D2 - GIS data set layers of census data and constructed EMF radiation geospatial propagation model into hazard conditions (Part E).

5.3.5 Part G: Social & cultural factors and ecosystem service values:

As discussed in the previous chapter, an investigated community's scientific views and beliefs towards EMF radiation exposure are dictated by their values risk threshold limits. As defined in Section 1.5, values risk threshold limits is a subjective value determined by the associated community's scientific paradigm, social and cultural values. It is the level to which it is believed a person can be exposed to on a daily basis without adverse effects. The subjective level of tolerable risk and the assigned economic value to ecosystem services are determined by the investigated community's social and cultural values with the framework entity. The carrying out of a study may not require the gathering of input data for an investigation area, but, by using the benefit transfer method, discussed in the previous chapter and Chapter 7, data may be extrapolated, using a study of an area with similar properties of interest. This framework entity's inputs, processes and outputs are summarized below:

1) Inputs:
   a) C3 - framework and model data extraction methods and tools (Part C) - output from first iteration; and
   b) F2 - feedback results for test mitigation options and scenario(s) for next system iteration (Part F) - output from second iteration.
2) Process:
   a) Construction of ecosystem service values (ESV) table;
   b) Application of the benefit transfer method; and
   c) Systematic and critical analysis of investigation community social and cultural factors (paradigms).
3) Outputs:
   a) G1 - into knowledge bases (Part D): scope of instantiated models and GIS value metric parameters, i.e. STEP or LTCEP model, classification of population, vulnerability index, social vulnerability index, climate change index. Application of closed accounting, economic accounting and/or social accounting.

b) G2 - values risk threshold limits per the STEP or LTCEP model and community paradigm toward risk into hazard conditions (Part E).

5.3.6 Part E: Hazard conditions

As discussed in the previous chapter, incidence and recognition of a hazard condition are determined by the social and cultural values processed in the previous framework entity. Hazard conditions are identified by overlapping the spatial and temporal output data layers from the other framework entities. The spatial and temporal data layers are interested and coupled in order to identify patterns that fall within the hazard conditions, as defined and processed by the other framework entities. This framework entity's inputs, processes and outputs are summarized below:

1) Inputs:
   a) D2 - GIS dataset layers: census and EMF radiation geospatial propagation model (Part D); and
   b) G2 - values risk threshold limits (Part G).
2) Process:
   a) Intersection of GIS dataset layers' inputs and coupling with impact predictors;
   b) Design of demonstration runs of hazard condition scenarios per the STEP and LTCEP models; and
   c) Generation of heat maps and scenarios per impact predictor category.
3) Outputs:
   a) E1 - hazard condition scenario(s) model outputs into the EMF radiation HYGEIA framework.

5.3.7 Part F: Research outputs

As discussed in Chapter 1, the aim in demonstrating a public interest override for this study is to create greater awareness regarding the problem space and to present a scientific basis for further exploration of the fundamental nature or essence of the EMF radiation health issues. The purpose of this framework entity in the fulfilment of RQ_5 may aid policy makers to develop a regulatory EMF radiation exposure standard that balances between public health concerns and controlling the levels of exposure, while remaining a digital economy. Therefore the goal of this framework is to create a public interest modelling tool which can incorporate stakeholder input and biophysical datasets for valuation of ecosystem services to inform decision-making by simulating (1) ecosystems and socio-economic systems in space and over time; and (2) the interactions between ecosystems and socio-economic systems through coupling. This framework entity's inputs, processes and outputs are summarized below:

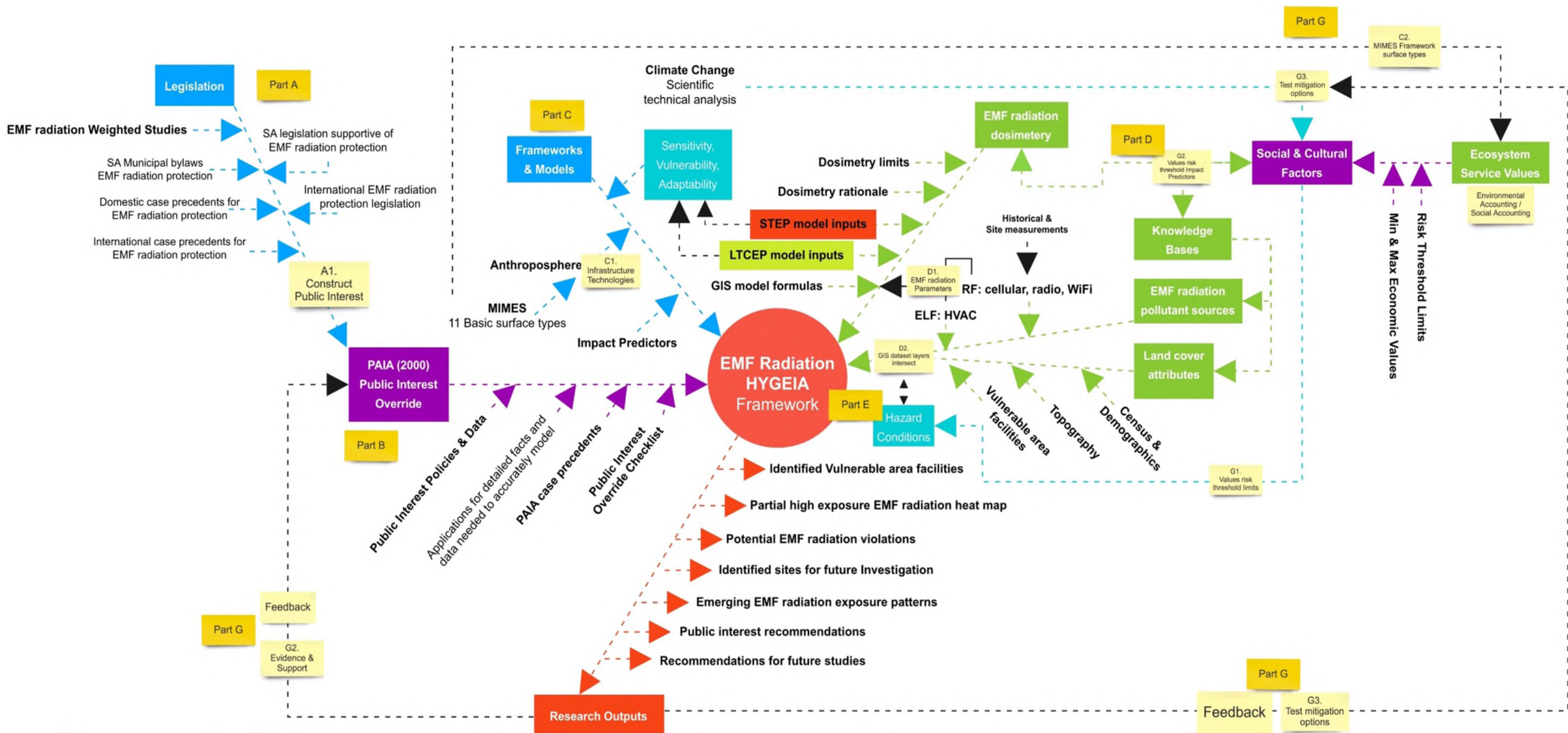
1) Inputs:
   a) Public interest model scenarios: Parts B to G all flow into the EMF radiation HYGEIA framework; and
   b) The outputs from Parts B to G are intersected and, through coupling, the framework outputs public interest model scenarios.
2) Process:
   a) Coupling of EMF radiation HYGEIA model with PAIA (2000) PIO matrix.
3) Outputs:
   a) F1 - feedback of evidence and support for the PAIA (2000) 'balance of probabilities assessment' into PAIA (2000) PIO (Part B); and
   b) F2 - feedback on formulation of alternative EMF radiation mitigation options for the next demonstration run forecast scenario, based on previous iteration research outputs (Part F) into social & cultural factors and ecosystem service values (Part G).

The proposed EMF radiation HYGEIA framework is a multidisciplinary application of CHANS science; a system requiring inputs, processes and outputs in a nonlinear and parallel progression. The aim of the proposed EMF radiation HYGEIA framework is to aid in the construction of a public interest EMF radiation HYGEIA model by running a second iteration of the EMF radiation HYGEIA framework based on the process outputs of the first iteration. This will provide a system feedback mechanism to refine and re-test.

5.4 EMF radiation HYGEIA framework, second level analysis

The previous section prepared the reader to be able to briefly identify and clarify the meaning of key concepts used in this framework systems flowchart before the second-tier analysis of the framework is discussed in further detail in this section.

The review of literature in Chapters 2, 3 and 4 led to the construction of the second-tier level of the EMF radiation HYGEIA framework, as discussed in this section. The framework serves as a visual summary of the reviewed literature. An analysis of the framework reveals a nonlinear framework structure constructed by attaching framework entities drawing input from multiple disciplines to several other multidisciplinary elements in a manner that reflects a specific relationship among them. Derived from the science-based literature discussed in Chapter 2 and 4, the nonlinear framework and data structure conform to the nonlinear mechanism of EMF radiation exposure and attribute potential adverse health effects. Within each part (A-G) in Figure 5.2 on the next page, there is an identifiable array of minimum and maximum ranges defined by scientific views and influenced by social and cultural factors for each framework entity. The intersection and coupling of inputs, processes and outputs that adjust the model producing forecast scenarios through feedback mechanisms according to the *very specific* and *defined* scientific scope and values risk threshold limits identified by a community, would thus, allow multiple simulation and/or demonstration runs for different contexts or scenarios.



Literature review linkage:

Part A = Chapter 2

Part B = Chapter 3

Part C, D, E ,G = Chapter 4

Part F = Chapters 8, 9 (fused findings)

Figure 5.2 EMF radiation HYGEIA framework

5.4.1 Part A: Legislation

As discussed in Chapter 1, public interest is defined by the systemic threat and/or violation of human rights (Practitioner9, 2016). The parameters for a public interest are defined in the framework entity of legislation. A legislative framework can compose a range of components, from binding instruments, such as acts, regulations and standards, to non-binding instruments, such as objectives and guidelines. The baseline defining parameters for legislation is the Constitution. Acts and defining metrics that subsequently developed, would be based on the Constitution.

Legislation, however, is constructed as an evolving framework entity capable of processing outputs that, through feedback mechanisms, would adjust the model (judicial review process) for the next legislation iteration (forecast scenario). Case law and the review of case rulings are model demonstration runs based on the framework entity (legislation).

The SA Constitution (1996) mandates input from academic public interest research findings. As stated by Prof. Dvzimbo (2016:1): As an academic and/or citizen, you must be "able to disrupt existing knowledge with your work. Development of new knowledge is only possible through postgraduate studies. Invent new things that change and impact people's lives".

Part A requires the investigation of scientific opinions in a public interest topic and the establishment of the existence (or not) of a weighed-studies phenomenon. The advantage of a weighted-studies analysis table is the clear metric distinction between scientific opinions in applied methodology, scope of analysis, statistical approach and benchmark findings. The output is a more comprehensive understanding of whether scientific opinion awareness campaigns are in line with or a threat against legislation parameters.

A systematic analysis of EMF radiation similarities, or contradictions, to the spirit of the law (baseline parameter), in relation to the public interest, is revealed by a review of both domestic and international legislation. Review of case law is an advantage because multidisciplinary experts present their cases and findings. The legislative framework entities are tested and scenarios are modelled based on both scientific and cultural factors, as well as ecosystem accounting. The outcome is a judicial review deliberation on the defining parameters for an EMF radiation public interest. Review of international case rulings is vital, because some domestic legislation is bound by international legislation and their case rulings, for example: UN declarations must be invoked by member states when creating domestic legislation.

The systematic processing of the legislation section (Part A) addresses the “terra incognita” as science issue regarding EMF radiation exposure to the public and potential adverse health effects (Tuengler & von Klitzing, 2013). Both domestic and international legislation and case law confirm the existence of EMF radiation hazard conditions (Part E) related to associated potential adverse health effects. High Court judicial review deliberations ruled that, the weaker the EMF radiation regulation and the higher the tolerance for risk, the greater the incidence of hazard conditions (Part E). Environments that provide no EMF radiation exposure standard regulation provide the highest potential incidence of hazard conditions (Part E).

A review of scientific opinions, domestic and international legislation and judicial review deliberations on scientific evidence and culture values led to the construction of a PIO checklist (Part A1). The constructed PIO checklist (A1) is output into the PAIA (2000) PIO function (Part B) where is it tested on the ‘balance of probabilities’ for a demonstrated PIO (RQ_5).

5.4.2 Part B: PAIA (2000) public interest override

As discussed in Chapter 2, the purpose of PAIA (2000) is to promote the right of access to information and to foster a culture of *transparency* and *accountability* in SA. A framework and entity used should engage with government and should participate in decisions which affect the public’s lives (SAHRC, 2014). PAIA (2000) provides the unique right to enable the realization of other human rights and can be used to monitor and enforce those rights against systemic violation (Practitioner9, 2016).

The constructed public interest (A1) input into Part B forms the heads of argument for a PAIA (2000) application enabling the request for potentially permissible access to information from data sources. Permissible access to information is determined by the established minimum and maximum values range defined by social and cultural factors and ecosystem values (Part G) by means of a process called the ‘balance of probabilities’ in PAIA (2000). Review of PAIA related legislation, permissible extracted data parameters and case law constructs a structure of supportive warrants to the PAIA (2000) heads of argument.

The purpose of the EMF radiation HYGEIA framework is the construction of a public interest model that is dependent on *real facts* and *data* held by data sources (Boumans et al., 2015).

The review of PAIA (2000) and case law enabled the construction of a PIO function checklist and vulnerability index. The PIO function checklist serves as a structural template in accordance with the 'balance of probabilities', guiding the outputs of the public interest framework research outputs (Part F). If the minimum evidence supports the requirements for a PIO, the latter will be confirmed, following a favourable judicial review process (Part F).

5.4.3 Part C: Frameworks and models

Academia and research agencies output an array of frameworks and models, but it is advantageous to use multidisciplinary frameworks and models that have been tried, tested and endorsed, both by scientists and by an array of countries that have tested them against their cultural values and against the values risk threshold limits encompassed in their legislation.

Part C utilizes inputs from the climate change framework, as well as from its associated MIMES framework and public interest HYGEIA model (UNFCC, 2014). The proposed frameworks and models are known to many countries and can act as binding agents to domestic legislation. The framework entities employed enable the study of the effects of the anthroposphere on ecosystem services. Ecosystem services are assigned economic values (Part G) to help inform decision makers regarding the design and implementation of appropriate environmental and population development policies (Part F) (Boumans et al., 2015).

The climate change framework's scientific-technical analysis divides adverse effects from environmental pollutant into indexes for coupling human systems with natural systems (CHANS science) and forms three (3) parameter variables for the EMF radiation HYGEIA framework, namely: sensitivity, vulnerability and adaptability. Sensitivity is the degree to which the investigated system will respond to a change in the variable EMF radiation. Adaptability is the degree to which adjustments are possible to both projected and actual changes in EMF radiation levels, in respect of the practices, processes or structures of a system. Vulnerability is the extent to which the EMF radiation may damage or harm a system, thus the result of a system inefficiently able to adapt to sensitivity.

STEP and LTCEP models' inputs (Part D), established from science-based findings, provided data and parameter values for the climate change framework's scientific-technical analysis index. An advantage of the LTCEP model is that it provides data obtained from more than half a century of EMF radiation studies, including human experiment studies. Additionally, the STEP and LTCEP models have undergone lengthy deliberations in High Court judicial review processes on an international level, involving numerous countries' array of ministries responsible for different organs of the state, driven by the PIO function (Part B).

The MIMES framework provides an ecosystem analysis of eleven (11) basic surface types and four (4) tiers of resolution analysis (refer to Chapter 2 for an elaboration of both). This research has only focused on one (1) basic surface type, Tier 1 and parts of Tier 2 of the MIMES framework. The core focus basic surface type utilized in this research is the anthroposphere. This research chose to scope the anthroposphere investigation into EMF radiation infrastructure technologies (C1) against the scientific-technical analysis of facilities that primarily accommodate the vulnerable population. Vulnerable population is defined by the input of selected impact predictors. The selected census block of impact predictors scoped to this research are: the youth (under sixteen (16) years of age), the chronically ill and the elderly. The impact predictors were selected based on a systematic literature review of legislation (Part A) and EMF radiation dosimetry rationale (Part D) per the STEP and LTCEP models.

The outputs from the frameworks and models section (Part C) input into the EMF radiation HYGEIA framework, EMF radiation dosimetry and knowledge bases (Part D) as well as social and cultural factors and ecosystem service values (Part G).

5.4.4 Part D: EMF radiation dosimetry and knowledge bases

The EMF radiation dosimetry provides clear EMF radiation reference levels for the STEP model and exposure limits for the LTCEP model. The public health exposure scientific safety scopes for the STEP and LTCEP models are science-based and spelt out in length in the dosimetry rationale for both models. Both the STEP and LTCEP models provide their minimum and maximum value inputs for social and cultural factors, ecosystem service values (Part G), hazard conditions (Part E), related legislation (Part A) and scoped research outputs (Part F).

The selection of an investigation area or community (G2) provides the inputs from social and cultural factors and ecosystem service values (Part D), on which the EMF radiation dosimetry is applicable, to the knowledge bases model forecast scenario. For example: studies' analysis patterns on catholic and protestants communities revealed very different EMF radiation values risk threshold limits and, therefore, different knowledge bases spatial planning and EMF radiation dosimetry application (Mazar, 2009).

Knowledge bases are the GIS dataset layers used as an input in the simulation and identification of hazard conditions (Part E). The knowledge bases are divided into categories namely, EMF radiation pollutant sources and land cover attributes. EMF radiation pollutant sources are the spatial and temporal datasets of EMF radiation infrastructure sources for both ELF and RF-EMF radiation.

Land cover attributes are the census and demographic inputs for impact predictors (Part C) to process the identification of vulnerable area facilities. Topography provides the boundary conditions that influence EMF radiation propagation calculations employed in the GIS model formulas for EMF radiation dosimetry.

Increased accuracy and completeness of the datasets will increase the validity of the model outputs. D1 EMF radiation infrastructure parameters provide inputs for EMF radiation dosimetry GIS model formulas. D1 outputs, coupled with the boundary conditions of land cover, attribute results in the output of EMF radiation geospatial propagation models (D2). The output from D2 provides the input for the scenarios of hazard conditions (Part E).

The advantage of Part D is that the investigation resolution can be a high-level overview or high resolution analysis. For example: the EMF radiation dosimetry provides science-based data inputs for a high level of geospatial proximity and temporal analysis for a potential EMF radiation dose-relationship to infrastructure sources.

5.4.5 Part G: Social & cultural factors and ecosystem values:

The input of C2 MIMES framework surface types (Part C) define the selection of surface types on which ecosystem service values are calculated and processed by using the ecosystem service values (ESV) tool and the benefit transfer method (BTM). The ESV tool establishes the minimum and maximum economic values per ESV spatial grid from the policy makers. The

BTM is a data quality benchmark and resource constraint tool used to estimate economic values for ecosystem services by transferring available information from case studies to another location and/or context (King and Mazzotta, 2000). The BTM is employed when it is too expensive and/or when there is too little time available to conduct an original valuation study.

The ESV provides representative economic values to the investigation area community's values risk threshold limits. It also provides the incorporation level of social accounting into economic accounting for defining the scope for minimum and maximum social and cultural economic values.

G1 output metric values risk threshold limits by social and cultural factors, coupled with ESV, provide input for the subjective EMF radiation hazard conditions (Part E).

5.4.6 Part E: Hazard conditions

A hazard is a subjective concept of the circumstances under which ecosystem services intersect and/or may influence the complex system, thereby posing a level of threat to life, health or environment (Zaplatynskyi, 2013; Boumans et al., 2015; EDA, 2016). Inputs D2 and G1 provide the advantage for a 'declarative modelling' approach enabling the researcher to focus on the *context* of the public interest research and data, instead of getting caught up in the software and procedural line programming issues (Boumans & McNally, 2011). Processing GIS dataset layers (D2) individually from EMF radiation geospatial propagation model (Part D1) may not initially reveal hazard conditions, but, when they are intersected and coupled with other EMF radiation pollutant sources and/or interactions with the anthroposphere (Part C) and land cover attributes (Part D2), they may reveal the occurrence of (hidden) hazard conditions (Part G1 input) when coupled with impact predictors (Part C).

Very specific EMF radiation exposure conditions may trigger biological responses in one individual, but not in others (Belyaev et al., 2016). Individual responsiveness or susceptibility could expand over time, however, and the intolerance to EMF radiation could extend over a broad range of exposure conditions or cumulative total body burdens (Belyaev et al., 2016). The selected MIMES framework tier (Part C) will dictate the resolution and scope of the spatial and temporal data sets in Part D2 outputs and will result in the analysis of hazard conditions.

The advantage of the proposed EMF radiation HYGEIA framework feedback mechanism (Part G3) is that multiple hazard conditions forecast scenario demonstration runs can be executed. Each system iteration may reveal a potentially different hazard condition output from a single alteration to a variable within any of the EMF radiation HYGEIA framework sections.

5.4.7 Part F: Research outputs

The investigating and proposing of EMF radiation public interest related protection policies are not a single discipline linear systems analysis but involve a nonlinear, multidisciplinary CHANS science approach. The advantages of each of the research outputs (Part F) is that they are based on the review of sections within the proposed EMF radiation HYGEIA framework (Parts A - G).

The identification of vulnerable area facilities, by processing and coupling outputs of Parts A, B, C, D and G, revealed the definition and classification of EMF radiation vulnerable area facilities. Outputs from knowledge bases land cover attributes (Part D), anthroposphere (Part C) and PAIA (2000) applications (Part B) enabled the construction and processing of GIS layer datasets as an input for impact predictors (Part C) under the scenario of hazard conditions (Part E).

This research was limited in constructing a detailed high exposure EMF radiation heat map (Part D) but, by means of the MIMES framework Tier 1 (Part C) and ESV - BTM (Part G), the research was able to process a resource efficient evaluation analysis as evidence (RQ_5) to gather the resources required to identify areas that need a further evaluation study, thereby contributing input for a demonstrated PIO (Part B). Construction of a geospatial propagation model (Part D2) was the result of knowledge bases processed through EMF radiation dosimetry and GIS model formulas (Part D). The output is ELF and RF-EMF radiation exposure heat maps used as inputs in identifying potential hazard conditions (Part E). The EMF radiation heat maps provide a visual comparison between STEP and LTCEP models' inputs (Part D).

Hazard conditions (Part E) are the intersection and coupling of GIS datasets (Part G2), the PIO checklist (Part B), frameworks and models of EMF radiation mitigation options (Part C, G3), social & cultural factors and ecosystem service values (Part G1). STEP and LTCEP models' inputs are intersected with the identified vulnerable areas facility research output (Part F) to reveal potential EMF radiation violations. These potential EMF radiation violations serve as system feedback inputs (G2) for the evidence and support for a demonstrated PIO (Part B).

Identified sites for future investigation: The outputs for hazard conditions (Part E) and potential EMF radiation violations list feedback (G2) for a series of sites for future investigation in future demonstration runs of the EMF radiation HYGEIA framework. Future demonstration runs may choose to conduct a more detailed MIMES framework tier analysis (Part C) or a higher resolution grid analysis and resource intense site evaluation (Part D). Access to resources and data for a second more detailed framework systems demonstration may be enabled by evidence of a demonstrated PIO (Parts F and G2), followed by a favourable judicial review.

Before and during the processing of the EMF radiation HYGEIA framework a series of forecast scenario demonstration runs are designed. The question is posed, for example, whether RF-EMF radiation from cellular transmitters poses the greatest incidence of hazard conditions (Part E) to the public. After processing the hazard conditions (Part E) in the first system iteration, the research outputs may reveal unanticipated hazard condition scenarios. ELF EMF radiation infrastructure may pose a potentially greater risk than RF-EMF radiation from public Wi-Fi in public transport (WHO, 2015a; WHO, 2016e). The research outputs are fed back into the system (G2 and G3) for a potential second iteration, demonstrating an evolving feedback mechanism.

The EMF radiation HYGEIA framework provides the researcher and reviewer with a more in-depth understanding of EMF radiation and public health concerns, because the framework does not only review a single publication source on the exposition for EMF radiation but also applies different scientific opinions, legislation, political, cultural and economic inputs to the rationale of EMF radiation dosimetry. The research quantitative outputs (Part F) enable production of supported EMF radiation recommendations, both in the interest of and to the public, based on science-based outputs and forecast demonstration runs.

The EMF radiation HYGEIA framework requires consultation and data sourcing from different disciplines and data sources. It is a lengthy and intense process, requiring administrative resources, and reveals an abundance of obstacles and consequent opportunities for finding solutions to overcoming those obstacles. The research output may reveal recommendations for conducting future iterations and how the framework itself can be improved upon in future studies.

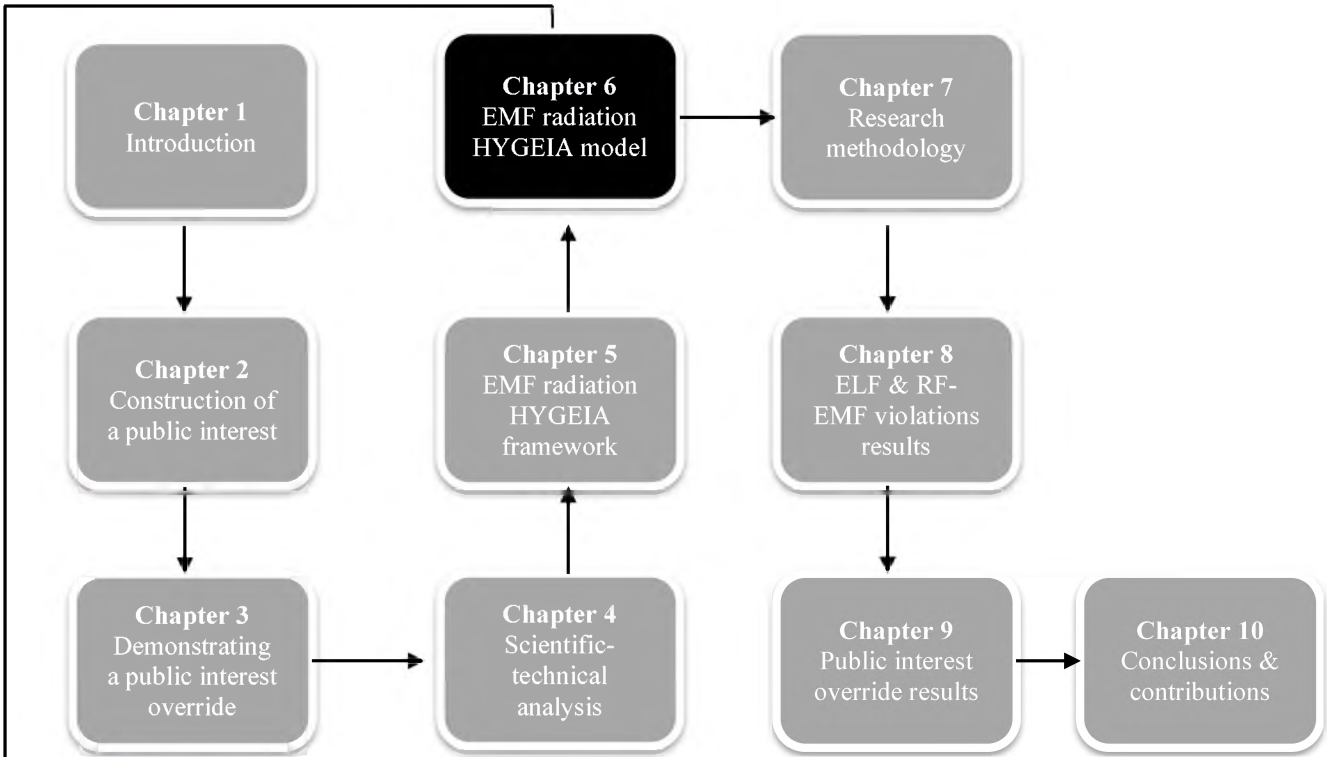
5.5 Conclusion

This chapter discussed the formulation of a proposed public interest EMF radiation HYGEIA framework, shown in Figure 5.2, sourced from the literature review findings in Chapters 2, 3 and 4, and consultations with expert practitioners (Appendix, Section 7.1).The constructed framework and associated IS methodology are presented as the potential integrative tool that may address both direct and indirect effects of anthroposphere EMF radiation exposure on a local, regional and national scale. The proposed elements of the framework fulfilled the requirements of RQ_1. In fulfilling RQ_1, an EMF radiation HYGEIA model was developed in fulfilment of RQ_2, as discussed in the next chapter.

The EMF radiation HYGEIA framework is complex because of the application of interdisciplinary CHANS science. As in the real world and in accordance with the rationale for the STEP and LTCEP models, there is no clear line but rather an intersection and coupling of multiple disciplines, with each framework entity (section) running iteratively and/or simultaneously to others, resulting in a framework entity that obtains multiple outputs and inputs from other entities. It is only when the outputs for all framework entities are overlaid and intersected, from spatial and temporal datasets in terms of the defined investigation scope that a pattern for the different public health interest forecast scenarios emerges.

The resultant advantage is a more comprehensive output of evidence and support for a PIO (Part B) in fulfilment of RQ_5. The increased comprehensive research outputs may result in a favourable outcome when the research is presented as evidence in support of a process of judicial review; thereby potentially reducing both subjective bias and the resource burden on the state that would otherwise have occurred as the result of lengthy judicial review deliberations due to weak supporting evidence for the heads of argument.

CHAPTER 6: EMF RADIATION HYGEIA MODEL



CHAPTER 6
EMF radiation HYGEIA model

6.1 Introduction

The previous chapter presented and discussed a visual summary of the literature review in the form of a public interest framework, focused on EMF radiation exposure, in the context of health prevention (HYGEIA). The construction of the framework in the previous chapter has led to the construction of the HYGEIA model, to be discussed in this chapter. Both framework and model were derived from a systematic literature review using systematic content analysis and scientific-technical analysis. The previous chapter concluded the fulfilment of RQ_1 and this chapter will discuss the fulfilment of RQ_2 by a discussion of the constructed model, based on the framework in the previous chapter.

The answer to the second sub-question will be presented in this chapter:

> RQ_2: How should a proposed framework construct a public interest EMF radiation model and can it be used to construct public health forecast simulations in a designated area?

The research question was driven by industries restricting access to data needed to monitor, investigate and regulate EMF radiation emissions in SA. Legislation requires the demonstration of a PIO to gain access to the needed data, as discussed in Chapter 3. The study constructed a framework (previous chapter), and a model (this chapter) to perform test simulations (Chapter 8) against the three (3) PIO criteria (Chapter 9) to demonstrate a PIO function.

This chapter will describe the process that was used to answer the research question:

- Section 6.2 discusses the proposed EMF radiation HYGEIA model; and
- Section 6.3 discusses the descriptive narrative systems flow of the model, followed by the chapter conclusion.

The remaining purpose of this section is to prepare the reader to understand the intentions and to briefly identify and clarify the meaning of key concepts used in this chapter. Additionally, after understanding the previous chapter, the reader should understand the framework entity concepts that were developed into model components used in this chapter.

A model differs from a framework. The latter is a basic support underlying a system and provides functionalities and/or solutions to the particular problem area, as presented in the previous chapter. This study created a model based on the framework to perform forecast simulations to demonstrate a PIO. Simulation is the imitation of the operation of a real-world process or system over time. The act of simulating something first requires that a model be developed (Vitatech, 2015). This model represents the key characteristics or behaviors/functions of the selected physical or abstract system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time (Vitatech, 2015).

Models are tools to run experiments that cannot be done in the real environment (OCCRI, 2010). Models can simulate alternative futures and thus can answer questions about which processes may or may not shape the future environment of a region (OCCRI, 2010). Environmental models are mathematical representations of the interactions of environmental systems. This is a complex task and therefore models are designed to estimate trends, rather than events (Wayne, 2016).

Modelling EMF radiation in public health has become ever more complex with modern devices emitting EMF radiation of different frequency ranges (Belyaev et al., 2016). For example: a wireless tablet or phone emits EMF radiation in RF, VLF and ELF frequency ranges and static magnetic fields. It is therefore important to consider combined EMF radiation exposures in the assessment of potential health effects (Belyaev et al., 2016).

As discussed in Chapter 1 and detailed in Chapter 7, the research design chosen for this model and study is a relatively quick and inexpensive, but rigorous, approach that may identify the potential STEP and LTCEP EMF radiation violations of EMF radiation related to vulnerable population areas affected by EMF radiation infrastructures, in fulfilment of RQ_4 and RQ_5 (Kheifets, 1995).

As discussed in Chapter 4, the HYGEIA model was chosen as it has been successfully applied to address the particular issue of environmental change case studies. The HYGEIA model makes use of the MIMES framework and model libraries, a framework entity discussed in the previous chapter. The constructed model in this chapter is a public interest model used in forecasting the effects of environmental change on human health and health environment interactions. It is a dynamic GIS designed to address the magnitude, dynamics, and spatial patterns of ecosystem service values (Boumans et al., 2011). It is employed in this research, in fulfilment of RQ_4 and in accordance with the practitioner research methodological output to potentially influence government policy, to visually identify EMF radiation islands occurring in cityscapes and design appropriate mitigation strategies. HYGEIA also predicts outcomes for a variety of demographic conditions, e.g. age, race and income level. HYGEIA was designed to be applied to any area in the country that has the requisite and standardized data input layers. These may include land cover, environmental scenarios and block census data (Boumans et al., 2011).

The investigated area classification of vulnerable population, from the literature review in Chapters 2 and 4, is based on a scientific-technical analysis of the definitions of the STEP model ICNIRP (2002), LTCEP model standards, international High Court rulings and UNEP (1995). The selected population sensitivity classification to serve as impact predictors, resulting from the application of the scientific-technical analysis, are “children, the elderly, chronically ill and potentially some adults” (ICNIRP, 2002:546). As discussed in Section 1.3, the following potential facility types fall within the scope of the study:

1. Primary facilities: early development centres, special needs schools, primary schools, high schools, colleges, hospitals, clinics, orphanages, hospices, juvenile prisons; and

2. Secondary facilities: community areas, parks, public tennis courts, public swimming pools, fire stations and prisons.

The model takes the data input of census block data sourced from reputable census datasets (Appendix, Section 7.1). The EMF radiation HYGEIA model datasets are entered and processed into visually unique representative GIS layers containing census, EMF radiation infrastructures and potentially vulnerable area facilities, transposed onto the satellite images recorded for the investigated area (Chapter 7). Framework EMF radiation policy inputs, associated legislative policies and municipal bylaws are incorporated into the GIS software as map overlays.

A limitation to the model is that it is a simulation experience; real world EMF radiation exposure detection will therefore be difficult and unexpected changes cannot be ruled out (IPCC, 1995). Unambiguous detection of EMF radiation exposure and climate induced changes in most ecological and social systems will prove extremely difficult in the coming decades (IPCC, 1995). This is due the complexity of these systems, their many nonlinear feedbacks, and their sensitivity to a large number of climatic and non-climatic factors, all of which are expected to continue to change simultaneously. The development of a baseline projecting future conditions without adverse EMF radiation exposure is crucial, for it is this baseline against which all projected impacts are measured. As future climate change variables extend beyond the boundaries of empirical knowledge (i.e., the documented impacts of EMF radiation exposure variation in the past), it becomes more likely that actual outcomes will include surprises and unanticipated rapid changes (IPCC, 1995).

The next section discusses the proposed EMF radiation HYGEIA model constructed from the framework in the previous chapter.

6.2 Proposed EMF radiation HYGEIA model

As discussed in Section 4.5, the proposed EMF radiation HYGEIA model is a visual modelling tool that incorporates stakeholder inputs and biophysical datasets for the valuation of ecosystem services to inform decision-making by performing the following steps:

1) Determine spatial and temporal variation in hazard exposure; land cover and pollution. The climate times series is not included in this research;

2) Analyze spatial variation and temporal variation in EMF radiation hazard exposure; measurement and quality metrics;

3) Estimate health outcome risk for population groups by means of hazard exposure and hazard response functions. Project estimates using GIS geospatial propagation model and hazard conditions;

4) Examine how mitigation options may affect health outcomes and their links to other ecosystem services; and

5) Demonstration runs explored.

   a) Historical, current and temporal variation RF-EMF radiation measurements are overlaid on the City of Cape Town; and

   b) GIS scenario models are run per the STEP and LTCEP models' EMF radiation power density, field intensity and proximity to vulnerable facilities.

A constructed EMF radiation HYGEIA model, an artifact, is shown in Figure 6.1, on the next page. The model is a conceptual system flow of the human health risk assessment based on the understanding of the literature from the construction of the framework in Chapter 5. Figure 6.1 illustrates a system flow for a multidisciplinary model requiring multiple inputs from multiple sources and feedback loops processing knowledge bases (Part A), spatial attributes (Parts C, D and E) and impact predictors (Part B), resulting in the occurrence of another anticipated or undiscovered EMF radiation hazard condition (Part D and E) mitigation option scenario (Part E1 and E2), known as systems iteration.

Ecological knowledge about land covers, land cover attributes, and pollutant behaviour informs a dynamic spatial simulation of hazard conditions (Part E) at locations specified as polygons (Part A). Dynamics in health outcomes (Part F) under the simulated hazard conditions (Part E) per the STEP and LTCEP model inputs (Part D) are estimated when the location-specific nature of the social fabric (Parts B and C), i.e. the impact predictors of race, ethnicity, gender, age, employment, income, and gender distributions of the local population, is confronted with estimates on how social fabric elements are impacted.

The proposed EMF radiation HYGEIA model is designed to utilize all the requested data from data sources, but the forecast simulation demonstration run had the following limitations:

1. EMF radiation data sources were not willing to provide detailed technical specifications and operational log files;

2. The EMF radiation HYGEIA model did not incorporate a 3D geospatial propagation model and temporal dataset;

3. Climate conditions (Part A2) time series were not scoped in this research;

4. A detailed ecosystem service values table was not completed because the primary focus for the first model iteration is the demonstration runs for a PIO function (RQ_5);

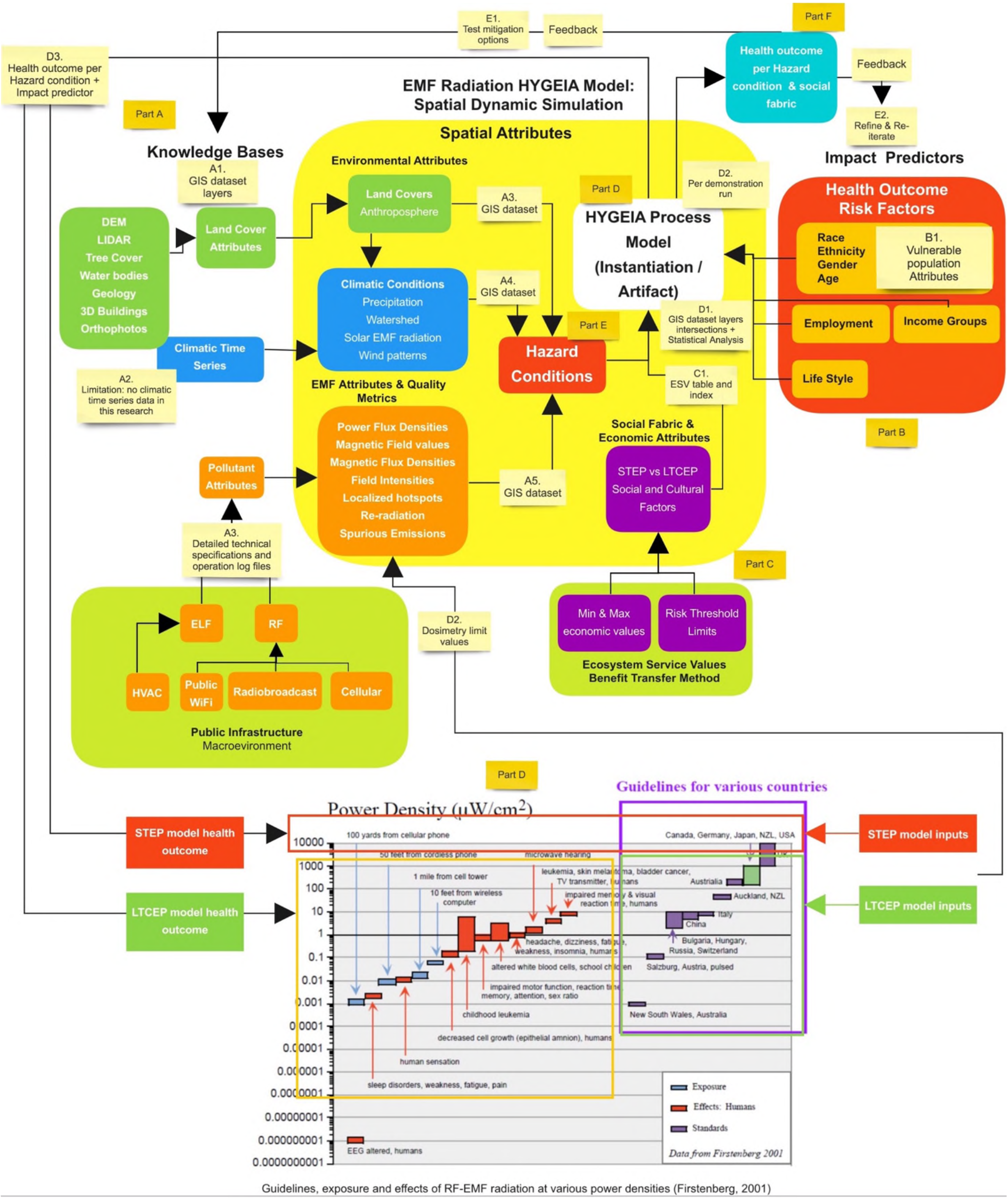


Figure 6.1 EMF radiation HYGEIA model

It was nonetheless still possible to demonstrate EMF radiation exposure PIO (RQ_5) scenarios per the framework EMF radiation policy inputs, because partial EMF radiation data was available from some data sources and generalized real world EMF radiation technical specifications were derived from literature, using the benefit transfer method (Part C).

6.3 Descriptive system flow of the EMF radiation HYGEIA model

6.3.1 Part A: Knowledge bases

Knowledge bases are different GIS dataset layers from data sources. The data is either already in a GIS dataset format, or data tables from data sources are used in the construction of a GIS dataset. The EMF radiation HYGEIA model takes inputs from three (3) knowledge base categories:

1. Land cover attributes;
2. Climatic time series; and
3. Pollutant attributes.

(1) Land cover attributes derives inputs from GIS datasets:

1. Digital elevation model (DEM), a 3D contour layer layout of the topography;
2. Light detection and ranging (LIDAR), a surveying method that measures distance to a target by illuminating that target with a laser light outputting a 3D topographical image layer;
3. Tree vegetation coverage. Tree coverage provides interference to RF-EMF radiation propagation;
4. Water bodies. Identification of open spaces that may hold confounding attributes for statistical health analysis;
5. Geology. An ELF EMF radiation mitigation strategy is the placement of HVAC power lines underground. For example, Von Winterfeldt et al., (2004) identified scenarios in the placement of power lines underground to yield the best return on investment. A geological analysis will determine which geological composition types may have a stronger reduction property;
6. 3D building models (CAD), enables calculation of RF-EMF radiation propagation and localized hotspots; and

7. Aerial orthophotos, high resolution aerial images of the investigation area. These can become dated, however.

Land cover attributes are collected and processed into land covers' environmental attributes to represent the anthroposphere. Additional datasets would include additional infrastructure sources, such as road and facilities. The land covers processed GIS dataset (A3) is output into the hazard conditions (Part E).

(2) Climatic Time series: Other climate change variables need to be assessed to account for other potential health related complaints that may be similar to those of EMF radiation exposure. Some climate conditions affect RF-EMF radiation propagation, for example: during periods of dense precipitation, the water absorbs RF-EMF radiation, resulting in transmitters to potentially emit more EMF radiation in order to compensate for the loss in signal. This research was limited in not including climate conditions because the EMF radiation HYGEIA framework was scoped to a Tier 1 analysis of the MIMES framework.

(3) Pollutant attributes: The study focused on macro EMF radiation sources. Macro EMF radiation sources are public infrastructure that micro sources are dependent on. Macro EMF radiation sources typically have the highest EMF radiation emissions and result in increased ambient (passive) EMF radiation levels when more micro EMF radiation devices are connected to it. As discussed in Chapter 4, micro sources attached to macro sources can cause knock-on exposure in the form of spurious emissions, polarization and re-radiation. Access to detailed infrastructure specifications and operational log files (Part A3) enables the processing of GIS formula models for the construction of an accurate geospatial EMF radiation propagation model. The geospatial propagation model is able to generate outputs for EMF radiation attributes and quality metrics, to wit: power flux densities, magnetic field values, magnetic flux densities, field intensities, localized hotspots, re-radiation and spurious emissions, provided that access to the needed data is available. Specified levels of the EMF radiation attributes and quality metrics, either alone or coupled, have the potential to arouse related adverse health effects.

Processed GIS dataset outputs (Part A3 - A4) are input into the hazard conditions function (Part E).

6.3.2 Part B: Impact predictors

The EMF radiation HYGEIA framework identified different members of the population (based on age and health) have a different health outcome risk factor (Part B) to EMF radiation exposure levels and sources. The EMF radiation HYGEIA model can process forecast scenario demonstration runs (Part D2) per impact predictor variable (Part B). The output is a health outcome risk factor heat map (Part F) per impact predictors variable (Part B).

This research limited demonstration runs to children under the age of sixteen (16), the elderly and the chronically ill.

6.3.3 Part C: Social fabric and economic attributes

The processed data extraction, using the ESV and BTM tools (Part C), is the output of the EMF HYGEIA framework. The tables hold the social fabric and economic attributes data (Part C1) of the investigated community. Each area and community within the investigation grid may have vastly different minimum and maximum economic values and risk threshold limits toward EMF radiation exposure.

The social and cultural factors of each investigation grid are input into the HYGEIA process model (Part D) in terms of the STEP and LTCEP models.

6.3.4 Part E: Hazard conditions

Processed GIS dataset outputs from Part A3 to A5 are overlaid, intersected and coupled in the hazard conditions function (Part E). An individual dataset from Part A3 to A5 may, by itself, not reveal a hazard condition, however, when the GIS layer dataset intersect, hazard conditions, in terms of the STEP or LTCEP models, may arise. For example: an RF-EMF radiation transmitter (A5) in a public space (in/on a building/vehicle) (A3), either by itself or with other infrastructure sources, may result in RF-EMF radiation propagation reflection, re-radiation, interference and/or form localized hotspots and or polarization, resulting in potential STEP and LTCEP models' hazard conditions.

The output of identified hazard conditions (Part E) is input (D1) into the HYGEIA process model (Part D).

6.3.5 Part D: HYGEIA process model (artifact)

The HYGEIA process model (Part D) receives inputs from Parts B, C and E. The input (D1) is the processed GIS dataset layers' intersections and statistical analysis inputs. The HYGEIA process model would process the inputs (D1) against the simulation forecast projections in terms of the STEP and LTCEP models' health outcome and inputs (Part D3), resulting in a health outcome per hazard condition and impact predictor (Part D3).

The HYGEIA process model would perform a demonstration run (D2) in terms of the Part D3 process. The output is a health outcome per hazard condition and social fabric (Part F) per demonstration run (Part D2).

6.3.6 Part F: Health outcome per hazard condition

The products of Part F are a series of heat maps and tables that enable stakeholders to visually and quantitatively assess on the 'balance of probabilities' whether PIO function, from an array of EMF radiation exposure simulation forecast demonstration runs, is evident (RQ_5).

The output of Part F is based on the stakeholder input and biophysical datasets for valuation of the assessed ecosystem services. The HYGEIA process model simulated ecosystems and socio-economic systems in space and over time per demonstration run (Part D2). Part F is the output of the simulated interactions between ecosystems and socio-economic systems, through coupling.

The results revealed in Part F are re-assessed by stakeholders for a second system iteration. Part F may reveal new scenarios and data that are fed back into the EMF radiation HYGEIA model (Part E1 and E2). Part E1 and E2 are feedback mechanisms providing input for refined data, re-iteration and alternative mitigation options to be tested in the next simulation forecast demonstration run.

6.4 Conclusion

This chapter presented and discussed the constructed EMF radiation HYGEIA model in fulfilment of RQ_2. The model demonstrated the constructed framework (from the previous chapter) by processing metric quantitative inputs from multiple disciplines, scientific opinions, economic practices, legislation, social and cultural values and associated values risk threshold limits. The outputs of the model have the potential to output evidence (RQ_4) and support for a PIO test in the framework in fulfilment of RQ_5.

The literature review investigation in Chapters 2 and 4 revealed many single discipline approaches toward the STEP and LTCEP model issues and concluded that there are no best or optimal solutions to EMF radiation exposure guidelines and/or standards, because the research conducted by STEP and LTCEP model endorsers is about choices and bounded decisions (Mazar, 2009).

The literature review found repetitive conclusions to the need for approaching EMF radiation risk exposure management as a multidisciplinary issue. However, no comprehensive multidisciplinary EMF radiation framework or model was identified in the literature. The conclusion for a multidisciplinary approach to EMF radiation risk management was derived from scholars' recommendations on future EMF radiation studies, regulatory agencies, practitioners and international High Court rulings. The recommending parties found that, within the literature, revealed EMF radiation public interest research would benefit from investigating alternative EMF radiation exposure guidelines, standard approaches of applied sociological theories, historical and political analysis, colonialism, religion and legal origins.

This research attempted to develop a proposed CHANS science framework (previous chapter) and model based on the multidisciplinary literature review in Chapters 2, 3 and 4. The output was a model that can be used to demonstrate and test the framework by means of a PIO (RQ_4 and RQ_5).

Qualitative and quantitative criteria were used in the systematic review of literature on experimental, biological and epidemiological studies, legislature policy, economic practices and social and cultural values risk threshold limits per the STEP and LTCEP models' EMF radiation dosimetry by the application of the systematic content analysis of judicial opinions and scientific-technical analysis,. The qualitative and quantitative criteria were structured to examine what qualifies as an adverse health effect as a definable measurement parameter for the constructed model.

The strategy was chosen as part of HYGEIA's functional model purpose in public health simulation forecasting. The HYGEIA model is one of the many approaches toward investigating STEP and LTCEP models' public interest concerns. The EMF radiation HYGEIA model was constructed to:

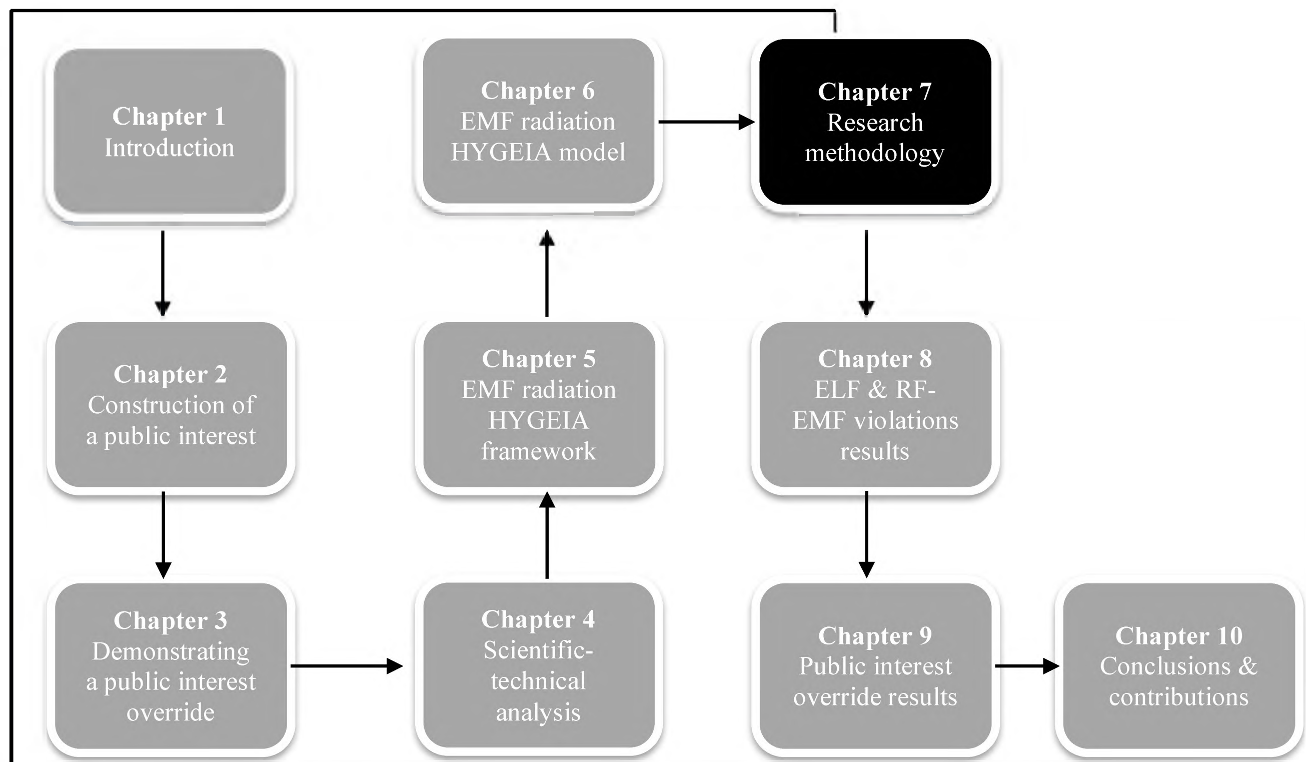
(1) Simulate the mitigation measures and reduced risks to individuals and public health from EMF radiation exposure hazard conditions (Part F) in accordance with the STEP and LTCEP models' input;

(2) Identify any links to potential health problems (Part D); and to

(3) Simulate mitigation options that may causally affect EMF radiation related health problems (Part E1 and E2) (Belyaev et al., 2016).

The next chapter will discuss the research methodology used in this study.

CHAPTER 7: RESEARCH METHODOLOGY



CHAPTER 7
Research methodology

7.1 Introduction

The previous two chapters provided the construction for a public interest EMF radiation HYGEIA framework, based on the reviewed research outputs from Chapters 2, 3 and 4 and the aforementioned framework led to the construction of the EMF radiation HYGEIA model, as discussed in the previous chapter. The purpose of the model is to perform test simulations against PIO criteria (Chapter 3) to demonstrate a PIO function (RQ5). This chapter will focus on the research process that will be used to answer the research questions by testing the model through PIO demonstration runs in a GIS. The research process, as shown in Figure 7.1 below, integrates the stages of the study as highlighted in the centre of Figure 7.1.

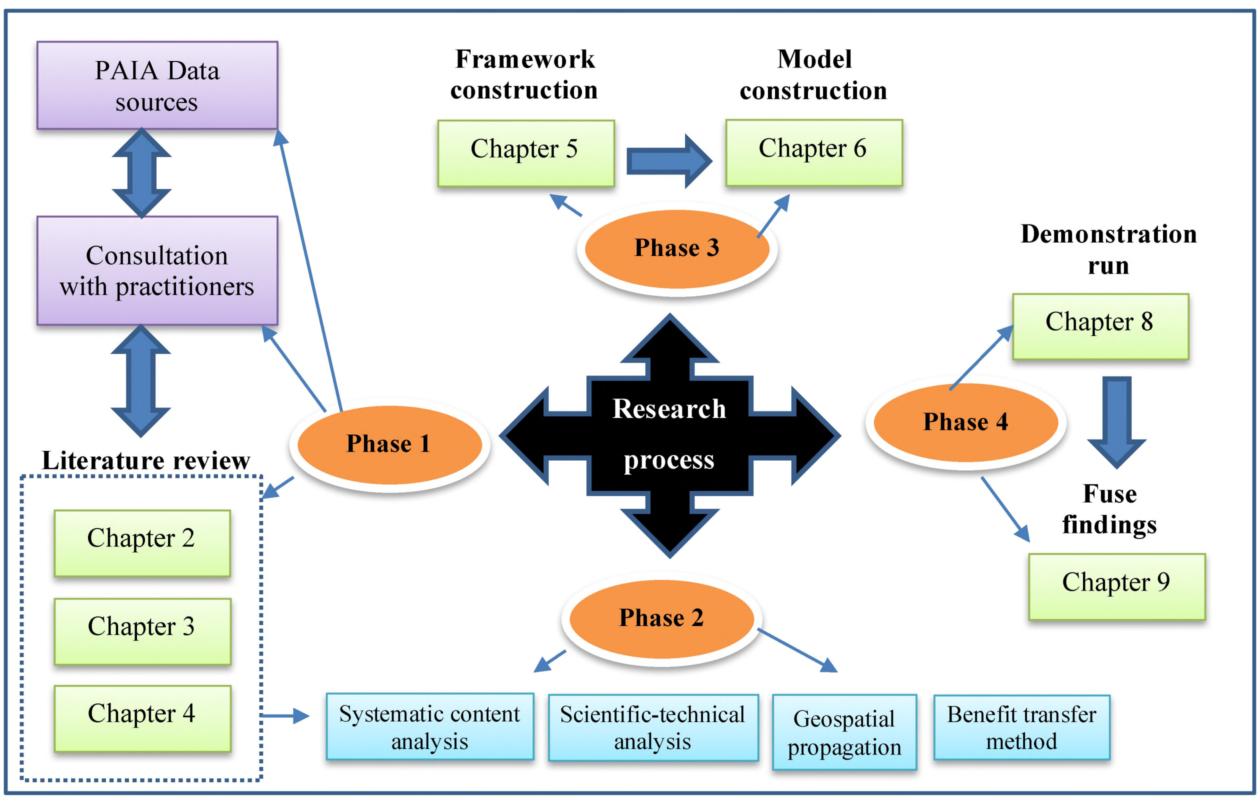


Figure 7.1 Research process employed in the study

The research process assists in attaining the main objective of the study. This chapter identifies the research philosophy, research approach, research strategy, the data collection methods, data analysis and limitations used in the study, in order to guide the research process.

The design process that is used in this study to answer these research questions is presented in various sections in this chapter. Section 7.2 presents the research design that has been chosen; Section 7.3 presents the research process; Section 7.4 introduces the investigated area that has been chosen specifically for this study; Section 7.5 reviews the research methodologies identified for the study and Section 7.9 discusses study limitations and bias. A summary of the chapter follows in Section 7.10

7.2 Research design

The research process (highlighted in Section 7.1 above) illustrates the research design. The design requires a systematic approach of drawing understanding and knowledge from multiple disciplines and therefore employs multiple methodologies in this study. Multiple discipline methodologies were required because different data sources from different disciplines needed to be explored and the data thereof needed to be extracted. Answers to the first and second sub-question are sought in this section. The first and second sub-questions were presented in Chapter 1 as follows:

> RQ_1: What should a multidisciplinary entities framework encapsulate to enable modeling of macro EMF radiation sources, considering domestic and international legislation and scientific opinions?
>
> RQ_2: How should a proposed framework construct a public interest EMF radiation model and can it be used to construct public health forecast simulations in a designated area?

Answers to these sub-questions contribute to the first stage of the study. The methodological aim of the dissertation, as overviewed in Chapter 1, is the construction of a basic PIO (Chapter 3) which could be put forward in future scenarios. The constructed EMF radiation HYGEIA model presented in the previous chapter needs to demonstrate the framework in Chapter 5 through demonstration runs using a GIS. As discussed in Section 1.5, the various paradigms that have been used to conduct research in the PIO (RQ_5) for EMF radiation exposure domain include:

1. **Systematic content analysis of judicial opinions**: The research design was driven by the establishment and confirmation of a public interest. A public interest was established by using a combination of systematic content analysis of judicial opinions based on case law and consultations with practitioners per the MIMES framework (Hall & Wright, 2008;

Boumans et al., 2015). The output led to the identification of a threat and/or violation of human rights, thereby qualifying a public interest (SAHRC, 2014; Practitioner9, 2016).

2. **Systems theory:** Rooted in systems theory, the MIMES framework and model libraries are the application of the interdisciplinary science of coupled human and natural systems (CHANS). CHANS science seeks to understand the connections, feedbacks, and trajectories that occur as a result of the natural system and human system processes and exchanges. An important goal of CHANS science is to uncover the current and future limits of natural system functions to support human wellbeing needs and to explore the tradeoffs associated with alternative futures (Gopal et al, 2016).
3. **Scientific-technical analysis:** Technical analysis lends to a random order, hence the need for non-linear statistical analysis, with the goal of establishing a principled classification of the possible patterns characterizing the deviation or defects from the random occurrence in the real world and its time translational invariant properties. (UNEP, 1995; Anderson et al., 2000; Caginalp & Balevonich, 2003; Kirkpatrick & Dahlquist, 2006:3).
4. **Ecosystem service valuation (ESV):** A tool within the MIMES framework for estimating the value of ecosystem services of a landscape or sphere. ESV offers a standardized method to utilize the results of existing valuation studies in estimating the value of ecosystem services for a specific study area, using the benefit transfer method (Boumans et al., 2015)
5. **Benefit transfer method:** A data quality benchmark and resource constraint tool used to estimate economic values for ecosystem services by transferring available information from case studies from another location and/or context (King and Mazzotta, 2000).
6. **HYGEIA:** Modeling in a preventative health context (Boumans et al; 2014).
7. **Design science**: Provides a foundation for the analysis of design artifacts in order to improve the challenges that exist in design aspects. It also provides researchers with a platform to generate new theories in relation to the existing design challenges (Zimmerman et al., 2007).

Although all of these paradigms exist within different discipline domains, each of them has weaknesses. It is of importance that the paradigm used should support the research study. In order to aid in answering the research question, the greatest value of the paradigms for this study is attained from practitioner experience. This is because it considers solving practical real world problems and explores subjective ways by means of which users can be provided with satisfaction and fulfilment, in addition to considering aspects on the 'balance of probabilities'. It also supports multidisciplinary studies and therefore allows the researcher to investigate the needs in demonstrating a model and a PIO.

The next section will discuss the research design process.

7.3 Research design process

The research design process used to guide the research study is based on the contributions of a practitioner research methodological output (Wilkinson, 2000). The various aspects discussed in the study therefore include the need for philosophies, research approaches, strategies, choices and techniques, as well as procedures used to aid the data collection process. These are illustrated in Chapter 5, together with the construction of the framework based on the review of literature in Chapters 2, 3 and 4. This is further discussed in the systematic literature review of framework entities (Chapter 4), domestic and international legislation, case law (Chapter 2 & 3), news reports, consultation with experts (Chapter 7) and peer-reviewed publications.

The attainment of quantifiable evidence in demonstrating a PIO, as discussed in the previous section, may be achieved in carrying out the proposed framework in Chapter 5.

As discussed in Chapters 2 to 4, each EMF radiation HYGEIA framework entity and EMF radiation policy inputs (STEP and LTCEP) spells out the research tools and methodology employed to construct and implement the constructed model in the previous chapter.

As detailed and illustrated in the previous chapter, the model was constructed to be tested by specific geospatial propagation model instances in accordance with the framework EMF radiation policy inputs. As discussed in Chapter 3, review of literature of the STEP and LTCEP models spelt out the employed methodologies in gathering inputs for the model. The model (in the previous chapter) is to be tested as proof of the concept by using data for the investigation area of Cape Town, SA.

The next section will discuss the investigated area.

7.4 Investigated area

The investigated area of Cape Town, Western Cape, SA, occupies an area of 2,445 square kilometers and has a population approaching four (4) million. The investigated area was selected due to the perceived easier access to data and to the experts to be consulted with being more readily available to the researcher when compared to other municipal areas within SA.

As discussed in the previous chapter, the EMF radiation HYGEIA model requires input data based on facts. Processed outputs from Chapters 2 and 3 opened this study to a review of news reports, activist groups, resident's associations, municipal permit applications and consultation with the Regulator4 (2016). The research process and design assisted in attaining the main objective of this study. As discussed in Chapter 1, the final requirement of a practitioner research methodological output is to influence government policy. The practitioner research process revealed that the investigated area has many biological effects complaints resulting from EMF radiation exposure, as well as a rapidly expanding unregulated EMF radiation exposure planning practice, as discussed in Chapter 2 (CCPTM Planning and Building Development Management [PBDM], 2014; EMRSA, 2014; CCPTM, 2015; SAHRC, 2015; Regulator4, 2016; CCPTM PBDM, 2016a; CCPTM PBDM, 2016b; DHSA, 2016c).

A methodological approach in understanding existing legislation and how it can be evolved to aid policy development in public interest problem spaces is required to influence government policy. The next section will discuss the application of systematic content analysis of judicial opinions, both nationally and focused on the investigated area.

7.5 Systematic content analysis of judicial opinions

As discussed in the previous two chapters, the data input for values risk threshold values of a community can be found and interpreted in legislation and case law. As discussed in Chapter 2, understanding legal principles and judicial precedent will aid in this research study that aims to potentially influence government policy. (Wilkinson, 2000; Hall & Wright, 2008; Hsieh, 2012; DOJCD, 2015).

As demonstrated in Chapters 2 and 3, systematic content analysis of judicial opinions is the application of basic social science methods to subjects of legal interest (Hall & Wright, 2008). Using this method, the researcher collects legislation and judicial opinions on a subject and systematically studies them, recording features of each and drawing inferences about their use and meaning (Hall & Wright, 2008).

As discussed in Chapter 2, content analysis is not a true legal science as it is incapable of scientifically analysing legal principles and precedent at the level that is relevant to traditional practitioners (Hall & Wright, 2008). This is a problem both discussed in Chapter 2 and experienced by the researcher when consulting with practitioners. As discussed in Chapter 3, in an effort to overcome the scientific methodological weakness of content analysis, the research employed the methodology of scientific-technical analysis to the problem space. The merging of the two methodologies into the framework (in Chapter 5) enabled the attaining of data inputs for the model in the previous chapter.

The next section will discuss the application of scientific-technical analysis to systematic content analysis of judicial opinions.

7.5.1 PAIA (2000): Public interest override matrix checklist

The previous section discussed the limitations of systematic content analysis of judicial opinions and how scientific-technical analysis was used in this study to address the scientific weakness of the content analysis method in answering RQ_3. In this section the method required to answer the third sub-question is sought:

> RQ_3: How should a legislative public interest override function be formulated into a quantitative metric checklist, or index, to be used in a simulation model?

The systematic content analysis of Kgomo's (2012) ruling in De Lange and another v Eskom Holdings Limited (2012) and PAIA (2000) was reviewed. The criteria were extracted from the literature in Chapter 3 for the construction of a checklist matrix for a PIO of 'substances released into the environment' and 'public safety' or 'environmental risk'. The PIO checklist guides criteria testing and provides a means of gaining pertinent information for further studies based on this dissertation (RQ_5). The PIO checklist is available in the Appendix, Section 3.1 (PAIA (2000) public interest override matrix).

The fulfilment of RQ_3 guides the search for potential EMF radiation violations identified for RQ_4 by using the Benefit transfer method, as discussed in Section 7.6 below:

1. Data derived from the literature review in Chapters 2, 3 and 4.
2. Consultation with experts.
3. Outcomes from the PAIA (2000) applications (discussed in the next section) are recursively processed through the PIO checklist. The results indicate whether a potential public PIO, in terms of PAIA (2000), holds merit.

As discussed in Chapter 3, demonstrating a PIO requires the merits of testing on the 'balance of probabilities' by means of PAIA (2000). Future studies will need to undergo a judicial review process to demonstrate a successful test in RQ_5. A favourable judicial review will have the capacity to influence government policy.

The next section will discuss data input sources needed to perform model test simulations in order to execute demonstration runs for RQ_4 and RQ_5, as presented in Chapter 1.

7.5.2 Data collected from PAIA (2000) applications

The previous section discussed the index of a PIO checklist needed to enable scientific application to the subjective problem space encountered in judicial review. The study followed the research process set forth in PAIA (2000) in engaging private and public bodies to obtain access to information for the study, as discussed in the next section. As discussed in Chapter 4, the MIMES framework recommended consultation with data practitioners in order to gain a greater understanding of the subject matter, the requested data and supportive literature.

The next section will discuss the ethics approach and argument to PAIA (2000) applications.

7.5.2.1 Ethical clearance procedures

This dissertation research proposal was submitted to the Rhodes Ethics committee regarding the PAIA (2000) applications (tracking number RU-HSD-16-07-0004). The committee decided on 14 July 2016 that no ethical clearance is required for this public interest research. Practitioner8 (2016) does not believe PAIA (2000) applications need to be submitted for ethical clearance (Practitioner8, 2016). In Practitioner8's (2016) opinion, PAIA (2000) is only a means to have access to datasets in those cases where access via the 'conventional routes' are unsuccessful. It is therefore rather a methodology and resource allocation issue for discussion with a researcher's supervisor or faculty. In the event of a refused PAIA (2000) application, the researcher may be required to lodge a court application for judicial review in relief for access to the requested dataset.

7.5.3 Sources of data and participants

As reviewed in the previous section, facts and data from both public and private bodies must be obtained to achieve the objective of the study. As discussed in Chapter 3 and illustrated in the constructed model in the previous chapter, there are a number of data sources drawn from multiple disciplines. The data sources selected to answer the fourth sub-question are sought in this section. The forth sub-question was presented in Chapter 1 as follows:

RQ_4: What are the simulation outputs in using the EMF radiation model?

As discussed in detail in Chapter 3, the selected knowledge bases and spatial attributes are key data input categories for the model (from the previous chapter). The greater the selection array of reliable knowledge bases and spatial attributes based on facts and data, the more reliable the EMF radiation HYGEIA model outputs in fulfilment of RQ_4. If there is a weak array and selection of knowledge bases and spatial attributes, the merits of testing a PIO in RQ_5 will be compromised. Greater array and detail of knowledge bases drawn from multiple disciplines add further credibility to the model outputs (RQ_4) and fused findings for RQ_5, as illustrated in Figure 7.1.

Section 7.1 of the Appendix (PAIA (2000) data sources, shown in Table 7.1 to Table 7.3) illustrates a breakdown of sources of data and consulted experts required in data inputs for the EMF radiation HYGEIA model, processing knowledge bases and spatial attributes of pollutant attributes (Appendix Table 7.2) and land cover attributes (Appendix Table 7.3).

Sources (Appendix, Section 7.1) were identified and engaged for access to data for the study from the literature review in Chapters 2, 3 and 4.

PAIA (2000) applications submitted to the data sources in acquiring the data for this dissertation are found in the references section.

As discussed in Chapter 4, Tier 1 of the MIMES framework, Appendix Section 7.1 lists the sources that were consulted in gaining a better understanding of the data values parameter EMF radiation related policies discussed in Chapter 2, using systematic content analysis, and their required metric configurations needed for the EMF radiation HYGEIA model. The research process that assisted in attaining the research objectives of the study is consultation with data sources in an unstructured format with two guiding theme questions:

1. What is the defined value for collateral damage for EMF radiation exposure before action is to be taken? For example, if members of the population were to experience adverse effects from EMF radiation exposure and die, what is the collateral damage limit of children living under a HVAC powerline dying of cancer before funds are allocated for a mitigation option? 0, 5, 10 or 15?
2. What are the base line required symptoms from EMF radiation exposure in order to be recognized and is there a specific institution that needs to provide peer-reviewed research thereon?

As key components to the empirical situation of the research pertinent to increasing the success of the PAIA (2000) applications, the practitioner consultants were part of the data fact-finding procedure in determining which department or company would hold the required data for the study. The fact-finding research process in Chapters 2 and 3 confirmed the problem space of an unregulated EMF radiation environment in SA and that data sources were willing to provide the data for the following:

1. It may provide practitioners and regulators with the necessary understanding to address the problem space of an unregulated EMF radiation exposure environment.
2. The data required to address EMF radiation health complaints/concerns from the public and members within the consulted departments.
3. This study aims to provide a framework and model that can be used in future demonstration runs to construct or investigate public interest overrides, but is limited to the testing of one scenario.

The next section will discuss the use of the benefit transfer method, as discussed in Chapter 4, within the MIMES framework.

7.6 Benefit transfer method (BTM)

As discussed in Chapter 4 of the MIMES framework, the BTM is a data quality benchmark and resource constraint tool used to estimate economic values for ecosystem services by transferring available information from case studies from another location and/or context (King and Mazzotta, 2000). It is proven as effective methodology in the resource constrained environment demonstrated in this study (Boumans et al., 2015). The next section highlights the consulted peer-reviewed data sources to which the BTM is applied.

7.6.1 Databases for EMF radiation literature

As discussed in Section 2.2, the following databases were used for the systematic literature review, extraction of parameters and data needed as inputs for the STEP and LTCEP models in the EMF radiation HYGEIA model, namely: ORSAA Database (2016), WHO's (2016d) recommended EMF Project research database, the EMF-portal (2016) and Google Scholar.

7.7 Construction of impact predictors vulnerability indexes

As discussed in Chapter 4, key entity requirements to executing a HYGEIA model constructed in the previous chapter are the investigation and establishment of impact predictors and their associated vulnerability indexes as defined in the scientific-technical analysis.

Risk analysis impact predictors vulnerability indexes were constructed by means of the MIMES framework and HYGEIA model methodology (Boumans et al, 2014; Boumans et al., 2015). An EMFVI (see Section 4.11.3.1) and PIO checklist (as discussed in Section 7.5.1) were generated, based on variables related to demography and social situations, in terms of the literature review in Chapter 4 of the STEP and LTCEP models and consultation with experts. Due to resource constraints of the study, the EMFVI and PIO checklist are limited in not including land cover, pre-existing health conditions, and micro EMF radiation exposure usage patterns.

The next section will discuss the methodological calculations employed in execution of the model in the previous chapter.

7.8 Geospatial EMF radiation propagation calculations

The aim of this section is to evaluate and apply the scientific-technical analysis methodologies associated with EMF radiation exposure, given the resource constraints of the study. The methodologies and data sources were selected to answer RQ_4. This section identifies the geospatial propagation calculations used to provide a visual comparative analysis of the STEP and LTCEP models and to identify potential EMF radiation violations. The limitations encountered to gain technical access in the study, corrupted data integrity and the manner in which these limitations were overcome, are also discussed.

As discussed in Chapter 1, the greatest public EMF radiation infrastructure source concern surrounds RF-EMF radiation. It is also the greatest challenge in the study, because SA regulatory practitioners expressed concern regarding the denial of access to basic and technical data by industry that renders them unable to regulate EMF radiation exposure in SA (Section 1.1)

The literature review of historical PAIA (2000) applications, regulatory data sources and consulted experts (Appendix, Section 7.1) identified that telecommunications companies refuse to provide the RF-EMF transmitter installation technical specifications and RF-EMF radiation emissions information from their sites (EMFDS12, 2012; EMFDS14, 2012; EMFDS13, 2012; EMFDS4, 2012; EMFDS3, 2012; Regulator9, 2015; ATI Network, 2016; Regulator10, 2016; Regulator7, 2016; Regulator8, 2016b; Practitioner18, 2016; Regulator4, 2016; Regulator5, 2016; Regulator2, 2016). Despite SA legislature mandating that industry supply the needed data for this study to regulators as discussed in Chapter 2, industry refuses to comply, as they claim that it would be contrary to their strategic economic interests. The lack of access to EMF radiation infrastructure technical specifications limited the research and rendered it unable to perform direct SAR and near-field power density evaluation calculations. Direct SAR is, however, not an accurate and viable dosimetry for assessing non-thermal biological effects of EMF radiation exposure, as discussed in Chapter 4.

The study's design research process (discussed in Chapter 4 and illustrated in Chapters 5 and 6) elected to use the geospatial propagation model to determine ELF and RF-EMF radiation exposure from infrastructure sources (Schoeni et al., 2016).

The geospatial representation for the framework EMF radiation policy inputs and proximity exposure were generated by using the far-field power density evaluation calculation, due to the resource constraints of the study that are discussed in further detail later in the chapter.

The generic real world RF-EMF radiation input values and calculation methodology employed for RF-EMF radiation infrastructure sources were based on the sources of the FCC (1997), Mann et al. (2000), Land of Salzburg (2000), Lung (2003), Kumar (2010), AUVA EMES (2015) and Practitioner5 (2016).

The far-field power density evaluation method is limited to providing the conservative geospatial propagation buffer proximity per the framework EMF radiation policy inputs. The conservative and simpler approach was required, because the lack of technical information per EMF radiation infrastructure site would have a varying boresight beam location, coupled with differing localized hotspots locations, due to the propagation reflection shown in Figure 7.2 below.

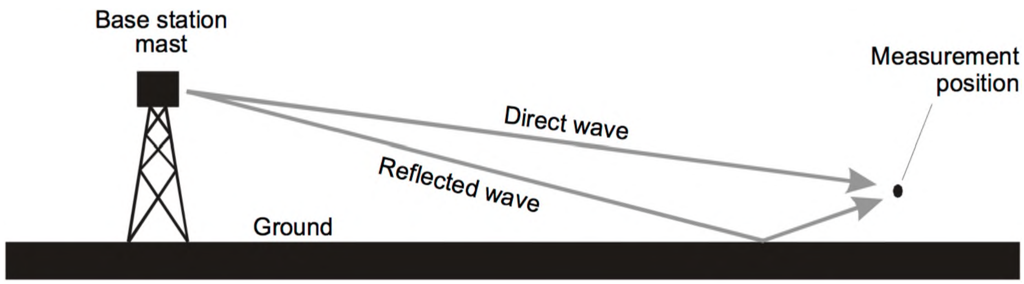


Figure 7.2 Direct and reflected waves arriving together to increase the power density at a measurement position (Mann et al., 2000)

Further limitations to RF-EMF radiation exposure estimates, calculated by the prediction calculation model of far-field power density, mainly depended on the function of distance.

The topography characteristics, to calculate the influence on RF-EMF radiation, were available through LIDAR but the lack of access to the characteristics of the transmitting ARD antennas (such as radiation frequency, power, radiation pattern, gain, and height) were not provided by the data sources. The far-field power density calculations were therefore unable to consider the existence of buildings or irregular geographic features (i.e. mountains and buildings) which could block the radiation and/or reflect and/or propagate it. The RF-EMF radiation exposure estimates may thus differ from the actual levels of RF-EMF radiation exposure.

Details of the calculation RF-EMF radiation geospatial propagation model outputs in terms of the STEP and LTCEP models are available in the Appendix, Section 7.2 (Far-field power density evaluation).

The next section discusses how the geospatial propagation model was applied to public Wi-Fi.

7.8.1 Calculation of public Wi-Fi RF-EMF radiation exposures

After exhausting and unsuccessful attempts in trying to engage with the public Wi-Fi industry's prominent players (listed in Appendix, Section 7.1) to participate in this academic research, the study completed and submitted PAIA (2000) applications (listed in References and Appendix, Section 7.1).

The next chapter discusses the details of some data providers complying with the PAIA (2000) application in providing some Wi-Fi model technical specifications and an asset registry, but lacked the detailed technical configuration per site. The far-field power density evaluation method was used in the construction of theoretical geospatial propagation of the RF-EMF radiation exposure model per site, using the BTM, as discussed in this chapter and Chapter 4.

The remaining (majority) service providers provided only the general locations for their sites. RF-EMF radiation proximity values were extracted from literature and a far-field power density evaluation, performed on public Wi-Fi routers and based on information supplied by some of the Wi-Fi routers vendor's technical specification sheets.

The approximated indoor public Wi-Fi locations were geospatially assigned a ninety (90) meter radial spatial buffer zone, whilst outdoor locations were assigned a two hundred and thirty (230) meter radial spatial buffer zone (Western Cape Government [WCG], 2016). The proximity buffer zones were increased to account for re-radiation resulting from the connection of devices to the public Wi-Fi router and/or acting as repeaters and/or secondary local Wi-Fi hotspots.

7.8.2 Calculation of radio broadcast RF-EMF radiation exposures

The detailed technical specifications for radio broadcast transmitters were not provided by EMFDS7, despite the specific request in the PAIA (2000) application. In addition thereto, a number of follow-ups on the requests were ignored. The ERP (kW) power levels and approximate location for radiation broadcast towers were made available by EMFDS7 (2016), however.

As discussed in Chapter 4, the HYGEIA model demonstration runs required the radial spatial proximity buffer zones to be calculated by the combination of epidemiological study findings and far-field power density calculations, using Lung's (2003) RF-EMF radiation exposure calculation spreadsheet, as employed in FCC (1997) RF-EMF radiation compliance applications

(STEP model). The far-field power density evaluation calculation assumed an omnidirectional isotropic antenna with a gain value of 1.

A geospatial propagation GIS map model output for the radio broadcast and explanation of the data inputs for the EMF radiation HYGEIA model are available in the Appendix, Section 7.3 (Calculation of radio broadcast spatial proximity buffer).

The next section discusses geospatial propagation calculation for ELF EMF radiation.

7.8.2.1 Calculation of HVAC power lines' ELF EMF radiation exposures

As discussed in Chapter 4, the HYGEIA model demonstration runs required geospatial propagation model buffer zones, based on epidemiological study findings for the following reasons:

(1) Epidemiological studies around HVAC power lines have been documented since the 1970's and ELF EMF radiation exposure metrics have been established a dose-relationship (Sage et al., 2007; Kelfkens et al., 2002; Kheifets et al, 2005; WHO, 2007:187; Huss et al, 2009; Belyaev et al., 2016);
(2) Countries have adopted their own STEP and LTCEP models' ELF EMF radiation standards and/or guidelines;
(3) Gaining access to the required technical and operational data from electricity service providers requires a lengthy process of negotiations and approvals, which is beyond the resource scope for this public interest research and should therefore be deferred to potential future studies. Gaining access to the technical information will allow detailed 3D space geometry ELF EMF radiation simulations to be conducted; and
(4) ELF EMF radiation governs fairly consistent physics modelling properties, unlike RF-EMF radiation propagation, that has become ubiquitous in the public space (Houndou et al., 2006; Rajasthan, 2012; Suzuki, 2014).

Following the completion of the BTM applied to ELF EMF radiation infrastructure sources in Chapter 4, the approximate geospatial model buffer zone input values for the model in the previous chapter to reach approximately below 2mG are:

11-33kV: 25 meters

66kV: 60 meters

132kV: 100 meters

220-400kV: 200 meters

As discussed in Chapter 4, an example of non-linear statistical analysis of EMF radiation exposure is shown in Figure 7.3. The inverse square law commands a decreasing magnetic field with increasing distance to the centre of the power line until a LTCEP model's safe exposure level of 0.2 µT = 2 mG, is reached. As shown in Figure 7.3, however, the combination of the powerlines' cumulative values demonstrate substantially greater distances (50% or 150-200m) required to reach ELF EMF radiation exposure levels below 2mG (Takemoto-Hambleton et al., 1996). The denied access to technical information from data sources can result in EMF radiation exposure values to be substantially underestimated in real world situations and, thereby, undervaluing the output of the EMF radiation HYGEIA model. To comply with speculative criticism while still demonstrating a PIO for RQ_5, the study elected to use the assigned distance of single HVAC lines as conservative values as part of the data modelling exercise. If RQ_5 is fulfilled in the study, potential future studies may be able to gather detailed 3D GIS data vector files and operation log files to more accurately model simulated ELF EMF radiation exposure levels developed and demonstrated by Bürgi et al. (2017).

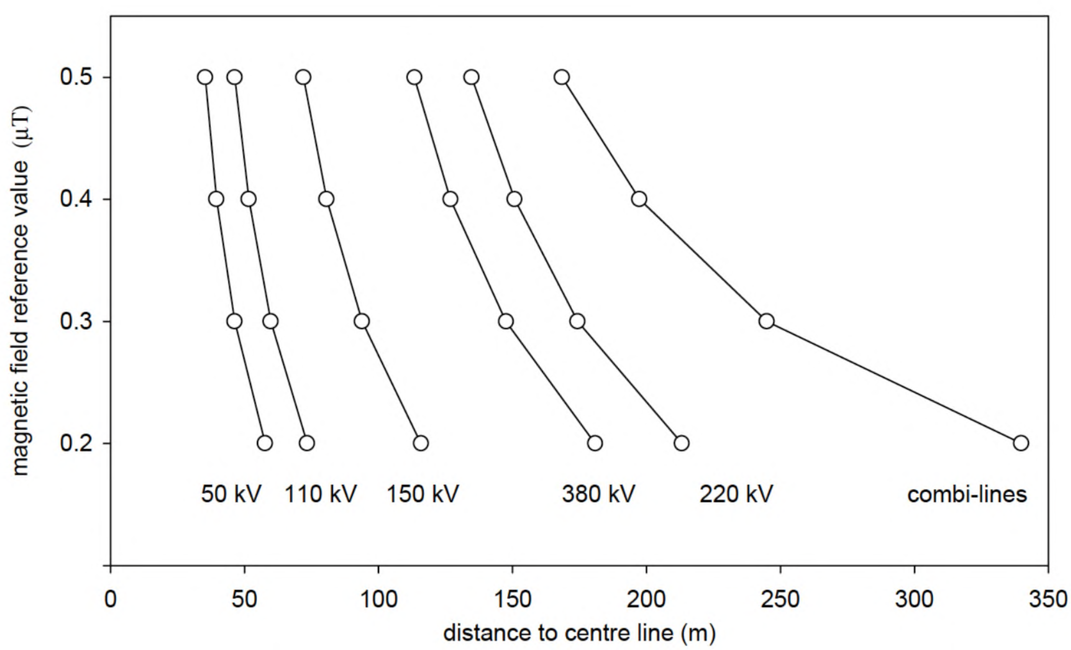


Figure 7.3 Decrease of the magnetic field with increasing distance to the center of the power line (Kelfkens et al., 2002)

The next section discusses the attempt at site measurements to verify the literature review findings from Chapter 4.

7.8.3 Site visit EMF radiation field measurements surveying technique

The previous section explored and defined the EMF radiation exposure data input values for the EMF radiation HYGEIA model, based on the geospatial propagation model, derived from literature in Chapter 4 and using the BTM.

As discussed in Chapter 1, an objective of the study is to demonstrate a PIO for EMF radiation exposure in SA on merits. The aim is to provide the demonstrated merit through simulated forecast demonstration runs, using the model constructed in the previous chapter (RQ_4). Some concerns were raised from supervisor level and epidemiological research design principles that site measurements may be needed to confirm the EMF radiation geospatial propagation model data input values for the model in the previous chapter.

The research process focused on attaining credibility for RQ_5. One of the study credibility measures was attained by a site visit measurement and training agreement between the study and the Regulator4 (2016). The agreement allowed the researcher to train Regulator4 (2016) officials in the use of their EMF radiation spectrum analyzer, the protocols in conducting field measurements in terms of the STEP and LTCEP models, as well as the manner in which EMF radiation measurements related to the STEP and LTCEP models.

The Regulator4 (2016) sent their EMF radiation spectrum analyzer away for re-calibration to the distributor, however. Several months later the EMF radiation spectrum analyzer has still not been returned.

In the light of the technical installation specifications and log files from EMF radiation infrastructure service providers being *withheld*, even to the Regulator4 (2016), accurate EMF radiation measurements and location of localized hotspots are not possible (FCC, 1997; Mann et al, 2000; USNA, 2016). Without the technical specifications the research or Regulator4 (2016) would be unable to process accurate 3D GIS simulation models to process the three (3) complex propagation conditions for reflection, diffraction and scattering (USNA, 2016).

EMF radiation infrastructure technical specifications would enable identifying appropriate environmental locations, which need to be included in the modeling calculations:

(1) Shielding and shadowing by structures;
(2) Absorption from organic matter (trees, humans, insects and animals);
(3) Multiple reflections from surfaces (walls, structures); and
(4) Re-radiation from conductive structures that are excited by EMF radiation (ELF and RF).

Points (1) to (4) have the potential to cause electric field strength (V/m) to be non-uniform over regions of space. This potential may cause miss-leading measurements (Mann et al, 2000). Additionally, localized hotspots and polarization of RF-EMF radiation may be unpredictable and similarly variable. Using 3D simulated software, the calculation and location of EMF radiation propagation, based on site specific technical data, would increase the reliability of the EMF radiation HYGEIA model outputs (USNA, 2016), thereby increasing the refinement of the non-linear statistical analysis of potential biological effects from EMF radiation exposure hazard conditions, as discussed in Chapter 4.

Failure to attain EMF radiation infrastructure technical specifications would result in multiple roughly calculated locations. Recording the maximum field strength (V/m) from every signal and over a volume of space will be needed to calculate a worst-case EMF radiation exposure quotient in the immediate vicinity of the measurement location (Mann et al, 2000).

Field intensity (V/m) valuation is achieved using an EMF radiation spectrum analyzer to make a continuous log of the maximum value of the measured EMF radiation signal strengths over a period during which the EMF radiation spectrum analyzer is manipulated over the region of the space of interest.

7.8.3.1 Limitations

As discussed in Chapter 4, the validity and value of the proposed model in the previous chapter in aiding policy makers is that the input data is based on reliable facts and data in fulfilment of RQ_4. The study is limited with industry data sources refusing to furnish site technical specifications, despite it being mandated by legislature and regulators. Due to resource constraints the study is unable to follow the PAIA (2000) procedures of engaging the courts for judicial review to gain access to the requested data. Despite the setbacks, using the BTM and evidence gathered from the literature review in Chapter 2, 3 and 4, the study can still argue in its fulfilment of RQ_5. To add additional credibility to the RQ_5 outputs, a research process of site measurements was investigated. Sadly, site measurements were not possible and are discussed in detail in this section. The limitation may serve as an additional supporting warrant for RQ_5 in demonstrating a PIO.

The study has applied for funding for a professional EMF radiation spectrum analyzer for both ELF and RF EMF radiation, but was unsuccessful due to the research being limited in designation to a Master's dissertation.

The Regulator4 (2016) RF-EMF spectrum analyzer has limited accessories for certain spectrums of RF-EMF radiation and it does not have ELF EMF radiation measuring accessories appropriate for this public interest research. Unfortunately, the unit was unavailable during the required research period.

Even if the Regulator4 RF-EMF spectrum analyzer had been made available, the potential site visits with Regulator4 (2016) officials would have been time constrained by Regulator4 (2016) personal availability and would only have been conducted on a weekday, during AM sessions (08:00-11:00). RF-EMF ARD sources provide fluctuating power outputs based on user demand. Conducting a measurement at the busiest site that has the highest RF-EMF radiation peak or average values in the afternoon or evening, would lead to misleading results if conducted during a weekday AM session. The most accurate means of RF-EMF radiation emissions measurements would be by the acquisition of operation log files from the telecommunication service providers (Israel Ministry of Communications, 2009; WHO, 2011).

Site measurements would need to be conducted following both the STEP and LTCEP models' protocols. For signals from sources that transmit intermittently, such as VHF mobile radio, the maximum instantaneous power density would be recordable (LTCEP). The STEP RF-EMF radiation exposure assessment protocol requires the RF-EMF radiation spectrum analyzer averaging RF-EMF radiation values over either six (6) or twenty (20) minutes (Mann et al, 2000). The STEP model RF-EMF radiation exposure measurements arising from intermittent pulsed RF-EMF radiation, may consequently be overestimated (Mann et al, 2000).

A further detailed elaboration to measurement uncertainties using an EMF radiation spectrum analyzer is available in the Appendix, Section 7.4 (EMF radiation spectrum analyzer measurement uncertainties). In future studies a potential feasible solution may be the use of personal experimenters attached to a pedestrian automatically logging multiple EMF exposure levels in multiple environments (Sagar et al., 2016). But in order for the data to be useful for environmental epidemiological studies, the raw data would be needed and not the average mean as published in Sagar et al., (2016). The study found relatively high variability between different environments of the same functional activity type. Additionally, Sagar et al., (2016) only at a specific time of day. The measurements could lead to chronological bias by the user and therefore future measurements should be conducted at different times of the day within the different measurement walking paths.

The next section discusses overcoming the site measurement limitation despite the resource constraints regarding access to an EMF radiation spectrum analyzer needed for the study.

7.8.4 Historical EMF radiation field measurements

In the previous section the credible value EMF radiation site measurements that may have contributed to the geospatial propagation model data input values for the model in the previous chapter, was discussed in detail. With the proliferation and ubiquitous of wireless devices, however, some companies have made a business by collecting their operational data. The collected data from these specialized businesses are sold to academic researchers and business wishing to perform statistical analysis and investigative research. The data may therefore prove useful in adding credible merit to the study in fulfilment of RQ_5.

As discussed in Chapter 2, the literature review identified that telecommunication companies in SA are reluctant to provide spatial, technical, operational logs and RF-EMF radiation emissions for their sites. In addition thereto, regulatory organs of the state do not fully collect and/or share this information as required by the SA Telecommunications Act (2000). To fulfil RQ_4 and RQ_5 and to overcome the limitations discussed in the previous sections, the study sought other data sources for information, namely: online data repositories and historical EMF radiation measurement reports.

(1) **Online data repositories:** OpenSignal (2016) and OpenCellID (2016) are examples of global collaborative community projects that collect GPS positions, power levels of cell towers and the

coverage of heat maps by mobile cellular devices, used for a multitude of commercial and private purposes. Both companies were approached and assistance for this study was requested. OpenSignal (2016) had suspended their academic collaboration partnership program, resulting in the historical measurement data for Cape Town, South Africa no longer being available free of cost. The purchasing of data is beyond the financial resource scope of this study.

The OpenCellID (2016) database is published under the creative commons license agreement and the distribution of the data is therefore free. The downloadable data from OpenCellID (2016) consists of two files, 'cell_towers.csv' and 'measurements.csv'. The contents of the database are detailed on the OpenCellID (2016) website wiki. Figure 7.4 to 7.6 are example screenshots of the data available from OpenCellID (2016). The data is appropriate, as it provides an overview of spatial and temporal cellular GIS data input layers for the model in the previous chapter. Although limited by restricting access to site information from data sources as discussed in the next chapter, the OpenCellID (2016) data still provides some data geospatial predictive modelling.

Multiple spatial measurements from multiple contributors are shown in Figure 7.4 on the next page. The identified cell tower with which the measurements are associated, is in the centre. Figure 7.5 shows the information expansion of some of the main data variables collected namely: network provider, MCC, MNC, LAC, CID, latitude and longitude. Figure 7.6 is a signal coverage heat map that could be re-calculated to give an approximation of areas that have high ambient RF-EMF radiation exposure levels.

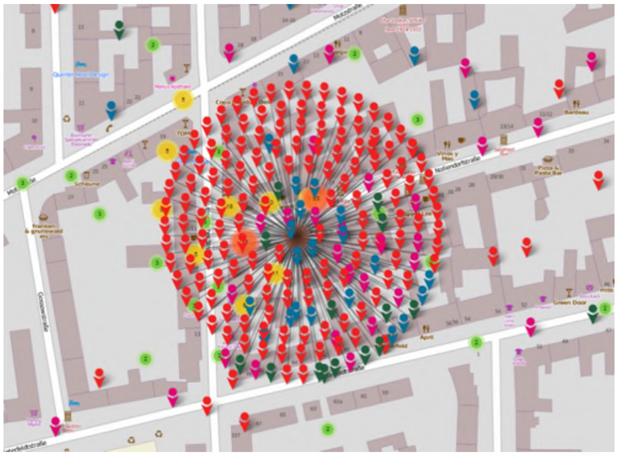


Figure 7.4 Multiple cells measurement shown on a map (OpenCellID, 2016)

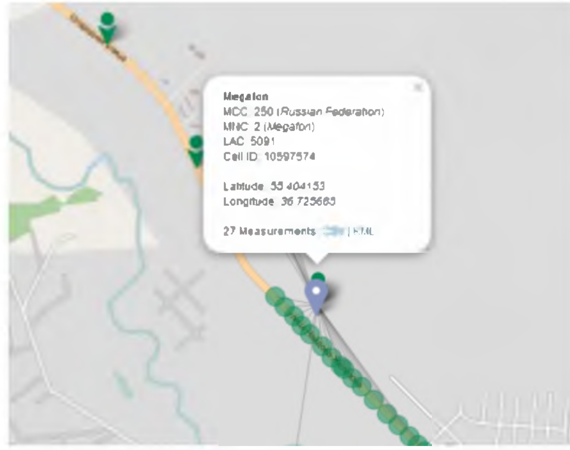


Figure 7.5 Measurement cell with expanded data (OpenCellID, 2016)

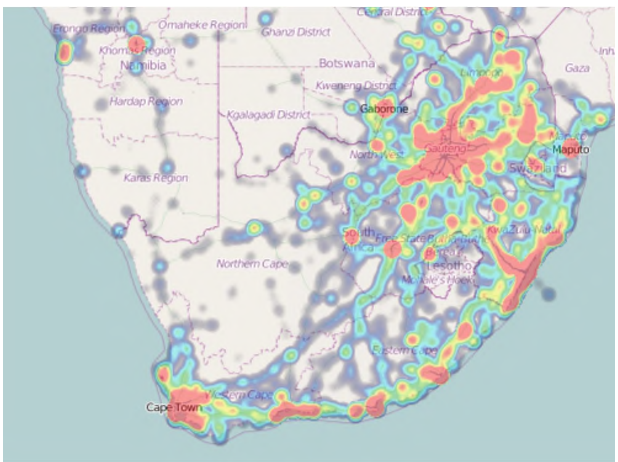


Figure 7.6 Cellular measurement coverage heat map (OpenCellID, 2016)

(2) **Historical RF-EMF radiation reports:** EMF radiation reports for 2008 and 2013, published in the DHSA annual activities, are the disclosure of data availability of EMFDS12's base stations and RF-EMF radiation measurements conducted over many years (DHSA, 2008; DHSA, 2013; Regulator8, 2016b). The researcher requested the advertised public data measurements from the Regulator8 (2016b), but the Regulator8 (2016b) reported that the measurement data and sites were never reviewed by the DHSA and that only a summary report of RF-EMF radiation compliance levels was financed and produced by EMFDS12 (weighted-study). Regulator8 (2016b) instructed that the requested data was to be acquired from EMFDS12 directly.

The researcher made a request to EMFDS12's for the publicly accessible data as advertised by the DHSA (2008, 2013). Practitioner18 (2016) rejected the request, claiming that the shared data would jeopardize EMFDS12's strategic economic interests, even for academic public interest research purposes. Despite the refusal, as discussed in Chapter 2 and 3, additional evidence was gathered in potentially demonstrating and warranting a PIO for RQ_5. Another source of historical RF-EMF radiation measurements data source for the study is EMFDS16.

During consultation with the Regulator4 practitioners, the Regulator4 (2016) reported that the RF-EMF data measurements may not be accurate, because they were unable to follow RF-EMF radiation measurement protocols. The telecommunications companies would not supply Regulator4 with the site installation technical specifications needed to carry out RF-EMF radiation measurement protocols. Additionally, Regulator4 (2016) admits to not fully understanding both the use the RF-EMF radiation spectrum analyzer, as well as how it relates to RF-EMF radiation exposure for the STEP and LTCEP models.

The EMFDS16 historical reports were reviewed and data values extracted, to be inputted into the EMF radiation HYGEIA Model GIS geodatabase. As demonstrated in Chapter 2, 3 and 4, the study needed to review, process and understand STEP and LTCEP EMF radiation field measurement methodologies to correctly interpret the EMFDS16 EMF radiation reports. Additionally, literature reviews were conducted on the processing of EMF radiation site measurements and potential user error conditions.

The next section discusses how the data collected from willing data sources (discussed in the next chapter) was processed, the issues encountered and how they were overcome for the data to be processed in the model discussed in the previous chapter.

7.8.5 Data processing and treatment/analysis for GIS datasets

As discussed in Chapter 4 of the MIMES framework, the accuracy of the EMF radiation HYGEIA model simulation model outputs for RQ_4 are only as reliable as the data input source and user experience. This section discusses how framework (Chapter 5), and model (Chapter 6) performed simulation tests using a GIS, what the dataset issues encountered were and how they were overcome during the processing of RQ_4.

Data from the data sources in the Appendix, Section 7.1 (Table 7.1 to Table 7.3) was reviewed and processed into a format that would be importable into the GIS application ArcMap. Below is an elaboration of the processing of the EMF radiation pollutant attributes (Appendix, Table 7.1) and land cover (Appendix, Table 7.2).

The vector and raster data for the model were housed within a geodatabase. The vector and raster data files from different sources were in different projections. All the data files had to be converted into a unified projection for the model simulations in order to maintain accuracy. High 8cm resolution aerial photographs for the investigated areas were sourced and they were all divided into grids. To create a single unified image the study had to create a mosaic database and then had to synchronise the images. The data input layers for the model were arranged into a feature dataset that houses feature classes. GIS data vector files received from data sources are feature classes. Data from the literature review, spreadsheets and scanned documents from the data sources were extracted and programmed into the GIS as feature classes. The researcher created feature datasets based on categories for analysis. For example: an RF-EMF dataset would consist of feature classes (geometry type points) of public Wi-Fi hotspots in CPT, SA.

For further explanations of the geodatabase, projections, mosaic dataset, and feature dataset handled in the study see Appendix, Section 7.5.

The next section discusses the creation of vulnerable facility feature classes in fulfilment of RQ_4 and RQ_5.

7.8.5.1 Vulnerable areas feature classes

As discussed in Chapter 4, the EMF radiation exposure LTCEP scientific-technical analysis for a vulnerable area facility is classified by potential EMF radiation sensitive occupants who reside within the facility for a 'long stay'. A 'long stay' can be interpreted as more than 4 hours per day, or 20 hours per week, or 14-18 hours a day during one year. The 'sensitive objects' have to be present, where the policy applies, i.e. dwellings, schools, and crèches, for these periods. Not only the building, but also the garden, is part of the sensitive object (Belyaev et al., 2016; EMFs.info, 2016b).

As discussed in Section 4.12, a scientific-technical analysis confirms that the population, when categorised by age and health, has differing vulnerability to low intensity electromagnetic field (EMF) radiation hazard conditions.

The study created vulnerable areas feature classes as buffer zones within the geodatabase. Limitations were encountered and data errors occurred, due to the data source supplier providing files that contained user errors. A detailed explanation of how the vulnerable area feature classes were created and how the errors were overcome, is available in the Appendix, Section 7.5.5. The methodology scope of the study is a PIO demonstration (RQ_5) data modelling exercise. Absolute accuracy for the entire investigation area of CPT, SA is not a requirement. In fulfilling RQ_5, potential future studies will be able to request correct and updated data from data sources through the successful PAIA (2000) PIO applications.

The primary vulnerable area feature datasets containing classes defined for this public interest research are: (1) education facilities; (2) youth related facilities; (3) care and treatment for the chronically ill; (4) the elderly.

Secondary feature classes are: (5) public grounds, parks, tennis courts, swimming pools and stadiums; (6) community centres; (7) public transport (IBRT bus network); (8) emergency services first responders (fire stations); (9) places of worship.

The primary feature datasets 1-4 were composed of the following feature classes:

(1) Education facilities classified by the EMFDS9 and WCED: ABET, combined schools, hospital schools, intermediate schools, pre-primary schools, primary schools, schools of skills, secondary schools, specialized schools, special needs schools, youth centres and libraries. Education facilities were divided into different categories to validate against STEP model reference levels and LTCEP model limits having differing protection classifications for different age groups and epidemiological findings.
(2) Youth related facilities: child day care centres, children's homes, orphanages, hospices, juvenile prisons.
(3) Care and treatment for the chronically ill: clinics, hospitals and hospices.
(4) The elderly: retirement homes and hospices.

7.8.6 Identifying potential STEP and LTCEP EMF radiation violations

The purpose of this section is to discuss how the GIS tools were used to process, interpret and analysis the processed geodatasets discussed in the previous section. The GIS had to be programmed in different iterative phases to process the simulation output heat maps and hazard conditions to test the model from the previous chapter in fulfilment of RQ_4. The outputs from RQ_4 serve as data inputs for RQ_5.

7.8.6.1 EMF radiation buffer feature classes

The ELF and RF-EMF radiation calculation values, presented in this research methodology, were processed into EMF radiation buffer feature classes by using the ArcMap 'buffer analysis' and 'multiple ring buffer analysis' tools. Shown in Figure 7.7 on the next page, for example, is the visual representation of the compliance distance calculations per STEP and LTCEP models' RF-EMF radiation policies.

As discussed in Chapter 2, the calculations are based on real world parameters and scenarios extracted from literature. As described in this research methodology the selected RF-EMF cellular infrastructure configuration is limited to a *single* operator with a 100 Watts cumulative isotropic antenna with 17 dB gain. As discussed in Chapter 2 and elaborated in the Appendix, sites could have a value $1/10^{th}$ the value or 300 to 400% greater.

Without the technical specifications from the telecommunications service providers, this public interest research is unable to plot the main beam (boresight) azimuth of the ARD transmitters. Attaining the azimuth parameters would plot a different RF-EMF radiation exposure pattern. The study therefore plotted a spherical buffer in accommodation of the azimuth being in any direction on the ARD transmitters array.

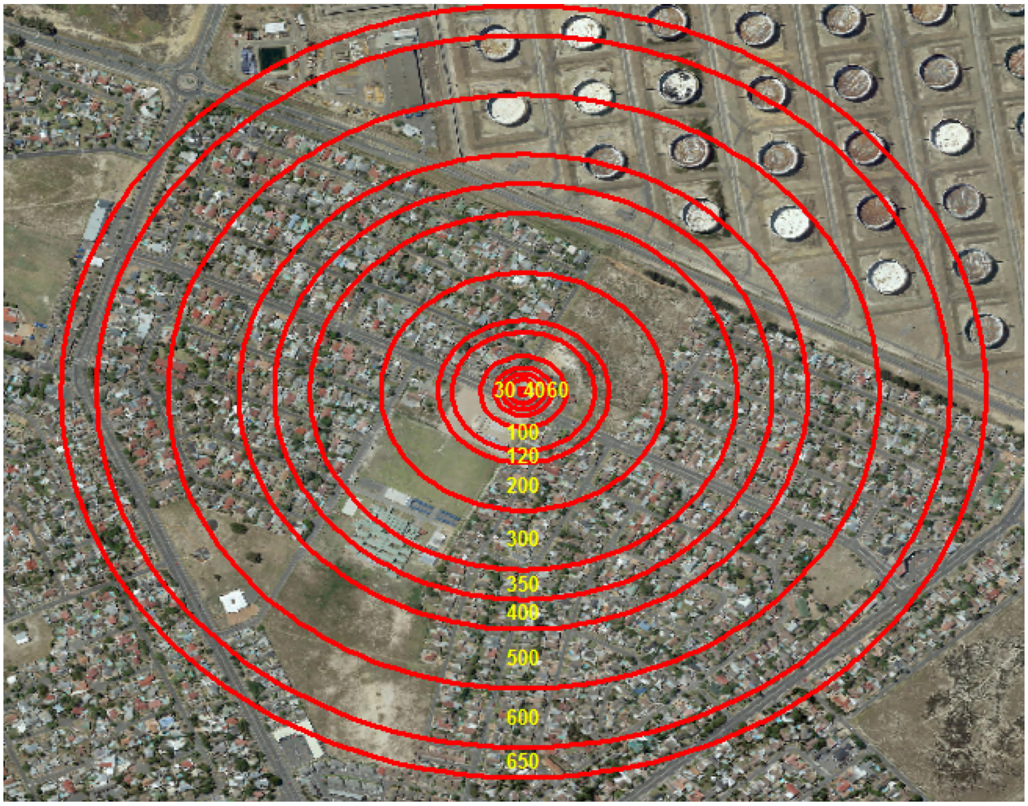


Figure 7.7 Multiple ring buffer analysis feature class of cellular RF-EMF radiation compliance distance from Table 6

The compliance distances for the cellular tower (RF-EMF radiation) are shown in red and the HVAC powerlines (ELF EMF radiation) are shown in orange in Figure 7.11.

Figure 7.8 Multiple ring buffer analysis feature classes of ELF and RF-EMF radiation compliance distances

7.8.6.2 RF-EMF radiation buffer feature class limitations

Data for public Wi-Fi and cellular RF-EMF radiation from data sources encountered limitations that would lead to certain data inaccuracies or that have failed to be plotted into the GIS RF-EMF radiation dataset.

Public Wi-Fi: Public Wi-Fi 'hotspot' locations (not localized RF-EMF hotspots), from the EMFDS9, contained latitude and longitude coordinates. The EMFDS9 also provided the technical specifications for the user manuals of the routers. An asset registry with the detailed models or locations using an indoor or outdoor configuration was, however, not provided, resulting in different RF-EMF radiation far-field exposure calculations. The study chose to utilize a representation value of outdoor units because the CCPTM mandate is to serve the public.

Data from EMFDS6 and EMFDS5 did not provide latitude and longitude coordinates or an asset registry. Only the street addresses and associated businesses were supplied, i.e. KFC. EMFDS6 confirmed that only indoor Wi-Fi router configurations are used in CPT. A review of the addresses did not reveal the locations of vulnerable area feature classes, except for a pilot project with the CCPTM regarding public Wi-Fi installed on the MyCiti bus network.

The MyCiti bus network was imported as a feature class and detailed documentation specifications were supplied by the EMFDS9. Potential future studies would be able to conduct SAR method, near-field, far-field and localized hotspot simulations by using the data provided.

Cellular ARD transmitters: EMFDS9 did not have the exact coordinates or technical specifications for cellular ARD transmitters within CPT on public land. The information provided were street ERF addresses from lease agreements on public land in 2012; renewal lease agreement from May 2016 and approved land permit applications from mid-2014 to September 2016.

EMFDS4 was the only private telecommunication company to supply the street addresses, but not the latitude and longitude co-ordinates. The street addresses were searched for by Google Maps and the approximate latitude and longitude coordinates were extracted and captured into the cellular feature class.

Some of the ERF description addresses from EMFDS9 and EMFDS4 were neither identifiable from the land parcel feature class supplied by the EMFDS9, nor by Google Maps. The location entries were thus not captured into the system as part of the cellular feature class. The addresses that were matched required the viewing of each location on the aerial photograph. Attempts to visually locate the cellular transmitters and to plot the point in the feature class, were also made. This was not possible for all sites because the photo was either out of date, or the cellular ARD transmitter was too camouflaged to be identified. In the aforementioned cases the best-assumed location was selected for the feature class, i.e. cellular ARD transmitter on a church tower.

In addressing the lack of exact technical specifications available from the data sources, the researcher recorded cellular transmitter locations visually through site visits. For example: notes were recorded whilst travelling through the different areas of CPT, checked against the aerial photographs and then captured into the cellular GIS feature class.

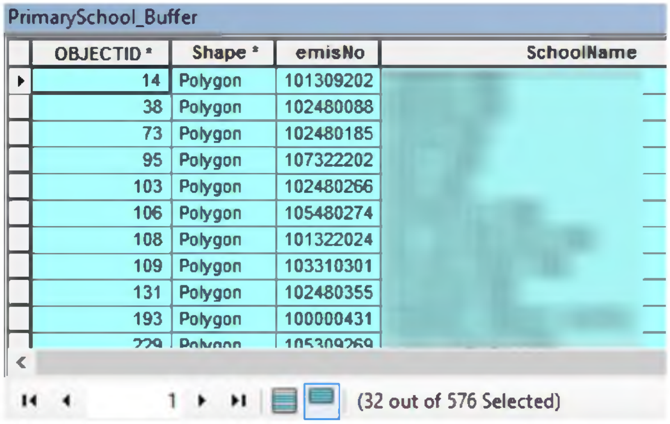
7.8.6.3 Identifying potential EMF radiation guidelines violations

RQ_4 and RQ_5 aimed to identify the number of potential STEP and LTCEP EMF radiation violations on the defined vulnerable population areas to demonstrate a PIO function (RQ_5).

Each framework EMF radiation policy inputs served as a mitigation option. A recursive SQL analysis query would be performed, querying feature classes intersected with the different EMF radiation feature classes for each vulnerable area.

For example: on the next page, thirty-two (32) primary schools were identified to have Wi-Fi RF-EMF radiation exposure. A screenshot of the search results table from the SQL query is shown in Figure 7.9.

A zoomed aerial photograph showing the outdoor public Wi-Fi ARD transmitters installed on the classified vulnerable area feature class, namely primary schools’, is shown in Figure 7.10. According to the Israel and French National Assembly (2015) policies, this would be considered a potential EMF radiation protection violation (Haifa municipality, 2016).



PrimarySchool_Buffer

OBJECTID *	Shape *	emisNo	SchoolName
14	Polygon	101309202	[illegible]
38	Polygon	102480088	[illegible]
73	Polygon	102480185	[illegible]
95	Polygon	107322202	[illegible]
103	Polygon	102480266	[illegible]
106	Polygon	105480274	[illegible]
108	Polygon	101322024	[illegible]
109	Polygon	103310301	[illegible]
131	Polygon	102480355	[illegible]
193	Polygon	100000431	[illegible]
229	Polygon	105309269	[illegible]

1 (32 out of 576 Selected)

Figure 7.9 Search results of SQL query for public Wi-Fi feature class that intersects with the primary school feature class

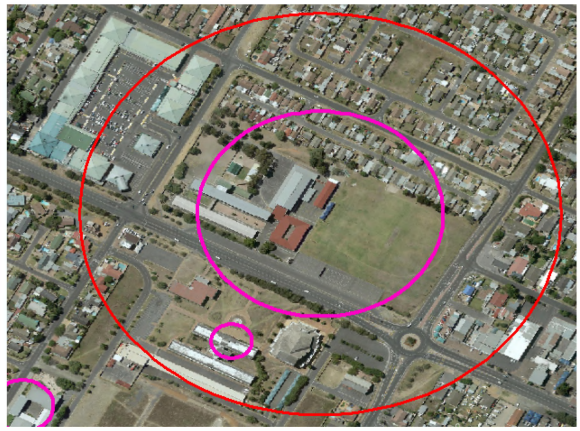


Figure 7.10 Visual representation of public Wi-Fi feature class (red) intersecting with the primary school feature class (large pink)

The intersection of the RF-EMF and ELF EMF radiation feature classes with the tennis courts, library, sports field and community centre vulnerable areas feature classes, is shown in Figure 7.14. All three vulnerable area facilities house ‘sensitive occupants’ for temporal periods that match the LTCEP model criteria. The EMF radiation HYGEIA model’s simulated hazard conditions for input ELF and RF-EMF radiation exposure levels are within reported potential biological associated health effects (impact predictors) per the LTCEP model.

Figure 7.11 Cellular transmitter and HVAC power lines EMF radiation exposure intersecting with tennis courts, library, sports field and community centre.

7.8.6.3.1 Limitations on vulnerable areas feature classes

Whilst processing the intersecting feature classes, shown in Figure 7.11, a visual analysis identified a pre-primary school not listed within the WCED data registry received. The detected data error revealed that other vulnerable areas might also not be identified during the SQL query analysis.

The researcher conducted a brief informal investigation into the pre-primary school/daycare (early development centre) that may be of interest for potential future studies. The pre-primary school is within 27 meters of the HVAC power lines shown in Figure 7.12 and therefore constitutes a potential identified violation of the LTCEP model.

Grapevine reports in the area revealed cases of childhood leukaemia diagnosed at the local hospital, with the diagnosing doctor linking a dose-response relationship to the ELF EMF radiation infrastructure sources.

In terms of the applied MIMES framework BTM there is *no* confirmation of the grapevine findings and a potential future study would need to apply PAIA (2000) applications to investigate the validity of the informal report (discussed in Section 3.5.2).

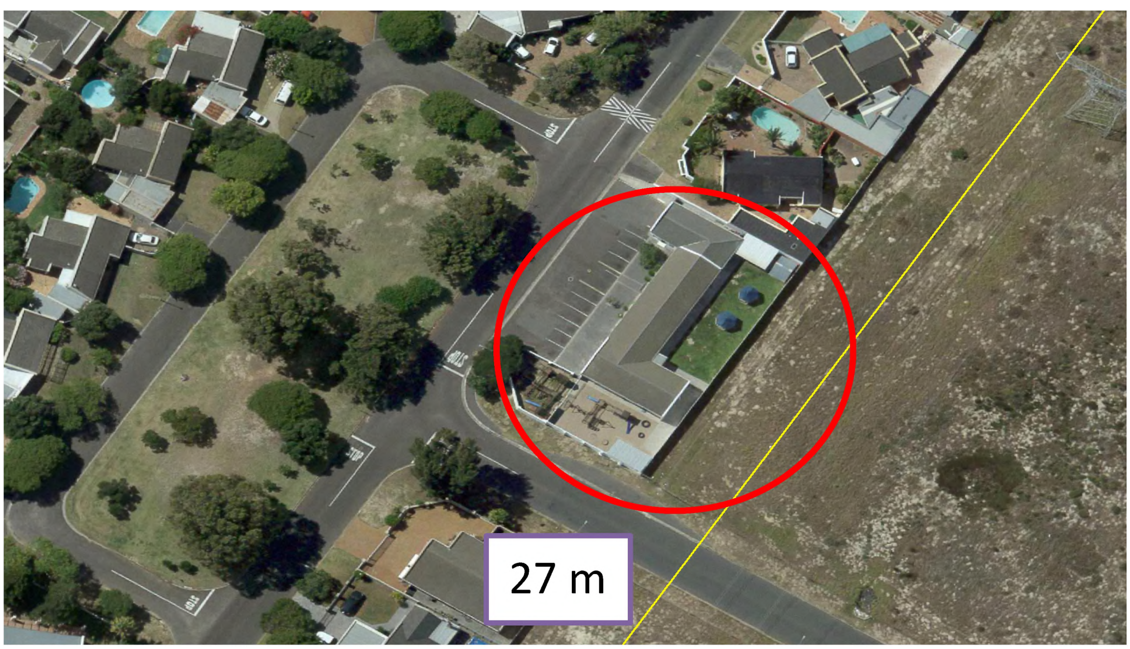
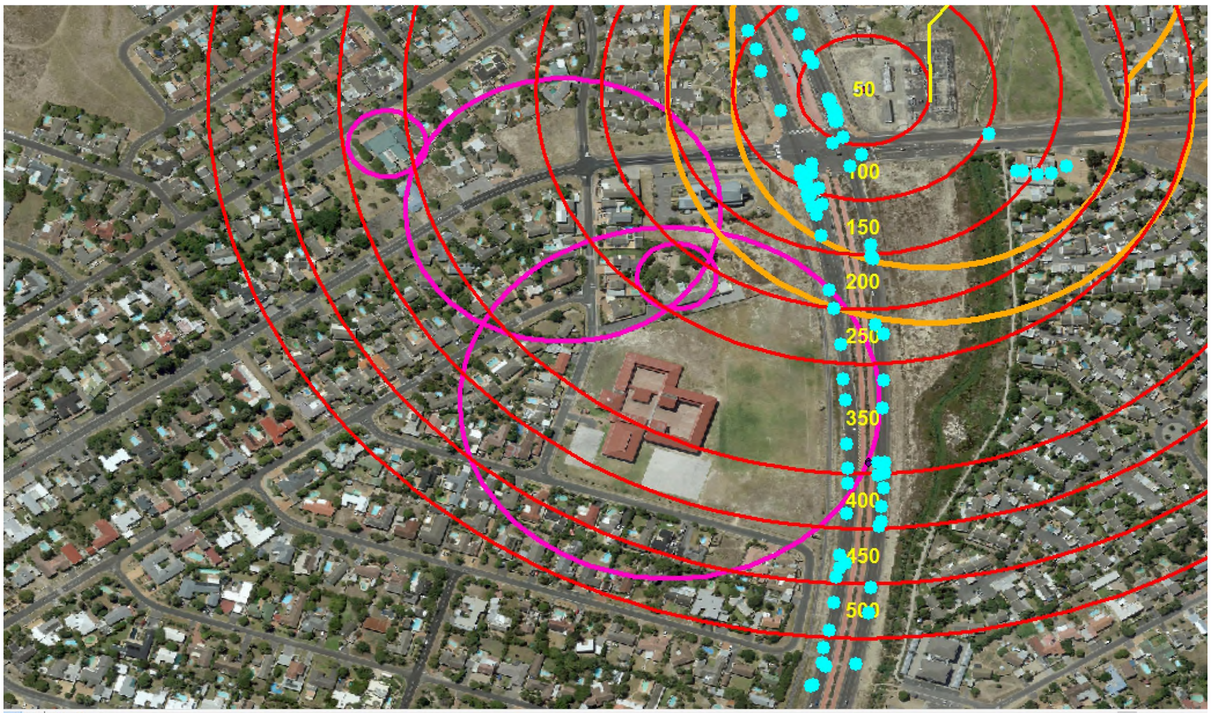


Figure 7.12 Undocumented pre-primary school/day care (early development centre) in the WCED database within HVAC ELF EMF radiation buffer zone

7.8.6.4 The development of an EMF radiation heat-map and on-site measurements of EMF radiation as potential EMF radiation violations

Historical RF-EMF radiation site measurements from the EMFDS16 and measurements from OpenCellID (2016) were imported as feature classes into the GIS. A screenshot of the historical OpenCellID measurements feature class is shown in Figure 7.16 on the next page.

The blue dots are the visual location representation of the measurements in the table. OpenCellID measurements that intersect with the RF-EMF radiation feature class are analyzed if they potentially correlate with the cellular RF-EMF radiation far-field calculations.



Table

CPTMeasurementsOpenCell

OBJECTID *	Field1	Field2	Field3	Field4	Field5	Field6	Field7	Field8	Field9	Field10	Field11	Field12	Field13	Field14	Fi
886	655	10	31823	20491	18.524113	-33.855117	-51	1461732476000	1467102026519	<Null>	<Null>	<Null>	GSM	<Null>	<Nu
887	655	10	31823	38152	18.517947	-33.869056	-51	1461776187000	1467102026890	<Null>	3.6	181.4	GSM	<Null>	<Nu
902	655	10	31823	20493	18.520895	-33.863226	-51	1461786990000	1467102027153	<Null>	54.5	15.9	GSM	<Null>	<Nu
903	655	10	31823	20493	18.521494	-33.859784	-51	1461792033000	1467102027164	<Null>	23.3	181.6	GSM	<Null>	<Nu
918	655	10	31823	38152	18.518521	-33.871524	-51	1461845163000	1467102027679	<Null>	36.5	164.9	GSM	<Null>	<Nu
943	655	10	31022	33653	18.484515	-33.990874	-51	1461671188000	1467102026413	<Null>	24.2	48	GSM	<Null>	<Nu
948	655	10	31823	20491	18.524256	-33.854925	-51	1461766431000	1467102026884	<Null>	<Null>	<Null>	GSM	<Null>	<Nu
955	655	10	31824	30464	18.851789	-34.100893	-51	1461779248000	1467102027030	<Null>	56.9	138	GSM	<Null>	<Nu
976	655	10	21823	6322	18.455548	-33.729532	-51	1461821302000	1467102027339	<Null>	58.6	0.7	GSM	<Null>	<Nu

Figure 7.13 OpenCellID measurements intersecting with EMF radiation and vulnerable areas feature classes

The lack of data, identifying all the cellular RF-EMF radiation ARD transmitters received, required a feature class heat-map constructed from the historical measurements of both OpenCellID (2016) and EMFDS16, along with the ELF EMF radiation feature class.

The EMF radiation HYGEIA model output heat-map helped categorized areas in CPT into potentially low and high EMF radiation exposure zones (discussed in Section 2.6). The heat-map and EMF radiation feature classes were intersected to aid in the identification of the locations in CPT that may provide the highest EMF radiation exposure and thus potential framework EMF radiation policy violations.

Based on the results and in agreement with the Regulator4 (2016), site visits were to be conducted at the most viable locations within resource parameters, as defined in this research methodology. This was unfortunately not possible, because the Regulator4 still do not have their EMF radiation spectrum analyzer in their possession. Both OpenCellID (2016) and EMFDS16 historical RF-EMF radiation measurements hold limitations which are discussed in the limitations section below.

An explanation of the theoretical measurements for RF-EMF radiation and the conversion of the values into poor density (W/m^2) are available in the Appendix, Section 4.11 (Theoretical measurement for RF-EMF radiation received).

7.8.6.4.1 Limitations on RF- EMF radiation historical measurements from EMFDS16 and OpenCellID

It is unknown whether the mobile cellular RF-EMF radiation devices used in the OpenCellID measurements were within line-of-sight of the ARD transmitter, blocked by the individual or taken within a vehicle. Any of the three parameters, and/or others, would affect the signal measurement recorded by OpenCellID.

Regulator4 (2016) disclaimed that historical RF-EMF radiation exposure measurements did not follow required measurement protocols, resulting in the values to be potentially underestimated.

7.9 Research bias and limitations

The purpose of this section is to provide the reader with a summary of the limitations in this chapter to prepare the reader to understand the intentions of this study, as well as how the problem statement was addressed, despite the limitations.

An identified bias in the research is that SA regulatory practitioners admit to not fully understanding how to use the RF-EMF radiation spectrum analyzer in EMF radiation exposure regulation and neither how it relates to RF-EMF radiation exposure for the framework (Chapter 5) EMF radiation policies (CCPTM 2015; Regulator8, 2016b; Regulator4, 2016).

The next section summarises the methodological limitations encountered in this study.

7.9.1 Methodological limitations

- **Lack of available data:** Detailed cellular telecommunication data from private companies historically proved politically challenging to obtain. The same obstacles were met by PAIA (2000) applications for the study, despite submitting potentially valid PAIA (2000) PIO case reference and justification for access to the data based, on Kgomo's (2012) ruling and cited SA (1996) constitutional rights from the municipal policy of KwaDukuza Municipality (2012). Public Wi-Fi providers were reluctant to provide a detailed asset registry and technical specification. This may be due to either the data source provider not having the data themselves, as cited by some, resulting in a plug-and-play installation mesh coverage network, or service providers feeling that sharing the information would result in commercial harm to their business. The limitation may be overcome in fulfilment of RQ_5 and the study undergoing a process of judicial review. Future studies may use this study as evidence for potential future PAIA (2000) applications as a potential PIO in a court application to retrieve the detailed specifications, asset registry and network plan from service providers. Unfortunately, research resources constraints do not allow this study to follow the process of a judicial review. Overcoming this data access limitation was achieved by identifying alternative sources of data that may provide a partial EMF radiation exposure picture of the investigated area.

- **Geospatial far-field propagation model**: As discussed in Chapter 4, using the SAR or field-field GIS model are valid measures of energy propagation and absorption but many different bio-effects can be seen at the same SAR level with continuous versus intermittent EMF radiation exposure, or with modulated versus unmodulated signals (Lathrop, 2003; WHO, 2003a: 69). The models are unable to accurately intersect an EMF radiation HYGEIA model's potential hazard conditions to potential biological effects impact predictors (health exposure function) due to the lack of technical specification and operation log files. The use of non-linear statistical analysis, as discussed in Chapter 4, is required to overcome the aforementioned limitation. The outputs thus require conservative limits and geospatial propagation modelling under the current limitation.

- **Benefit Transfer Method**: King and Mazzotta (2000) stipulated that issues and limitations in BTM may not be accurate, except for making gross estimates of recreational values, unless the sites share the entire same site, location, and user specific characteristics and that adequate studies for the policy or issue in question may not be available. For example; the literature review revealed strong weaknesses and contradictions in existing SA municipal EMF radiation related bylaws and policies, and that it may be difficult to track down appropriate studies, since many are not published. The literature review identified a high volume of popular Google search ranked STEP model endorsing weighted-studies which dominated LTCEP model science-based studies. Additionally, the researcher was confronted with and hindered by a multilingual language barrier issue in respect of many historically archived LTCEP studies and national standards. The reporting of existing studies may be inadequate to make the needed adjustments; and the adequacy of existing studies may be difficult to assess. Extrapolation beyond the range of characteristics of the initial study is furthermore not recommended; BTM extracted values can only be as accurate as the initial value estimate and unit value estimates can quickly become dated. The limitations may be overcome in future studies in the fulfilment of RQ_5.

- **Lack of reliable data**: In the instances of private cellular companies refusing to furnish regulators with detailed network specifications, partial data was attained from different municipal departments (Regulator9, 2015; EMFDS16, 2016; EMFDS8, 2016). The data did not hold technical specifications, but potentially addressed points of locations of transmitter properties that were documented in City Municipality public land lease agreements and permit applications. In the case of historical EMF measurements, Regulator4 (2016) admitted not having a full understanding of how to fully utilize the EMF measuring equipment. Additionally, cellular telecommunication companies refused to furnish Regulator4 with the specific information required to make a detailed and valid EMF site inspection and measurement (Regulator4, 2016). Site measurements could not be conducted in the study, because the EMF measuring equipment, supplied by Regulator4, only covered the limited EMF radiation bands. Furthermore, site measurement locations were estimated by visual inspection and approximation of potential hotspots, due to the lack of technical information by cellular telecommunications companies supplied to Regulator4. Due to these limitations, the study sought to create greater awareness regarding the problem space and to present a scientific basis for further exploration of the fundamental nature (or essence of) the EMF radiation health issues.

- **Lack of prior research studies on the topic**: The study topic holds a large body of peer-reviewed scientific literature of scientific views that validates and/or criticizes the STEP or LTCEP EMF radiation dosimetry models. SA legislation and cited literature, referencing the dosimetry models in SA policy, were weak and ill-defined. Future research may benefit by the application of critical theory on existing EMF related legislations and policies in South Africa.

- **Measures used to collect the data:** By not completing the PAIA (2000) lifecycle in submitting the PAIA (2000) rejection appeal to either the court for relief, the study was unable to either attain the required detailed technical specifications to complete a comprehensive EMF radiation HYGEIA model (RQ_4), or to confirm this research's findings in legally qualifying as a PIO under SA legislation (RQ_5). Future researchers would need to complete the PAIA (2000) lifecycle in requirements of points (1) and (2) above.

- **Self-reported data:** A discrepancy arose between the advertised data available in legislation and DHSA annual EMF radiation reports. The regulatory legislation requirements in the Telecommunications Act (2000), CCPTM Telecommunication Infrastructure policy (2015) and Regulator9 (2016) transmission license application form all request detailed technical specifications per EMF radiation infrastructure site. Unfortunately, the different regulatory bodies did not hold (or even partially held) the information and were unwilling to release it, due to a prior agreement with telecommunication data source suppliers (Regulator9, 2015; Regulator8, 2016b; Regulator4, 2016; Regulator7, 2016; Regulator10, 2016). The DHSA (2008, 2013) annual reports referenced historical EMF measurements as being available, but this data was never received or reviewed by the DHSA (Regulator8, 2016b). Due to weaknesses in existing legislative policies and failures in the fiduciary duties of regulators, the study required consultations with different municipal and government departments to identify the bottleneck in data access and to find solutions in attaining the above-mentioned information in future research. This was achieved by documenting the subjective views of the data administrators per department. Consultations with parties of interest were vital to the PAIA (2000) process, since each party is required to provide a detailed and valid reason as to why the requested data was unavailable. Consulting with the data administrators and the recording of their reasons aided in fulfilling the PAIA (2000) requirements and in avoiding the data integrity problems encountered when receiving a template response from the legal risk department of the data source service provider. The responses were uninformative, non-descriptive and did not follow PAIA (2000) protocol. Engaging to get a response regarding PAIA (2000) would result in a court application which is beyond the resource feasibility of the study.

7.10 Conclusions

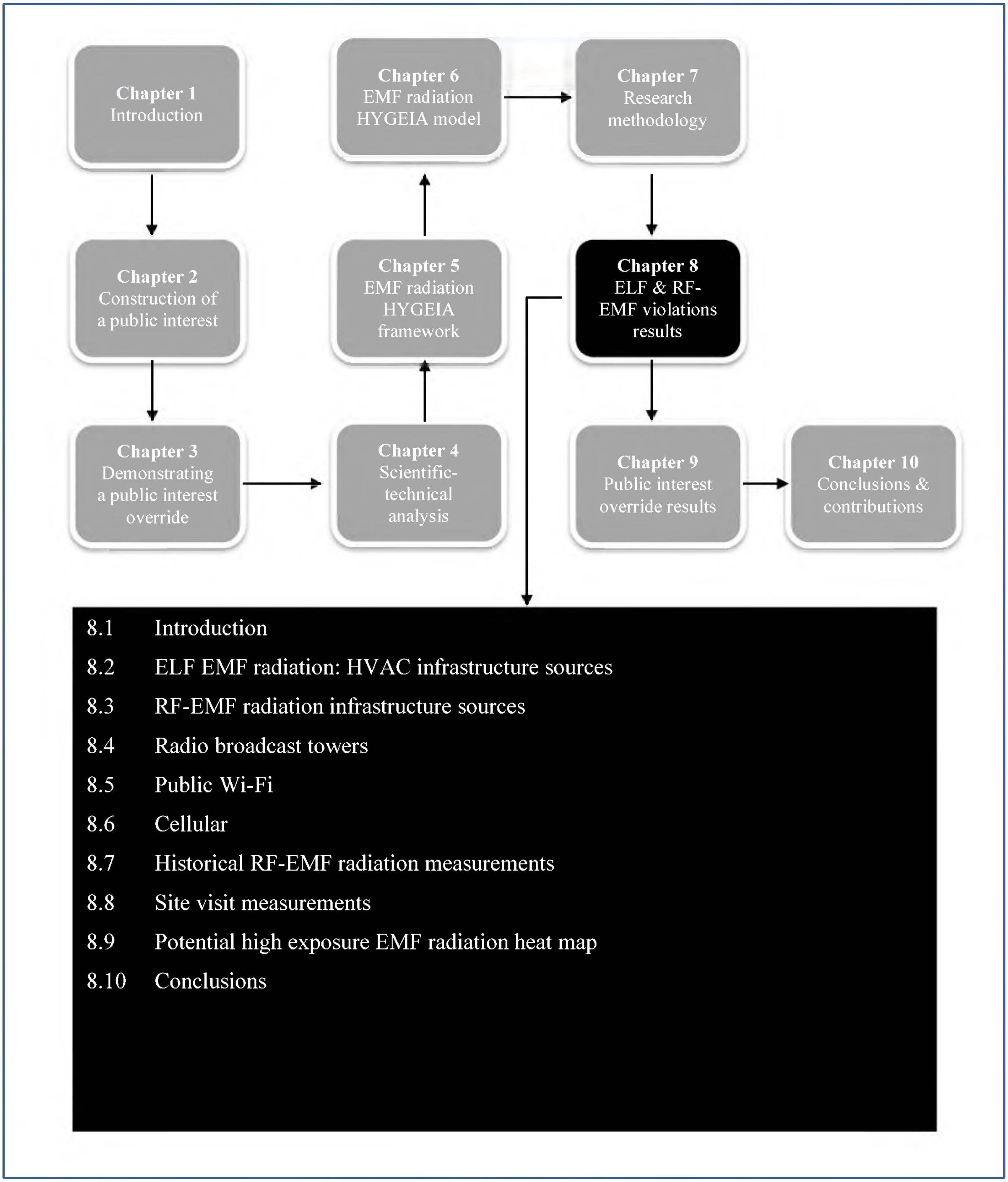
This chapter reviewed the research problems and questions and then laid out the design process that would be undertaken in answering the research questions. The philosophy, upon which the study is based, as well as the research approach, was discussed. The ethics relevant to this study were also mentioned in this chapter.

The research method and approach are appropriate for investigating the research question(s), given the theoretical framework or perspective of the research. The approach and method have also been applied in a systematic manner and is documented to allow for replication or corroboration by other researchers

The research methodology identified various approaches to measure EMF radiation levels, to model the results and to potential data sources in the attainment of accurate simulation models. Conducting site measurements with an EMF radiation spectrum analyser was also explored and was found to be resource intensive and potentially complicated with the additional risk of misleading results to the real world, because of operational handling errors or because of the choice of EMF radiation guideline protocols being utilized (STEP or LTCEP model).

Sadly, due to resource constraints, this study did not have the methodological access to accurately forecast EMF radiation exposure to the public in SA. The fulfilment of data research findings for RQ5, however, may potentially enable a future judicial review process to allow public interest regulators, academics and/or the public to gain access to EMF radiation data and emission levels from infrastructure service providers for the public domain (Stewart Report, 2000; Government of India, 2012; NEMA, 1998). Access granted to the data will enable recommended epidemiological studies to be conducted in terms of international policies and trends (WHO, 2006b). It may additionally permit the development of a second and more comprehensive EMF radiation HYGEIA model to be carried out in SA.

CHAPTER 8: POTENTIAL ELF & RF-EMF VIOLATIONS DATA ANALYSIS AND FINDINGS



CHAPTER 8
Potential ELF and RF-EMF violation data analysis and results

8.1 Introduction

In this chapter we analyze the results that were output from the demonstration runs of the EMF radiation HYGEIA model (Chapter 6) in order to answer RQ_5, as presented in Chapter 1. Furthermore in this chapter the EMF radiation HYGEIA model demonstration runs were implemented, using a GIS. The outputs from the model are sought to answer the fourth and fifth sub-questions:

RQ_4: What are the simulation outputs when using the EMF radiation model?

a) Develop an EMF radiation heat-map based on a broadly simulated geospatial propagation model.

b) Identify EMF radiation vulnerable area facilities.

c) Simulate hazard conditions per the STEP and LTCEP models' inputs.

RQ_5: How does the model demonstration runs identify potential EMF radiation violations that can be used to substantiate a PIO claim?

The goal of the study is to demonstrate a PIO by constructing a framework (Chapter 5) and model (Chapter 6). When the model ran a forecast simulation test case on the investigation area (Cape Town), it identified potential current and future public health issues related to EMF radiation exposure. Due to denied access to necessary data for computing a reliable estimate of the number of inhabitants at potential health risk from EMF radiation exposure, the model exposure outputs in this chapter are not publishable in their present state, but the principle effort is.

The processing of Chapters 2 to 4 was successful in fulfilling the minimum requirements for RQ_1 to RQ_5. Potential EMF radiation violations were identified for the framework EMF radiation policy inputs into the model, in fulfilment of a potential PIO function as discussed in the next chapter.

A potential qualification PIO (RQ_5), as discussed in the next chapter, was achieved based on evidence identified in the literature review and was supported by the model outputs (RQ_4).

As discussed in the previous chapter, the fulfilment of RQ_5 was the iterative process of identifying potential STEP and LTCEP EMF radiation violations through the development of a partial geospatial propagation model of an EMF radiation heat-map. This was achieved by highlighting high EMF radiation exposure zones in RQ_4. RQ_4 required the identification of the potential data sources essential for the generation of a 2D EMF radiation GIS geospatial propagation model (previous chapter) that could calculate, simulate and identify the framework policy inputs into the model as potential violations on the focus area of CPT, SA.

The remaining sections in this chapter are detailed discussions of the findings for RQ_4 to RQ_5. A list of EMF radiation infrastructure data sources used in the GIS dataset is available in the Appendix, Section 7.1.

This chapter is therefore structured as follows: Section 8.2 provides the findings of potential ELF EMF radiation violations and a generated heat map; Sections 8.3 to 8.6 provide the data analysis, findings and heat map of potential RF-EMF radiation violations; Section 8.7 presents and discusses the patterns that emerged from temporal RF-EMF radiation measurements; Section 8.8 discusses the limitations encountered regarding site measurements in the study; Section 8.9 presents the heat maps for high exposure hazard conditions areas that are of interest for future studies; while Section 8.10 provides the conclusion to this chapter.

The next section presents the potential violations for ELF EMF radiation based on the parameters set in the previous chapter.

8.2 ELF EMF radiation: HVAC infrastructure sources

As discussed in Chapters 1 and 4, there are two primary categories of low intensity EMF radiation exposure, namely ELF and RF-EMF, which, based on science-based reports, both have the capacity to cause biological effects. This section discusses the identification of potential ELF EMF radiation violations per the science-based literature review in Chapter 4. Findings for ELF EMF radiation are divided into the following sub-sections:

- Section 8.2.1: Potential LTCEP model violation results from HVAC power lines.
- Section 8.2.2: Public transport networks.
- Section 8.2.3: Partial ELF EMF radiation high exposure heat map.

8.2.1 HVAC Power lines: potential LTCEP model violation results

One out of the two HVAC ELF EMF radiation data sources was compliant with the PAIA (2000) applications. The non-compliant data source confirmed receipt of the PAIA (2000) application and numerous follow-up attempts were made regarding the delivery of the data, but the processing of the PAIA (2000) application to fruition was ignored by the data source.

Unfortunately, the non-compliant data source has higher capacity HVAC lines than the compliant data source, resulting in potential hazard conditions unprocessed in vulnerable areas.

In Figure 8.1, for example, two separate HVAC power line structures from two different data sources are shown. Data source one (1) is marked by the yellow GIS vector data line with the corresponding 132 kV buffer zone for 2 mG, with data source two (2) in the blue circle. When analysing the infrastructure from data source two (2)'s blue circle in the aerial photograph, the HVAC line would have a potential capacity of 132 kV or greater, resulting in the residential area on the left to fall within the ELF EMF radiation buffer zone of analysis. Discussed in Section 7.8.2.1, the proximity combination of lines could increase the buffer zone distance by up to forty percent (40%).

Figure 8.1 Data source comparison of omitted data from data source provider 2

When utilizing the LTCEP model, the EMF radiation HYGEIA model outputs the limited results shown in Figure 8.2 to Figure 8.5. Approximately 1/10th of primary and secondary vulnerable area facilities feature classes intersected with the HVAC ELF EMF radiation buffer zone feature class, as shown in Figures 8.2 and 8.3.

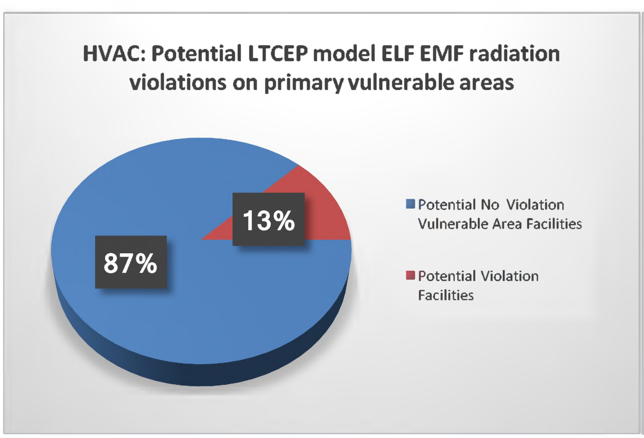


Figure 8.2 Summary: potential LTCEP model HVAC ELF EMF radiation violations on primary vulnerable areas

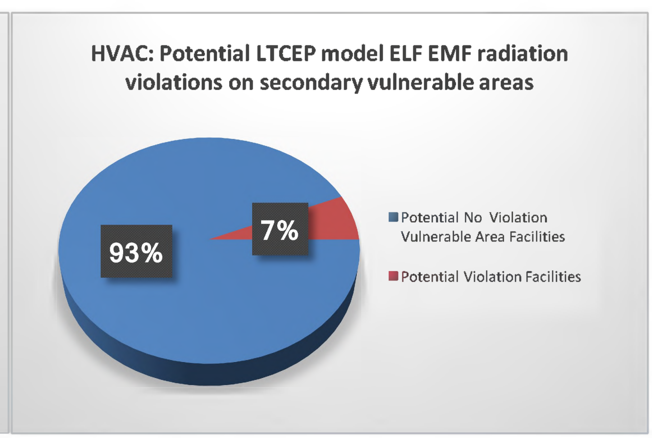


Figure 8.3 Summary: potential LTCEP model HVAC ELF EMF radiation violations on secondary vulnerable areas

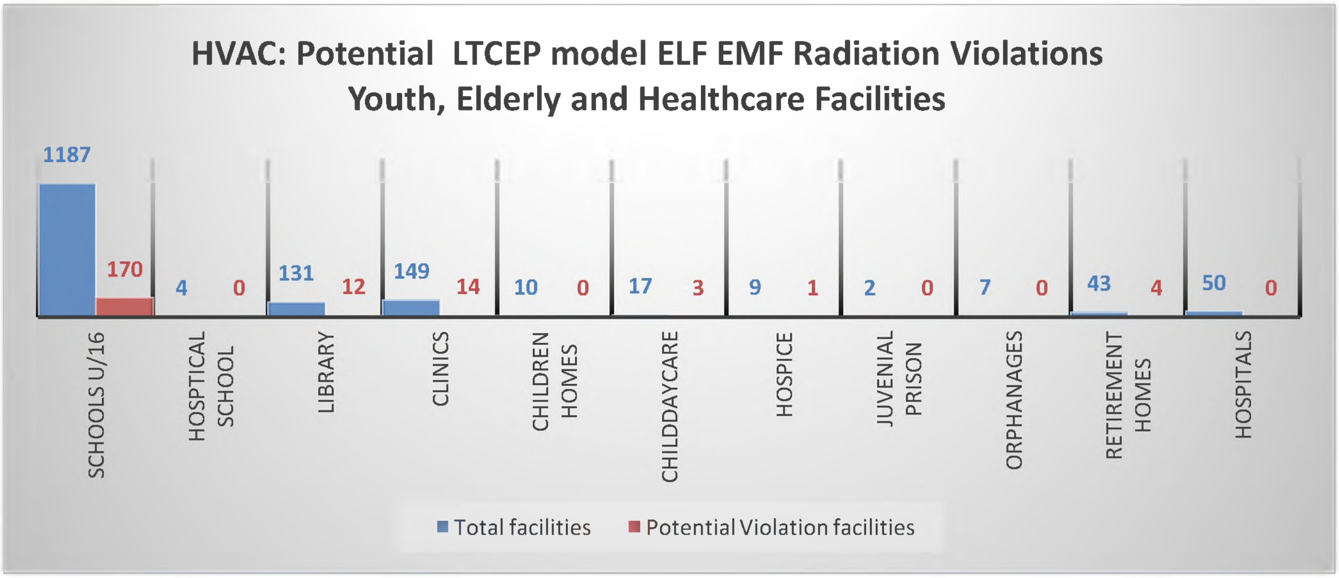


Figure 8.4 Potential LTCEP model violations of HVAC ELF EMF radiation on primary vulnerable areas: youth, elderly and healthcare related facilities

Each identified potential LTCEP model EMF radiation violation may be of interest for potential future studies. Further analysis and detailed GIS modeling could refine the selection of potential investigation facilities.

During the GIS analysis hospital feature classes did intersect with the HVAC ELF EMF radiation feature class, but, after visual inspection with the aerial photographs, it was decided to reduce the potential ELF EMF radiation violation count to zero, because hospital facilities do have a high-power consumption and HVAC sub-stations typically should be placed into a shielded setting due to medical equipment's sensitivity to external sources of EMF radiation. However, in consultation with hospital practitioners in SA, it was established that this is not the strict protocol.

Hospital ELF EMF radiation shielding compliance is not confirmed in this research and potential future studies may be carried out to confirm whether all hospital facilities have employed adequate LTCEP model EMF radiation protection protocols for both low and high capacity ELF EMF radiation sources.

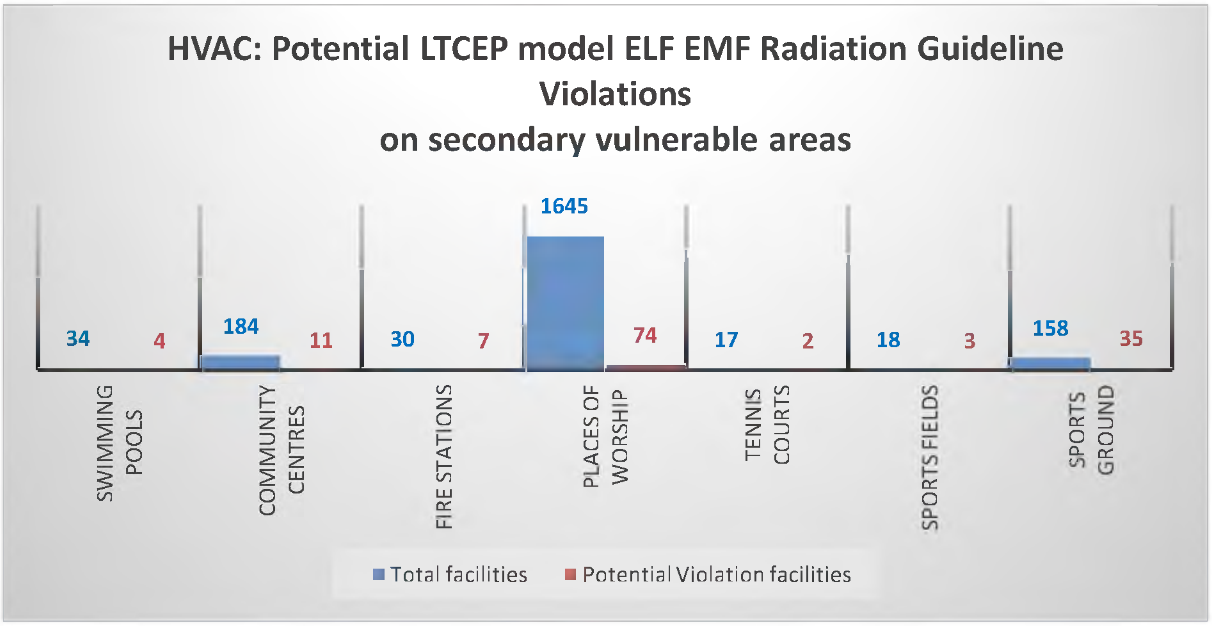


Figure 8.5 Potential LTCEP model violations of HVAC ELF EMF radiation guideline on secondary vulnerable areas

The CCPTM is currently developing a 3D building structure feature class of the city. Potential future studies may benefit in acquiring the 3D building structure feature class sets and applying intersection rules with the EMF radiation buffer zone feature class, i.e. to establish whether the HVAC ELF EMF radiation buffer zone intersect only a corner of the property/land or whether the building structure is enveloped within the EMF radiation buffer zone, This proposed application example would potentially assist in refining the accuracy of the GIS model in its identification of potential high EMF radiation exposure zones in future studies.

8.2.2 Public transport: trains and busses

The MIMES framework provides the ability to identify new data sources and patterns while simulating the current data set in a HYGEIA model. A pattern of an increase in potential ELF EMF radiation infrastructure sources and hazard conditions emerged while processing the EMF radiation HYGEIA model.

Protection policy simulations in areas of high ELF EMF radiation exposure could account for the installation of cost effective EMF radiation absorbing or shielding materials installed into the public transport hybrid infrastructure as a mitigating option in reducing public ELF EMF radiation exposure levels (WHO, 2013).

8.2.3 ELF EMF radiation HVAC heat map

The ELF EMF radiation heat map for values potentially above 2mG generated in development in fulfilling RQ_4 is shown in Figure 8.6.

Figure 8.6 ELF EMF HVAC radiation heap map for values potentially above 2mG

8.3 RF-EMF radiation infrastructure sources

The previous section discussed the findings for potential ELE EMF radiation violations. The following sections discuss the identification of potential RF-EMF radiation violations according to the science-based literature review in Chapter 4. Findings and partial high EMF radiation exposure heat maps for RF-EMF radiation are divided into the following sub-sections:

- Section 8.4: Radio broadcast towers.
- Section 8.5: Public Wi-Fi.
- Section 8.6: Cellular transmitters.

8.4 Radio broadcast towers: potential violation of LTCEP model RF-EMF radiation results

Only one data source for radio broadcast towers was available for this public interest research. Municipal, military and aviation low frequency (LF) RF-EMF radiation sources were excluded from the EMF radiation HYGEIA model data set.

The LF RF-EMF radiation data sources were omitted, because historical PAIA (2000) applications were denied access due to the claim that the sharing of the data would jeopardise national security. In fulfilment of RQ_5 however, potential future public interest studies may gain access to the requested data by means of negotiated research co-operation agreements or by judicial review.

Review of the RF-EMF radiation power transmission levels provided by EMFDS7 revealed that potential STEP model violations were unlikely. The occurrence of the hazard condition of localized hotspots or re-radiation is an exception to potential STEP model RF-EMF radiation violations. Due to the lack of detailed technical specification data provided by EMFDS7, localized hotspot simulations were not possible for the study.

Three percent (3%) of primary and seven percent (7%) of secondary vulnerable facilities may reveal results of potential LTCEP model EMF radiation violations as shown in Figure 8.7 and Figure 8.8 on the next page.

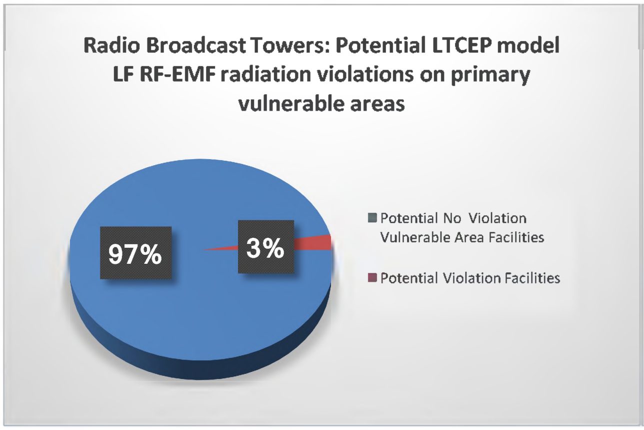


Figure 8.7 Summary: potential LTCEP model radio broadcast towers violations on primary vulnerable areas

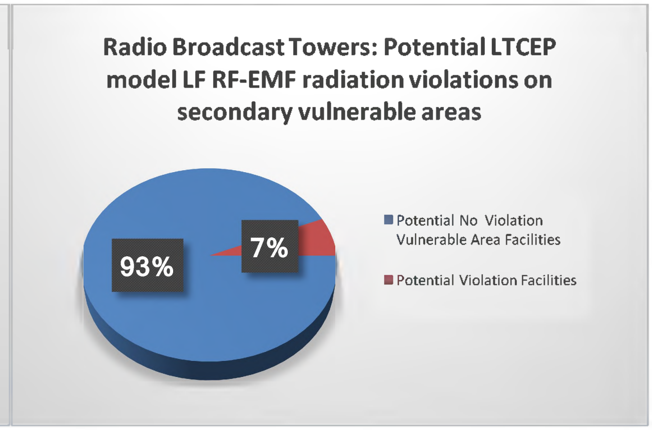


Figure 8.8 Summary: potential LTCEP model radio broadcast towers violations on secondary vulnerable areas

The results per vulnerable area facility of potential LTCEP LF RF-EMF radiation violations are shown in Figure 8.9 and Figure 8.10.

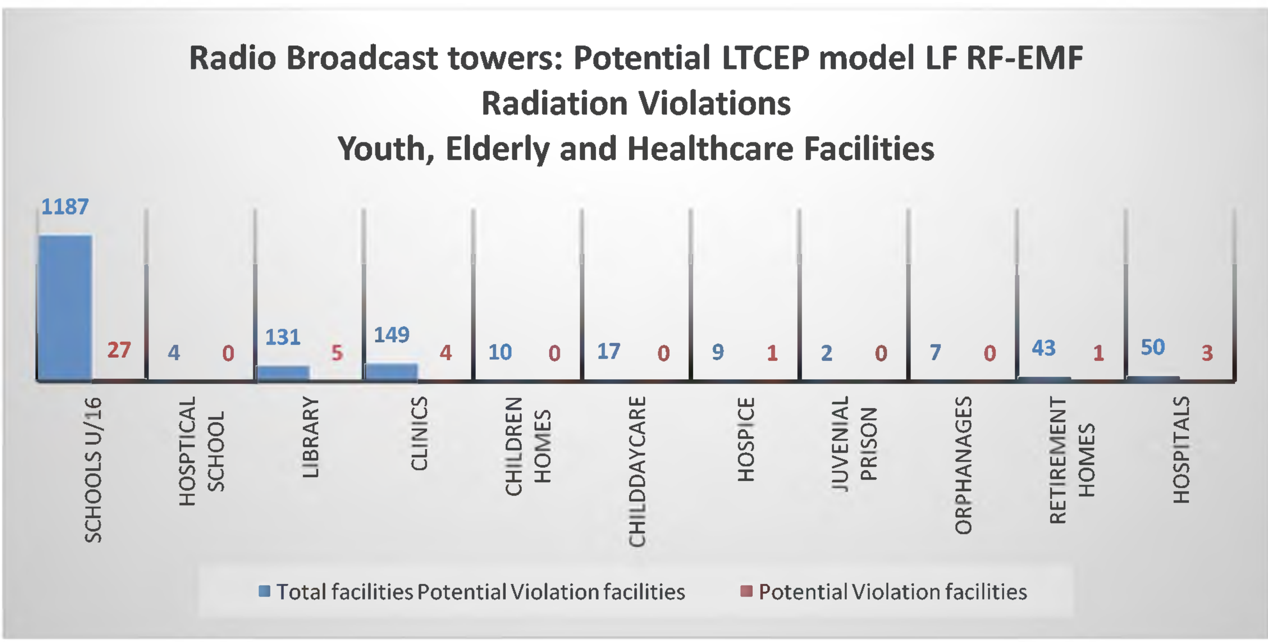


Figure 8.9 Potential LTCEP model violations of radio broadcast towers vulnerable areas: youth, elderly and healthcare related facilities

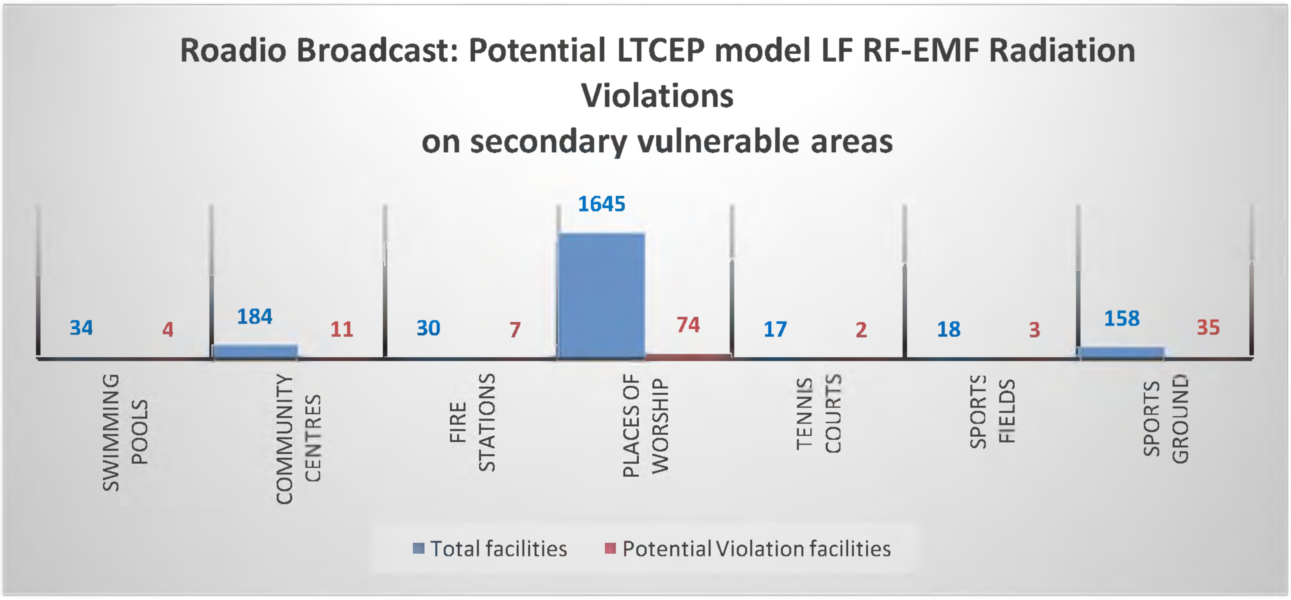


Figure 8.10 Potential violations of radio broadcast towers on secondary vulnerable areas

8.4.1 Radio broadcast towers LF RF-EMF radiation heat map

On the next page, the radio broadcast towers LF RF-EMF radiation heat map for potential field intensity values 1, 3 and 6 V/m, in development for RQ_4, are shown in Figure 8.11 and Figure 8.12

Areas in yellow have a potential field intensity value of 1 – 3 V/m, in orange 3-6 V/m and, in red, greater than 6 V/m. Regions outside of the Salzburg 2001 region are potentially within Salzburg limits for the specific EMF radiation infrastructure source.

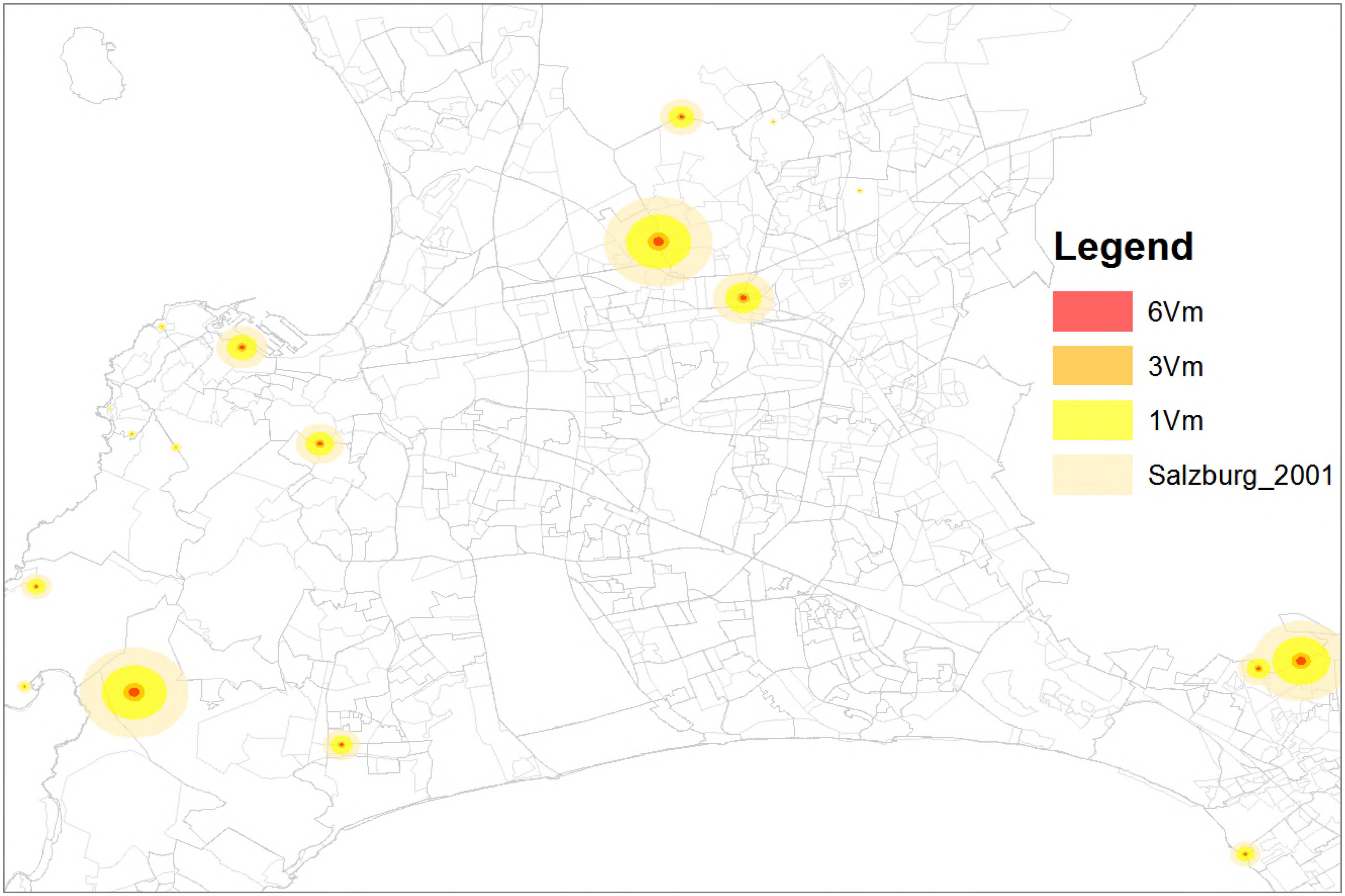


Figure 8.11 High level overview of LF RF-EMF radiation heat map

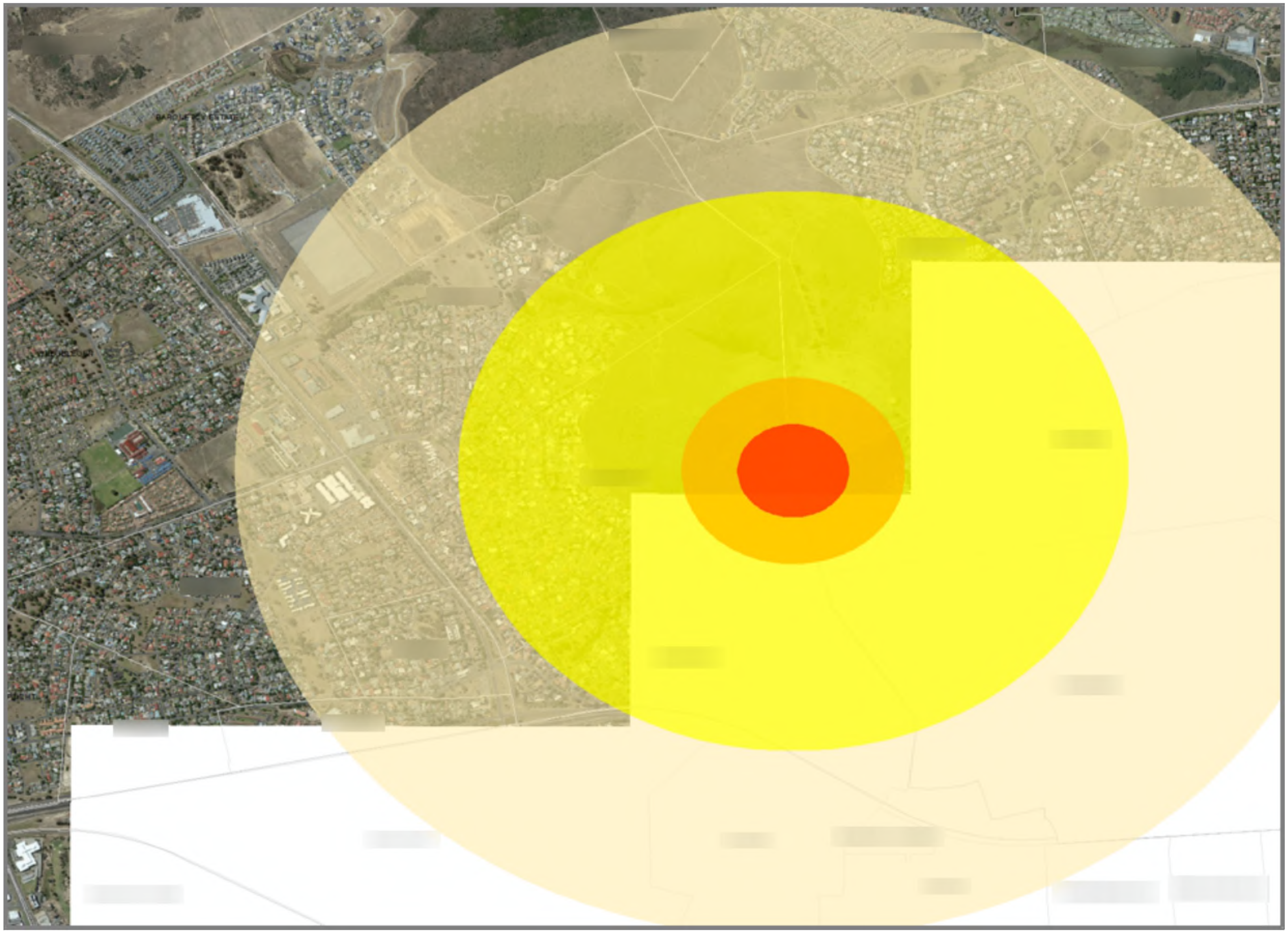


Figure 8.12 Close-up overview of LF RF-EMF radiation heat map

8.5 Public Wi-Fi: potential STEP and LTCEP model RF-EMF radiation violations

A list of public Wi-Fi data sources used in the GIS dataset is available in the Appendix, Section 7.1.

Potential public Wi-Fi violations per the STEP model are unlikely to be encountered, unless a micro-environmental RF-EMF radiation analysis is conducted, examining public participant proximity to the ARD transmitter.

A micro-environmental analysis may be possible, given that some service providers plot the location of their ARD routers in 3D CAD building drawings as part of their asset registry, thereby enabling potential 3D model simulations for RF-EMF radiation exposure to be conducted (see Appendix Figure 4.4).

STEP model EMF radiation violations are possible in environments that provide suitable anthroposphere boundary conditions for RF-EMF radiation reflection propagation, re-radiation and localized hotspots.

The dataset from EMFDS6 was not generated as a feature class in the GIS because, during the PAIA (2000) application, EMFDS6 claimed that the GPS co-ordinates on their website are incorrect and that they are in the process of re-configuring these co-ordinates. EMFDS6 did provide a list of street addresses and businesses for their public Wi-Fi service locations, however. An overview examination of the businesses listed in the EMFDS6 dataset provided did not identify the public Wi-Fi installations in vulnerable areas, but human error by the researcher is possible, since the points were not manually plotted to confirm the GIS geospatial analysis functions.

EMFDS6 stated that they only use indoor model public Wi-Fi routers in CPT and that there are, unlike in Gauteng, no installations at schools. EMFDS6's classification of indoor public Wi-Fi router models may, however, be erroneous, because, as stated in the pilot CCPTM EMFDS6 MyCiti bus project summary document, outdoor public Wi-Fi power RF-EMF radiation capacity routers were installed in the confined public transport vehicle space. Section 8.5.5 (Public transport: MyCiti bus network) below details the findings for public Wi-Fi found in public transport.

EMFDS6 claimed that CPT schools are not favourable to public Wi-Fi installations. This is in contrast with EMFDS3's partnership with the Western Cape Government (WCG), in that the said partnership aims to install public Wi-Fi in over three hundred (300) schools and their surrounding areas.

The EMF radiation HYGEIA model was successful in attaining impact predictors for approximate age categorisation (per level of education), ranging from pre-primary to high school, from the Western Cape Government Department of Education. The EMF radiation HYGEIA model's impact predictor for age classification is vital in conducting future RF-EMF radiation field measurements. As discussed in Section 4.8, future studies will need to apply RF-EMF radiation factor corrections to account for whole body SAR, in accordance with the height/age classification of the children/population, to the correlated RF-EMF radiation wavelength frequency (Dimbylow & Bolch, 2007; WHO, 2009).

The age categorisation was set to children under the age of sixteen in fulfilment of RQ_5. A potential future study second iteration of an EMF radiation HYGEIA model would, however, need to process risk assessment models for each age/height categorisation to the corresponding RF-EMF radiation frequency ranges. Even though SAR is a valid measure of energy absorption, it is not a quantity indicator of biological effects (Lathrop, 2003; WHO, 2003a: 69). SAR values can also be misleading, because SAR in a human body, resulting from EMF radiation exposure, strongly depends on the environment (Vermeeren et al., 2010; Kos et al, 2011; Yahya and Khalil, 2015) The percentage of potential LTCEP model public Wi-Fi RF-EMF radiation violations found in primary and secondary vulnerable area facilities is shown in Figure 8.13 and Figure 8.14.

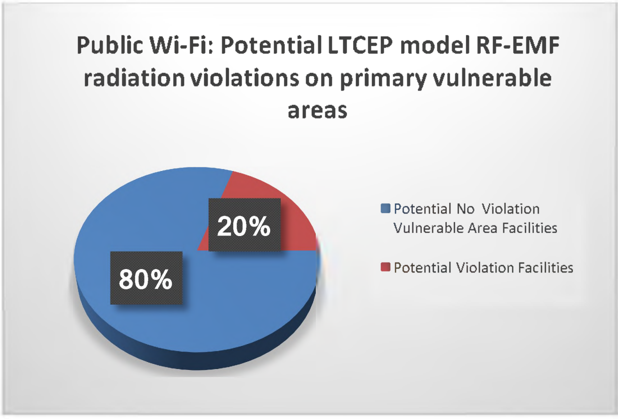


Figure 8.13 Summary: potential LTCEP model Public Wi-Fi RF-EMF radiation violations on primary vulnerable areas

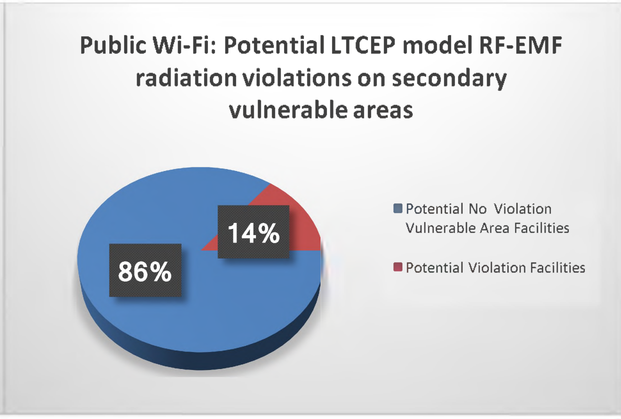


Figure 8.14 Summary: potential LTCEP model Public Wi-Fi RF-EMF radiation violations on secondary vulnerable areas

8.5.1 Youth and elderly facilities

A breakdown of the potential LTCEP model public Wi-Fi RF-EMF radiation violations for primarily vulnerable area facilities, designated primarily for the youth and elderly is shown in Figure 8.15.

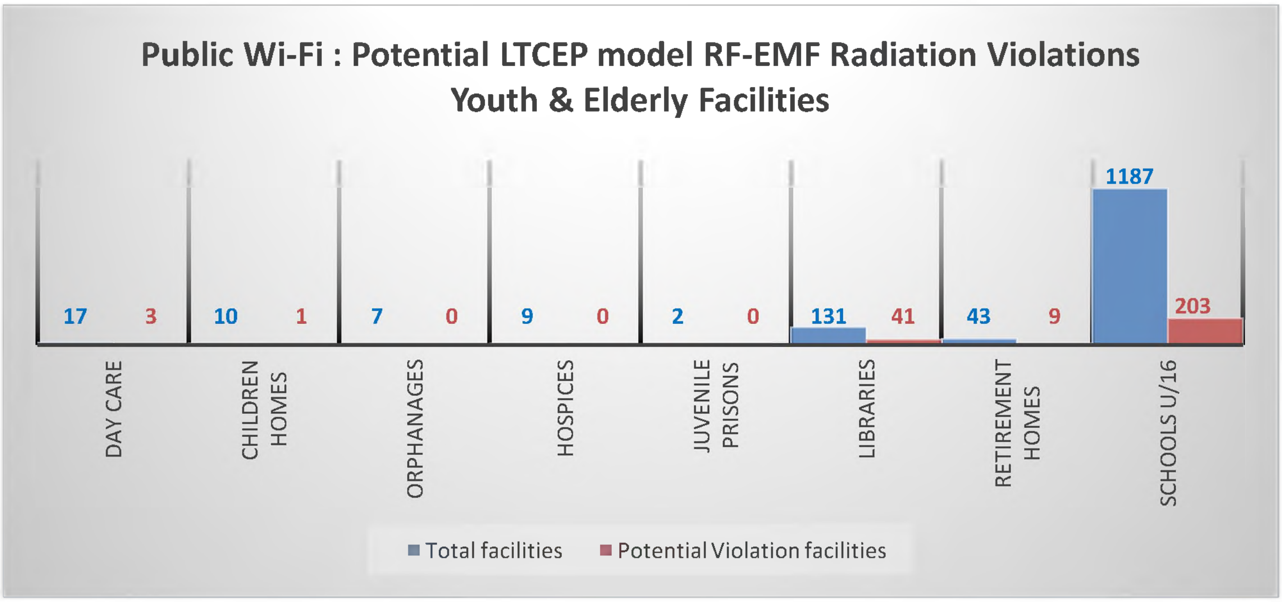


Figure 8.15 Potential LTCEP model violations of public Wi-Fi RF-EMF radiation on vulnerable areas: youth and elderly related facilities

8.5.2 Healthcare facilities

A breakdown of the potential LTCEP model public Wi-Fi RF-EMF radiation violations for primarily vulnerable area facilities, designated for healthcare is shown in Figure 8.16.

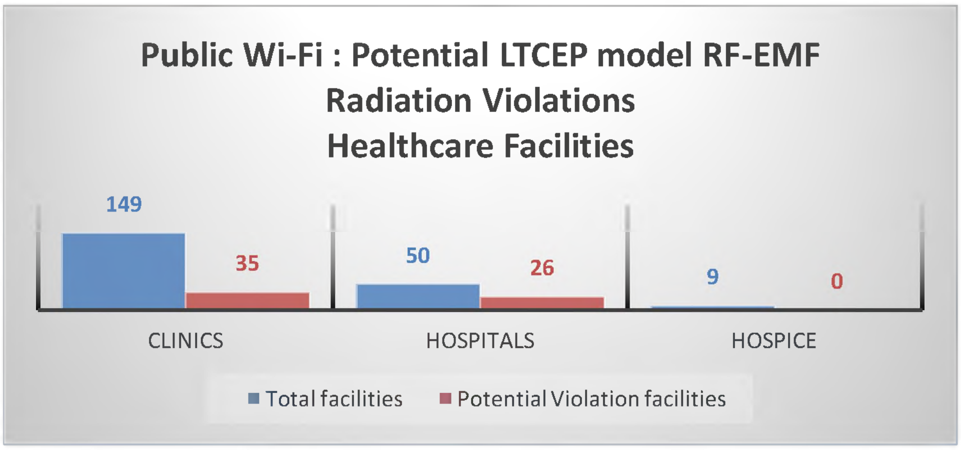


Figure 8.16 Potential LTCEP model violations of public Wi-Fi RF-EMF radiation on vulnerable areas: healthcare related facilities

8.5.3 Secondary vulnerable area facilities

A breakdown of the potential LTCEP model public Wi-Fi RF-EMF radiation violations on secondary vulnerable area facilities is shown in Figure 8.17.

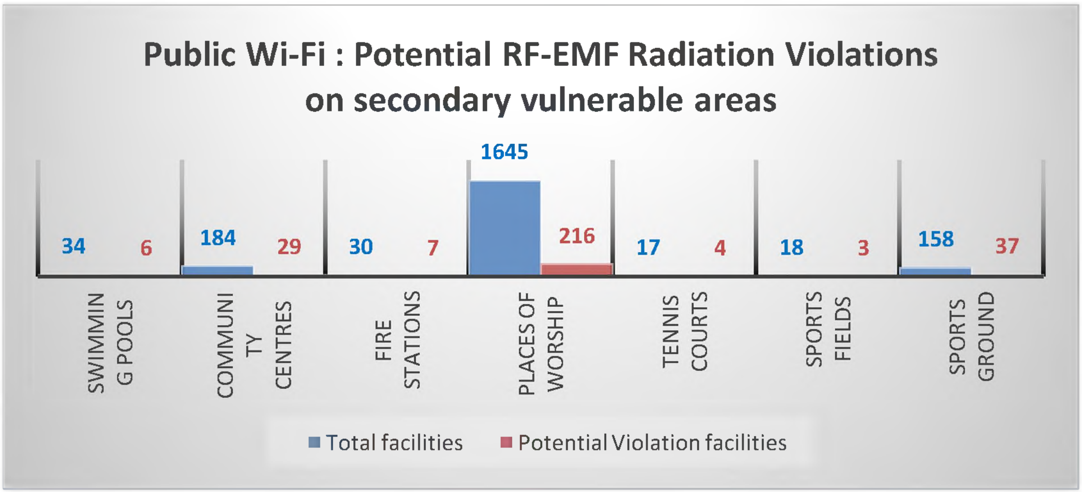


Figure 8.17 Potential LTCEP model violations of public Wi-Fi RF-EMF radiation guideline on secondary vulnerable areas

8.5.4 Public Wi-Fi RF-EMF radiation heat map

On the next page, the public Wi-Fi RF-EMF radiation heat map, generated in development for RQ_4 is shown in Figure 8.18. The GIS model was unable to generate field intensity values (V/m) due to the lack of an asset registry and technical information by public Wi-Fi data sources. The approximate buffers were used as potential high RF-EMF radiation exposure areas for potential future studies to accommodate the absence of calculating localized hotspots, re-radiation and micro EMF radiation exposure from personal devices.

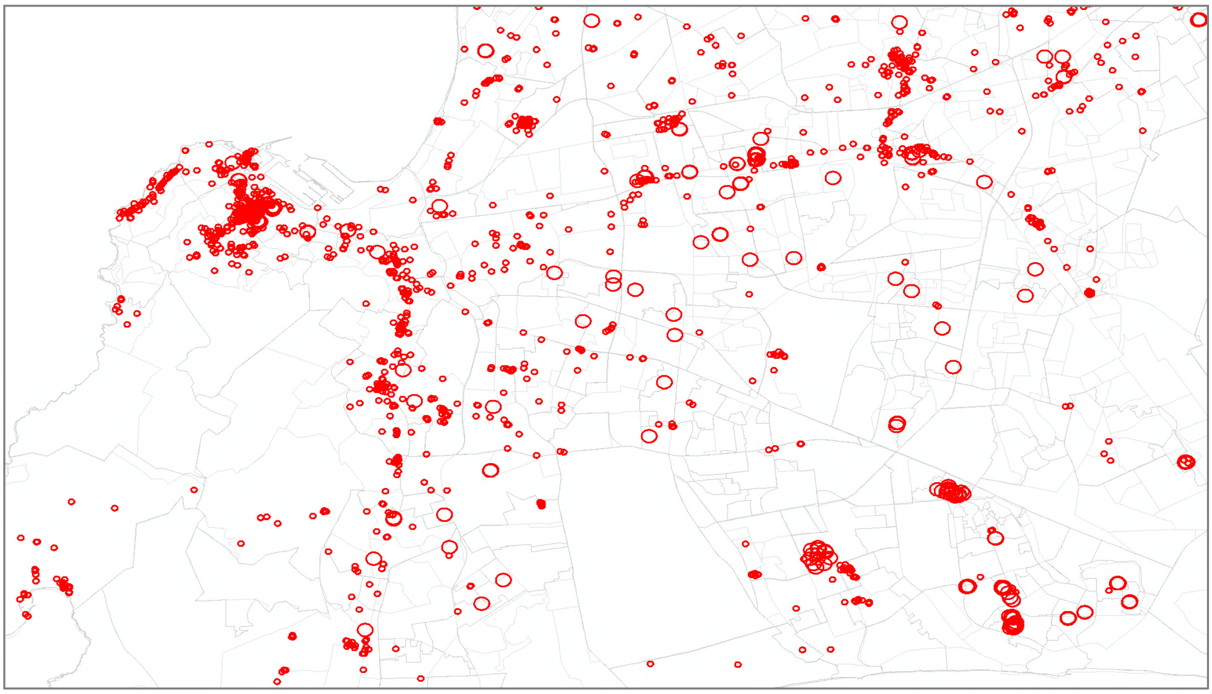


Figure 8.18 Partial public Wi-Fi RF-EMF radiation heat map buffer zones

8.5.5 Public transport: MyCiti bus network

PAIA applications with the EMFDS9 were successful in obtaining the detailed specifications and asset registry for the public Wi-Fi installations on the MyCiti bus network.

Ten (10) buses currently provide a free public Wi-Fi service as part of the CCPTM and EMFDS6 pilot project on three (3) major transport routes (CBD, Greenpoint / Seapoint and Tableview). According to the project summary document, the aim is to have the public Wi-Fi service rolled out to around three hundred and eighty (380) buses in the first year, as per the tender requirement, and the remainder of the fleet in the following two (2) years.

However, in EMFDS6's PAIA (2000) application process, Practitioner7 reported that the CCPTM MyCiti pilot project would likely not proceed due to the CCPTM not being willing to spend the money. However, Practitioner7 statement is contradicted by the CCPTM EMFDS6 project summary report.

There was no information from the CCPTM EMFDS6 project document to indicate whether the bus stops will also have public Wi-Fi access.

The MyCiti EMFDS6 installation sheet illustrated that the Wi-Fi router is installed near the rear of the bus. The three (3) router technologies listed are Ruckus ZoneFlex 3000, Moovbox 340 and Cisco Router IR829.

The RF-EMF radiation power ratings for the routers match those of outdoor public Wi-Fi capacity classification, with a 200-398 mW antennae and a gain of 2-4 dB between the three (3) router models listed.

The theoretical projections of potential RF-EMF radiation level values for field intensity (V/m) and power density (W/m^2) based on the calculations in the Appendix, Section 7.2 (Far-field power density evaluation) and Hondou et al., 2006 are shown in Table 8.1 on the next page. The values for inverse square law free space propagation without boundary conditions (non-real world, laboratory values) are in blue and the potential boundary propagation reflection conditions (real world) are in red.

Table 8.1 Theoretical RF-EMF radiation calculation potential projections on a 398 mW antennae with gain of 2dB for a single router installed

V/m	W/m^2	V/m	W/m^2	V/m	W/m^2	V/m	W/m^2	V/m	W/m^2
0.1 m		**0.5 m**		**1 m**		**4.6 m hotspots**		**Potential hotspots**	
43	5	8.7	0.2	4.35	0.05	43	5	86	20

The predicted simulated values in Table 8.1 concur with simulated and real world studies (Paffi et al., 2015; WHO, 2015b; WHO, 2016e). In the scenario of some Wi-Fi transmitting devices operating in close proximity to the body or by localized hotspots, local exposure can reach the same order of magnitude in accordance with potential hazard conditions as those in accordance with the STEP model reference levels (Gajšek et al., 2015; WHO, 2015b) .

No potential violations are encountered in free space propagation without boundary conditions (blue) by the STEP model reference levels. However, an enclosed space, like a bus, is susceptible to potential localized hotspots, re-radiation, spurious emissions and environmental noise due to reflection propagation. It could be argued that the STEP model reference level for RF-EMF radiation levels is exceeded at localized hotspots, because the STEP model reference level focuses on SAR (thermal heating effect on the body only). This study's assumptions are supported by another domestic study's simulation models that revealed that STEP model reference levels are not always showed compliant with the basic restrictions (Vermeeren et al., 2010).

Potential RF-EMF radiation guidelines and standards are in violation in terms of the LTCEP model limits. Additionally, the advertisement of a free public Wi-Fi allowance for daily data could be considered a violation of the ASA (2004, 2016) ruling because the public Wi-Fi is a non-essential service. Children under the age of sixteen (16) that use the MyCiti bus network are potentially exposed to prolonged cumulative periods of RF-EMF radiation exposure.

Point ten (10) of the CCPTM EMFDS6 proof of concept project summary document described the benefit of public Wi-Fi on the MyCiti bus as enabling commuters to have "access to the Internet for work, school or pleasure, resulting in a more productive, fun and/or relaxing commute". The calculated science-based RF-EMF radiation levels have the potential capacity to contradict the described benefits by the telecommunications operator EMFDS6 (WHO, 2016e) in terms of the LTCEP model and ASA (2004) ruling.

8.6 Cellular: potential violation of STEP and LTCEP RF-EMF radiation results

Unfortunately, the researcher was unable to obtain the detailed GPS coordinates and technical specifications for cellular ARD transmitters from the different data sources, despite submitting PAIA (2000) applications with warranted PIO criteria.

An agreement was signed with EMFDS15's legal department for the delivery of the GIS data vector files and technical specifications for the different sites. However, despite follow-up email requests and telephone calls, the data was never received.

The researcher was able to program approximate location of cellular ARD sites, based on site visits and partial address listings from willing data sources, into the GIS. The outcome of the PAIA (2000) applications to the telecommunications companies is discussed in the next chapter.

Despite the lack of detailed information from data sources for this public interest research, the researcher was still able to identify several potential EMF radiation violations in terms of both domestic bylaws, policies, and international policies.

The EMF radiation HYGEIA model identified patterns of spatial planning practices matching cultural and community threshold limits by means of the STEP and LTCEP models, as discussed in Chapter 4.

In the interest of public health and protection sites containing high potential for high exposure RF-EMF radiation levels were identified for future studies and for further investigation by the Regulator4.

8.6.1 Cellular ARD data limitations results

Five hundred and forty (540) unique addresses of cellular transmitters were identified from the combination of data sources. However, only four hundred and sixty-four (464) of the addresses could be matched to map addresses with the EMFDS9 GIS address dataset and/or GoogleMaps. The matched addresses were programmed as polygon points and used within the EMF radiation HYGEIA model.

The evaluation of EMF radiation STEP model reference levels and LTCEP model limits was challenging, because different STEP and LTCEP models have different RF-EMF radiation reference levels or limits per frequency.

For example: the STEP model ICNRIP 1998 GSM900 reference level is a power flux density of 4.5 W/m^2 but the reference level is 9.2 W/m^2 for GSM1800. Additional complexity restrictions between countries include geospatial proximity restrictions to vulnerable areas and duration (temporal) of RF-EMR radiation exposure levels.

The denied access to technical data from data sources resulted in the researcher using simulated a generic RF-EMF radiation geospatial propagation model for GSM1800 in terms of the STEP model reference levels and the LTCEP model limits. The buffer zones were calculated on a 2D plane and not on a 3D propagation model.

8.6.2 Visual display of STEP and LTCEP model narrative

The EMF radiation HYGEIA model (created in Chapter 6) was successful in generating a visual display of the STEP model reference levels and the LTCEP model limits in fulfilment of RQ_4. Displaying all the visual STEP and LTCEP model layers in print would reveal a jumbled mess at certain zoom levels. It is therefore recommended that the STEP and LTCEP models' heat map results are either demonstrated live during a presentation, or packaged into an online platform, allowing the viewer access to interactive and perspective viewing methods and tools.

Korte (2001) demonstrated that the visual GIS capabilities are extremely useful because they utilize the human visual system that can recognize complex patterns from a visual display.

Graphics output not only provides visual assistance to explore hidden information in patterns and to recognize potentially problematic areas but, it also enhances work quality, particularly in the investigation of crucial sites (Korte, 2001).

8.6.3 Potential RF-EMF radiation violations per the STEP and LTCEP models

The EMF radiation HYGEIA model performed simulation demonstration runs for the STEP model reference levels and LTCEP model limits on the investigated area, namely the City of Cape Town municipality. The model was tested by using a GIS to construct a geospatial EMF radiation propagation model, as discussed in the Appendix, Section 7.2 (Far-field power density evaluation). The geospatial propagation model was coupled with the STEP and LTCEP models' guidelines table as set out in Section 2.1 of the Appendix.

SQL queries were used to identify the potential framework EMF radiation policy violations in the GIS. The results revealed that the lower the EMF radiation policy values risk tolerance threshold limit, the greater the number of identified potential RF-EMF radiation violations.

Details of the STEP and LTCEP models' geospatial propagation model table and potential violation charts per EMF radiation guideline policy is available in the Appendix in Sections 8.1 and 8.2.

8.6.4 Cellular RF-EMF radiation heat map

On the next page, the cellular RF-EMF radiation partial propagation heat maps for potential high exposure field intensity values 1, 3 and 6 V/m in development of public interest research question four (4) are shown in Figure 8.19 and Figure 8.20. Areas in yellow have a potential field intensity value of 1 – 3 V/m, in orange 3-6 V/m and areas in red have a potential field intensity value of greater than 6 V/m.

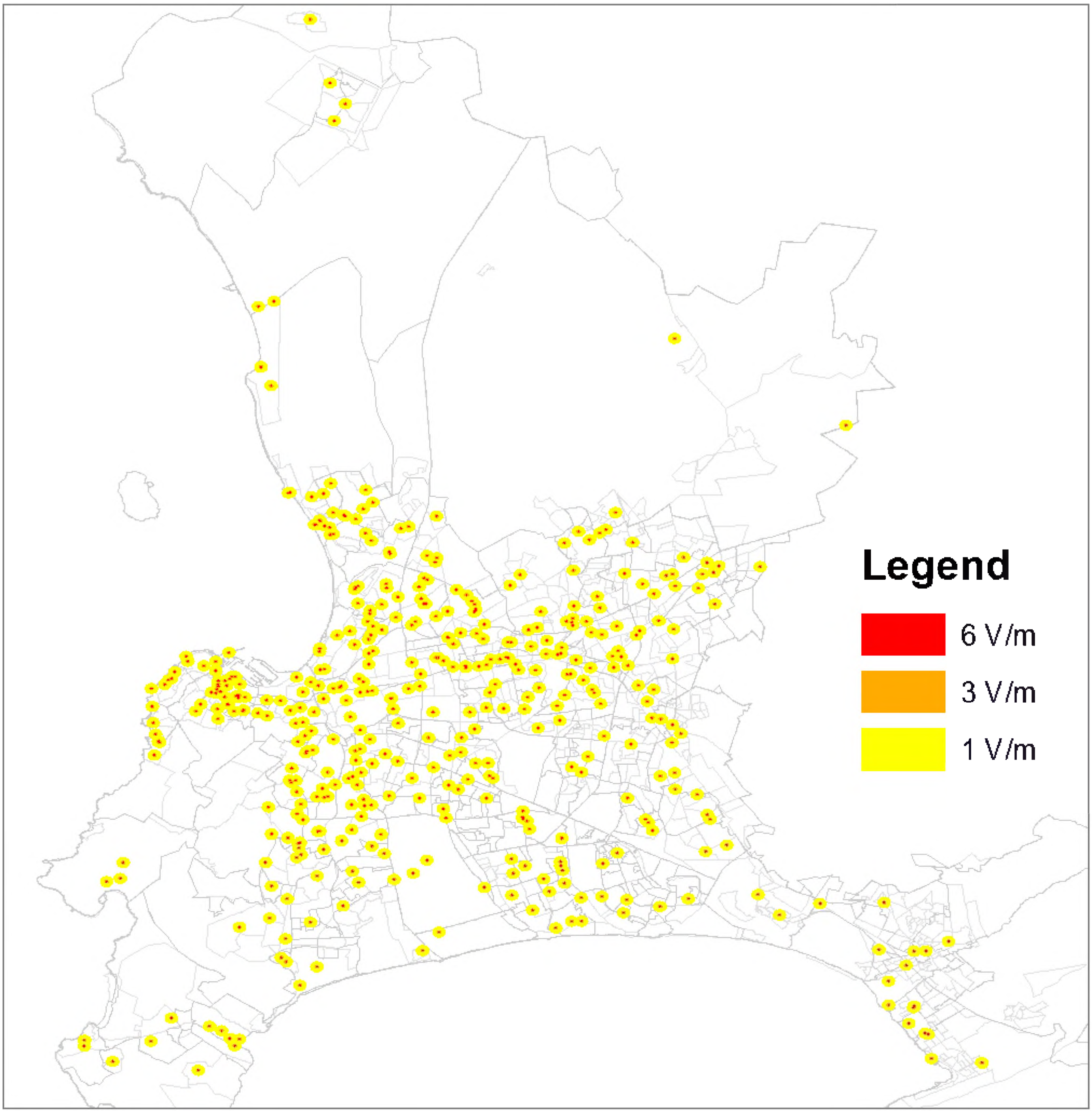


Figure 8.19 High level overview of cellular RF-EMF radiation heat map

Figure 8.20 Close-up overview of cellular RF-EMF radiation heat map

8.6.5 EMFDS9 City permits: cellular transmitter site findings

As discussed in the previous chapter, the city permits feature class was constructed from data received from the EMFDS9 by a PAIA application (EMFDS9, 2016). The excel file from EMFDS9 contained approved land use permits for the erection of cellular transmitter structures. There were a few limitations to the data, namely:

(1) The online CCPTM permit portal system, called DAMS, was only established in 2014. Approved cellular permits received were limited to the period of 27 August 2015 – 7 June 2016. Permits before this period were not accessible;

(2) CCPTM permit regulators that review applications do not review the cellular transmitter specifications installed and the site survey inspectors are not trained to review cellular technical specifications; only to review the mechanical engineering installation parameters, i.e., the height of the physical structure (Regulator2, 2016). For example: in the permit application of CCPTM Planning and Building Development

Management [PBDM] (2016a), the engineering diagrams illustrated an omnidirectional cellular transmitter to be installed but a downward tilt directional RF-EMF radiation transmitter was installed on the site instead. No RF-EMF radiation power or frequency configuration was supplied. Furthermore, the external base station structure in the illustration differs from what has been installed. CCPTM 2015 requires the structure to be enclosed and inaccessible to the public; however, the base station structure configuration that has been installed, is accessible to the public;

(3) Some property ERF sites already have a cellular ARD permissible classification heading and do not require a cellular ARD permit;

(4) Where a permit is granted, it does not restrict the number of transmitters installed in terms of type, configuration or number of operators. For example: Regulator5 (2016) stated that a lease agreement and permit were provided for an installation for a single operator on public land, based on the submitted plans. As time progressed, co-locating of additional ARD transmitters formed on the site resulted in more ARD transmitters installed and, subsequently, in higher RF-EMF radiation exposure levels. No application or review is required on either the ARD transmitter configuration, or the RF-EMF radiation levels (Regulator5, 2016), under current CCPTM (2015) policy. The EMF radiation HYGEIA model's risk hazard conditions for such an instance would be altered. The increase in the number of ARD transmitters and operators, without a regulated total accumulation RF-EMF radiation limit, can greatly inflame the RF-EMF radiation exposure levels (Mann et al., 2000; Kumar, 2010);

(5) ARD transmitters are still installed, even without permits completed or granted (CCPTM PBDM, 2016a; Regulator2, 2016; Regulator10, 2016; Regulator7, 2016);

(6) Cellular ARD transmitter GPS coordinates were not provided and only the ERF address description was disclosed. Not all the sites were found against the EMFDS9 ERF property address feature class.

In line with the CCPTM (2015) policy being open to EMF radiation public health evolution, Regulator2 (2016) confirmed that, if they received science-based literature findings on the LTCEP model and if members of the public registered complaints regarding the RF-EMF radiation ARD transmitter, the permit would be investigated and may be revoked by the CCPTM.

8.6.5.1 City permits: places of worship findings

As established in the literature review in Chapter 4, Mazar (2009) identified a correlation between EMF radiation tolerance of risk and religious values, for example: Protestant values (in which the world and God are explained by the 'book') and Catholic values (where God can be explained by many sources i.e. saints and books).

Review of the permit applications within the feature class revealed a pattern supporting Mazar's (2009) findings. Of 127 permit applications granted, 13 were for Protestant values places of worship and none for Catholic values. A review of EMRSA (2016) revealed that the Corpus Christi Catholic Church has rejected the request to erect a cellular ARD transmitter.

8.6.6 EMFDS8 property management leasing: cellular transmitter site findings

In line with the CCPTM (2015) policy being open to evolution, Regulator5 (2016) confirmed that, if they received science-based literature findings on the LTCEP model and if a *single* member of the public registered a supportive complaint to the RF-EMF radiation from a cellular ARD transmitter, the lease agreement would be investigated and may subsequently be rejected or terminated. Regulator5 (2016) rationale is in line with NEMA (1998) Section 2(4)(a)(ii) measures (Dämvik & Johansson, 2010).

Regulator5 (2016) reported being in the process of decommissioning lease agreements for cellular transmitters on fire stations, following complaints from the fire station personnel feeling uncomfortable with RF-EMF radiation exposure hazard conditions from the ARD transmitters on their training facilities.

The CCPTM fire stations' personal concerns are warranted by a 2004 resolution made by the International Association of Fire Fighters (IAFF) (2004:1). The IAFF is the largest union of first responders in the STEP model endorsing countries of North America.

An RF-EMF radiation dose-relationship was established to the reported symptoms of slowed reaction time, lack of focus, lack of impulse control, severe headaches, anesthesia-like sleep, sleep deprivation, depression, and tremor by following an LTCEP model hazard conditions assessment and an IAFF (2004) pilot medical study on the fire station personnel.

The IAFF (2004) identified the decrease in cognitive performance as a liability and as a threat to their members' well-being while trying to carry out their duties (Kolodynski & Kolodynska, 1996; Milham, 2009; Fragopoulou et al., 2012; Belyaev et al., 2016).

A feature class of the EMFDS8 (2012) property lease agreements revealed four (4) fire stations having cellular transmitters installed on their property. A review of the data from the EMFDS9 PAIA application for the EMFDS8 (2016) property lease agreements revealed that there had been no decommissioning of cellular ARD transmitters at CCPTM fire stations, however. Some of the land lease agreement applications were reviewed in consultation with Regulator5 (2016), as a result of which a pattern of installers purposefully misleading informed public safety, emerged.

One application, for example, depicted the structure of a cellular ARD transmitter, but only a single microwave line-of-sight transmitter was revealed. In addition thereto, no technical specifications were provided and only a copy of the CCPTM (2015) fifty (50) meters restriction colourful overlay was added in an attempt to project assurance that safety measures were planned for. The researcher's investigated findings did not correlate with what was presented. The lease application site installation plan did disclose that the site may install cellular ARD transmitters in future.

If the site permit and lease agreement were approved in accordance with CCPTM (2015) policy, and bylaws, and in consultation with Regulator5 (2016), the installer would not have been restricted in respect of either the number of cellular ARD transmitters installed, or on their frequency, EMF radiation power exposure levels or boresight reference angle. That would have resulted in potential STEP and LTCEP models' hazard conditions. For example: RF-EMF radiation power output can be three to four times greater than advertised by a single operator, see Appendix, Section 4.10 (Far-field density evaluation calculation for cellular RF-EMF radiation exposures).

Regulator5 (2016) confirmed not having the expertise in reviewing RF-EMF radiation applications regarding technicality or safety. It is unknown whether the lease agreement applications reviewed by the researcher were successful or not.

Review of the EMFDS8 cellular lease agreements (PMCLA) revealed:

(1) The approved lease agreements to cellular operators on public land;
(2) A lease rental period;
(3) A monthly rental of eight thousand five hundred rand (R8, 500.00) per month, excluding VAT; and
(4) A rental escalation of eight percent (8%) per annum.

Eighty-six (86) lease agreements were found in the EMFDS9 PMCLA summary document. Based on the EMFDS9 PMCLA list, the projected income of the city, resulting from the cellular agreements, is seven hundred and thirty-one thousand rand (R731, 000.00) per month (excluding VAT) for the base year.

A potential future study with a second iteration of the EMF radiation HYGEIA model could simulate the social accounting cost to the city under present hazard conditions. For example: it should be determined whether the EMFDS9 PMCLA total rental income (R8, 772,000.00 p.a. ex. VAT) out-weighs the potential public health costs, associated with the RF-EMF radiation infrastructures based on current CCPTM EMF radiation spatial planning practices and simulated hazard conditions, to the CCPTM.

EMF radiation related regulatory bodies in SA reported financial resource constraints to the employment of EMF radiation monitoring (Regulator8, 2016b; Regulator4, 2016). Contrary to international practices, funds in SA are not extracted from industry or government bodies for EMF radiation monitoring or enforcement (Government of India, 2012). The finding of potentially available funding for EMF radiation regulation in SA is an additional warrant to support the fulfilment of RQ_5, as evaluated in the next chapter.

The EMFDS9 PMCLA document revealed additional data sources that were not considered in the EMFDS PAIA applications. Potential future studies should include the additional data sources identified.

8.6.6.1 EMFDS8 (2012) property cellular lease agreements data findings

The PAIA EMFDS8 (2012) property cellular lease agreements excel spreadsheet contained seventy-three (73) lease agreement's unique addresses. Of those, only thirty-seven (37) were identifiable in the CCPTM land parcel data set supplied by the EMFDS9 GIS data source. Only approximately half of the potential sites were therefore programmable into the EMF radiation HYGEIA Model.

A limitation was encountered in plotting the cellular ARD features into the GIS due to the lack of GPS coordinates provided. The researcher relied on examining aerial photographs for the land parcels. In instances where the land parcel coverage was too extensive to examine and/or where the aerial photograph was taken before the cellular ARD was erected, the best approximate location for the ARD transmitter was selected. Additionally, some property ERF land parcels would have cellular ARD transmitters in more than one location. The above limitations would affect the extent to which the generated RF-EMF radiation buffer zone would intersect with vulnerable area facilities, thereby further affecting the forecast of the EMF radiation HYGEIA model.

8.6.6.2 EMFDS8 (2016) property cellular lease agreements findings

The EMF radiation HYGEIA model processed a temporal analysis by analyzing the EMFDS8 (2016) property lease agreements. A pattern similar to the EMFDS8 (2012) property cellular lease agreements occurred, in that many addresses supplied by the EMFDS8 PAIA application results did not match the EMFDS9 land parcel dataset.

The researcher did question whether export of the data vector land parcel polygons from EMFDS8 was possible, but it seemed that EMFDS8 does not use the EMFDS9 GIS system and that those lease agreements are handled by a manual process of data capturing into an excel spreadsheet.

8.6.7 Potential CCPTM (2015) policy violation findings

As discussed in Chapter 2, the CCPTM policy endorses an EMF radiation exposure STEP model. The literature review identified that very limited and selective elements of the STEP model are encompassed within the policy. Despite these limitations the study was able to identify a number of potential violations that go unregulated and, as a result, EMF radiation exposure to the public goes unchecked. This section discusses those findings.

The primary RF-EMF radiation safety criteria in the CCPTM (2015) policy prohibit habitable buildings within fifty (50) meter line-of-sight of a cellular ARD transmitter. The GIS was unable to examine 3D model cellular ARD transmitter sites, due to the technical specifications of ARD transmitters being unavailable and/or due to the data sources being unwilling to provide the said specifications.

A total of tweleve (12) separate potential violation sites were identified as being within the fifty (50) meter line-of-sight of a habitable building by the visually identified site visit feature class generated by the researcher. As discussed in Section 2.10, a recent Supreme Court ruling in India is deliberating civil damages to a man who claimed that cancer resulted from his place of employment being within the 50 meters of the transmitter (Government of India, 2017; Mahapatral, 2017). In the mean-time an interim order removed the illegal transmitter. The Indian Supreme Court deliberation on science-based evidence may thus present implications to the identified potential bylaw violations.

The CCPTM's failure to obtain technical specifications on cellular ARD transmitters sites, as required by the CCPTM (2015) policy, is a second instance category of violations. When the GPS coordinates are provided in permit applications, they are also not captured into the CCPTM database by the CCPTM.

For example: only the GPS coordinates of the cellular ARD transmitter in the permit application public participation site plan were provided in CCPTM PMDM (2014, 2016a, 2016b. When submitting PAIA applications to the different CCPTM departments, it was alleged that the CCPTM does not possess the information, because the telecommunications providers are unwilling to provide the requested data. The researcher found the following conflicts within the CCPTM's statement:

(1) Regulator9 (2015) confirmed having the GPS co-ordinates in their database but denied that they had the technical specifications as required by the Telecommunications Act (2000). In reviewing the PAIA application results from EMFDS4, Regulator9 (2015) and CCPTM PMDM (2016), there is a variety of telecommunications companies providing some location information on their sites, but no technical information is provided; and
(2) The CCPTM receives GPS location information in applications to them but they do not follow prescribed administrative procedures and, therefore, potentially violate the CCPTM (2015) policy themselves by not capturing the partially received data. Administrative negligence resulting from Point (2) would account for the data limitations experienced in the above Section 8.6.6 (EMFDS8 property management leasing: cellular transmitter site findings).

8.6.8 Potential NMBM (2011) policy violation findings

The GIS model revealed thirty-eight (38) potential RF-EMF radiation violations of cellular ARD transmitters within the 'SchoolsU/16' buffer feature class in terms of the SA NMBM (2012) policy, as discussed in Chapter 2. Three hundred and twenty-three (323) potential EMF radiation violations were identified concerning identified cellular ARD transmitters within 300 meters of the 'SchoolsU/16' buffer feature class.

8.6.9 Potential KM (2012) policy violation findings

The GIS model revealed one thousand, one hundred and eighty (1180) potential RF-EMF radiation violations in terms of the SA KM (2012) policy, as discussed in Chapter 2.

8.6.10 Illegal RF-EMF cellular ARD site findings

The first and highest ranking evaluation variable in demonstrating a PIO, is the substantial contravention of the law, as discussed in Chapter 3. This section discusses the findings of three (3) separate categories of contravention, namely: (1) the illegal erection of RF-EMF radiation transmitters; (2) the CCPTM not complying with PAJA (2000) in enforcing the Telecommunications Act (2000) site technical requirements; (3) industry biased favouritism over public interest. These categories are discussed as follows:

(1) **Illegal sites**: CCPTM PMDM (2014, 2016a), Regulator4 (2016), Regulator7 (2016) and Regulator10 (2016) all reported the illegal erection of cellular RF-EMF radiation transmitters as being a problem to the CCPTM. The CCPTM is unable to address this problem, because they lack the required tracking RF-EMF radiation spectrum analyser equipment and the training essential to the detecting and tracing of illegal ARD transmitter sites (Regulator4, 2016; Regulator2, 2016).

(2) **CCPTM not complying with PAJA (2000)**: The telecommunication companies are unwilling to provide the spatial information of ARD sites to the CCPTM for their IS and GIS. The researcher established that the CCPTM has been aware of illegal ARD transmitter erections, but that no action has taken by them (CCPTM PMDM, 2016a; May, 2016).

(3) **Industry biased favouritism over PIO**: The permit application CCPTM PBDM (2016a) for a cellular ARD transmitter site submitted to the CCPTM, is an example tied into the previous point. In this case the cellular ARD transmitter had been installed before the public participation process date had been reached. The public participation reached a quorum of over sixty percent (60%) of participants rejecting the permit application. The Regulator2 (2016) confirmed that the permit had not been finalized and therefore there was thus no authorisation for the operation of the cellular ARD site. CCPTM officials reported that this is not an isolated incident, but that is a common occurrence that sites are erected despite public participation reaching a rejection quorum of over sixty percent (60%) and that the cellular ARD site is erected and operational before a CCPTM permit is approved (May, 2016). To date, the illegal site is still operational as a EMFDS4 cellular ARD transmitter (May, 2016). This was confirmed by the researcher during a site visit. The illegal site was not listed on the

EMFDS4 PAIA (2000) response application of listed cellular ARD site street addresses in CPT.

(4) Additionally identified separate potential violations include the Regulator4 not recommending that a permit be issued for other cellular ARD sites, but that the erection of the cellular ARD transmitters took place, regardless. Access to these reports was not granted at the conclusion of the EMFDS9 PAIA applications, but could be requested for further investigation in potential future studies.

As discussed in Section 2.10, when the precautionary principle is legislatively invoked, weight is given to the complainant if the operator is unable to provide proof in complying with all aspects of the law (SCIO, 2017).

The next section discusses the temporal data findings and analysis from the EMF radiation HYGEIA model demonstration run.

8.7 Historical RF-EMF radiation measurements

As discussed in the previous chapter, the refusal by cellular RF-EMF telecommunications to provide site technical specification data, both for this academic public interest research and to regulators, is a limitation to this study. As discussed in Chapters 2 and 7, industries reported that it would be detrimental to their strategic economic interests to supply the data, in opposition to the argument of PIO. The encountered study limitation was partially overcome through the acquirement of historical RF-EMF radiation measurements from the EMFDS16. OpenCellID was also divided into feature classes for the EMF radiation HYGEIA model. The findings and results for EMFDS16 and OpenCellID are discussed in the sub-sections below.

8.7.1 EMFDS16 findings

The twenty-two (22) EMFDS16 historical EMF radiation measurement reports were received and reviewed. One (1) was not a report but, in fact, EMFDS16 requirements on a proposed cellular site installation and another was a duplicate of an existing report.

Unfortunately, the RF-EMF radiation measurements from the EMFDS16 reports are not useable in the EMF radiation HYGEIA model for the following reasons:

(1) Section 7.8.3 (Site visit EMF radiation field measurements surveying technique) elaborated on the different manners in which the data readings could be corrupted or misleading;

(2) No details were provided regarding the make, model and accessories of the EMF radiation spectrum analyzer;

(3) No details on the GPS co-ordinates of the measurement points, or of the cellular ARD transmitters under investigation, were provided;

(4) No technical specifications for the cellular ARD transmitters within proximity of the investigation area were provided;

(5) No information whether the EMF radiation spectrum analyzer factor correction was applied to the measurements was provided and consultation with the Regulator4 confirmed factor correction was not applied;

(6) No details on a measurement methodology were provided;

(7) No details on the time duration of measurement for each point were provided;

(8) No measurements on the field intensity (V/m) and peak values were provided;

(9) No information was provided as to which ICNIRP guideline is referenced (i.e. ICNIRP 1998) regarding the measurements reference EMF radiation safety levels to the STEP model;

(10) RF-EMF radiation power density measurements were taken at the time of day that power densities are likely to be at their lowest. Assessing EMF radiation exposure at variable times is critical, because the degree of EMF radiation exposure may vary at different times (Mann et al., 2000; Belyaev et al., 2016). For example: measuring solar EMF radiation power density for a solar panel would derive the highest values during the noon period and the lowest at dawn, dusk and midnight. The power density measurements taken by the EMFDS16 is equivalent to dawn and dusk for solar EMF radiation where the least possible cellular ARD transmitter activity is to be present in the time periods recorded in the EMFDS16 reports; and

(11) The EMFDS16 reports stated that RF-EMF radiation measurements were within the WHO standards. The WHO, however, does not have an EMF radiation standard, but a body of the WHO economic forum recommends the STEP model ICNIRP guidelines. WHO (2006a) does have a framework for developing health-based EMF standards. The interchange of guidelines and standards may seem trivial, but have different legal bindings, as addressed in Section 2.5 (Guidelines versus standards). Some of the EMFDS16 reports did provide the street addresses of the cellular ARD transmitter under investigation, but not the GPS co-ordinates.

The investigation areas' street addresses, contained within the reports, could be used in potential future studies for further examination and for conducting full spectrum EMF radiation measurements following standardized STEP and LTCEP models' methodology and protocol.

The EMFDS16 reports referenced street addresses were developed into a feature class to identify a spatial correlation with identified potential high EMF radiation exposure areas. Due to telecommunication companies not providing spatial coverage information for all sites, accurate model evaluations of the complaints were not possible.

However, an overlay intersection analysis, with the generated heat map layer for public interest research, questions four (4) out of sixteen (16) identified sites of interest for potential future studies; the four (4) sites modeling a potential high RF-EMF radiation exposure field intensity above 6 V/m.

These EMFDS16 measurement report sites did intersect with the EMF radiation HYGEIA model overlay feature sets that could partially be supported by the RF-EMF radiations in the EMFDS16 measurement reports.

One of the earliest EMFDS16 reports (in 2011) provided interesting findings. EMFDS16 identified relatively higher readings at 30 MHz compared to other readings. Part of the recommendations from EMFDS16 was for the complainant to consider the installation of physical RF-EMF radiation deflectors on the property. It is, however, in terms of NEMA (1998), based on the EMFDS16 report, the responsibility of the polluter source (telecommunication company) to adjust their transmitter or to cover the costs for the upgrades to the property, because an independent evaluation was provided by a statutory body.

The aforementioned comments are not intended to be derogative towards the EMFDS16, but are made merely to provide supportive substantiations to literature review findings and identified weaknesses in existing policies in terms of Regulator3 (2016) and Regulator1 (2016). By demonstrating a PIO, a judicial review process may potentially be enabled to mandate the formalization and allocation of resources towards EMF radiation protection measures in the interest of public health and social accounting, which would only benefit the EMFDS16.

8.7.2 OpenCellID findings

Historical archived data from OpenCellID was imported and generated as feature classes in the GIS. The two (2) measurement files provided by OpenCellID were processed into heat maps, as illustrated in Figure 8.21 and Figure 8.22 on the next page. Figure 8.21 comprised measurements from cellular measurements for the temporal period of 2014 only, with the recorded RF-EMF radiation network types of GSM and UTMS.

Figure 8.22 comprised measurements from the cell tower 'cell' for the temporal period 2012 - 2014, with the recorded RF-EMF radiation network types of GSM, UMTS and LTE. The legend for the heat maps are in dBm. Red would be the approximate equivalent to four (4) bars on your cellphone and blue the equivalent to one (1) bar.

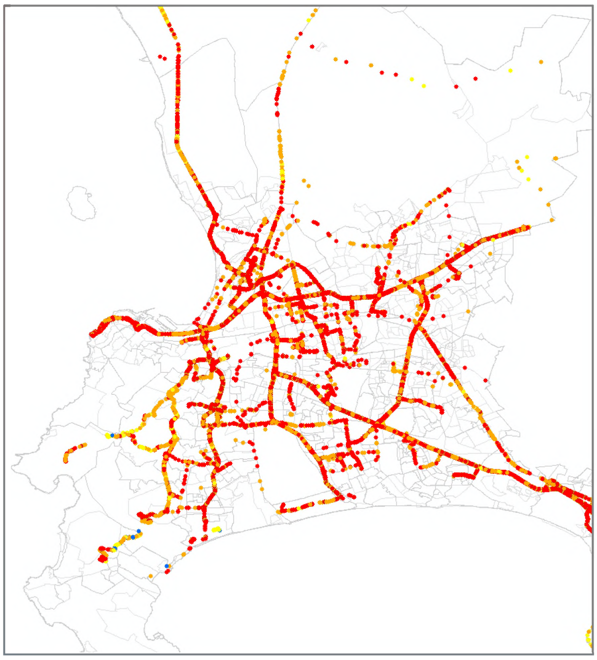


Figure 8.21 OpenCellID historical cellular measurements heatmap

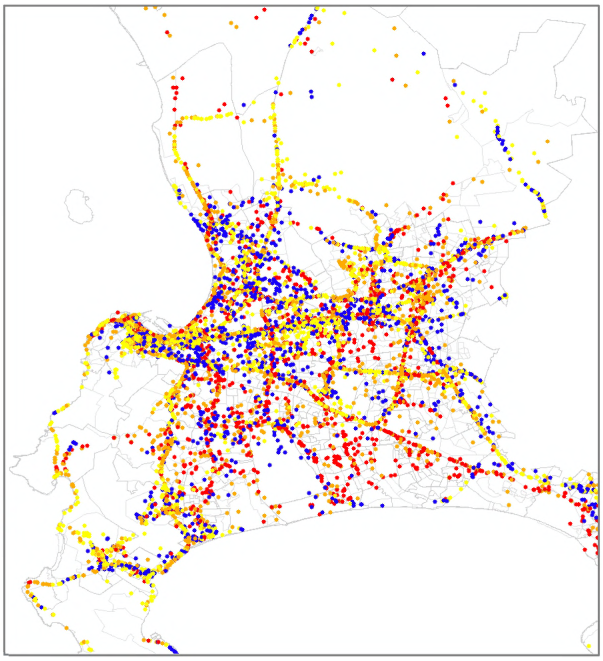


Figure 8.22 OpenCellID historical cell tower cell measurements heat map

LEGEND (dBm values)

- -126 - -100
- -99 - -84
- -83 - -67
- -66 - -51

8.7.2.1 OpenCellID Limitations

In the realm of cellular telecommunications infrastructure expansion growth a span of two years is vast, as demonstrated in the reviewed EMFDS9 permit applications. Overlaying the OpenCellID layers with the EMFDS9 permits layer revealed that several low reception (blue) areas are now occupied with cellular ARD transmitters post the OpenCellID recorded measurement dates. An updated OpenCellID measurement may therefore potentially reveal many blue (low cellular RF-EMF radiation exposure) and yellow points to be converted to red or orange.

Even though the recorded data may be dated, it still provides an approximation of areas that may potentially have high RF-EMF radiation exposure zones needed in the development of the heat map for RQ_4.

8.8 Site visit EMF radiation measurements

As discussed in the previous chapter, part of the research design is to add further credibility to the study. In such a credibility measure, the researcher attempted to follow STEP and LTCEP models' protocols in conducting site measurements for EMF radiation.

The first requirement was the attainment of a professional grade EMF radiation spectrum analyzer and accessories. A review of the literature (Chapter 4) and product reviews (Chapter 7) revealed the potentially favourable service product to be Aaronia (2016).

Aaronia (2016) was selected because the EMF radiation spectrum analyzer provides a GUI interface, as well as a wide array of functions and settings for dealing with noise frequency environments and a USB interface download with the spectrum analyzer software. The most important features were the upgrade modules for an extended data logging capacity and the built-in GPS unit. The combination of features potentially provides for the best and resource efficient post-data collection analysis environment, with the capacity of generating 3D time scale models that could be imported into the GIS and uploaded onto the public domain, i.e., Google Earth. The researcher obtained quotes from Aaronia (2016) and other competitive products, but the Aaronia (2016) was still viewed as the optimum choice for this specific public interest research.

Applications for equipment grants were investigated and submitted, but were, sadly, unsuccessful for the following reasons:

(1) Masters level research did not provide enough access to the needed funds;
(2) The depreciated ZAR to foreign currencies exchange rate and the associated import duties substantially increased the purchasing cost of the EMF radiation spectrum analyzer;
(3) The researcher did request assistance from his supervisors but they were unable to locate funding sources;

(4) The researcher was not an employee of a research institute or the university and did not have a principle investigator at the university willing to apply for funding on the student's behalf. The researcher believes that, in potential future studies at the PhD level, and/or in collaboration with other students, favourable opportunities to attain funding to further carry out this public interest research and to obtain the recommended EMF radiation spectrum analyzer, would be provided, by, for example, the Medical Research Council grant or National Research Foundation.

As a result of the unsuccessful attempts in acquiring an equipment research grant, the researcher sought out other avenues of access to an EMF radiation spectrum analyzer. The researcher managed to establish a co-operation agreement with Regulator4 (2016) to conduct site measurements with the department, in exchange for the researcher sharing his knowledge and teaching Regulator4 (2016) how to use their Aaronia EMF radiation spectrum analyzer, how to conduct site measurements per STEP and LTCEP models' protocols and how to explain the meaning of EMF radiation measurement values in relation to the STEP and LTCEP models.

Prior to the co-operation agreement, Regulator4 (2016) sent their Aaronia EMF radiation spectrum analyzer to the manufacturer for re-calibration. Months later, the Regulator4 still does not have the unit back in their possession, despite several follow-ups by the researcher. Unfortunately, the researcher was therefore unable to conduct site measurements by the time this study was submitted for examination. The researcher shall, however, continue to await further communication from the Regulator4 and, upon confirmation of the availability of the unit, the researcher shall aim to maintain the co-operation agreement in conducting site measurements and the collection of data for potential future studies.The success of the study did not hinge on the attainment of EMF radiation site measurements, but the latter would have aided in supporting the EMF radiation HYGEIA model; would have enriched the demonstration runs and potentially could have led to the attainment of ARD transmitter technical specifications from telecommunication service providers at investigated sites, upon the request of the Regulator4.

It is unknown whether conducting EMF radiation site measurements with the Regulator4 would have been successful because Regulator4 (2016) reported that, historically, in contravention with the CCPTM (2015) policy, telecommunication providers would not provide Regulator4 with the requested technical site data required to carry out accurate EMF radiation site modeling and measurements.

The successful fulfilment of RQ_5 may contribute to the Regulator4 in attaining ARD site specifications under the demonstrated PAIA (200) PIO function, as discussed in the next chapter. Additionally, the demonstrated PAIA (2000) PIO may leverage access to an equipment research grant for potential future studies.

8.9 Potential high exposure EMF radiation heat map

The previous sections detailed the iterative process of the EMF radiation HYGEIA model outputting an EMF radiation exposure heat map for each demonstration run. This section discusses the findings of the above sections' generated heat maps overlaid, intersected and coupled in identifying potential hazard conditions. The identified potential hazard condition area may be of interest for potential future studies and for investigation by interested regulatory practitioners consulted in this study. RQ_5 sought to develop an EMF radiation heat map and on-site measurements of EMF radiation identified as potential STEP and LTCEP models' EMF radiation violations.

Feature classes for the EMF radiation HYGEIA model were developed based on the information from data sources and on modeling potential EMF radiation projections. Additionally, historical archive measurements from data sources were also programmed into the EMF radiation HYGEIA model. A partial EMF radiation heat map was developed from the GIS feature classes, identifying potential high exposure zones, based on the scope defined in the literature review. EMF radiation exposure zones of potential EMF radiation field intensity readings for the following are shown in Figure 8.23 to Figure 8.25 on the next few pages:

(1) Cellular and radio broadcast transmitters of 1-3 V/m (Figure 8.23), 3-6 V/m (Figure 8.24) and greater than 6 V/m (Figure 8.25);
(2) The ELF EMF radiation layer displays a buffer zone with potential values above 2 mG; and
(3) The public Wi-Fi also remains a constant buffer because the exact position and configuration of the public Wi-Fi ARD router was not provided by data sources. Therefore, potential high EMF radiation exposure hot spots could occur within buffer zones of the public Wi-Fi feature class.

The intersecting overlay of the historical RF-EMF radiation field measurements from OpenCellID (2016) in Figure 8.23 to Figure 8.25, is shown in Figure 8.26.

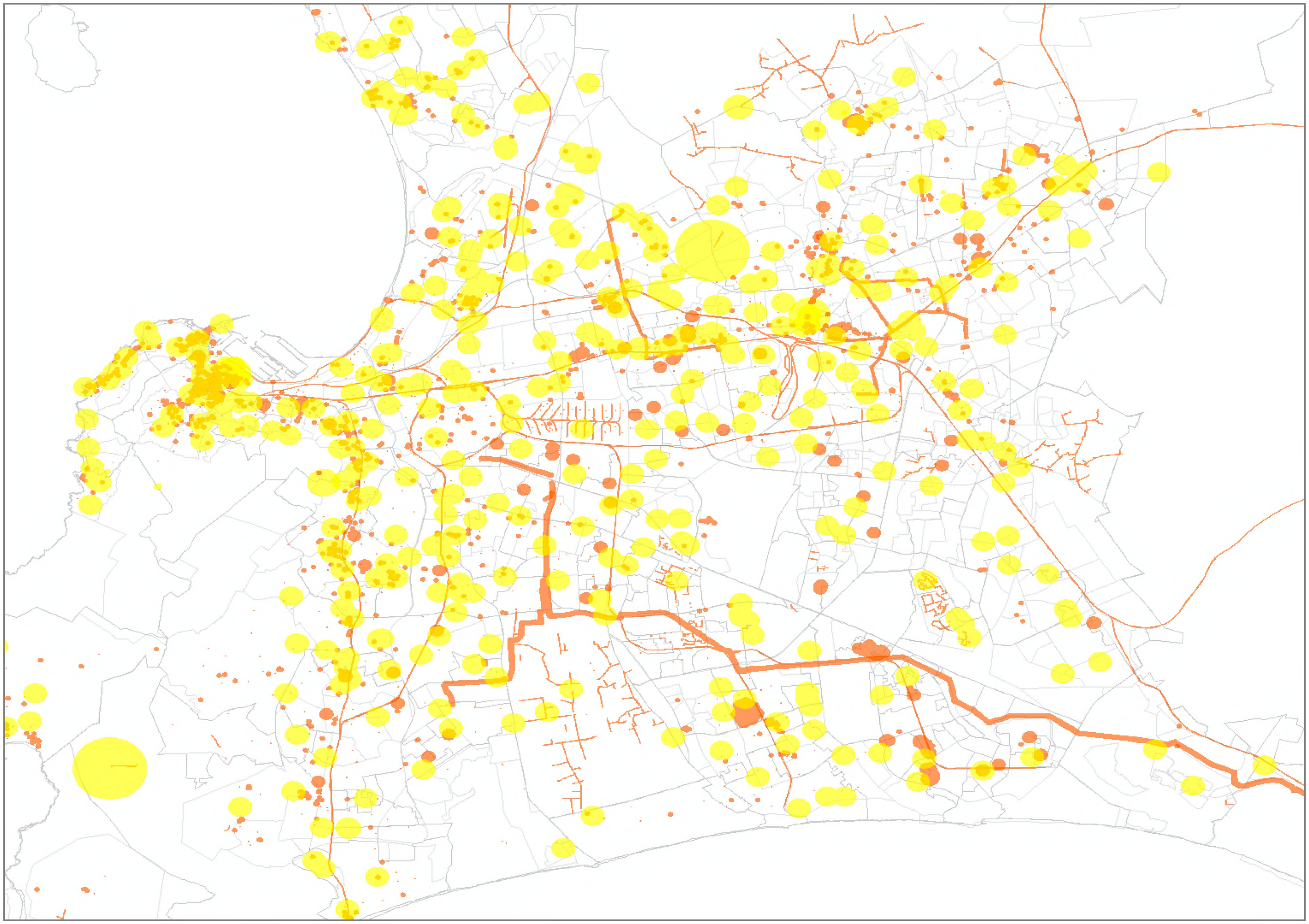


Figure 8.23 Partial EMF radiation heat map of potential ELF above 2 mG, RF at 1-3 V/m and public Wi-Fi

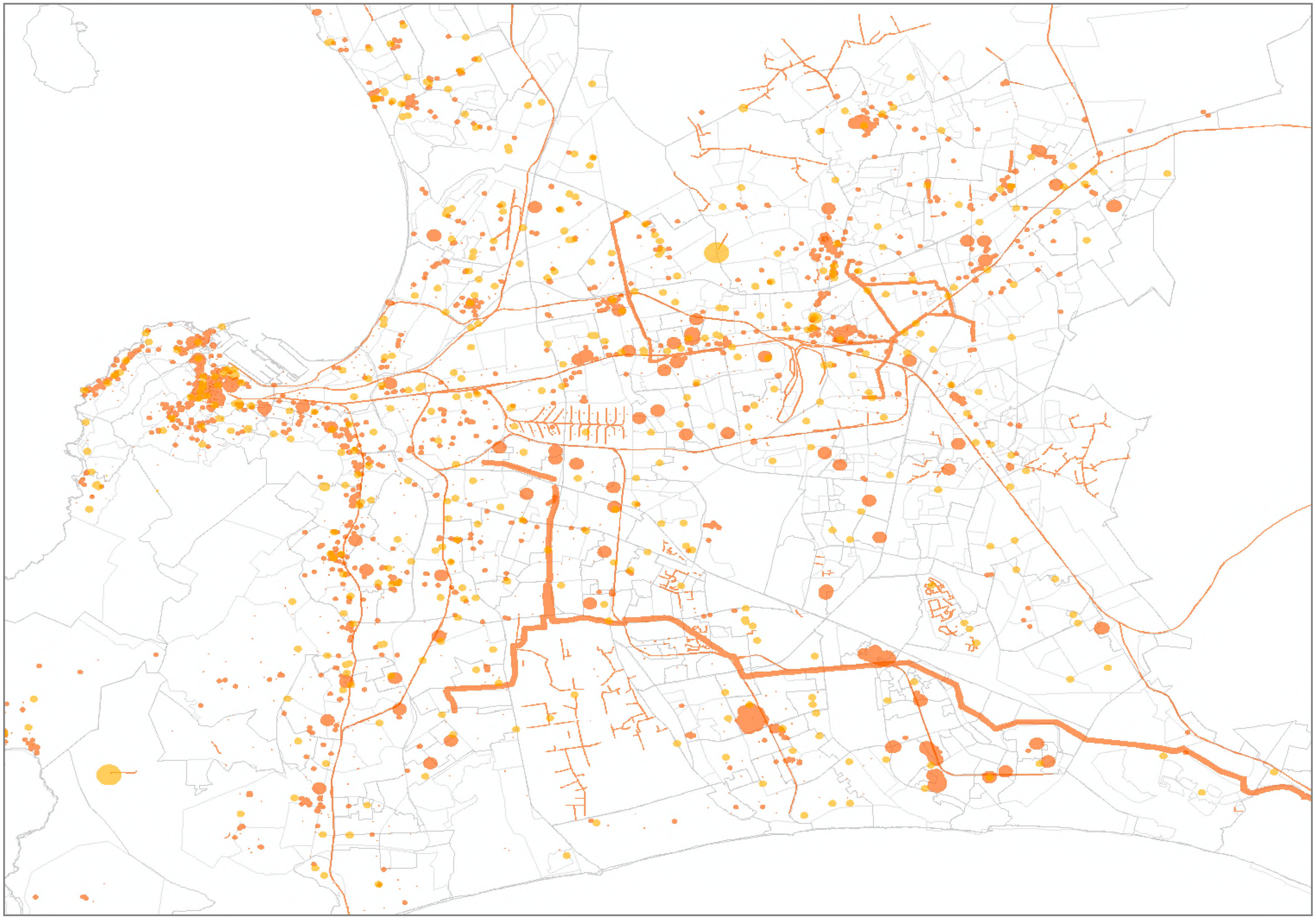


Figure 8.24 Partial EMF radiation heat map of potential ELF above 2 mG, RF at 3-6 V/m and public Wi-Fi

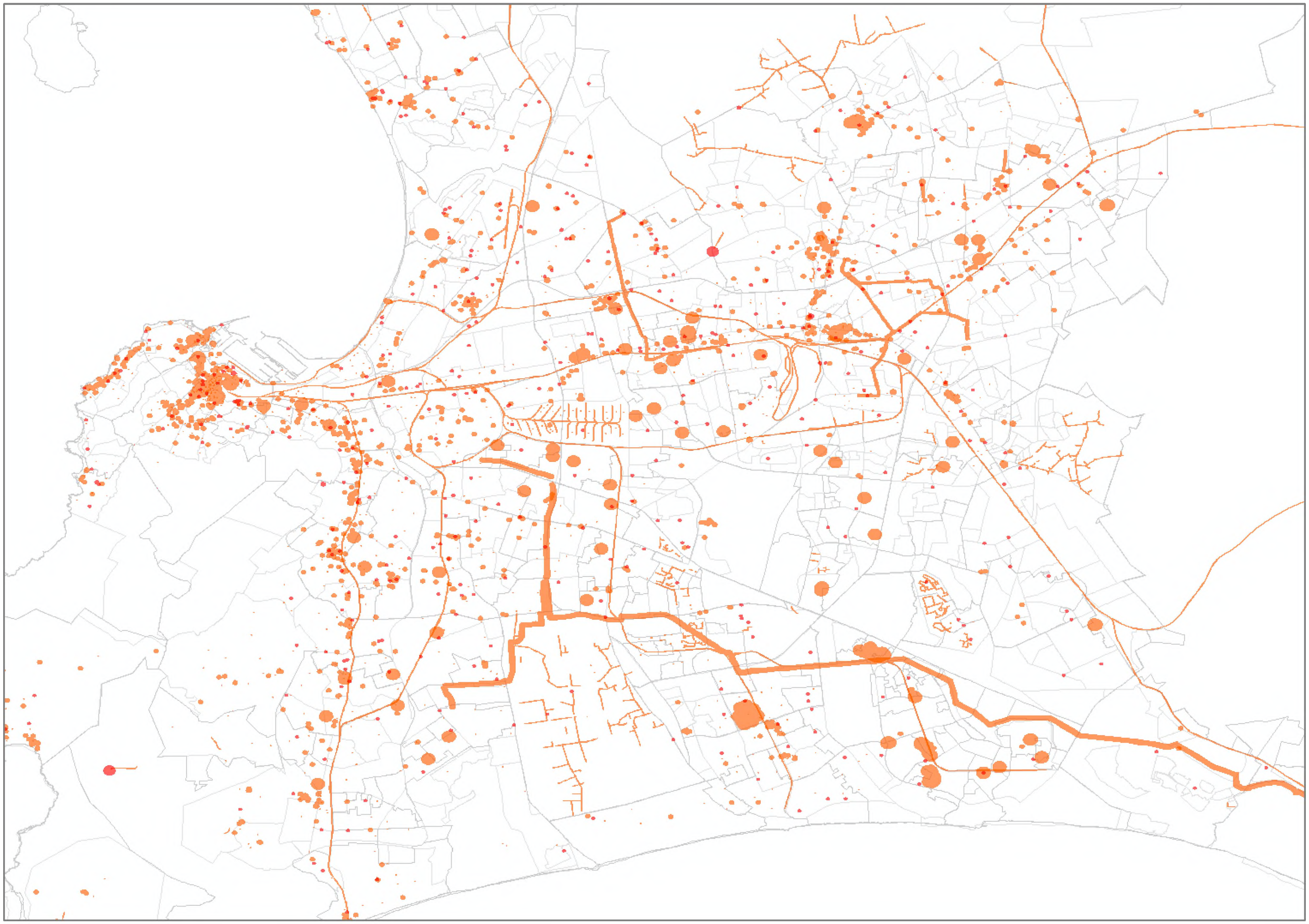


Figure 8.25 Partial EMF radiation heat map of potential ELF above 2 mG, RF greater than 6 V/m and public Wi-Fi

Figure 8.26 Overlay of partial EMF radiation heat map with historical measurements by OpenCellID with ELF and radiobroadcast, cellular and public Wi-Fi RF-EMF radiation buffer zones.

8.9.1 Identification of areas for site measurements based on potential high exposure EMF radiation heat map model

The intersecting data layers from Figure 8.23 to Figure 8.25, as well as the vulnerable area facilities for schools that are occupied by children under the age of sixteen (16), are shown in Figure 8.27.

Sites that modeled a potential high field intensity and magnetic field of EMF radiation exposure were identified by using a visual analysis and SQL query on Figure 8.27. The identified sites would serve as public interest for potential future studies or EMF radiation site measurements by the Regulator4 in the interest of employable EMF radiation mitigation strategies.

Figure 8.28, on the next page, illustrates a school with contributing EMF radiation sources from public Wi-Fi, cellular ARD transmitters and HVAC.

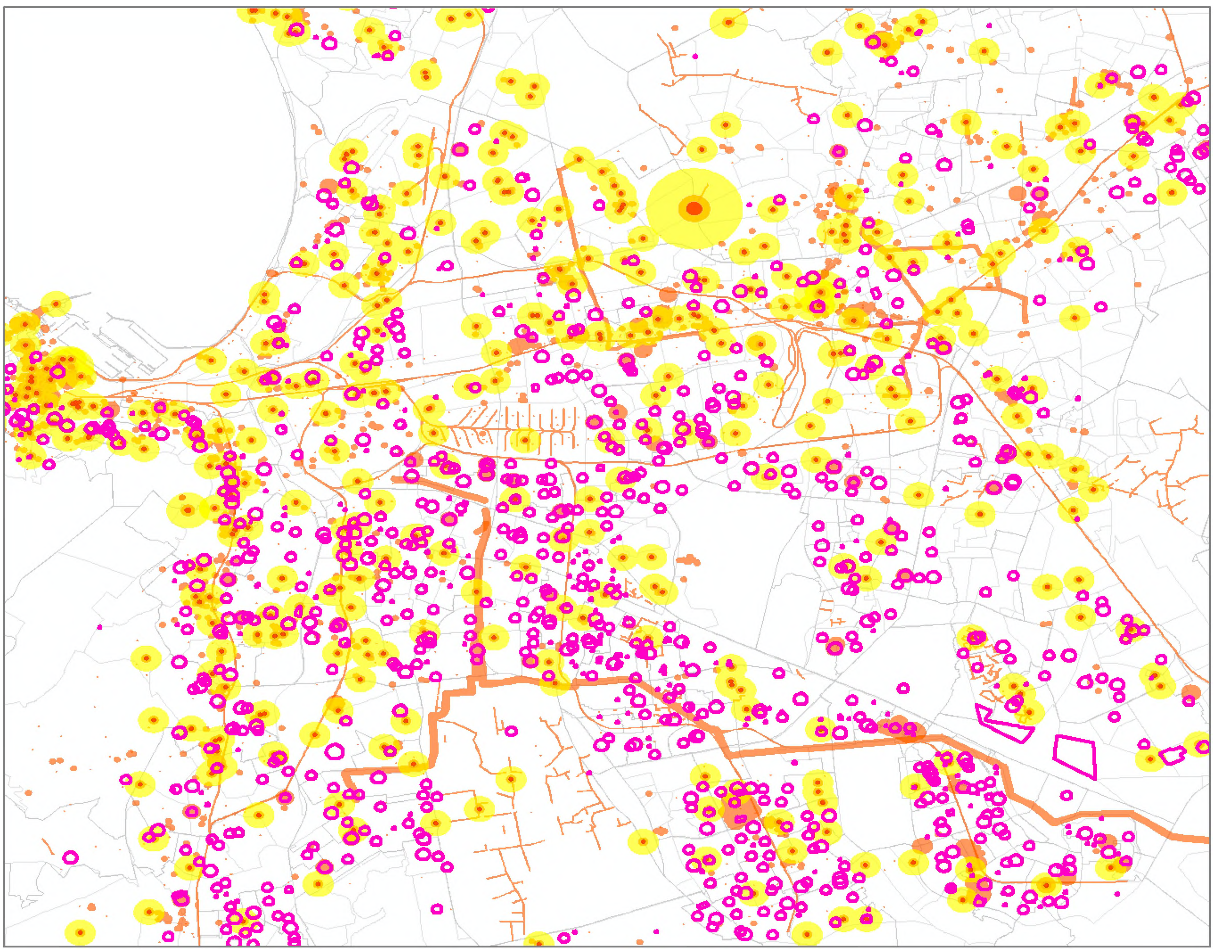


Figure 8.27 Partial EMF radiation heat map with U/16 schools

Figure 8.28 Example of an identified U/16 school for potential future site measurements

8.10 Conclusions

This chapter focused on presenting the findings and analyzing the output data from the EMF radiation HYGEIA model, as constructed in Chapter 6. The purpose of the model is to use inputs from the EMF radiation HYGEIA framework, as contrasted in Chapter 5. The model outputs were presented into the categories of potential ELF and RF-EMF radiation violations in terms of the framework EMF radiation policies. Additionally, the data was further evaluated for patterns and inconsistencies that may provide warrants as data inputs in demonstrating a PIO, as discussed in the next chapter.

An analysis of the results of RQ_4 and RQ_5 revealed the potential qualification for a PAIA (2000) PIO (RQ_5 and the next chapter) and areas of interest for potential future studies.

As discussed in Chapter 1, 2 and 4, it is helpful to investigate all EMF radiation sources, in both the macro and micro environments, to address the concerns and complaints of public fears and speculation (WHO, 2009; Government of India, 2010; WHO, 2011; Belyaev et al., 2016) when investigating EMF radiation complaints. Additionally, EMF radiation site measurements need to follow both STEP and LTCEP models' protocols, as discussed in the previous chapter.

During the processing of the EMF radiation HYGEIA model (Chapter 6) and the model feedback output identified in a future iteration, a factor correction should be applied to the whole body SAR (STEP model) measurements for members of the population under 1.3 meters in height. SAR values can be misleading, because SAR in a human body, resulting from EMF radiation exposure, strongly depends on the environment. As discussed in Chapter 4, the interaction between the human body harmonics and RF-EMF radiation infrastructure emissions frequency provides different whole body SAR absorption rates for different vulnerable groups of the population.

As discussed in Chapter 4, there is a steady increase in LTCEP model supporting studies and international High Court orders revealing evidence contrary to historical STEP model findings. The contradictory findings are explained by the STEP model being typically geared toward engineering technological performance and mitigating operation interference from other devices and to only being adapted to short-term thermal effects of analysis on the human body post STEP model formalization. Therefore, as discussed in Chapter 2, these STEP model findings do not provide adequate protection for potential biological effects in terms of the proposed EMF radiation HYGEIA framework (Chapter 5).

As discussed in Chapters 2, 4 and 7, consultation with experts and data sources revealed RF-EMF radiation infrastructure sources, such as cellular ARD transmitters and Wi-Fi, to cause the greatest public concern. However, demonstration runs in the model, as discussed in this chapter, revealed a that high power Wi-Fi router installed in a neighbour's apartment, within a building or office, has the capability to emit more RF-EMF radiation within proximity than a cellular ARD transmitter hundreds of meters away. Alternatively, a radio broadcast tower, or ELF EMF radiation source, may be the source of EMF radiation exposure complaints and not the cellular

RF-EMF radiation transmitter that was the basis of the complaint. However, as discussed in Chapter 4, a radio broadcast tower, if not configured correctly, may lead to cellular sites experiencing interference and other issues due to spurious emissions that are not regulated in SA. SMART meters causing 'dirty electricity' or re-radiation from neighbouring devices are other possible sources.

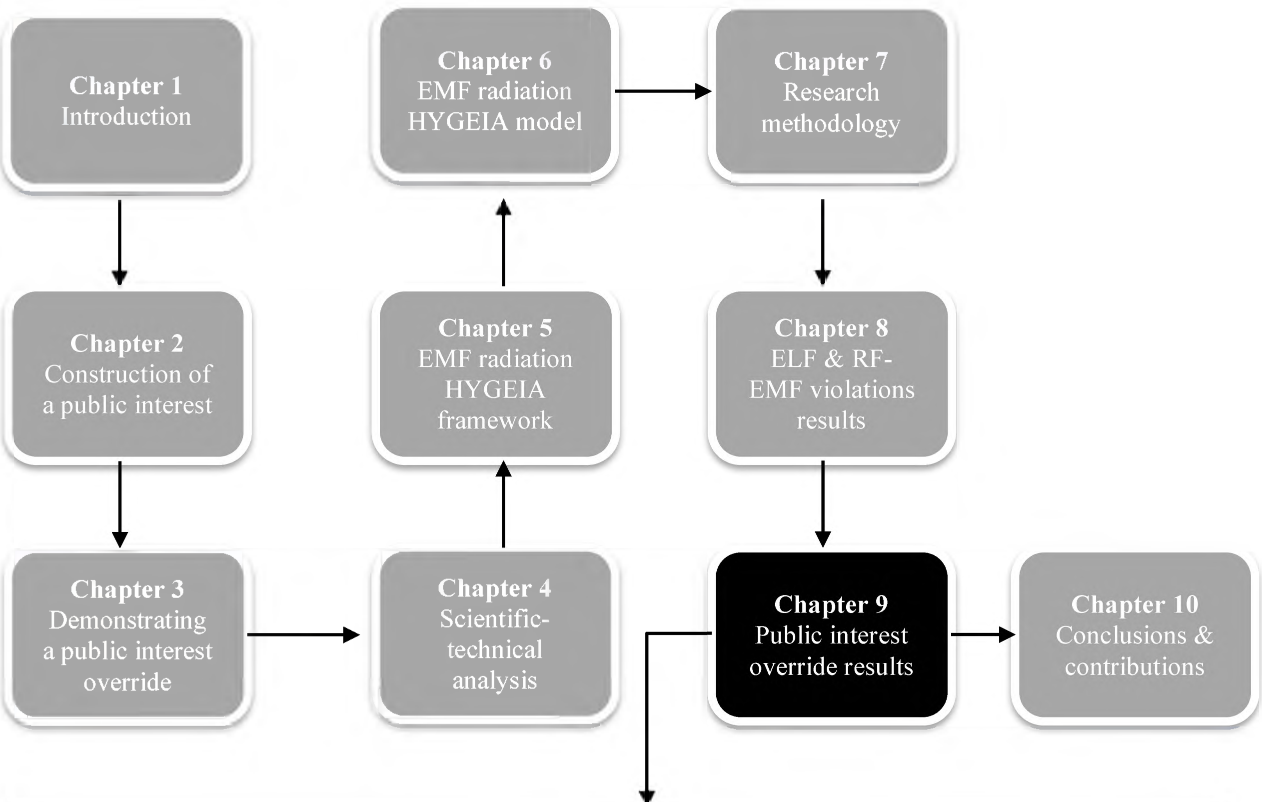
Interestingly, the study found ELF EMF radiation exposure to be a greater concern than RF-EMF radiation infrastructure, as a result of the different propagation properties, as discussed in Chapter 4. The EMF radiation HYGEIA framework and model's investigation into emerging energy hybrid technologies, expanding infrastructures, renewable energy projects and supporting HVAC infrastructure development, revealed ELF EMF radiation infrastructure sources to be on the rise, as well as a potential increased incidence of ELF EMF radiation hazard conditions (WHO, 2016c).

The model demonstrated its potential to be a broadly applicable modelling and support platform for decisions at local level, with consideration of potential EMF radiation-related health effects and the effectiveness of different mitigation policy options and spatial design strategies.

Using census block data, the model assesses the vulnerability, in terms of the STEP and LTCEP models, of various demographic groups over time and location and forecasts morbidity and mortality under future EMF radiation infrastructure planning policies and under conditions that mitigate EMF radiation extremes.

The next chapter discusses the findings in demonstrating a PIO function (RQ_5) using the results of Chapters 2, 4 and, in particular, of this chapter.

CHAPTER 9: PUBLIC INTEREST OVERRIDE FUNCTION DATA ANALYSIS AND RESULTS



9.1 Introduction

9.2 The purpose of PAIA (2000)

9.3 PAIA (2000) application results

9.4 Public interest override results

9.5 Conclusions

CHAPTER 9
Public interest override function data analysis and results

9.1 Introduction

The previous chapter discussed the data analysis and results from EMF radiation HYGEIA model demonstration runs. The outputs from the previous chapter serve as data inputs for the PIO checklist constructed in Chapter 3. In this chapter the findings of Chapter 2, 3, 5 and 8 are processed through the PIO checklist and discussed. The outputs from this chapter are sought to answer the fifth sub-question; to complete the demonstration of the constructed framework in Chapter 5 and to provide a practitioner research methodological output of producing a framework and model that may contribute to influencing government policy through the demonstration of public interest overrides. The fifth sub-question was presented in Chapter 1 as follows:

> RQ_5: How does the model demonstration runs identify potential EMF radiation violations that can be used to substantiate a PIO claim?

This public interest research seeks to create greater awareness regarding the problem space and to present a scientific basis for further exploration of the fundamental nature or essence of EMF radiation health issues. There is currently no agreed upon framework, or regulation of EMF radiation exposure, to protect the public.

The above fulfilments of the public interest RQ_1 to RQ_5 were carried out by a systematic literature review (Chapter 4) of (a) STEP and LTCEP models; (b) their rationales; (c) EMF radiation exposure risk threshold limits; (d) quantitative values for public health; (e) scientific-technical analysis; (f) legislative policies for both international and domestic science-based publications (Chapter 2); and (g) domestic and international court case precedents (Chapter 2). The aforementioned were analyzed and formulated within the MIMES framework (Chapter 4).

The first fulfilment of RQ_5, in the previous chapter, identified potential STEP and LTCEP models' EMF radiation violations that were investigated from RQ_1 to RQ_3. In Chapters 2, 3 and

4, the literature review findings from the historic PAIA (2000) applications, domestic SA bylaws, policies, legislation and case precedents in terms of the PAIA (2000) PIO function, were reviewed.

The construction of a PAIA (2000) PIO checklist (RQ_5) in Chapter 3, was a required entity within the EMF radiation HYGEIA framework in Chapter 5. The PAIA (2000) PIO checklist requires the provision of sufficient substantiated evidence to determine whether the disclosure of the requested information in the public interest outweighs the argument for confidentiality claimed by the data sources (RQ_5).

As discussed in Chapter 7, the submission of PAIA (2000) applications to data sources provided access to some of the data for the EMF radiation HYGEIA model demonstration runs. The rejected PAIA (2000) applications were processed through the PAIA (2000) PIO checklist in partial fulfilment of RQ_5.

The final data input discussed in this chapter is the framework EMF radiation policy inputs that were in potential violation in terms of the previous chapter. In the previous chapter forecast simulation demonstration runs of the model outputted EMF radiation heat maps of potential high EMF radiation exposure areas in CPT (RQ_5). Outputs from the model in fulfilment of RQ_5 potentially demonstrate a PIO function within the EMF radiation framework iteration and identify sites for potential future studies.

This chapter reminds the reader of the purpose of PAIA (2000) in Section 9.2, while 9.3 discusses the PAIA (2000) application results, Section 9.4 discusses the public interest override results and Section 9.5 summarizes and concludes the chapter.

9.2 The purpose of PAIA (2000)

It is necessary to briefly identify and clarify both the purpose and spirit of PAIA (2000) used in reviewing the results in this chapter in order to prepare the reader to understand the intentions of this study, as well as the problem statement.

As discussed in Chapter 3, the right of access to information is a unique right since it enables the realization of other human rights and embodies how PAIA (2000) can be used towards monitoring and enforcing those rights against systemic violation (Practitioner9, 2016). Examples are as follows:

(1) Provision of government services: PAIA (2000) can be used to empower people and to *hold* government *accountable* for the provision of basic services.
(2) Civil and political rights: PAIA (2000) can be used to gather information that individuals can use to *exercise* rights.
(3) Discrimination and Equality: PAIA (2000) can be used as an *advocacy tool* to fight discrimination by public or private bodies.

As discussed in Chapter 3, the purpose of the PAIA (2000) findings in the sections below is to contribute towards measures against the systemic threat and/or violation of human rights in respect of EMF radiation exposure and potential adverse health effects to the public (SAHRC, 2015; Practitioner9, 2016).

The qualification of a PAIA (2000) PIO function through a judicial review process may enable EMF radiation emissions' *transparency* and may also enable *accountability* towards public and private bodies in EMF radiation public awareness, by the monitoring and regulation of protection measures (NEMA, 1998; SAHRC, 2014).

It is not the intent of this research to ban technologies that emit EMF radiation, but rather to permit access to data that will enable the simulation of EMF radiation HYGEIA model scenarios in the interest of policy decision makers selecting a suitable national EMF radiation exposure protection standard, based on facts, data and values risk tolerance threshold limits in accordance with SA legislation and with the requirements the community (Foster, 2001; WHO, 2004b; WHO, 2006a).

The next section discusses the application results of the PAIA applications to the selected data sources, as discussed in Chapter 7.

9.3 PAIA (2000) application results

As discussed in Chapter 3, the preparation of PAIA (2000) applications for the study required the literature review of historical PAIA (2000) applications and consultation with experts and department heads as a means to achieve a greater statistical success rate in the PAIA (2000) applications. Reviewing historical PAIA (2000) applications revealed:

(1) Submitting PAIA (2000) applications (in respect of private companies) to the listed PAIA (2000) information officer on the company website, resulted in the application going into a

holding folder on the company server instead of reaching the intended recipient and/or the company failed to complete their own administrative purposes as mandated by legislation and as advertised on their respective websites (SAICA, 2016). Similar obstacles were encountered when approaching the regulatory body, Regulator9. The EMFDS9 was responsive and functional in accordance with PAIA (2000);

(2) In the event of a failed response in point (1), several phone calls were required to obtain the direct contact email address and phone number of the assigned PAIA (2000) officer. The latter would be either the personal assistant of the CEO, CIO, CTO or COO, and/or the legal department of the company;

(3) The PAIA (2000) application was emailed and a follow-up phone call or email was required after the fact in order to attain a confirmation of receipt;

(4) Follow-up communications were required to remind the company of the PAIA (2000) processing deadline of thirty (30) calendar days, starting from the submission of the PAIA (2000) application;

(5) Many of the companies ignored the PAIA (2000) deadline, or failed to provide a rejection response and ignored further communication requests;

(6) Responses from the companies' legal departments would consist of a template response and disregarded the human rights PIO criteria contained within the PAIA (2000) application.

The next subsection discusses the list of rejected responses to PAIA (2000) applications by data sources.

9.3.1 PAIA (2000) application rejected response outcomes

PAIA (2000) applications in the study were successful in identifying some of the direct information holders. In the PAIA (2000) application to the EMFDS9, the contact particulars for each dataset administrator were provided, enabling the legal compliance department to fast track the information collection process, because the dataset administrators have been briefed in advance. PAIA (2000) applications to private companies were directed to the relevant legal department authorities, as identified in the literature review.

The historical and recent PAIA (2000) rejection responses conducted in this public interest research is shown in Table 9.1 on the next page. The Table 9.1 results showed that all private telecommunication companies had refused to provide the requested public interest data. The only (partial) exception is EMFDS4, who provided the street addresses of sites, but not the exact GPS co-ordinates or technical specifications.

The following refers: (A):EMFDS3, (B):EMFDS4, (C):Regulator9, (D):EMFDS15 (E):EMFDS13, (F):EMFDS14, (G)EMFDS12, (H)EMFDS17, (I):EMFDS1 . The abbreviated number refers to the reference year i.e. 2015 =, 15.

Table 9.1 Rejected PAIA (2000) response categories

	Data source reason for denial to requested information. Response categories	Historical reference	2016
1	The information is commercially sensitive, confidential and has economic value.	A, 12; B, 12; G, 12	E
2	The release of the information would likely cause harm to the commercial or financial interests of the company.	A, 12; F, 12	A, B
3	The information would prejudice the security of the site locations.	A, 12	E, G
4	There exists no globally proven scientific evidence to the effect that radiation from towers cause any harm to the well-being of people.	A, 12	
5	There is no demonstrated public interest, because of no imminent and serious public safety or environmental risk at this stage. Therefore, the public interest in the disclosure of information, does not outweigh the harm that is likely to be suffered by the company	A, 12	A
6	The company is in compliance with ICNIRP EMF radiation guidelines (STEP model reference levels).	B, 12;	
7	Company is compliant with international telecommunication union and 3rd generation partnership project (STEP model reference levels).		A
8	Would break confidentiality of contracts with third parties, i.e., lease agreement with property owners.	F, 15	G, A
9	Response ignored	F, 13	I, F, H, D

Only two (2) out of the five (5) telecommunications companies (6 and 7 of Table 9.1) confirmed that they do comply with STEP model EMF radiation guidelines.

Annual reports of EMFDS4, for the years 2012 and 2013, confirmed that the STEP model reference levels implemented are only scoped to the thermal capabilities of RF-EMF radiation. However, no data was provided confirming the complied guidelines or the advertised database. The data required to model and establish said RF-EMF radiation compliance was also not made available.

Furthermore, no statutory body in SA reviews or monitors EMF radiation compliance in SA (Regulator9, 2015; CCPTM, 2015; DHSA, 2016c; EMFDS9, 2016; Regulator10, 2016; Regulator7, 2016; Regulator6, 2016). The three (3) most common response categories from Table 9.1 were 1, 2, 3 and 8. Points 1 – 3 of Table 9.1 are discussed in the section below.

The PAIA (2000) respondents that did supply some information only expressed willingness to accommodate the PAIA (2000) application, because it was for academic purposes and would not have done so otherwise. Companies' selective terms of accommodation are a potential violation of PAIA (2000), because PAIA (2000) both allows and enforces the rights of private individuals to submit the same request (Connor, 2013; Practitioner8, 2016). Not a single private telecommunication company data source provided the requested detailed technical specifications as requested in the PAIA (2000) applications. A similar PAIA rejection and ignore response was found in the ATI Network (2016) Shadow report that identified both public and private bodies failing to uphold the PAIA right of access to information.

9.3.2 Prisoner's dilemma

When comparing the literature review results from Chapter 3 with the PAIA (2000) rejection responses and data received, a possible pattern of the non-zero sum game prisoner's dilemma emerged. Prisoner's dilemma, in game theory, is a situation in which two or more parties each have two options and where the outcome crucially depends on the simultaneous choices made by both. It shows why two or more completely rational parties might not cooperate, even when it appears to be in in their best interests to do so.

If all telecommunications companies, along with the DHSA, agreed on a specific EMF radiation safety paradigm, it would be easier to maintain their best strategic economic interests (DHSA, 2005; DHSA, 2013; Regulator4, 2016; Regulator5, 2016; Regulator2, 2016; Regulator10, 2016;

Regulator7, 2016). However, if one party deviates from the cooperation agreement, the outcome is detrimental to the remaining parties.

Only EMFDS15 and EMFDS4 (partially; street locations only) agreed to provide the technical specifications as requested in the PAIA (2000) application. The researcher had signed an agreement with EMFDS15 for the detailed specification information, but the data was never delivered despite follow-ups by phone and email.

9.4 Public interest override results

A PIO function checklist on the 'balance of probabilities', weighing and qualifying a potential PAIA (2000) PIO function of 'substances released into the environment' and 'public safety or environmental risk', was generated in Chapter 2.

A summary of the results discovered in this study is shown in Table 9.2 on the next page.

Table 9.2 PAIA (2000) public interest override results summary

#	**Public interest override questions**	**Y/N**
1a	The disclosure of the record would reveal evidence of a substantial contravention of, or failure to comply with, the law; or	Y
1b	Of an imminent and serious public safety or environmental risk; and	Y
2a	The public interest in the disclosure of the record clearly outweighs the harm contemplated in the provision in question.	Y
2b	Additionally, it may include the public interest in upholding the law, as well as the public's awareness of public safety or environmental risks.	Y
3	There may also be the public interest in furthering the general goals of the Act.	Y
	Under 'substances released into the environment' and 'public safety or environmental risk'	
4	Public interest in upholding the law, as well as the public's awareness of public safety or environmental risks.	Y
5	*Public safety or environmental risk is defined as follows: "... means harm or risk to the environment or the public (including individuals in their work place) associated with -*	
5a	A product or service which is available to the public;	Y
5b	A substance released into the environment, including, but not limited to, the work place;	Y
5c	A substance intended for human or animal consumption;	N
5d	A means of public transport; or	Y
5e	An installation or manufacturing process or substance which is used in that installation or process.	N
6	Different versions, based on one party's word against another. The applicant presents evidence and grounds for the requested information, but the data holding company refuses to present or share the information for review by the court. This situation brings into reckoning the issue of public interest – whether the potential harm reviewed in the refusal to disclose is outweighed by the public interest. In Kgomo (2012), favour was granted to the applicant on the grounds that the information holder refusing to provide the requested information to the court for review, perceived harm.	Y

Each sub-section below is a discussion heading of the results for each checklist question in Table 9.2 on the previous page. The results are either discussed or referenced to the above findings in this study.

9.4.1 (1a) The disclosure of the record would reveal evidence of a substantial contravention of, or failure to comply with, the law; or

1. As discussed in Section 3.4, in CfSAvSPo (2010) it was ruled the words 'substantial' and 'would' in section 46 (a) do not require any heavier onus than the accepted standards of civil procedure. Thereby, a contravention or failure can be either a minor or substantial breach. Therefore, it is simplified to a contravention or failure.
2. Section 2.9 (Domestic case precedents for EMF radiation protection): The literature review and review of PAIA documents revealed a systemic threat or violation of human rights, thereby qualifying as a public interest (Practitioner9, 2016).
3. Sections 2.2 (Preliminary literature review): The ICNIRP STEP model confirms an incidence of the population (including domestic) experiencing adverse health effects from EMF radiation exposure, as discussed in Section 4.12 (Hazard conditions) (ICNIRP, 2002; WHO, 2004b; WHO, 2006a). A small incidence of STEP or LTCEP models' EMF radiation violations would therefore concur with the NTP (2016) model that even a very small increase in the incidence of diseases resulting from exposure to EMF radiation could have broad implications for public health, social accounting and the economy.
4. Section 2.7.2 (Suspended national EMF radiation standards in SA).
5. Section 2.5 (Guidelines versus standards).
6. Sections 2.6 (Weighted studies) and 2.6.1 (DHSA weighted published findings and misleading public awareness campaigns): As stipulated by the ICNIRP STEP model chairman, Prof. Vecchia, recommendation of the STEP model is neither a mandatory prescription for safety, nor a defensive wall for industry or others (Vecchia, 2008).
7. Section 8.6.5 (EMFDS9 City permits: cellular transmitter site findings): Evidence of the EMFDS9 processing permits that are in violation of legislation, bylaws, and policy was presented, for example: Regulator2 not inspecting and verifying the public safety violations of infrastructure permit sites; EMF radiation infrastructures illegally installed and no action taken by the CCPTM, despite complaints submitted. As discussed in Section 2.10, when the precautionary principle is legislatively invoked, weight is given to the complainant if the

operator is unable to provide proof in complying with all aspects of the law (Government of India, 2017; SCIO, 2017).

8. Section 8.6.10 (Illegal RF-EMF cellular ARD site findings).
9. Section 8.6.7 (Potential CCPTM (2015) policy violation).
10. Section 3.6 (Application for detailed facts and data needed to accurately model public interest): The SA Telecommunications Act (2000) requires the regulatory bodies, Regulator9 and the CCPTM (2015), to issue all technical site installation transmission specifications with the granting of a license. However, Regulator9 (2015), Regulator4 (2016), Regulator5 (2016), Regulator10 (2016), Regulator7 (2016) and Regulator2 (2016) confirmed that this is not the case.
11. Section 2.7.1 (EMF radiation responsibilities by organs of State): ASA (2004) ruled, in line with SA's NEMA (1998) Section 2(4)(a)(ii), that children under the age of sixteen (16) are at a greatest risk of potential EMF radiation health effects. The public are not aware of the potential health risks and industry still violates the ASA (2004) ruling (Regulator1, 2016). ASA's (2004) ruling is supported by experimental domestic research carried out by Daniels et al. (2009), international legislation and High Court rulings.
12. Section 8.5.5 (Public transport: MyCiti bus network).

9.4.2 (1b) an imminent and serious public safety or environmental risk; and

1. Section 2.2 (Preliminary literature review): SA has *no* national EMF radiation exposure protection standard. There is no statutory body that monitors, regulates or monitors EMF radiation emissions in SA. EMF radiation exposure levels to the public may go unchecked, possibly resulting in the highest incidence of EMF radiation hazard conditions (Government of India, 2010; Rajasthan, 2012).
2. Sections 4.8.2 (LTCEP model inputs) and 9.3.2 (Prisoner's dilemma): Scientific studies and the telecommunication company SWISS-AG confirmed that pulsed RF-EMF radiation from modern wireless devices within STEP model reference levels has the capacity to cause damage in DNA.
3. Appendix Section 4.10 (far-field power density evaluation calculation for cellular RF-EMF radiation exposures): There are no restrictions on co-located RF-EMF radiation cellular transmitters energy exposure output (Regulator5, 2016). The advertised RF-EMF radiation energy levels capacity of a single operator at a site is underestimated. When multiple

collocated operators are at the same site, the directional RF-EMF radiation exposure can be three to four hundred percent (300-400%) greater than advertised to regulators or the public.

4. Section 4.12 (Hazard conditions): EMF radiation exposure-related morbidity complaints have been reported nationally in SA to legislative and regulatory bodies.
5. Sections 8.2.1 (HVAC Power lines: potential LTCEP model violation results).
6. Section 8.4 (Radio broadcast towers: potential violation of LTCEP model RF-EMF radiation results).

Section 8.5 (Public Wi-Fi: potential STEP and LTCEP model RF-EMF radiation violations) and 0 (

7. Youth and elderly facilities): ASA (2004) ruled (Regulator1, 2016) that the STEP model's endorsed SAR EMF radiation limits do not account for members of the population under 1.3 meters in height, typically children eight (8) years and younger. Whole body SAR EMF radiation values can reach levels up to forty percent (40%) *greater* than the specified STEP model reference level set for an adult male.
8. Section 8.6.7 (Potential CCPTM (2015) policy violation).
9. Section 8.6.8 (Potential NMBM (2011) policy violation findings).
10. Section 8.6.9 (Potential KM (2012) policy violation findings).
11. Section 8.5.5 (Public transport: MyCiti bus network): the ASA (2004) ruling coupled with (Regulator1, 2016) the Regulator2 (2016), Regulator5 (2016) and Regulator4 (2016) have confirmed not having adequate training or expertise to fully understand, monitor, investigate and enforce EMF radiation protection measures.
12. Section 2.10 (International case precedents for evolved EMF radiation protection): 'Mushroom' growth of ARD transmitters in favour of operators' results in the potential for RF-EMF radiation exposure levels to be detrimental to public health.
13. Sections 2.2 (Preliminary literature review), 2.6 (Weighted studies), 2.7.1 (EMF radiation responsibilities by organs of State): DHSA advocates that there are "no RF-EMF radiation protection measures with respect to cellular spatial planning and that local and other authorities *should not attempt* to create" any EMF radiation spatial planning restrictions from a *public health* point of view (CCPTM, 2015:47). Evidence from the science-based literature review findings, existing policies in SA and identified potential STEP and LTCEP EMF radiation policy violations, identified as a result of the EMF radiation HYGEIA model,

contradict the public health statement by DHSA. Review of the DHSA EMF national reports identified only weighted studies in favor of the DHSA STEP model endorsing statement.

14. Section 8.7 (Historical RF-EMF radiation measurements): RF-EMF radiation measurements and generated reports by Regulator4 did not follow a measurement methodology or protocol. Simulation calculation models were not created beforehand and measurement factor corrections were not applied, resulting in potentially misleading information contained within EMFDS16 reports. Additionally, the Regulator4 admitted to not having adequate training in the use of the equipment or its application to EMF radiation STEP and LTCEP models. Therefore, potential sites may have been authorized based on incorrect Regulator4 RF-EMF radiation measurements, potentially resulting in RF-EMF radiation exposure levels that may be a danger to public health.

9.4.3 (2a) The public interest in the disclosure of the record clearly outweighs the harm contemplated in the provision in question

1. Section 3.6 (Application for detailed facts and data needed to accurately model public interest): International trends reveal that the release of the location and technical specification of cellular ARD transmitters to the public domain did not jeopardize the commercial interests of private telecommunications in meeting the public interest.
2. Section 2.10 (International case precedents for evolved EMF radiation protection): International trends, practice and High Court orders do not reveal economic protection of industry to override the public health interest. Access to the data will enable the carrying out of potential future non-speculative and scientific epidemiological studies.
3. Access granted to the data may enable the formulation of a national EMF radiation exposure protection standard. The current lack of national EMF radiation monitoring and enforcement results in the potential highest incidence of EMF radiation exposure hazard conditions. Increased hazard conditions equate to an increased public risk of potentially related adverse EMF radiation health effects.
4. PIO is existing legislation that invokes public interest as the ‘right to know’. Multinational judicial deliberations have ruled in favor of a PIO as demonstrated in this study. For example, in the City of Berkley, California ‘right to know’ matter of CTIA *v* City of Berkeley (2017); the court order mandated RF-EMF device retailers to inform consumers that operating and or handling the device in certain ways may cause them to exceed STEP model guidelines for exposure to RF-EMF radiation exposure (Kos et al., 2011; Yahya &

Khalil, 2015; CTIA *v* City of Berkeley, 2017). It was deliberated on the 'balance of probabilities' that disclosure was reasonably related to a substantial governmental interest and was purely factual. The judicial panel held that far from conflicting with federal law and policy, the Berkeley ordinance complements and reinforces it. The 'balance of probabilities' tipped in Berkeley's favor because the science-based LTCEP judicial deliberations ruled the 'right to know' ordinance was in the public interest, and that an injunction from industries to protect their strategic economic interest, would harm that interest (CTIA *v* City of Berkeley, 2017).

5. Economic threshold limits: weighted-study EMF radiation recommendations and guidelines regarding the exposition for pulsed RF-EMF radiation signals are *very* different depending on the organization which publishes it.
6. Section 2.7.1 (EMF radiation responsibilities by organs of State).
7. Section 7.8.4 (Historical EMF radiation field measurements): DHSA's referenced reports stated that historical EMF radiation measurements of EMFDS12 are available. Regulator8 (2016b) stated, however, that the EMF radiation data was neither received, nor reviewed. EMFDS12 refused to provide the data advertised in the DHSA reports for this public interest research claiming that it would be contrary to EMFDS12's strategic economic interests.
8. Section 2.7.3 (SA municipal bylaws supportive of EMF radiation protection): Both NMBM (2011) and KM (2012) municipalities recognize the tolerance of risk values in favour of public health and require that RF-EMF ARD transmitter sites and technical specifications be provided.
9. Sections 7.8.3.1 (Limitations) and 7.10 (Conclusions): Access to the data may enable the development of a national continuous EMF radiation monitoring system within a constrained resource and scarce skills environment. The EMF radiation monitoring system may aid in increasing the efficacy of EMF radiation application permits and enable real-time enforcement.
10. Sections 2.5 (Guidelines versus standards) and 2.7.2 (Suspended national EMF radiation standards in SA).

9.4.3.1 Withholding information in speculative fear of public outcry or protest

EMFDS9 PAIA application (2016) results for the historical EMFDS16 EMF radiation measurement reports were provided by the EMFDS9 on condition that the detailed contents of the reports would not be shared with the public and that the EMFDS9 is indemnified against any civil claim against the city as a result of the records shared.

A potential reason behind EMFDS9's fear is that the reports have the potential to cause public outcry due to them displaying a lack of credible methodology and potentially misleading EMF radiation measurement values. This speculative reason is supported by newspaper reports of EMFDS9 officials leaking alleged safety protocols and measures, that are contradictory to the EMFDS9 documentation and consultation, to the media (Regulator4, 2016; Regulator5, 2016; Regulator2, 2016; DHSA, 2016c; May, 2016). An explanation of the EMFDS16 results is discussed in Section 8.7 (Historical RF-EMF radiation measurements) below.

The terms and conditions set forth by EMFDS9 are in potential violation of PAIA (2000) according to the Practitioner8 (2016). In terms of PAIA (2000), access to records held by a public body must be granted without a motivated reason, provided that the data is not in contravention of PAIA (2000) subsections.

The researcher established that the terms and conditions of the EMFDS16 data are contradictory to the CCPTM policy and regulatory practices. It is stated by Regulator3 (2016) and Regulator1 (2016) that SA regulatory enforcement and policy development operate on a 'reactive system'. This system will only investigate a potential violation when a complaint is submitted. Therefore, even if the regulatory body observes a violation, they are not mandated to act unless a complaint is received. When the public is misinformed and/or unaware of the potential risks of EMF radiation, complaints cannot be submitted (Regulator1, 2016).

Regulatory bodies are also potentially compromised when they are misinformed by another regulatory body regarding the legislative criteria in respect of EMF radiation exposure (CCPTM, 2015; Regulator4, 2016; Regulator5, 2016; Regulator6, 2016). The Regulator4 (2016) reported that they had their hands tied, because EMF radiation complaints may only be handled by the DHSA, as instructed by the DHSA. This instruction is contradicted by an official statement of the DHSA and is in potential violation of Schedule 4 of the SA (1996) Constitution and of the Municipal Systems Act (KM, 2011; NMBM, 2012; CCPTM, 2015).

New policies are only developed in the interest of public health when the public and experts identify weaknesses in and provide recommendations to be made to current policies (CCPTM, 2015; Regulator1, 2016; Regulator2, 2016; Regulator3, 2016; Regulator5, 2016).

The aforementioned provides added support to the literature review findings that the DHSA, in conjunction with industry, demonstrates purposeful intent in misleading the public regarding EMF radiation exposure safety measures and status in SA.

9.4.3.2 Economic interest clause

The responding party is required to provide a valid and detailed reason for the refusal to grant access to information in PAIA (2000) (Kgomo, 2012; Connor, 2013; Practitioner8, 2016). The common rejection amongst the data sources was that "sharing of data may lead to economic or commercial harm" (Table 9.1).

The PAIA (2000) respondents (Table 9.1) did not provide a detailed and/or specific reference as to how the release of the data may lead to economic or commercial harm.

A possible reason for citing "economic or commercial harm" in accordance with LTCEP model science-based EMF radiation findings, NEMA's (1998) Section s 2(4)(p), referred to as the polluter-pays principle, and international High Court rulings, may be that evidence of EMF radiation public health complaints and violations of existing laws would result in a potential economic loss to the PAIA (2000) respondents (Table 9.1).

The NEMA's (1998) polluter-pays principle ensures that the party responsible for producing the pollution is liable for paying for the damage done. NEMA (1998) Section 2(4)(p) defines this as "the costs of remedying pollution, environmental degradation and consequent adverse health effects and of preventing, controlling or minimizing further pollution, environmental damage or adverse health effects must be paid for by those responsible for harming the environment".

The literature review identified that, if a complainant approaches the court for relief against an EMF radiation infrastructure provider, in accordance with the LTCEP model, and identifies adverse health effects, it can potentially be argued that compensatory damages may be awarded to the complainant. In the event of EMF radiation infrastructure sources (Table 9.1) refusing the information requested in the PAIA (2000) applications, their efforts may hinder the administration of PAIA (2000) public interest and NEMA (1998) (prisoner's dilemma).

The second common economic related rejection by the PAIA (2000) respondents (Table 9.1) was that the disclosure of locations would cause harm to their strategic economic interests.

No detailed specifications were provided by PAIA (2000) respondents (Table 9.1) on how this would be an issue. International practice and trends do not support the strategic economic competitive advantage argument over public health. Countries endorsing the LTCEP model demonstrated a stronger economic presence in comparison to SA telecommunications companies (Deloitte and GSMA, 2012; GSMA, 2016). Furthermore, telecommunications companies have the capacity to use their technology networks to locate competitors. Additionally, telecommunications can purchase the approximate coverage locations and economic opportunistic areas from 3rd parties like OpenCellID (2016) and OpenCell (2016).

This public interest research also identified potential economic disinterests in respect of which the telecommunications companies should be providing data as follows:

(1) Illegal erection of ARD sites may lead to fines or prosecution;
(2) Environmental penalties and reparations to the environment and members under NEMA (1998) S 2(4)(p);
(3) The release of the information may provide grounds for a PIO function, resulting in the reinstatement of a national EMF radiation exposure protection standard following a judicial review process. The implementation of such a national standard may require telecoms to decommission existing ARD sites and to possibly re-locate to others. The outcome may also affect telecoms' current open planning business practice of 'mushroom' growth ARD installations.

9.4.4 (2b) Additionally, it may include the public interest in upholding the law as well as the publics' awareness of public safety or environmental risks

1. Section 3.6 (Application for detailed facts and data needed to accurately model public interest): Access to the data would enable epidemiological studies and judicial reviews, in turn enabling the formulation of a national EMF radiation exposure protection standard.

2. Section 2.6.1 (DHSA weighted published findings and misleading public awareness campaigns).
3. Section 3.5.2 (Academic public interest override).

Public bodies and/or private companies refusing to provide information to regulators or academia, may fuel advertised speculative public EMF radiation concerns expressed by the DHSA (2016c). If statutory bodies or academic public interest research is denied access to conduct EMF radiation exposure investigations (requiring simulation models and measurements), the benefit of public concern can only be awarded to the concerned party (precautionary principle), since the polluting party, under NEMA (1998), is unwilling to mandatorily disclose pollution emissions to the public (Kgomo, 2012; Regulator9, 2015; Regulator4; Regulator2, 2016; Regulator7; 2016, Regulator10, 2016; Government of India, 2017; SCIO, 2017).

Additionally, the ASA (2004) ruling (discussed in Chapters 2 and 4) regarding the prohibition of RF-EMF radiation devices to be advertised to children under the age of sixteen (16) for non-essential purposes, is not well publicized or regulated and, as such, EMF radiation public health safety violations continue in SA (Regulator1, 2016).

Similar protection policies and/or warnings to the ASA (2004) ruling are issued internationally, except that they are extended to pregnant women and age grouping to children under the age of eighteen (18) (O'Connor, 2012; WHO, 2014).

Examples of countries with national policies and/or warnings are Russia, Germany, India, UK, Israel, Finland, France, Italy, Switzerland, Taiwan, Belgium and parts of North America (O'Connor, 2012; WHO, 2013).

9.4.5 (3) There may also be the public interest in furthering the general goals of the Act

PAIA (2000) has a limited number of case precedents in SA and monitoring the administration implementation of PAIA is of interest to the DJCD (Connor, 2013, Practitioner8, 2016).

The PAIA (2000) applications in the study identified that fifty-three percent (53%) of companies/public bodies were neither PAIA (2000) compliant, nor did they follow the PAIA

(2000) procedures as set forth by the South African Institute of Charted Accountants and the SA's Minister of Justice Government Notice No. 39504 mandate (SAICA, 2016).

For example: in Regulator9 (2015), in terms of PAIA (2000), is a private body that has a CEO, but as discussed in Chapter 2, when a private body is appointed to serve a public regulatory function, they are to be treated as a public body in terms of PAIA (2000) (Practitioner19). Thereby, they are required to follow an internal appeal process but this was denied in the PAIA application to Regulator9 (2015).

Review of the PAIA rejection responses (Table 9.1) from the data sources revealed that approximately forty percent (40%) of the data sources ignored the PIO argument in the PAIA (2000) application. In applying the game theory (Section 9.3.2 'Prisoner's dilemma') it appears that data sources providing a template denial response are hedging the risk by disclaiming to the applicant that they could approach the courts per PAIA (2000). The employed prisoner's dilemma strategy in Table 9.1 is in potential violation of the spirit of PAIA (2000) by allowing only the privileged few, who have access to legal resources, expertise and funds, to be served (Connor, 2013).

The judicial review process by SAHRC (2015) ruled that members of the SA population can be negatively affected by EMF radiation exposure and that their human rights are violated.

9.4.6 Under 'substances released into the environment' and 'public safety or environmental risk': (4) Public interest in upholding the law as well as the publics' awareness of public safety or environmental risks.

1. Section 2.4 (A summary review of regulation and practice in SA: STEP versus LTCEP).
2. ASA (2004) ruling, NTP (2016), Ramazzini Institute (Soffritti et al, 2016) and Daniels et al. (2009) findings.
3. Section 2.10 (International case precedents for evolved EMF radiation protection).
4. Economic threshold limits: weighted-study EMF radiation recommendations and guidelines regarding the exposition for pulsed RF-EMF radiation signals are *very* different depending on the organization and or manufacturer which publishes it (Vitale, 2005; EDA, 2016).

9.4.6.1 (5) Public safety or environmental risk is defined as follows: "... means harm or risk to the environment or the public (including individuals in their work place) associated with –

9.4.6.2 (5a) a product or service which is available to the public;

1. Section 2.6 (Weighted studies).
2. Section 2.3 (Construction of a public interest).
3. Section 4.8 (EMF radiation dosimetry rationale).
4. Section 8.2 (ELF EMF radiation: HVAC infrastructure sources).
5. Section 8.3 (RF-EMF radiation infrastructure sources).

9.4.6.3 (5b) a substance released into the environment, including, but not but not limited to, the work place;

1. Section 2.6 (Weighted studies).
2. Section 2.3 (Construction of a public interest).
3. Section 4.8 (EMF radiation dosimetry rationale).
4. Section 8.2 (ELF EMF radiation: HVAC infrastructure sources).
5. Section 8.3 (RF-EMF radiation infrastructure sources).
6. Section 2.2 (Preliminary literature review).

9.4.6.4 (5c) a substance intended for human or animal consumption;

Not applicable.

9.4.6.5 (5d) a means of public transport; or

1. Section 8.5.5 (Public transport: MyCiti bus network): ASA (2004) ruling (Regulator1, 2016).

9.4.6.6 (6e) an installation or manufacturing process or substance which is used in that installation or process

Not applicable.

9.4.7 (6) Differing opinions of one party's word against another

Sections 7.8.4 (Historical EMF radiation field measurements), 9.3.1 (PAIA (2000) application rejected response outcomes) and 2.6.1 (DHSA weighted published findings and misleading public awareness campaigns): In Chapters 2 and 4 a literature review of historical PAIA (2000) applications, DHSA national activities, annual EMF reports, Regulator9 (2015), telecommunication companies' annual reports and results from the PAIA (2000) rejected responses revealed statements by telecommunication companies and the DHSA that industry and public bodies are operating within STEP model regulations and that site surveys have been carried out.

However, review of the reports and requests for the data revealed that *no statutory* body in SA has access to EMF radiation infrastructure site data, emission levels or to the implementation of an EMF radiation monitoring system.

This public interest research revealed that EMF radiation emission data are not even available for academic public interest research purposes, a potential violation warrant for PAIA (2000) (Horn et al., 2015:19).

As discussed in Chapter 3, the data sources have refused to provide evidence for the information to be contemplated and weighted, as it is to be kept confidential, even to a statutory body Therefore, in terms of Kgomo (2012) and NEMA (1998), the PAIA (2000) PIO is in favour of the applicant.

9.5 Conclusions

This chapter completed the final requirements in fulfilling all the research questions and objectives for this study. It also focused on processing the findings from the literature review in Chapters 2, 3, 4, as well as the previous chapter, as data inputs for the PIO checklist constructed in Chapter 3. Discussion of the data outputs processed from the PIO checklist presented a case in demonstrating the framework constructed in Chapter 5 and recommended that this study is to undergo a process of judicial review to confirm the findings. The designed system feedback mechanism for the framework, and model was successful in providing feedback that can be used to improve the tools.

Fulfilment of RQ_5 and the discussion of the results presented in this chapter were motivated within the identified problem space of current SA EMF radiation recommended voluntary guidelines, that may not guarantee adequate protection against long-term exposure, as discussed in Chapters 1, 2, 4, 7 and presented in this chapter.

The study sought to create greater awareness regarding the problem space and to present a scientific basis for further exploration of the fundamental nature or essence of the EMF radiation health issues. There is no agreed upon framework or regulation for EMF radiation exposure protecting the public. The PIO checklist results presented the evidence for a national LTCEP model EMF radiation protection standard, based on consultations with SA regulatory practitioners, the reviewed legislation and the case law in Chapter 2, 3 and 4.

A review of the domestic literature in Chapter 2 denied access to metric data for EMF radiation emissions in SA, both historically and in the study, and revealed this as an obstacle in conducting potential future epidemiological studies and accurate identification of violations of existing EMF radiation supportive policies in SA.

Findings from Chapter 1, 2, 7 and this chapter revealed that organs of the state do not enforce or monitor EMF radiation in SA. Consultations with regulatory sources (Regulator2, Regulator4, Regulator5, Regulator7, Regulator8, Regulator9, Regulator10, Practicioner3), and data sources (EMFDS3, EMFDS4, EMFDS14, Practitione18) presented collective evidence of intervention by industries who cited that it would be contrary to their strategic economic interests to allow access to the data for the said EMF radiation emissions monitoring. The model demonstration runs in the previous chapter were limited, because of access to required technical site data from data sources being denied.

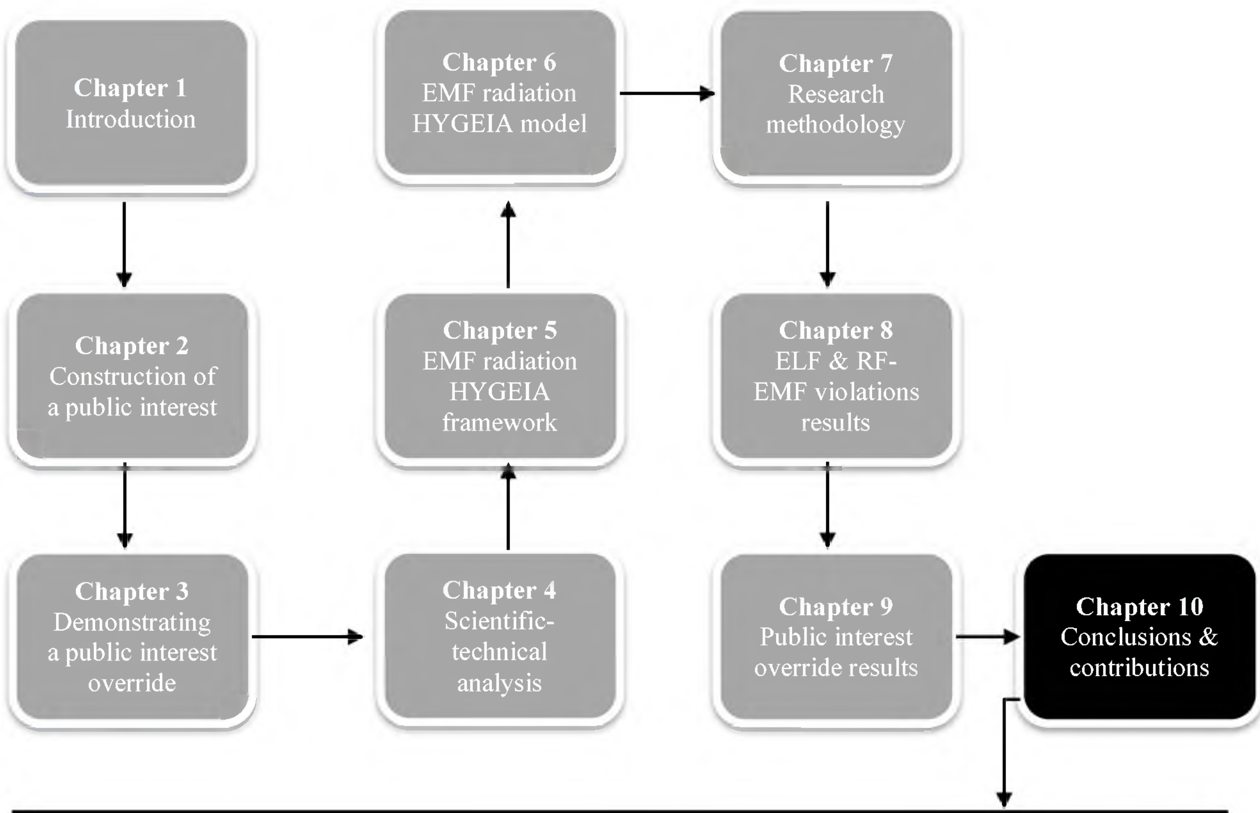
The chapter also identified and assessed the scenario of a prisoner's dilemma between the organs of the state and industries, as well as how it may fuel and justify public concern toward EMF radiation exposure (discussed in Chapter 1 and 4) when examined against Judge Kgomo's (2012) ruling.

PIO is existing legislation that invokes public interest as the 'right to know'. Multinational judicial deliberations on the 'right to know' have ruled in favor of a PIO as demonstrated in this study (CTIA *v* City of Berkeley, 2017). Deliberations on the 'balance of probabilities' found disclosure was reasonably related to a substantial governmental interest, was purely factual, and that the request was far from conflicting with national law and policy.

The researcher recommends the implementation of a continuous EMF radiation monitoring information system (MIS) to address both public concern and EMF radiation enforcement violations identified in the study. The EMF radiation MIS may be the most efficient solution in a resource constrained environment, implementable as a result of future PAIA (2000) PIO applications that utilize this research's findings to be confirmed through a judicial review process. An EMF radiation MIS would provide accurate real-time data that may be used in the model forecast simulation demonstration runs.

The next chapter provides a summary in conclusion to this study and an analysis of the contributions it may have toward academics, practitioners and to potentially influencing government policy.

CHAPTER 10: CONCLUSIONS AND CONTRIBUTIONS



10.1 Introduction
10.2 Summary of the dissertation
10.3 How the research questions were answered
10.4 Key contributions
10.5 Recommendations and limitations
10.6 Summary

CHAPTER 10
Conclusions and contributions

10.1 Introduction

The main purpose of the research study was to provide a framework and model that can be used in future demonstration runs to construct or investigate public interest overrides. This study was limited to the testing of one scenario, as described in the previous chapters. This research was done in response to a public health issue that was identified as indicating that industries refuse to supply EMF radiation emissions and technical data needed to monitor, regulate and investigate EMF radiation unregulated exposure in SA. The fact that there is no EMF radiation exposure protection standard in SA and that practitioners require an appropriate framework and modelling tool to implement said protection standard, despite intervention by industries since 2003, was an additional gap that led to the proposed framework and model.

This chapter will summarize the process that was used to answer the research questions set by the research goal in this study and the presentation thereof in this chapter:

- Section 10.2: Summary of the dissertation
- Section 10.3: How the research questions were answered
- Section 10.4: Limitations and recommendations.

10.2 Summary of the dissertation

Ten chapters, aimed at answering the research questions and at meeting the objectives that were outlined in Chapter 1 have been presented in this dissertation.

This study focused on constructing a public interest EMF radiation exposure HYGEIA framework (Chapter 5) and model (Chapter 6) that can perform forecast simulation demonstrations runs to demonstrate a PIO (Chapter 9). In order to achieve this, factors that enabled the demonstration of a PIO (Chapters 3 and 9), using scientific and objective modelling, were sought through literature reviews (Chapters 2, 3 and 4) and consultation with practitioners (Chapter 7). In this chapter a summary of what has been involved during the research period is presented.

Various outputs were obtained from each chapter. This chapter will focus on providing a conclusion of the study. In the next section the author reflects on the research process and the extent to which the research questions were answered.

10.3 How the research questions were answered.

To answer the research questions listed in Chapter 1, the study followed Wilkinson's (2000) practitioner research methodology outputs by:

- Section 10.3.1: Solving a specific problem.
- Section 10.3.2: Contributing to the learning of the discipline.
- Section 10.3.3: Contribution to influencing government policy.

The practitioner research methodology approach in this study is elaborated on in this section.

10.3.1 Solving a specific problem

A review on the kind of EMF biological effects (toxicology, subclinical, and epidemiology), classification by authoritative bodies and knowledge gaps was carried out in Section 2.2. The author is not a medical expert and therefore further investigation study would be needed. The literature review concluded that low dose EMF radiation exposure can affect multiple biological systems in different ways and population categories have varying vulnerability thresholds. Due to the potential harm from exposure to EMF radiation, legally binding exposure standards have been established in many countries worldwide.

There is no national EMF radiation exposure protection in SA for static, ELF and RF (discussed in Section 1.1). However, the development and implementation of a national EMF radiation protection standard is supported by a number of SA legislative Acts and international treaties binding on SA (Chapter 2). In this study a review of public and private bodies' documents, coupled with consultations between regulatory and legislative practitioners (listed in Section 1.4 and Appendix Section 7.1), revealed a suspension of a national EMF radiation protection standard by industries since 2003 (Section 2.7.2). Industry cited that the granting of access to data would be contrary to their strategic economic interest. Industries and the DHSA recommend a voluntary EMF radiation exposure guideline, that is a selectively scoped paradigm to the potential biological effects (STEP model), instead. The DHSA's reports may be identified as 'weighted' and in conflict with international judicial deliberations. International judicial deliberations ruled that the STEP model may not guarantee adequate protection against long-term exposure to EMF radiation. When the problem space is reviewed against SA's legislation (defined in Chapter 2 and 3) EMF radiation exposure in SA demonstrates the case for a public interest.

Regulatory and legislative development practitioners ('practitioners' listed in Section 1.4) in SA revealed the denial of access to data needed in monitoring EMF radiation exposure, by industry. The consulted domestic practitioners also acknowledged lacking the required understanding and expertise in EMF radiation regulation and monitoring.

Recent model findings declared that a tiny incidence of diseases resulting from exposure to EMF radiation could have broad implications to public health, social accounting and the economy (Chapters 1 and 4). For that reason 'practitioners' have expressed the need for a public interest framework and modelling tool which can incorporate stakeholder input and biophysical datasets for the valuation of ecosystem services (discussed in Section 4.5)

The goals of the framework and model are to uncover the current and future limits of EMF radiation exposure system functions to support human wellbeing needs and to explore the benefits and losses associated with alternative futures.

A comparative visual geospatial analysis outputs from the constructed model contributed to demonstrating a PIO function. The model, coupled with the PIO function, may assist policy makers to develop a regulatory EMF radiation exposure standard that balances between public health concerns and controlling the levels of exposure, while remaining a digital economy.

10.3.2 Contributing to the learning of the discipline

The purpose of this section is to highlight the four contributions of this study:

- Section 10.3.2.1: Enable a greater understanding of the EMF radiation exposure problem space to academics and practitioners.
- Section 10.3.2.2: Construction of a public interest EMF radiation framework.
- Section 10.3.2.3: Construction of an EMF radiation HYGEIA model to demonstrate the constructed framework.
- Section 10.3.2.4: Demonstrate a PIO function from the outputs of the EMF radiation HYGEIA framework and model.

10.3.2.1 Greater understanding of EMF radiation problem space

The public health safety recommendations, standards and guidelines, regarding the exposition for EMF radiation, differ considerably depending on the organization, manufacturer or body which publishes it (Section 2.2). As discussed in Chapter 2, the general contention is that EMF radiation dosimetry models' safety limits can be organized into two categories, namely STEP and LTCEP models.

The publishing of two considerably separate EMF radiation dosimetry paradigm models has led to confusion and debate between practitioners. The contribution to solving the specific problem therefore requires drawing stakeholder input and biophysical datasets from multiple disciplines.

10.3.2.2 Construction of public interest EMF radiation framework

The study aimed to construct a public interest framework, from the systematic literature review (Chapters 2-4) by drawing input from multiple disciplines (Chapter 5). The purpose of the framework is to provide a supporting underlying system providing functionalities and/or solutions to the particular problem area. Coupled entities within the framework provide abstraction in which parts of multiple established frameworks can be extracted and selectively specialized by the researcher, providing specific functionality to the particular problem area. The constructed framework enables the construction of an EMF radiation HYGEIA modelling tool.

10.3.2.3 Construction of an EMF radiation HYGEIA model

A HYGEIA represents a public health modelling tool that focuses on prevention in the context of public interest. The outputs from the constructed EMF radiation HYGEIA model (Chapter 6) provided a comparative geospatial analysis of the framework EMF radiation policy inputs to the model for the investigated area. Using census block data, the HYGEIA model can be used to assess the vulnerability of various demographic groups over time and location and can forecast morbidity and mortality under current and future STEP and LTCEP model conditions, as well as under conditions that mitigate EMF radiation extremes.

Both the framework and model contain a systems feedback loop. After each demonstration run iteration the feedback mechanism enables both the framework, and model to be updated and to evolve, based on the previous iteration outputs. Furthermore, during the demonstration run, new data patterns may emerge that were not anticipated in the original research design.

10.3.2.4Demonstration of a public interest override function:

The processed framework and model outputs serve as inputs to the constructed PIO checklist (Chapter 3). The demonstration of a PIO in Chapter 9 may enable academics and practitioners to further explore the problem of EMF radiation exposure in SA and to potentially gain access to detailed facts and data needed to enable monitoring and regulation.

10.3.3 Contribution to influencing government policy

The study aimed to provide a contribution that may influence government policy. The investigation of existing EMF radiation and public health knowledge in SA was conducted by critically reviewing literature and SA practitioner understanding of the STEP and LTCEP models, scientific opinions, domestic and international legislation, case rulings and framework entities used in the construction of a proposed public interest model.

SA has various legislation supporting the implementation of a national EMF radiation exposure protection standard using the LTCEP model. The construction, demonstration and testing of the EMF radiation HYGEIA framework and model in this study presented the single iteration case for a PIO function. Following this study, a favourable judicial review of the research findings would validate the presented PIO function. The demonstrated PIO function would enact the public interest clause within multiple SA pieces of legislation and may thereby enable academics and practitioners in the development of new EMF radiation exposure regulations in the interest of public awareness and public health. Furthermore, the PIO would enable access to detailed facts and data for practitioners to use in successive iteration demonstration runs of the framework and model. The exposed public interest scenario has led to interest (by the practitioners listed in Section 1.4) in the findings of this study. If relevant thereto it may be used in the development of new regulations in the interest of public awareness and public health (discussed in Chapter 2).

The next section discusses the recommendations and limitations of the study.

10.4 Recommendations and limitations

The study was limited in the application of an EMF radiation HYGEIA model to humans only, but future studies should be extended to include other ecosystem services, such as pollinators, vegetation and sea life (discussed in Section 4.13).

The researcher faced a steep learning curve in conducting this CHANS interdisciplinary scientific research. The data modeling exercise revealed that there is still a great deal to be learnt, but that it is challenging to be proficient in all EMF radiation related disciplines. The application of the MIMES framework (Chapter 4) brings relief to the overwhelming pressure of trying to be proficient in the related EMF radiation disciplines, because the MIMES IS enables online collaboration of experts in the construction and running of forecasting simulation models.

In consultation with international experts in the field of the research of EMF radiation, it was criticized that, traditionally, only one thread of this research would be explored as a full thesis or dissertation. Comments referred to the scope of this public interest research being too large. The researcher would agree under typical circumstances, however, the international researchers seemed to fail in identifying the purpose of this public interest research, given the following domestic problem spaces:

(1) Research in the field of EMF radiation and public health has been extremely limited and stifled in SA (Regulator8, 2016b). Consultation with domestic researchers prior to this study, who attempted to conduct EMF radiation and public health in SA, were hindered, reporting political obstacles, in addition to restricted access to data required for epidemiological studies;

(2) The fulfilment of RQ_5 as a PAIA (2000) PIO (Chapter 9) may potentially enable future studies and researchers to gain access to data that has hindered prior attempts of EMF radiation related public interest research in SA;

(3) The researcher believes that the conventional single thread approach in point (1) is ineffective in isolation, because common complaints by published studies are the lack of integrative multidisciplinary modelling of potential EMF radiation exposure, the effect it may have on the population and the identification of the economic impactors in order to leverage policy development. The choice of the MIMES framework IS may contribute to addressing these complaints.

Future academic SA research should attain proactive support from the university law department, or judicial review body representative, in its PAIA (2000) applications as part of the data mining methodology. Unfortunately, this research was unable to get assistance from the Rhodes University law department and linked legal aid clinic, because the department is not well versed in PAIA (2000) and was therefore not confident in submitting a PAIA (2000) application to the court for relief in a judicial review. The study was thus unable to get assistance in gaining access to detailed data needed in this study and, in addition thereto, the research findings were also unable to be confirmed under judicial review.

Based on the literature review, it is recommended that cooperative agreements with the investigated municipality are established well in advance, as this has proven to be a lengthy administrative process. The delay may be expedited by hands-on support from a senior university representative with the necessary authority. The formalized co-operation agreement may aid in the access to unfiltered data and may leverage inter-personal relationships with municipal personal that may develop during the research term.

This form of applied research may take many years, due to administrative delays, and, therefore, it is recommended that a member of faculty research staff or PhD candidate be involved in the research programme and for him/her to be present during the lifecycle of the public interest research. Sub-sections of the research may be delegated to post-graduate studies, i.e., masters and honours.

Review of highly cited published findings in the domain of EMF radiation and public health identified a common pattern of the interdisciplinary collaboration of researchers. The development of a longer term research programme may also provide improved access to research funds for specialized equipment and for commercial software licenses needed in the proposed public interest research.

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APPENDIX TO

CONSTRUCTING AN EMF RADIATION HYGEIA FRAMEWORK AND MODEL TO DEMONSTRATE A PUBLIC INTEREST OVERRRIDE

MASTERS OF SCIENCE

of

RHODES UNIVERSITY

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APPENTIX TO CHAPTER 1
Introduction and project overview

1.1 Key terms and definitions

To prepare the reader to understand the intentions of this study and the problem statement it is necessary to briefly identify and clarify the meaning of key concepts used in this and following chapters.

Anthroposphere: sometimes also referred as technosphere, is that part of the environment that is made or modified by humans for use in human activities and human habitats. It is one of the Earth's spheres.

Broad Implications for Public Health: EMF radiation exposure related diseases have wide ranging and mostly adverse impacts on human health (IPCC, 1995). These impacts would arise by both direct and indirect pathways and it is likely that the indirect impacts would, in the longer term, predominate. Members of the public whom display reactions to intolerable EMF radiation exposure levels may be diagnosed with Electromagnetic Field Intolerance Syndrome (EMFIS) (Belpomme, 2011). The intolerance is clinically described as a syndrome due to the broad group of symptoms that consistently occur together or as a condition characterized by a set of associated symptoms.

Direct health effects include increases in morbidity, mortality and illness due to an anticipated increase in the intensity and duration of unregulated EMF radiation exposure. An increase in hazard conditions would cause a higher incidence of death, injury and psychological disorders.

Indirect effects include neurological impairment or abnormal brain functions and allergic disorders due to Anthroposphere enhanced increases in some ambient EMF radiation levels. Exposure to other pollution and stressful events combine to increase the likelihood of morbidity and mortality. Some regions could experience a decline in human functional status as a result of adverse impacts on economic and mental productivity. Limitations on human service delivery capacity also will have human health consequences (IPCC, 1995).

Quantifying the projected impacts is difficult because the extent of EMF radiation exposure health disorders depends on numerous coexistent and interacting factors that characterize the

Vulnerability of the particular population group, including environmental and socioeconomic circumstances, nutritional and immune status, population density, EMF radiation regulation and access to quality health care services.

Census block data: census block data is the smallest geographic unit used by a countries census bureau for tabulation of 100-percent data, data collected from all houses, rather than a sample of houses.

Couple Human and Natural Systems (CHANS): is an emerging field of interdisciplinary science that is used to address natural resource management and sustainability questions at an ecosystem scale. Rooted in systems theory, CHANS science seeks to understand the connections, feedbacks, and trajectories that occur as a result of natural system and human system processes and exchange.

Climate change: is a change in the statistical distribution of environmental patterns when that change lasts for an extended period of time. A change in global or regional climate patterns, attributed largely to the increased levels of detrimental effects produced by unregulated pollutant emissions often referred to as global warming.

Climate Change Framework: The United Nations Framework Convention on Climate Change (UNFCCC) is an international environmental treaty negotiated at the Earth Summit in Rio de Janeiro from 3 to 14 June 1992, then entered into force on 21 March 1994. The framework set no binding limits on climate change pollutant emissions for individual countries and contains no enforcement mechanisms. Instead, the framework outlines how specific international treaties (called "protocols" or "Agreements") may be negotiated to set binding limits on climate change pollutant emissions.

Dosimetry: measurement of the absorbed dose delivered by EMF radiation, the term is better known as a scientific sub-specialty in the fields of health physics and medical physics, where it is the calculation and assessment of the radiation dose received by the human body.

Dosimetry scientific views: Similar to the argument of global warming, there are groups of scientists that believe that global warming is real and others who do not. In EMF radiation, scientists have different opinions on the scope of EMF radiation exposure and how it is to be measured. The dosimetry equations, approaches and scope employed between STEP and LTCEP model endorsers are considerably different hence, both the STEP and LTCEP model having considerably different scientific views.

Ecosystem services: Humankind benefits in a multitude of ways from ecosystems. Collectively, these benefits are known as ecosystem services. Ecosystem services are regularly involved in the provisioning of essential services to the facilitation and growth of life on Earth. Ecosystem services have been grouped into four broad categories: provisioning, regulating, supporting and cultural. Increasingly, government bodies and research agencies are assigning economic values to ecosystem services to help inform decision-makers.

EMF (Electromagnetic Field): a field of force that consists of both electric and magnetic components, resulting from the motion of an electric charge and containing a definite amount of electromagnetic energy. EMFs are mainly characterized in terms of frequency and strength.

EMR (Electromagnetic Radiation): is the radiant energy released by certain electromagnetic processes. Visible light is an electromagnetic radiation. Other familiar electromagnetic radiations are invisible to the human eye, such as radio waves, infrared light and X-rays.

Framework: a basic supporting underlying a system providing functionalities / solution to the particular problem area.

Framework entities: an abstraction in which parts of multiple established frameworks can be extracted and selectively specialized by the researcher providing specific functionality to the particular problem area.

GIS (Geographic Information System): a system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data.

Hazard conditions: A hazard is a *subjective* concept of the circumstances under which ecosystem services intersect and or may influence the complex system, posing a level of threat to life, health or environment. Hazards can be dormant or potential, with only a *theoretical* risk of harm. Hazard and possibility interact together to create risk

Heat map: a geographical representation of data where the individual values contained in a matrix are represented as colours.

HYGEIA: originates from the Greek gods and goddesses stated in the medical 'Hippocratic Oath'. The symbolic representation is the 'Bowl of Hygeia', the cup symbol of medicinal potion with the serpent of wisdom. Hygeia represented a public health model that focused on prevention in the context of public interest. HYGEIA in this research makes use of the Multi scale Integrated Models of Ecosystem Services (MIMES) Framework and model libraries. It is a model in forecasting the effects of climate change on human health and health-environment interactions.

ICNIRP (International Commission on Non-Ionizing Radiation Protection): an independent scientific organization, whose aims are to provide guidance and advice on the health hazards of non-ionizing radiation exposure.

Localized radiation Hotspots: exposure in the body of a nearby person that exceeds the partial-body limits while not exceeding the whole-body limit. The whole-body-limit is the regulatory limit for minimizing the potential risks of stochastic biological effects associated with radiation.

Multi scale Integrated Models of Ecosystem Services (MIMES) Framework: the Multi scale Integrated Models of Ecosystem Services is a dynamic Geographical Information Systems (GIS) system designed to address the magnitude, dynamics, and spatial patterns of ecosystem service values. Uses an integrated suite of models coupled through an interaction matrix. The matrix allows a MIMES case study to pass information among surveys, Geographical Information Systems, and process knowledge for developing fully functional spatial dynamic models. Considers multiple ecosystem goods and services simultaneously and aims to explore their tradeoffs, and responses to multiple, potentially interacting, environmental and human drivers. Allows users to understand the long-term sustainability of ecosystem services under different scenarios of human action. Is a sophisticated and transferable system that allows researchers to upload improved models and datasets while simultaneously allowing model users to calculate the dynamics of ecosystem services, their links to human quality of life, and their sustainability under various management scenarios.

PAIA (Promotion of Access to Information Act, 2000): to give effect to the constitutional right of access to any information held by the State and any information that is held by another person and that is required for the exercise or protection of any rights; and to provide for matters connected therewith.

Public Interest Override function: Section 46 and 70 contained within PAIA (2000) is a benchmark clause for determining if access to information must be granted stating (a) the disclosure of the record would reveal evidence of a substantial contravention of, or failure to comply with, the law; or (ii) an imminent and serious public safety or environmental risk; and (b) the public interest in the disclosure of the record clearly outweighs the harm contemplated in the provision in question. Additionally, it may include the public interest in upholding the law as well as the publics' awareness of public safety or environmental risks. There may also be the public interest in furthering the general goals of the Act.

Power Density W/ m^2 (Watts per square meter): in high radio frequency applications, is typically described by the non-directional power density multiplied by the gain of the transmitter.

RNCNIRP (Russian National Committee on Non-Ionizing Radiation Protection): an independent scientific organization, whose aims are to provide guidance and advice on the health hazards of non-ionizing radiation exposure.

SAR (Specific Absorption Rate): a thermal measure of the rate at which radiofrequency (RF) energy is absorbed by the human body over a period of time. This is divided into three localized categories of the whole-body average, head and trunk, and limbs.

Science-based: EMF radiation exposure limits are based on expert evaluation of the scientific literature to identify potential adverse effects of exposure. The resulting limits are designed to exclude identified hazards with an appropriate margin of safety.

Spurious emissions: is any RF EMF frequency not deliberately created or transmitted, especially in a device which normally does create other frequencies. A harmonic or other signal outside an RF EMF transmitter's assigned channel would be considered a spurious emission. Emission on a frequency or frequencies which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information.

µW/cm^2 (microWatts per square centimeter): an increasingly common unit of measurement for measuring radio frequency radiation defined as the amount of power per unit area in a radiated microwave field or other type of electromagnetic field. It is used as a reference for Power Density limits in STEP model regulatory guidelines.

WiFi: a technology that allows electronic devices (computers, smartphones, tablets or other devices) to connect to a wireless local area network (WLAN) to connect to the internet or communicate with one another wirelessly within a particular area, using high frequency radio signals (ARD) to transmit and receive data over distances.

Values Risk Threshold Limit: a subjective value determined by the associated community's scientific paradigm, social and cultural values. It is the level to which it is believed a person can be exposed to day after day without adverse effects. It is not a static definition since new research can often modify the risk assessment of substances and new laboratory or instrumental analysis methods can improve analytical detection limits. It also reflects the amount of risk acceptable to the community of interest given the economic benefit. Economic can be further defined as some communities include social accounting into the economic forecasts while others do not include it in their paradigm.

Appendix to CHAPTER 2 Construction of a Public Interest Review of Literature

2.1 International RF-EMF radiation power flux density limits for GSM1800

STEP model reference levels in red. LTCEP model limits in green.

Table 2.1 International EMF Radiation Density Limits for GSM1800 (Kumar, 2010)

Power density (W/m^2)	International exposure limits adopted by various countries
10	FCC (USA, Canada, Japan) OET-65
9.2	**ICNIRP and EU recommendation 1998**
3	Canada (Safety Code 6, 1997) – certain states
2	Australia
1.2	Belgium (ex Wallonia)
1.0	India, Israel
0.5	New Zealand
0.24	Exposure limit in CSSR, Belgium, Luxembourg
0.1	Exposure limit in Poland, China, Italy, Hungary
0.06	Paris
0.095	Exposure limit in Italy in areas with duration > 4hours
0.095	Exposure limit in Switzerland
0.09	ECOLOG 1998 (Germany) Precaution recommendation only
0.025	Exposure limit in Italy in Vulnerable areas
0.02	Exposure limit in Russia (since 1970), Bulgaria, Hungary
0.001	"Precautionary limit" in Austria, Salzburg City only
0.0001	*EU Parliament Scientific & Technological Options Assessment (STOA)*
0.0009	BUND 1997 (Germany) Precaution recommendation only
0.00001	New South Wales, Australia

2.2 EMF radiation guidelines, exposures and effects of RF-EMF radiation

In purple are the various RF-EMF radiation guidelines per country referenced in Table 2.1. In blue are the various RF-EMF radiation devices and spatial correlation of RF-EMF radiation levels per the Inverse Square Law and red is the potential related health effects per the peer-reviewed studies listed in Firstenberg (2001). The red speech bubble highlights the STEP model endorsing countries. The green speech bubble highlights the LTCEP model endorsing countries and their recognition of the respective health effects.

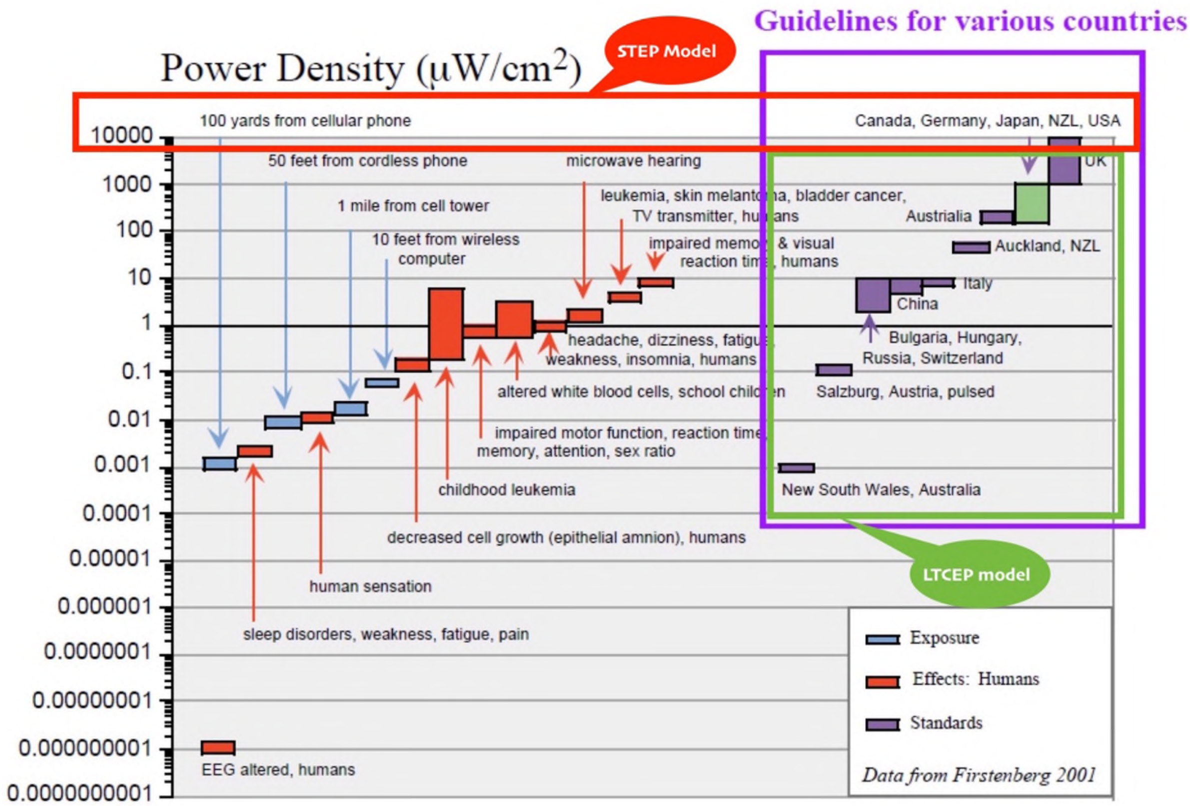


Figure 2.1 Guidelines of various countries matched against spatial EMF radiation dissipation by the inverse square law and potential associated health effects to the EMF radiation (Firstenberg, 2001)

2.3 DHSA weighted published findings and misleading public awareness campaigns

A possible pattern of selective published EMF radiation research and misleading public awareness campaigns by the DHSA were identified. An examination of the DHSA's historical EMF activities reports and reference to the DHSA in other public bodies and industry reports, the following were identified:

(1) misleading EMF radiation public safety monitoring by the DHSA's annual EMF radiation reports. Contained within the DHSA annual activities EMF radiation reports for 2008 and 2013 is the disclosure of data availability of EMFDS12's base stations and RF-EMF radiation measurements conducted over many years (DHSA, 2008; DHSA, 2013). The DHSA (2008, 2013) reports stated RF-EMF radiation measurements conducted by EMFDS12 of over six thousand cellular ARD base stations, are within STEP model reference levels and that the data is available. However, when the researcher requested Regulator8 (2016b) for the data,

the response was that the data has never been reviewed or audited by the DHSA and only the summary notification was provided to the DHSA;

(2) in reviewing further DHSA national EMF radiation reports and literature on the public domain, it appears that the DHSA may be providing false conflicting information to the public about the academic EMF radiation research activities in SA;

(2a) the DHSA is selective on publishing reports on domestic research studies. In a review of EMRSA's (2014) open letter to the DHSA, the DHSA was notified of Daniels et al. (2009) University of KwaZulu-Natal's experimental study. Daniels et al. (2009) identified RF-EMF radiation may lead to abnormal brain functioning, however, the domestic research was never published in any of DHSA annual EMF radiation reports;

(2b) DHSA's (2016c) annual EMF radiation report stated, that for 2016, it is not aware of any current research activity involving EMF radiation and public health. This is contradicted by the researcher engaging in lengthy consultations with Regulator8 (2016a, 2016b) at the start of 2016, on the EMF radiation GIS application for this dissertation. In Regulator8 (2016a, b), the researcher was informed there had been no EMF radiation and public health research in SA since the 1990s but the DHSA (2005) annual EMF radiation report revealed research being conducted at the University of Tshwane by Falzone et al., (2008) on the potential effects RF-EMF radiation has on sperm. Falzone et al., (2008) findings that RF-EMF radiation has no effect on sperm, however, multiple studies confirmed otherwise (Ozguner et al., 2005; Erogul et al., 2006; Li et al., 2010). In examining Falzone et al., (2008), the explanation of no identified RF-EMF radiation correlation may be because the applied methodology followed the STEP model. The exposure was based on short-term exposure however, a literature review within Falzone et al., (2008) examined the LTCEP model and prolonged exposure identified a correlating negative effect on sperm. Examination of the Falzone et al., (2008) methodology appears scientifically sound, however, in line with STEP model limitations, the research findings are based on very specific parameters. Falzone et al. (2008) later republication Falzone et al., 2011, re-assessed and concluded that the original study results could indicate a significant effect of RF-EMF on sperm fertilization potential;

(3a) the DHSA is advertised to industry and regulatory bodies, as the responsible body, for regulating, maintaining and investigating EMF radiation standards in SA (CCPTM, 2015; Regulator4, 2016). In Telkom's annual report (2012:104) under "product responsibility", it was advertised that the DHSA is responsible for regulating human health aspects to EMF radiation. That the DHSA has safety standards in place, which specifies the limit of RF-EMF radiation being the STEP model ICNIRP. The report refers to supporting STEP model endorsing publishing organizations. Telkom's annual report (2012:104) is contradictory to statements published by the DHSA in CCPTM (2015:47) in that (3a) STEP model reference levels are voluntary;

(3b) there is no national EMF radiation standard because of industry objections since 2003. As such, the DHSA has no mandatory safety standards and systems in place with respect to EMF radiation (DHSA, 2005); (4) the DHSA strongly advocates the public to ignore LTCEP and Precautionary model literature and endorsing bodies;

(4a) Identified in CCPTM (2015) and DHSA's (2016c) report, the STEP model is the only science-based means of dealing with EMF radiation and public exposure;

(4b) groups in SA that advocate LTCEP model are labelled as activists that "exploit the general public's ignorance about and the fear of electromagnetic fields for their own purposes" (DHSA, 2016c:1).

Points (4a) and (4b) of the DHSA are contradicted by over half the world's population endorsing science-based LTCEP models. Additionally, SA operates on a reactive system requiring members of the public to lodge complaints with regulatory bodies, weaknesses in current policies and recommendations in order for the judicial review process to produce new and or updated national protection standards to be implemented in the interest of public safety and awareness (Regulator1, 2016; Regulator3, 2016; Government Gazette, 2016).

2.4 SA municipal bylaws supportive of EMF radiation protection

The NMBM (2011) policy recognizes public concerns for potential RF-EMF radiation over both the short and long terms. Stipulation from the DHSA within the NMBM (2011) policy recommends the STEP model, and as such, there is no public health risk in SA. However, the policy recognizes global trends following the LTCEP model.

The NMBM (2011) has chosen to incorporate elements of both the STEP and LTCEP models in requiring all cellular transmitter installations subject to review. Additional requirements are:

(1) installer is required to provide proof that RF-EMF emissions are within STEP model reference levels;

(2) Co-location sites do not allow combined RF-EMF emissions to exceed STEP model reference levels;

(3) no transmitter shall be within school grounds without the school's governing body providing proof that parents have been consulted and that parents are aware of the lack of knowledge concerning RF-EMF radiation on humans.

Potential weaknesses and contradictions identified in the NMBM (2011) policy are:

(1) the ICNIRP (2002) of the STEP model recommends lowered enforcement EMF radiation levels in vulnerable population areas but the NMBM (2011) policy recommends one limit for all areas regardless of age or environmental sensitivity;

(2) EMF radiation levels at sites must be provided by service providers to prove that they are within STEP model reference levels. In contradiction, Regulator9 (2015), Regulator8 (2016b) and CCPTM (2015) confirm private telecommunications companies are not willing to provide technical specifications of ARD transmitters or values of EMF radiation levels at sites;

(3) the restriction of no cellular transmitters on school grounds does follow international trends, however, under the cited LTCEP Precautionary model practices a buffer zone of 300 - 350 meters around school grounds is also established (van Leeuwenhoeklaan, 2011). The rationale for the buffer zone is shown in **Error! Reference source not found.** below. Cellular ARD transmitter parameters typically have a height above ground of 15-50 meters and an ARD transmitter angle of 5 - 10 degrees' downward tilt, the boresight (main beam) would intersect the ground between 50 – 300 meters. Plus, an additional distance must be added in consideration of EMF radiation propagation Reflection, Diffraction and Scattering (Mann et al., 2000).

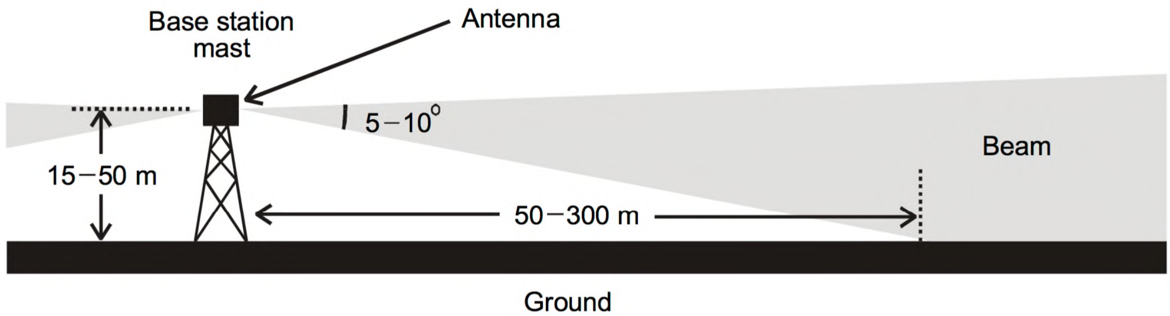


Figure 2.2 Elevation showing the shape of the EMF beam formed by a typical antenna used with a macro cellular base station (Mann et al., 2000)

The KM (2012) policy draws its mandate from the SA (1996) Constitution requiring the promotion of a safe and healthy environment for its citizens, and measures that prevent pollution-related environmental degradation while promoting justifiable economic and social development. As a result, KM (2012) specifies acknowledgment to health implications that cellular RF-EMF transmitters pose to communities. The KM (2012) policy declares it possible in selecting cellular transmitter locations to maximize the coverage area that can be reached while at the same time ensuring that the environment and heritage value of the area is not adversely affected and that negative visual impacts and impacts on human health are avoided. However, KM (2012) also acknowledges it is not possible to prohibit the erection of cellular transmitters in densely populated residential areas as the greatest number of users are in this area, and therefore they have to be covered. The KM (2012) policy is summarised with the following restrictions:

(1) options for installations in industrial, commercial and business areas must be explored first before investigation into residential areas as a site option;

(2) no installation is allowed within an area of environmental and heritage significance;

(3) if a transmitter is installed on a residential property, the installer must provide valid reasons for the site choice;

(4) cellular transmitters should not be located within a buffer zone of five (5) km radius to any educational facility;

(5) service providers are required to provide a five (5) year plan on-site installations and locations with co-location options explored first;

(6) illegal erections of cellular transmitters may be sentenced to a fine or imprisonment for a period not exceeding five (5) years. In reference to point 5 above, KM (2012) encourages co-location and provides a lowered cost to telecommunication providers, but that telecommunication companies are typically unwilling to co-operate on said co-location arrangements.

The KM (2012:9) policy concludes its RF-EMF radiation public health resolution in accordance with Schedule 4 of the SA (1996) Constitution as "a local government entity it is our responsibility as council to ensure that these structures are well managed and that principles are in place to control the way these structures are developed to ensure that our environment is sustainable for present and future generations".

The KM (2012) policy has used SA legislation in the development of a policy that endorsers the LTCEP and Precautionary model. Specific EMF radiation limits are not set within the policy in line with EMF radiation power density Far-Field calculations. As a result, it can be assumed that vulnerable areas would hold lowered EMF radiation levels in line with the LTCEP model. The enablement of buffer zones eases the municipal zone planning procedures in avoiding technical EMF radiation specifications and monitoring which are proving challenging with SA telecommunications providers unwilling to provide the technical data required for EMF radiation monitoring (Regulator9, 2015; CCPTM, 2015).

The CCPTM (2015) policy prioritizes and ranks economic considerations and visual impact above possible EMF radiation public health and safety concerns. With respect to public health and safety, the CCPTM (2015) contradicts itself in the following:

(1) stipulates that DHSA has set the STEP model reference levels for adoption by the CCPTM (2015), but within the CCPTM (2015) policy the DHSA states that it has no national mandate and that STEP model reference levels are only a recommendation. Additionally DHSA, within the policy, states "local and other authorities, in considering the environmental impact of any particular base station, do not need to and should not attempt, from a public health point of view, to set any restrictions with respect to parameters such as distance to the mast, duration of exposure, height of the mast, etc." (CCPTM, 2015:47);

(2) should the CCPTM (2015) receive research linking EMF radiation to health issues, the CCPTM (2015) may impose further restrictions on EMF radiation limits. EDA (2016) warned that recommendations and safety to RF-EMF radiation signals are very different depending on the organization which publishes it. The DHSA only publishes guidelines on the STEP model. However, no reference is made to review of LTCEP model literature or international standards. Additionally, within the CCPTM (2015) policy reference is made to literature investigated from the Department of Planning, Australia. Australia's RF-EMF power density limits are 1/5th the value of the STEP model reference levels in CCPTM (2015);

(3) finally, a spatial restriction of no habitable building is permitted within fifty (50) meters line-of-site of a cellular ARD transmitter. The CCPTM (2015) policy does not provide an indication for the reasoning of the established safety levels, except, the diagrams used to explain the rationale exclude units of measurement and additional specific contexts, rendering it non-viable to criticize or validate the rationale limits from a regulatory or academic perspective.

Odeku's (2014) investigation into management and administrative challenges in environmental pollutants in SA in general, states there is inadequate information dissemination creating little public awareness and threat to the environment. For example, the EDA (2016) warned that recommendations and guidelines regarding the exposition to pulsed RF EMF radiation signals are very different depending on the organization which publishes it. If the majority of environmental safety guidelines are published according to the STEP model, the science-based exposition of the LTCEP model is unlikely to be known to the public or government agencies. Odeku's (2014) investigation also identified that the specialist and technical expertise required for effective environmental investigations and litigations are scarce because most officials do not have the required skills.

For example, Regulator2 (2016) explained their department is not having the skills or training to review the technical parameters of RF-EMF transmitters. CCPTM site building inspectors are not trained to inspect or verify RF-EMF ARD transmitters installed at a site to which a permit was authorized. Therefore, no investigation, monitoring or testing is conducted or followed up on unless it is mechanically engineering related, for example, the height of the tower.

Another example is from Regulator4 (2016) explaining holding ownership of some of the RF-EMF measuring equipment required for a site measurement, however, they do not fully understand how to utilize the equipment or what the site RF-EMF radiation research measurement protocol is. When a public concern is raised at a cellular site installation, the procedure is for the private telecommunication company to hire an external private consultant. The only report given to Regulator4 is a page stating that RF-EMF radiation levels are safe within STEP model regulatory reference levels, but no measurement values or specific information is shared (Regulator4, 2016).

Odeku (2016) points out that the skill gap can easily be solved through sufficient training. The problem tied to this solution is that there are inadequate resources to implement sufficient training. Regulator8 (2016a, 2016b) confirmed with the department not having the allocated resources to setup an RF-EMF radiation monitoring database or survey, let alone having the resources to attend conferences on the subject matter.

Odeku (2014) expresses that environmental pollution continues to thrive mainly due to lack of expertise in the prosecution of environmental offenses in SA. Odeku (2014) explains this problem is linked to inadequate penalties in the statues to deter perpetrators.

For example, Walton (2016:1) explains the erection of RF-EMF transmitters occurs illegally with the lack of ARD transmitter location information being a problem for the city with telecommunication service providers being "very reluctant to publish their structures spatially".

In cross correlating Odeku's (2016) study with issues in EMF radiation tracking, monitoring and evaluation by different government departments this dissertation would need to identify recommended solutions that provide an exposition of both STEP and LTCEP models as well as possible practical survey and monitoring solutions in a resource constrained environment.

2.5 The debate of EMF radiation protection implementation within the EU

For EU member states, EU Parliament EMF radiation guideline recommendations are not legally binding. The EMF radiation policy in member states can be divided into three different approaches.

In the first group of member states, the recommendations have been transposed into binding national legislation (van Leeuwenhoeklaan, 2011). This means that the basic restrictions and reference levels must be applied. Countries in this group are Cyprus, Czech Republic, Estonia, Finland, France, Hungary, Ireland, Malta, Portugal, Romania and Spain. van Leeuwenhoeklaan (2011) highlights the Spanish region of Catalonia having stricter regulations than the federal government. However, in Germany and Slovakia, the EMF radiation reference levels have become de facto exposure limits despite internal conflicts with regulatory bodies advocating the LTCEP model (Bavarian State Ministry of Education and Cultural Affairs, 2007). Due to continued efforts the German national legislation, defined in the Twenty-sixth Ordinance Implementing the Federal Immission Control Act, Ordinance on Electromagnetic Fields, has mandated LTCEP model limits and spatial planning policies, particularly to ELF EMF radiation infrastructure sources (WHO, 2016c). Additionally, a strategy adopted by Germany in addressing the Precautionary Principle while still enabling proximity between the public and EMF radiation infrastructure sources, is the improvement of technologies and quality parameters, thereby decreasing adverse EMF radiation capabilities toward public health (WHO, 2016c).

In the second group of member states, the national limits based on the STEP model are not binding, and there are more lenient limits, or there is no regulation. Countries in this group are Austria, Denmark, Latvia, Netherlands, Sweden and the United Kingdom (van Leeuwenhoeklaan, 2011:4).

In the third group of member states, there are stricter EMF radiation restrictions in line with the Precautionary and ALARA principle. Countries in this group are Belgium, Bulgaria, Greece, Italy, Lithuania, Luxembourg, Poland, Slovenia, Catalonia of Spain and Switzerland (non-EU member) (van Leeuwenhoeklaan, 2011:4).

For the foreseeable future debates and differing paradigms will likely remain on the scientific and political agenda. This is predominantly, in part, due to EMF radiation emissions continually altering in characteristics and levels due to new infrastructure deployments, smart environments and novel wireless devices (Dürrenberger et al., 2014). Due to the altering in characteristics and levels, the values referenced in this public interest research may be incorrect, outdated and or different because each country may have its independent EMF radiation restriction context, (Commission on the European Communities, 2008; Bärtels & Haak-Nebbe, 2015).

2.6 STEP and LTCEP Model endorsement by country population vs GDP summary

Shown in Table 2.2 on the next page is an approximate EMF radiation protection Values Risk Threshold Limits weighted support by population and GDP values between the STEP and LTCEP models. Charted in Figure 2.3 and Figure 2.4 is a modelled comparison based on values in Table 2.2. The representation in the table is an approximation because, as discussed in Section 2.2 in the study, there are significant differences in the principles, methods and science base used for establishing EMF exposure standards in these countries. Countries that employed the LTCEP model for either ELF or RF EMF were counted in the LTCEP endorsing country. For example, Germany employs the STEP model for RF-EMF but LTCEP for ELF-EMF after a recent High Court ruling. But the employed STEP model measures for RF-EMF have stringent license applications, spurious emissions regulations, visual placement and planning etc... It can be argued that the stringent planning, monitoring and enforcement, in practice, poses less incidence of hazardous conditions when compared to a country like Poland or India that endorse the LTCEP model but have limited EMF exposure practices in comparison. Charting a detailed expansion of Table 2.2 would be a thesis on its own and is out of the scope of this study.

From a population view point, over half the world's population countries endorse the LTCEP model. Historically, the world's population majority endorse the LTCEP model with the greatest GDP economic power held by STEP model endorsing countries. However, until recently, STEP model endorsing countries have been switching over to the LTCEP model. The LTCEP model endorsement as a national EMF radiation protection standard has arisen following a High Court ruling within the respective countries, following extensive deliberation on science-based research and the EMF radiation public interest debate. (Government of Italy, 1998; Foster, 2001; Perov et al., 2009; Kumar, 2010; van Leeuwenhoeklaan, 2011; Government of India, 2012; Rajasthan, 2012; WHO, 2015a; BfS, 2016; WHO, 2016c).

Table 2.2 STEP and LTCEP endorsing countries

Country	Population (million	GDP (USD) trillion
LTCEP model endorsing countries		
Russia	143,5	2,097
China	1 357,0	9,240
Ukraine	45,5	0,177
Poland	38,5	0,525
Switzerland	8,0	0,685
India	1 252,0	1,877
Slovinia	2,0	0,005
Italy	59,8	2,149
Netherlands	16,8	0,850
Luxembourg	0,5	0,010
Liechtenstein	0,0	0,040
Bulgaria	7,3	0,054
Hungary	9,9	0,133
New Zealand	4,4	0,185
Greece	11,0	0,242
Germany	80,6	3,730
Israel	8,0	0,290
Taiwan	23,5	0,474
France	66,0	2,800
East Total	**3 134,3**	**25,6**
STEP model endorsing countries		
UK	64,1	2,678
USA	316,5	16,770
Canada	35,2	1,827
Japan	126,0	4,920
South Korea	50,2	1,305
Sweden	9,6	0,579
Spain	46,8	1,393
West Total	**648,3**	**29,5**
World Total	**7 400,0**	**107,000**

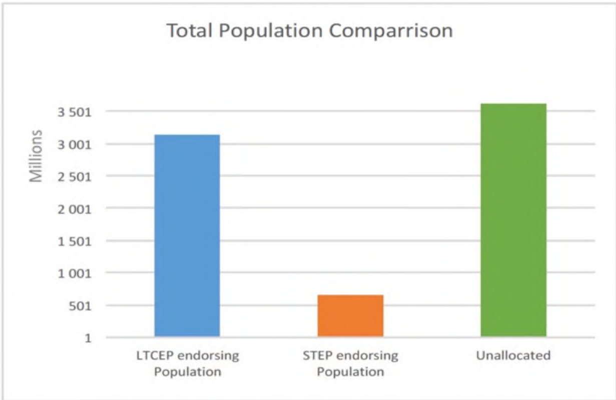


Figure 2.3 STEP versus LTCEP endorsing countries by population

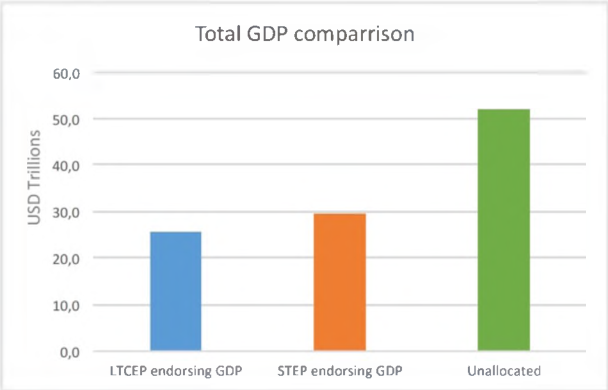


Figure 2.4 STEP versus LTCEP endorsing countries by GDP

2.7 International case precedents for evolved EMF radiation protection in India

The Government of India (2010) inter-ministerial committee report lead to the High Court order in 2012 mandating lowered RF-EMF radiation levels, stricter cellular transmitter installation permits, funds for RF-EMF radiation health hazard risk research, RF-EMF radiation public health awareness campaigns and a public access portal of cellular sites, EMF emissions and status of compliance in India (Government of India, 2012). Additionally, the Rajasthan (2012) case follows the same argument of SA's Constitution (1996) Schedule 4 Concurrent competencies of a state to employ improvements and or stricter guidelines on national policies.

Rajasthan is a State in India with a population of approximately seventy-five (75) million and a land area a quarter of SA. Rajasthan (2012) investigated the rationale of the STEP model and its practical safety implications for its citizens in determining formalized LTCEP model limits. Rajasthan's (2012) review of the STEP model revealed an evaluation of thermal EMF radiation effects, similar to the cooking effect in a microwave, and LTCEP model review includes non-thermal EMF radiation effects.

Rajasthan (2012) stated that even though non-thermal EMF radiation effects are not well defined, they are three to four times more harmful than thermal effects. Rajasthan's (2012) example of impractical STEP model safety reference levels referred to personal mobile phones which transmit between 1-2 Watts of power. The US ICNIRP STEP model reference levels for mobile devices is 1.6 W/kg (SAR) based on 6 minutes per day usage. The STEP model warns that a person should not use a mobile device emitting cellular RF-EMF for more than eighteen to twenty-four (18 – 24) minutes per day.

Evidence presented in Rajasthan's (2012) revealed crores of people using cell phones for more than sixty (60) minutes a day without realizing the violated EMF radiation health hazard.

Rajasthan (2012) then also examined the supportive EMF radiation infrastructure in cellular communications. Rajasthan (2012) identified (1) a cell operator to be divided into regions; each region is divided into a large number of cells; (2) each cell is divided into a number of sectors; (3) base stations are configured to transmit different signals in each of these sectors ,so that more operators can emit within the same area on different channels and avoid clashes with each other on the similar spectrum; (4) the emissions from base stations are twenty-four seven (24/7); (5) as a result people within ten (10) meters receive a ratio of 10,000:1 crores times required for mobile communication.

To simplify cellular RF-EMF radiation enforcement and planning, the State of Rajasthan (2012) employed a reduced RF-EMF radiation power density emission level provided by the national government and a buffer zone around vulnerable population areas. Filed as a public interest, the buffer zones were defined as follows: no towers in residential areas, especially, hospitals, schools and no erection on historical monuments; no towers within five hundred (500) meters of hospitals, school buildings, playgrounds and jails. The inclusion of jails was motivated as part of a crime prevention strategy because signal jammers proved ineffective with cellular towers within the prescribed buffer zone enabling criminals to carry out their illegal activities still.

The Rajasthan (2012) case documentation revealed an investigation that was extensive and detailed with the evidence presented by lobbyists from both sides (STEP and LTCEP, Precautionary model endorsers). The case demonstrated the power of a community/municipality/province to refine and develop its EMF radiation safety protocols that were upheld by the Indian High Court of Appeal.

2.8 SAR thermal heating example

An example of RF-EMF thermal heating in real-world application is in microwave ovens. By generating enough energy and localizing it into a small enough area results in heating the tissue due to the presence of water, as explained by Huygen's principle. EMF radiation is stored in water in several frequency ranges and because of the coherence domains from an extremely high dielectric constant, EMF waves that enter water are slowed down substantially. It is for this reason that large bodies of organic matter are an issue for wireless RF-EMF radiation signal propagation (Bärtels & Mosler, 2008). When a microwave (RF-EMF radiation) irradiates water, the EMF radiation is slowed down and broken as it enters a thicker medium, resulting in the development of ELF and ultra-low frequencies (ULF), particularly in the frequency range of 0-30 Hz (Bärtels & Mosler, 2008). When RF-EMF radiation radiates organic water containing molecules, relational resonances of EMF frequencies in the biologically relevant range result in high magnetic flux densities (Bärtels & Mosler, 2008).

APPENDIX TO CHAPTER 3
Demonstrating a Public Interest Override Review of Literature

3.1 PAIA (2000) Public Interest Override checklist

Kgomo's (2012) ruling in De Lange and another v Eskom Holdings Limited (2012) was reviewed. The criteria checklist for public interest override of 'substances released into the environment' and 'public safety' or 'environmental risk' for public interest research question three (3) were extracted into **Error! Reference source not found.** below. The data derived from the literature review, potential EMF radiation violations identified from public interest research question five (5), consultation with experts and outcomes from the PAIA (2000) applications shall be recursively processed through **Error! Reference source not found.** The result will identify if a potential public interest override holds merit.

Table 3.1 PAIA (2000) public interest override - 'substances released into the environment' and 'public safety or environmental risk' evaluation checklist (Kgomo, 2012)

#	**Public interest override questions**	**Y/N**
1a	The disclosure of the record would reveal evidence of a substantial contravention of, or failure to comply with, the law; or	
1b	an imminent and serious public safety or environmental risk; and	
2a	The public interest in the disclosure of the record clearly outweighs the harm contemplated in the provision in question.	
2b	Additionally, it may include the public interest in upholding the law as well as the publics' awareness of public safety or environmental risks.	
3	There may also be the public interest in furthering the general goals of the Act.	
	Under 'substances released into the environment' and 'public safety or environmental risk'	
4	Public interest in upholding the law as well as the publics' awareness of public safety or environmental risks.	
5	Public safety or environmental risk is defined as follows: "… means harm or risk to the environment or the public (including individuals in their work place) associated with -	
5a	a product or service which is available to the public;	

5b	a substance released into the environment, including, but not limited to, the work place;	
5c	a substance intended for human or animal consumption;	
5d	a means of public transport; or	
5e	an installation or manufacturing process or substance which is used in that installation or process.	
6	Differing opinions of one party's word against another. The applicant presents evidence and grounds for the requested information but the data holding company refuses to present or share the information for review to the court. This situation brings into reckoning the issue of public interest – whether the harm contemplated in the refusal to disclose is outweighed by the public interest. In Kgomo (2012), favor was granted to the applicant on the grounds of the information holder refusing to provide the requested information to the court for review under contemplated harm.	

Appendix to CHAPTER 4
Scientific-Technical Analysis Review of Literature

4.1 EMF radiation dosimetry

Shown in Table 4.1, is a side-by-side comparative narrative analysis of the STEP and LTCEP model in terms of field characterization, dosimetry, and measurement. Both the STEP and LTCEP models are science-based and therefore valid in their scientific findings. However, both have very different scoped science-based analysis parameters.

Table 4.1 Comparative narrative analysis of EMF radiation dosimetry models rationale

STEP model	LTCEP model
(1) Legal accountability: guideline reference level versus standard exposure limit	
EMF radiation exposure is set as a reference level for investigation.	EMF radiation exposure is set as a limit not to be exceeded.
(2) Scientific scope	
One scientific input into the formulation of societal policies.	Culmination of multidisciplinary scientific inputs into the formulation of societal policies.
(3) Scope for exposure safety assessment	
Thermal effects only: scoped to tissue heating or electrical shock.	Low intensity biological effects and cumulative exposure.
(4) Scope of dosimetry assessment and units of measurement to display results	
Tissue heating effects focus on an average effect over time. EMF radiation dosimetry reading over 6 or 20 minutes only. Unit of measurement Power Flux Density (PFD) W/m^2	Field intensity EMF radiation in V/m unit of measurement. Investigates instant peak values of EMF radiation which may be 2-100 x the PFD value. Calculates human EMF radiation cumulative exposure time over hours, days and years.
(5) Fiduciary duty and economic mandate	
Market driven, more tolerant of risk.	Social well-being accounting, less tolerant of risk.

(6) Funding source of weighted studies	
Science-based reviews are predominantly industry sponsor funded weighted-studies.	Science-based reviews are predominantly non-industry sponsor funded weighted-studies.
(7) Municipal spatial planning accountability	
Municipal spatial planning on operators' needs and economic strategy. Does not emphasize vulnerable areas.	Municipal spatial planning on public health and social accounting. Long term economic growth strategy. Recognizes vulnerable areas.
(8) Social and cultural factors	
Protestant values.	Catholic values.
(9) Methodology in establishing exposure safety levels	
Safety testing model reference levels based on single phantom to represent the general public.	Testing models incorporate safety parameters for pregnant, youth, elderly and chronically ill.
(10) Scenario scope for establishing exposure levels	
Inverse Square Law equation (selective) in Free Space propagation in RF-EMF radiation safety documentation.	Inverse Square Law equation (complete) with Maxwell's set of partial differential equations boundary parameters. Enables identification of localised hotspots and re-radiation to be included in public policies.
(11) Selective attributes, product and quality metrics	
Non-stringent spurious emissions policies.	Stringent spurious emissions policies.
(12) Period of ongoing research	
Established guidelines 1960, 1991.	Established standards 1910, 1940, 1970.
(13) Scientific opinion	
ICNIRP do not consider that the available scientific evidence regarding reported adverse health effects at lower EMF radiation exposure levels justifies a more precautionary attitude.	

4.2 STEP model reference levels and LTCEP model limits

Shown in Figure 4.1 Pulsed signal modulation comparison of V/m2 (peak) versus W/m2 PFD (average) EMF radiation levels (Maret, 2014) below is a side-by-side comparison between pulsed digital RF-EMF radiation modulation on the left and continuous analog modulation on the right. The pulsed RF-EMF radiation signal modulation peak (V/m) value is ten times (10x) in amplitude (900 units greater) than the PFD (W/m2) value (average). In contrast to the pulsed digital RF-EMF radiation signal the continuous analog waveform on the right only differentiates by 50 units between peak (V/m) and PFD (W/m2) values.

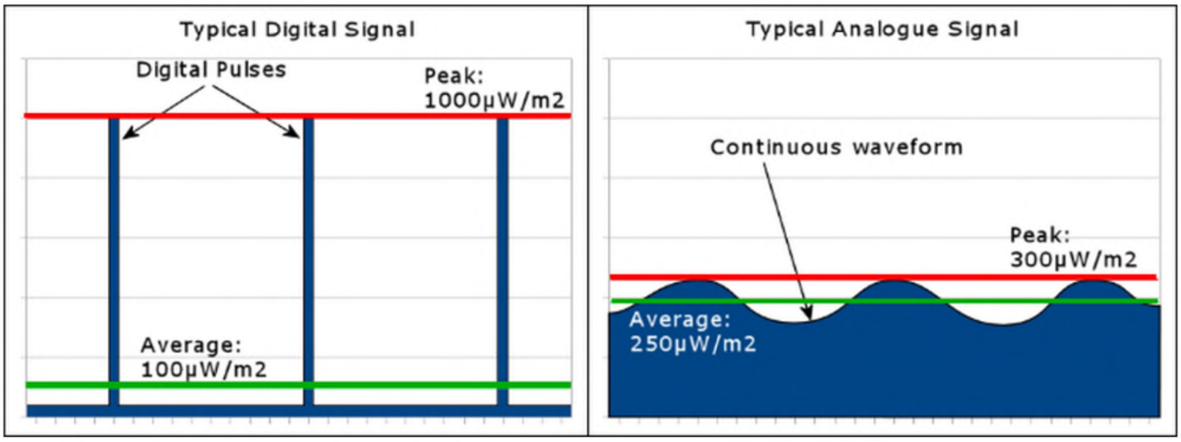


Figure 4.1 Pulsed signal modulation comparison of V/m2 (peak) versus W/m2 PFD (average) EMF radiation levels (Maret, 2014)

LTCEP models incorporate into their limits the peak pulsed values. In a study by Maret (2004), an evaluation was carried out on the iPhone and five (5) SMART meter measurements shown in Figure 4.2 iPhone versus 5 SMART meters inside a building power amplitude measurements (Maret, 2014). The modern RF-EMF devices operate on a pulsed modulation versus a continuous modulation. When analyzing the intermittent and inconsistent peaks associated with these devices, it is easier to understand how the STEP's model PFD six (6) minute averaged measurement can result in a relatively low value. When the recorded measurements are examined using the LTCEP model rationale, the PFD values and safety limits can be extremely misleading.

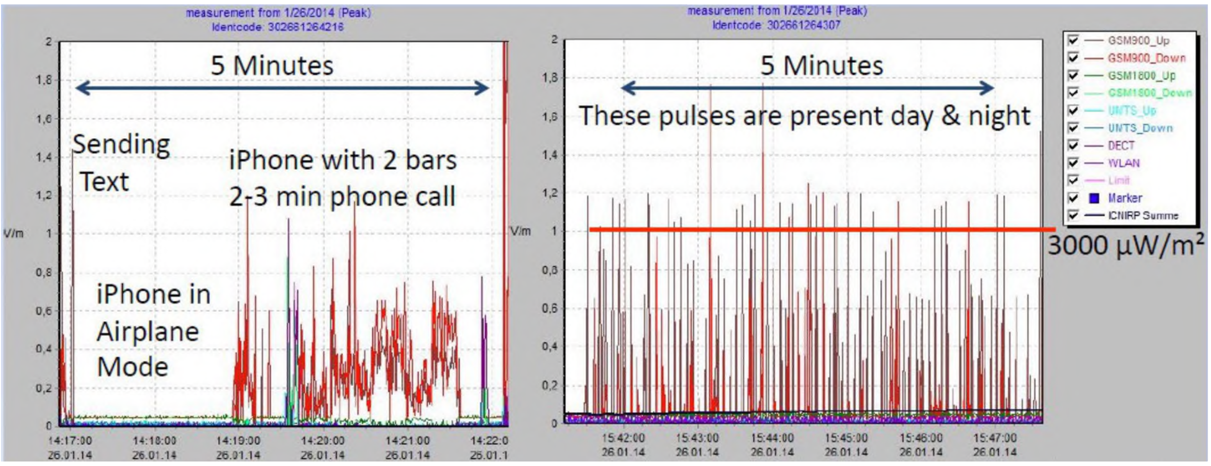


Figure 4.2 iPhone versus 5 SMART meters inside a building power amplitude measurements (Maret, 2014)

4.3 STEP and LTCEP dosimetry model

4.3.1 STEP model dosimetry

The ICNIRP science-based STEP dosimetry model restrictions frequency band 100 kHz-10 GHz hinge on the concept of SAR which requires the measurement of electric (E), magnetic (H) field strength and power density (PD) defined as (ICNIRP, 1998):

Equation 1 SAR (American National Standards Institute [ANSI], 1966)

$$\mathrm{SAR} = \frac{\sigma E^2}{\rho} = c_i \frac{dT}{dt}$$

where E is the RMS value of the electric field in tissue, σ and ρ are the tissue conductivity and mass density. In ANSI (1966) and ICNIRP (1998) selecting the chosen dosimetry methodology, a national standard was set in the US, resulting in scientists scoping their science-based reviews and studies only from reproducible thermal mechanisms and safety limits set primarily on the effects of acute, single exposures (typically, 6 or 20 minutes) (Perov et al., 2009; FCC, 1997).

Finally, the STEP model requires SAR measurements on phantoms (simulated humans) (Perov et al., 2009). LTCEP model endorsers criticize the phantom approach because the measurements do not simulate the effects on the human anatomy. The anthropometric measurements of a normal-build adult male and normal temperature regulation capacities.

The assumption would not offer the same protection to more sensitive subjects or with limited capacity for temperature regulation (Giuliani, 2002).

For example, blood vessels, innervations and fine multi-layered structures. However, in contributions to science and better supporting LTCEP model findings, the STEP model dosimetry SAR has proven useful in the measurements of (1) Near and Far Field RF-EMF sources (explained in the research methodology section of this dissertation), (2) mapping the distribution of RF-EMF radiation absorption in tissue with localized 'hot spot' locations, (3) spatial mapping and pinpointing interaction sites useful in accessing the potential cause of a detected biological effect in animal studies (Perov et al., 2009).

4.3.2 LTCEP model dosimetry

The Russian science-based LTCEP dosimetry model differs on two main counts to the ICNIRP STEP dosimetry model:

(1) the concept of STEP's SAR dosimetry was never originally adopted into the LTCEP dosimetry model because Near Field measurements were not required until the establishment of STEP's ICNIRP EMF radiation guideline (Perov et al., 2009). Perov et al. (2009) explained that Near Field measurement evaluations are performed by computations that extrapolate the Far Field measurement values using theoretical equations.

(2) LTCEP's dosimetry is based on the dynamic estimate of EMF radiation related biological effects from exposure known as Power Exposition (PE) (Perov et al., 2009). The parameter PE differentiates the EMF radiation exposure dose during a given time interval (typically, hours or more), resulting in the calculation of limits based on biological effects resultant from RF-EMF (Yu, 1998; Perov et al., 2009). PE measurement values are dependent on the variables Time, Field Level and Frequency range defined as:

Equation 2 Power Exposition for 300 kHz-300 MHz (ICNIRP, 1998)

$$PE_E = E^2 \cdot t \quad PE_H = H^2 \cdot t \quad (\text{for } 300\,\text{kHz–}300\,\text{MHz})$$

and

Equation 3 Power Exposition for 0.3 kHz-300 MHz (WHO, 2003b; Perov et al., 2009)

$$PE_{PD} = PD \cdot t \quad (\text{for } 0.3\,\text{kHz–}300\,\text{MHz})$$

LTCEP's model use of PE dosimetry defines a science-based dose-dependent biological action of RF-EMF safety limits calculated by time (t) and intensity (Yu, 1998; Perov et al., 2009). This means that PE is based on PD measurements and exposure time (PD is a unit of measure used in both the STEP and LTCEP model dosimetry standards).

The LTCEP's model support of PE over the STEP's model PD measurements because of its usefulness in survey situations as it does not require further exposure evaluations using phantoms, rendering Far Field safety determinations immediate (Perov et al., 2009).

In line with the LTCEP model, the dosimetry rationale is aimed at avoiding any discomforting biological effects resultant from chronic EMF radiation exposure (Commission on the European Communities, 2008). Referred to in the section above STEP science-based dosimetry, the Russian LTCEP dosimetry model has an inherent weakness in evaluating Near Field EMF radiation exposure.

Perov et al. (2009) explained that in most cases, the near E and H-field values cannot be reconstructed from Far Field measurements because the evaluated Far Field patterns can bear values by RF-EMF radiation sources with strikingly different Near Field values. Perov et al. (2009) Near Field, Far Field calculation dilemma example is explained further in the research methodology section of this dissertation.

4.4 EMF radiation dosimetry rationale continued

Historically, attempts at a harmonious relationship between the STEP and LTCEP models have been a 'head-butting' relationship of who is right and who is wrong due to discussions not only a technocratic exercise. The lack of synergy was sourced to differences between these science-based standards of different medical traditions holding different metric concepts of health, disease, and standards of proof.

Additional base issues were the language barrier in trying to understand the literature and complaints from the STEP model endorsers that the LTCEP model historical archived reports lacked crucial information in test replication. Such as the EMF radiation frequency, intensity of exposure or understandable current academic engineering descriptions of experimental designs needed to ensure the validity of findings in today's era (Foster, 2001).

However, this is contradicted by a review collaboration translated publications and studies between the USA, Germany and Russia supplied by the US Department of Commerce

(Bergman, 1965; Glotova & Sadcikova, 1970; Swanson et al., 1970; Troyanskiy, 1972; Sadchikov et al., 1972; Reno & Beischer, 1973; Cook et al., 1979; Lester & Moore, 1982).

STEP model endorsers criticize LTCEP model biological research findings because they do not provide a consistent repeatability. LTCEP model endorsers explain research results repeatability inconsistencies to the inherent nature of biological systems being complex and dynamic, unlike engineering systems. Thus, STEP model endorses excluded LTCEP model historical findings as they did not meet the minimum standards of STEP model academic methodology and reporting.

For example, regardless of the quality of the original LTCEP model Russian studies may have been, they were excluded from the IEEE C95.1-1999 review (STEP model developer) because of inadequate documentation not being "only peer-reviewed, that received favorable engineering and biological validation" (Foster, 2001:3; IEEE, 1999).

A final difference between STEP and LTCEP model biologist endorsers is the quantifiable and qualifying criteria used in diagnoses. Most STEP model related health agencies do not consider or recognize Russian or Chinese LTCEP model Medicine criteria that recognize temporary disturbance in the homeostasis, for example, subtle changes in EEG or heart rate variability identified in the Russian LTCEP model standard Sanitary Rules and Norms SanPin 2.2.4/2.1.8.055-96, sections 2.2.4. physical factors of industrial surroundings and 2.1.8. physical factors of the environment (Foster, 2001; WHO, 2003b).

Recently in studies by the US NTP (2016) and Soffritti et al. (2016) of the Ramazzini Institute, both biologists and engineers could work in fruitful co-operation in STEP model scientists fully understanding and methodically replicating historical LTCEP model results and achieving STEP model standards of proofs. The results of the studies called for the re-evaluation of the STEP model to endorse scientific findings and EMF radiation exposure limits of the LTCEP model.

4.5 Science-based studies demonstrating biological/health effects of low-intensity RF-EMF radiation

Table 4.2 List of studies reporting biological effects at low intensities of RF EMF radiation (RFR) (Levitt & Lai, 2010)

Reference	Frequency	Form of RFR	Exposure duration	SAR (W/kg)	Power density (μW/cm²)	Effects reported
Balmori (2010) (in vivo) (eggs and tadpoles of frog)	88.5–1873.6 MHz	Cell phone base station emission	2 months		3.25	Retarded development
Belyaev et al. (2005) (in vitro)	915 MHz	GSM	24, 48 h	0.037		Genetic changes in human white blood cells
Belyaev et al. (2009) (in vitro)	915 MHz, 1947 MHz	GSM, UMTS	24, 72 h	0.037		DNA repair mechanism in human white blood cells
Blackman et al. (1980) (in vitro)	50 MHz	AM at 16 Hz		0.0014		Calcium in forebrain of chickens
Boscol et al. (2001) (in vivo) (human whole body)	500 KHz–3 GHz	TV broadcast			0.5	Immunological system in women
Campisi et al. (2010) (in vitro)	900 MHz	CW (CW– no effect observed) AM at 50 Hz	14 days, 5, 10, 20 min per day		26	DNA damage in human glial cells
Capri et al. (2004) (in vitro)	900 MHz	GSM	1 h/day, 3 days	0.07		A slight decrease in cell proliferation when human immune cells were stimulated with mitogen and a slight increase in the number of cells with altered distribution of phosphatidylserine across the membrane
Chiang et al. (1989) (in vivo) (human whole body)	Lived and worked close to AM radio and radar installations for more than 1 year				10	People lived and worked near AM radio antennas and radar installations showed deficits in psychological and short-term memory tests
de Pomerai et al. (2003) (in vitro)	1 GHz		24, 48 h	0.015		Protein damages
D'Inzeo et al. (1988) (in vitro)	10.75 GHz	CW	30–120 s	0.008		Operation of acetylcholine-related ion-channels in cells. These channels play important roles in physiological and behavioral functions
Dutta et al. (1984) (in vitro)	915 MHz	Sinusoidal AM at 16 Hz	30 min	0.05		Increase in calcium efflux in brain cancer cells
Dutta et al. (1989) (in vitro)	147 MHz	Sinusoidal AM at 16 Hz	30 min	0.005		Increase in calcium efflux in brain cancer cells
Fesenko et al. (1999) (in vivo) (mouse- wavelength in mm range)	From 8.15–18 GHz		5 h to 7 days direction of response depended on exposure duration		1	Change in immunological functions
Forgacs et al. (2006) (in vivo) (mouse whole body)	1800 MHz	GSM, 217 Hz pulses, 576 μs pulse width	2 h/day, 10 days	0.018		Increase in serum testosterone
Guler et al. (2010) (In vivo) (rabbit whole body)	1800 MHz	AM at 217 Hz	15 min/day, 7 days		52	Oxidative lipid and DNA damages in the brain of pregnant rabbits

Reference	Frequency	Form of RFR	Exposure duration	SAR (W/kg)	Power density (μW/cm²)	Effects reported
Hjollund et al. (1997) (in vivo) (human partial or whole body)	Military radars				10	Sperm counts of Danish military personnel, who operated mobile ground-to-air missile units that use several RFR emitting radar systems, were significantly lower compared to references
Ivaschuk et al. (1997) (in vitro)	836.55 MHz	TDMA	20 min	0.026		A gene related to cancer
Jech et al. (2001) (in vivo) (human partial body exposure-narcoleptic patients)	900 MHz	GSM— 217 Hz pulses, 577 μs pulse width	45 min	0.06		Improved cognitive functions
Kesari and Behari (2009) (in vivo) (rat whole body)	50 GHz		2 h/day, 45 days	0.0008		Double strand DNA breaks observed in brain cells
Kesari and Behari (2010) (in vivo) (rat whole body)	50 GHz		2 h/day, 45 days	0.0008		Reproductive system of male rats
Kesari et al. (2010) (in vivo) (rat whole body)	2450 MHz	50 Hz modulation	2 h/day, 35 days	0.11		DNA double strand breaks in brain cells
Kwee et al. (2001) (in vitro)	960 MHz	GSM	20 min	0.0021		Increased stress protein in human epithelial amnion cells
Lebedeva et al. (2000) (in vivo) (human partial body)	902.4 MHz	GSM	20 min		60	Brain wave activation
Lerchl et al. (2008) (in vivo) (hamster whole body)	383 MHz 900 and 1800 MHz	TETRA GSM	24 h/day, 60 days	0.08		Metabolic changes
Magras and Xenos (1997) (in vivo) (mouse whole body)	"Antenna park"	TV and FM-radio	Exposure over several generations		0.168	Decrease in reproductive function
Mann et al. (1998) (in vivo) (human whole body)	900 MHz	GSM pulse-modulated at 217 Hz, 577 μs width	8 h		20	A transient increase in blood cortisol
Marinelli et al. (2004) (in vitro)	900 MHz	CW	2–48 h	0.0035		Cell's self-defense responses triggered by DNA damage
Markovà et al. (2005) (in vitro)	915 and 905 MHz	GSM	1 h	0.037		Chromatin conformation in human white blood cells
Navakatikian and Tomashevskaya (1994) (in vivo) (rat whole body)	2450 MHz 3000 MHz	CW (no effect observed) Pulse-modulated 2 μs pulses at 400 Hz	Single (0.5–12hr) or repeated (15–60 days, 7–12 h/day) exposure, CW–no effect	0.0027		Behavioral and endocrine changes, and decreases in blood concentrations of testosterone and insulin
Nittby et al. (2008) (in vivo) (rat whole body)	900 MHz,	GSM	2 h/week, 55 weeks	0.0006		Reduced memory functions
Novoselova et al. (1999) (in vivo) (mouse whole body – wavelength in mm range)	From 8.15–18 GHz		1 s sweep time – 16 ms reverse, 5 h		1	Functions of the immune system
Novoselova et al. (2004) (in vivo) (mouse whole body – wavelength in mm range)	From 8.15–18 GHz		1 s sweep time16 ms reverse, 1.5 h/day, 30 days		1	Decreased tumor growth rate and enhanced survival

Reference	Frequency	Form of RFR	Exposure duration	SAR (W/kg)	Power density (μW/cm²)	Effects reported
Panagopoulos et al. (2010) (in vivo) (fly whole body)	900 and 1800 MHz	GSM	6 min/day, 5 days		1–10	Reproductive capacity and induced cell death
Panagopoulos and Margaritis (2010*a*) (in vivo) (fly whole body)	900 and 1800 MHz	GSM	6 min/day, 5 days		10	'Window' effect of GSM radiation on reproductive capacity and cell death
Panagopoulos and Margaritis (2010*b*) (in vivo) (fly whole body)	900 and 1800 MHz	GSM	1–21 min/day, 5 days		10	Reproductive capacity of the fly decreased linearly with increased duration of exposure
Pavicic and Trosic (2008) (in vitro)	864 and 935 MHz	CW	1–3 h	0.08		Growth affected in Chinese hamster V79 cells
Pérez-Castejón et al. (2009) (in vitro)	9.6 GHz	90% AM	24 h	0.0004		Increased proliferation rate in human astrocytoma cancer cells
Persson et al. (1997) (in vivo) (mouse whole body)	915 MHz	CW and pulse-modulated (217 Hz, 0.57 ms; 50 Hz, 6.6 ms)	2–960 min; CW more potent	0.0004		Increase in permeability of the blood–brain barrier
Phillips et al. (1998) (in vitro)	813.5625 MHz 836.55 MHz	iDEN TDMA	2, 21 h 2, 21 h	0.0024		DNA damage in human leukemia cells
Pologea-Moraru et al. (2002) (in vitro)	2.45 GHz		1 h		15	Change in membrane of cells in the retina
Pyrpasopoulou et al. (2004) (in vivo) (rat whole body)	9.4 GHz	GSM (50 Hz pulses, 20 μs pulse length)	1–7 days postcoitum	0.0005		Exposure during early gestation affected kidney development
Roux et al. (2008*a*) (in vivo) (tomato whole body)	900 MHz				7	Gene expression and energy metabolism
Roux et al. (2008*b*) (in vivo) (plant whole body)	900 MHz				7	Energy metabolism
Salford et al. (2003) (in vivo) (rat whole body)	915 MHz	GSM	2 h	0.02		Nerve cell damage in brain
Sarimov et al. (2004) (in vitro)	895–915 MHz	GSM	30 min	0.0054		Human lymphocyte chromatin affected similar to stress response
Schwartz et al. (1990) (in vitro)	240 MHz	CW and sinusoidal modulation at 0.5 and 16 Hz, effect only observed at 16 Hz modulation	30 min	0.00015		Calcium movement in the heart
Schwarz et al. (2008) (in vitro)	1950 MHz	UMTS	24 h	0.05		Genes in human fibroblasts
Somosy et al. (1991) (in vitro)	2.45 GHz	CW and 16 Hz square-modulation, modulated field more potent than CW		0.024		Molecular and structural changes in cells of mouse embryos

Reference	Frequency	Form of RFR	Exposure duration	SAR (W/kg)	Power density ($\mu W/cm^2$)	Effects reported
Stagg et al. (1997) (in vitro)	836.55 MHz	TDMA duty cycle 33%	24 h	0.0059		Glioma cells showed significant increases in thymidine incorporation, which may be an indication of an increase in cell division
Stankiewicz et al. (2006) (in vitro)	900 MHz	GSM 217 Hz pulses, 577 ms width		0.024		Immune activities of human white blood cells
Tattersall et al. (2001) (in vitro)	700 MHz	CW	5–15 min	0.0016		Function of the hippocampus
Velizarov et al. (1999) (in vitro)	960 MHz	GSM 217 Hz square-pulse, duty cycle 12%	30 min	0.000021		Decrease in proliferation of human epithelial amnion cells
Veyret et al. (1991) (in vivo) (mouse whole body)	9.4 GHz	1 μs pulses at 1000 pps, also with or without sinusoidal AM between 14 and 41 MHz, response only with AM, direction of response depended on AM frequency		0.015		Functions of the immune system
Vian et al. (2006) (in vivo) plant	900 MHz				7	Stress gene expression
Wolke et al. (1996) (in vitro)	900, 1300, 1800 MHz 900 MHz	Square-wave modulated at 217 Hz CW, 16 Hz, 50 Hz, and 30 KHz modulations		0.001		Calcium concentration in heart muscle cells of guinea pig
Yurekli et al. (2006) (in vivo) (rat whole body)	945 MHz	GSM, 217 Hz pulse-modulation	7 h/day, 8 days	0.0113		Free radical chemistry

Note: These papers gave either specific absorption rate, SAR, (W/kg) or power density ($\mu W/cm^2$) of exposure. (Studies that did not contain these values were excluded). **AM**, amplitude-modulated or amplitude-modulation; **CW**, continuous wave; GSM, global system for mobile communication; iDEN, integrated digital enhanced network; **TDMA**, time division multiple access, **TETRA**, terrestrial trunked radio; **UMTS**, universal mobile telecommunications system.

4.6 Spurious emissions continued

STEP model endorsers within themselves have a different values tolerance for risk concerning spurious emissions. Among STEP model adopted countries there is a significant difference in the allowance of spurious emissions (Mazar, 2009).

For example, Europe is more stringent than North America having a stark discrepancy of up to 37 dB, i.e., North America allows spurious levels to five thousand times (5000x) higher in power than in Europe. The only North American spurious emissions exception to the loose regulations are the frequency domains 1,559-1,605 MHz band to protect their strategic GPS transmissions.

Mazar's (2003) study identified each STEP model endorsing country to display a compromise between lower spurious emissions and the cost of equipment. Europe was recognized as the most stringent in its spurious emissions limits and protection of the natural RF-EMF resource.

North America and Japan are invested in their views motivated by being more sensitive to the market driven needs. Additionally, Europe imposes spurious emissions regulations on unlicensed Short Range Devices, whereas North America and Japan do not. Identified in the literature review, North America's only exemption was for the protection of their strategic GPS transmission system.

4.7 Wireless RF-EMF radiation propagation

Propagation is the study of how to get a data packet in an RF-EMF radiation signal from Point A to Point B in establishing a 'hand-shake' protocol (United States Naval Academy

[USNA], 2016). Wireless device consumers may believe it to sound simple, but propagation is the most fundamental aspect of wireless communications. Unlike wired communications, the study is simpler concerning propagation. Wireless transmission requires a fundamental understanding of how RF-EMF radiation transports data through the atmosphere. The engineering discipline of propagation is vast and complex, divided into two categories of large and small scale propagation. This dissertation is scoped to a high-level analysis of propagation in meeting the model calculation requirements in the research methodology. Free Space Propagation is what product technical specification and STEP safety limits are based on. However, the real world is not devoid of terrain, mountains, buildings, ground and the atmosphere (USNA, 2016). To tackle the real world inherent Anthroposphere limits and because a perfect isotropic antenna does not exist, RF-EMF radiation ARD transmitters will concentrate the RF-EMF radiation energy in one or more directions. Concentrating the same amount of power in a smaller area is referred to as antenna Gain represented by the equation below (USNA, 2016).

Equation 4 Antenna Gain

$$g_t = \frac{energy\,density\,antenna\,boresight}{energy\,density\,isotropic\,sphere}$$

Covered in the Section 'model differences in EMF radiation measurement' is the dosimetry calculation measurements used in the STEP and LTCEPT models in determining EMF radiation safety limits. As referenced in the section, the antenna Gain equation is only valid in Far-Field RF-EMF radiation calculations. Needed in measuring against STEP and LTCEP model limits in a spatial analysis is the calculation of the amount of RF-EMF radiation that an ARD transmitter would have produced, referred to as Effective Radiation Power (ERP or EIRP). ERP is the Gain of the antenna (concerning an isotropic radiator) multiplied by the input power represented by the equation below.

Equation 5 Effective Radiation Power

$$EIRP = \text{input power} \times \text{antenna gain}$$
$$EIRP = p_t g_t$$

The RF-EMF radiation propagating the data packet from the ARD transmitter is not a narrow beam but, like an enlarging balloon, representing a sphere/dome. As the balloon (dome) increases in size, the total RF-EMF radiation energy is going to remain constant, but the RF-EMF radiation power density is going to decrease (USNA, 2016). The equation below is used to calculate the RF-EMF radiation power density at the ARD receiver (spatial analysis coverage area of a human proximity to ARD transmitter). p_d is power density in W/m^2.

Equation 6 Power density

$$p_d = \frac{EIRP}{4\pi d^2} = \frac{p_t g_t}{4\pi d^2}$$

A more sophisticated and accurate analysis that could be used in future studies is determining how much power is received and absorbed by humans within an ARD transmitter. The balloon effect of dissipating RF-EMF radiation power density and the receiving ARD antenna (recipient/absorber) requires a relatively large receiving area to capture and process a 'hand-shake successfully.' The larger the antenna, the more RF-EMF radiation it can collect. Remember, the ARD transmitter cannot distinguish between human or ARD receivers that it is transmitting data packets within the RF-EMF radiation. Calculating the received RF-EMF radiation is a geometry problem of how much the power density (W/m^2) intersects with the effective area of the RF-EMF radiation energy absorbing recipient. The effective receiving area from a single direction is calculated in the equation below:

Equation 7 Effective receiving area

$$A_e = \frac{g_r \lambda^2}{4\pi} \text{ where}$$

λ is the wavelength [meters]

g_r is the gain of the receive antenna/area

Next, the sum resultant can be inputted into the Friis Free Space equation in calculating the received RF-EMF radiation energy in the equation below:

Equation 8 Friis Free Space

$$p_{rec} = \frac{EIRP}{4\pi d^2} A_e = \frac{p_t g_t g_r \lambda^2}{(4\pi d)^2}$$

p_{rec} is the received power [Watts]

p_t is the transmit power [Watts]

g_t is the Gain of the transmit antenna [linear units]

g_r is the Gain of the receive antenna [linear units]

λ is the wavelength [meters]

d is the distance between transmitter and receiver [meters]

The USNA (2016) warns that the Friis Free Space equation is only valid for Free Space environment calculations (laboratory environments) therefore adjustments will need to be made in accounting for anthroposphere and topography variables.

4.8 Reflection, diffraction and scattering

Propagation is composed of three modes and is listed below in order of their dominance (USNA, 2016):

Reflection: is the RF-EMF radiation energy reflecting off larger conductive objects relative to the RF-EMF radiation wavelength.

Diffraction: per Huygen's principle, all points on a RF-EMF radiation wave-front serve as point sources for secondary RF-EMF radiation wave-fronts. Used in establishing a 'hand-shake' between an ARD transmitter and receiver when the line-of-sight path is blocked. The RF-EMF radiation is able to diffract around the object in such a way that the RF-EMF radiation energy is able to get to the ARD transmitter/receiver even if it is in a shadow zone (behind or inside a building).

Scattering: known as Diffuse Reflection, occurs when RF-EMF radiation energy impacts a rough surface and is re-radiated in numerous directions.

The three modes of propagation play a complex role in the interaction between RF-EMF radiation in the VLF (very low frequency) to HF (3 kHz – 30 MHz), the Anthroposphere and Earth's atmosphere. For example, Figure 4.3 below illustrates the scenario of a mobile device engaging with an RF-EMF cellular ARD tower. The establishment of a 'hand-shake' between the two ARDs is a combination of Reflection, Diffraction and Scattering. The combination of the three propagation modes enables real-time wireless mobile communication, allowing a user to move about and communicate within a local environment because of the ARD principle.

Figure 4.3 Propagation modes of Reflection, Diffraction and Scattering (USNA, 2016)

As the vehicle with the mobile device moves about the environment, the three propagation modes will have an impact on the almost instantaneous received signal in different ways. A relatively stable ‘hand-shake’ signal is Reflected from Mahan Hall, resulting in RF-EMF radiation energy coming from diffraction off the back corner of the Nimitz Library, then there is RF-EMF radiation energy scattered by the clock tower on top of Mahan Hall. The car then drives towards Alumni Hall, resulting in the line-of-sight of the RF-EMF radiation to the ARD transmitter being blocked. Referring to the propagation order of dominance, Reflection is overtaken by Diffraction as being the dominant ‘hand-shake’ signal mode. Conversely, if the vehicle moved towards Rickover, the ARD receiver would receive an RF-EMF radiation energy from RF-EMF radiation line-of-sight signal from the ARD transmitter, along with RF-EMF radiation reflection from the Northeast side of Nimitz as well as RF-EMF radiation scattering from all the parked cars in the Triangle Lot.

Understanding the three propagation modes only adds to the complexity of calculating ambient RF-EMF radiation levels of the resulting ARD power level and identifying localized hotspots. USNA (2016) explains the clinical Friis Free Space equation as impractical in real-world modeling. USNA (2016) explains ground wave/sky wave propagation effects are small and can be neglected. However, the researcher believes this must be further investigated in future studies that wish to conduct LTCEP model environmental modeling forecast of potential health effects. The USNA (2016) recommends using commercial software information systems to perform the sophisticated modeling of the propagation modes operating simultaneously in the Anthroposphere. The simplest modeling equation to describe the propagation modes in a real-world environment is the Log-Normal or Log-Distance model. The model is widely used to predict RF-EMF radiation coverage as well as other RF-EMF radiation sources interfering with the ARD 'hand-shake' and intersecting with the human absorber. Figure 4.4 below is an example of a mobile application called WiFi Solver used to help model the RF-EMF radiation in the propagation modes to identify the strongest propagation mode in positioning the ARD devices.

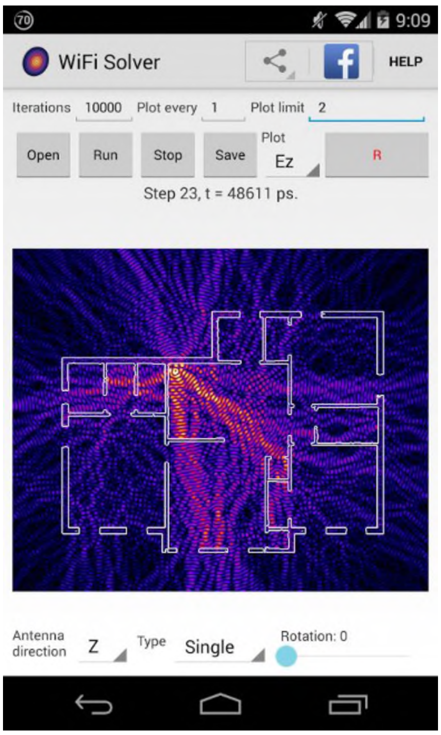


Figure 4.4 WiFi Solver mobile app

4.9 Direct SAR and Near-Field evaluation

4.9.1 Direct SAR evaluation

The Frii Space Equation, modifiable into the direct SAR evaluation, is the most rigorous and complex geometry approach to calculating the variation of the RF-EMF radiation energy exposure, as a function of distance, produced by an ARD transmitter (USNA, 2016).

Per Mann et al. (2000), accounting for the RF-EMF radiation coupling between the ARD transmitter and the exposed human being (geometry calculations would need model variations for age, gender and size based on the Anthroposphere population). Mann et al. (2000) and USNA (2016) advocated the approach to be accurate for RF-EMF radiation energy exposure at all distances. Thus, the accuracy will generally give the shortest RF-EMF radiation compliance distances for the STEP and LTCEP models.

Commercial software has the capability to generate a computer model of an ARD and the human body for analysis of RF-EMF radiation energy deposition in the human body, using implemented algorithms of Maxwell's equations (Mann et al., 2000; USNA, 2016). An alternative real world field testing approach of the direct SAR evaluation method, are measurements producing a physical model of the human body for different population compositions placed in the boresight field of the ARD transmitter.

Small RF-EMF radiation meter field probes are implanted inside the physical model and, if sufficiently sensitive for the RF-EMF radiation power transmitted, the readings could be used to measure the SAR that is produced (Mann et al., 2000).

An important note, SAR was developed by the STEP model which is only scoped to acute thermal heating effects over an averaged short period of minutes. The SAR method is unable to evaluate the biological effects found in the LTCEP model over a longer period (hours, days or years exposure). Due to the resource budget, complexity and scope of this public interest research, the direct SAR evaluation method cannot be used.

4.9.2 Near-Field power density evaluation

The Near-Field is calculable provided the detailed electrical structure of an ARD transmitter is known. Thereby, it becomes possible to perform a rigorous calculation of RF-EMF radiation power density. A Near-Field RF-EMF radiation calculation can model the precise variation of field strength (V/m) or power density (W/m2) at all distances and in all directions from an ARD transmitter (Mann et al., 2000).

4.10 Far-Field Power Density Evaluation Calculation for cellular RF-EMF radiation exposures

Mann et al. (2000) identified larger capacity cellular base stations, having multiple cellular ARD transmitters the output power can vary over time with the number of calls being handled.

For example, one of the transmitters may transmit continuously at full power, whereas the other transmitters will operate intermittently and with varying power levels up to the maximum. As an example, the RF-EMF radiation power output of a macro cellular base station, with ten 10 Watts transmitters, could vary between a minimum of 10 Watts and a maximum of 100 Watts over time. Microcellular base stations tend to operate at lower power levels around 1 to 10 Watts and have fewer transmitters because of their smaller coverage areas.

Mann et al. (2000) field research only scoped a single base station but Kumar's (2010) real world findings supported by the Government of India (2010) and Rajasthan (2012) identified a different reality to RF-EMF radiation that may potentially be the case in SA.

Kumar's (2010) analysis identified a GSM900 ARD base station to transmit data in the RF-EMF radiation frequency range of 935 - 960 MHz to produce the following hazard condition exposure outcomes:

(1) The available licensing frequency band of 25 MHz is divided into twenty sub-bands of 1.2 MHz each, with each sub-band allocated to the various telecommunication operators;

(2) in addition to the twenty sub-bands, there may be several carrier frequencies (1 - 5) allocated to one operator with an upper limit of 6.2 MHz frequency bandwidth with each carrier frequency having the capacity to transmit 10 Watts to 20 Watts of RF-EMF radiation power. In reality, a single operator may transmit between 50 Watts to 100W of power. Typically, as in the case of SA, there may be three to four (3 – 4) operators within close proximity (same roof top, tower, grounds) may result in the total transmitted RF-EMF radiation power being between 200 Watts to 400 Watts. The 'cherry on the cake' is that the majority of ARD transmitters are directional antennas, covered above in Section 'Wireless RF-EMF radiation propagation'. Cellular ARD transmitters may typically have a gain of

around 17 dB, resulting in several kW of RF-EMF radiation ERP power, may be transmitted in the main beam boresight direction (Mann et al., 2000; Practioner5, 2016).

4.11 Theoretical measurement for RF-EMF radiation received

Shown in Field 7 is the average signal strength in dBm from OpenSignal (2016). The theoretical measurement of the RF-EMF radiation power received (P_r) at a distance R, by an ARD antenna (mobile device) used to receive the RF-EMF radiation P_r at a specific spectrum / frequency modulation (λ).

Equation 9 Friis Transmission equation for RF-EMF radiation power received equation (Kumar, 2010)

$$P_r = P_t \times G_t \times G_r \times \left(\frac{\lambda}{4\pi R} \right)^2$$

Kumar (2010) explained that P_r is directly proportional to:

(1) the transmitted RF-EMF radiation (P_t);

(2) gain for both the transmitting (G_t) and receiving ARD antennas (G_r);

(3) square of the wavelength (λ) of the signal (frequency) that is inversely proportional to the square of distance (4∏R).

For example, a single ARD transmitter, for a single operator, with the following scenario value of:

a transmitting RF-EMF radiation power P_t = 20 watts, transmitting ARD gain G_t = 17dB, receiving ARD monopole antenna gain G_t = 2 dB; at a distance of R = 50m for the following frequency modulations (λ) is:

Where λ = 887 MHz, P_r = -3.2 dBm (ARD transmitter frequency for CDMA).

Where λ = 945 MHz, P_r = -3.8 dBm (ARD transmitter frequency for GSM900).

Where λ = 1872 MHz, P_r = -9.7 dBm (ARD transmitter frequency for GMS1800).

The P_r dBm values (λ = 887 – 1982 MHz) demonstrate a relationship of a decreasing received RF-EMF radiation power (P_r) the greater the frequency over the same distance. This is because the higher the frequency, the smaller the wavelength distance, i.e. λ = 887 MHz the wavelength = 0.338 meters and at λ = 1872 MHz the wavelength = 0.1691 meters.

As RF-EMF radiation wireless technologies evolve to transmit greater data speeds, the 'hand-shake' protocol distance decreases because the shorter wavelength at high frequencies is increasingly susceptible to absorption by organic matter containing water, i.e. plants, animals, humans (Kumar, 2010). Demonstrated in Chapters 2 and 4, the relationship of wavelength and modulation, have a large impact on epidemiological studies and the RF-EMF radiation dose-relationship.

For example, a 50kW RF-EMF ARD radio broadcast transmitter with a P_t = 50,000 watts (50kW), transmitting ARD gain G_t = 1dB; receiving ARD monopole antenna gain G_r = 2 dB, at a distance of R = 1,260 meter and of wavelength of λ = 626 MHz (0.4789 meters), the P_r = -10.39 dBm.

An ARD transmitter's function is to ensure that the RF-EMF radiation mobile device receives an adequate signal (RF-EMF radiation Power Density) for a 'hand-shake' protocol in enabling network operation.

For example, a cellular RF-EMF radiation device displays a full strength (four bars) at P_r = -69 dBm (Kumar, 2010) and operates satisfactorily in the P_r range of -80 to -100dBm. Comparing the RF-EMF radiation power levels between -80 dBm and at distance R = 50 meters for P_r dBm values λ = 887 – 1982 MHz, the measured RF-EMF radiation power level is at least 50 to 60 dB higher (Kumar, 2010).

The scenario at distance R = 50 meters, translates to a RF-EMF radiation signal strength (power density W/m^2) *one hundred thousand to one million (100,000 – 1,000,000) greater* than is needed by the cellular RF-EMF radiation mobile device.

LTCEP model endorsers recognize the large difference in RF-EMF radiation power needed in operating wireless networks. Thereby, the ALARA principle was developed toward reducing EMF radiation guideline power density levels.

4.12 Conversion calculation from measured RF-EMF radiation to power density

Shown in Table 4.3, are varying P_r values, in dBM, to the RF-EMF radiation power density international standards, where:

λ = 900 MHz represents the approximate center transmission frequency range for a CDMA ARD transmitter (869 to 890 MHz) and GSM900 (935 to 960 MHz).

λ = 1800 MHz represents a GSM1800 (1810 to 1880 MHz).

λ = 2450 MHz represents the approximate center transmission frequency range for WiFi, WLAN, Bluetooth and Microwave oven.

Table 4.3 Conversion table from P_r (dBm) from a monopole antenna of G_r = 2dB to RF-EMF radiation power density (W/m^2) at different frequencies (Kumar, 2010)

Power received (P_r)	RF-EMF radiation power density (W/m^2) at different frequency wavelengths (λ)		
	900 MHz	1800 MHz	2450 MHz
10 dBm = 0.01 W	706.86	2,827.44	5,238.18
3 dBm = 0.002 W	141.37	565.49	1,047.64
0 dBm = 0.001 W	70.69	282.74	523.82
-7 dBm = 0.0002 W	14.14	56.55	104.76
-10 dBm = 0.0001 W	7.07	28.27	52.38
-17 dBm = 0.00002 W	1.41	5.65	10.48
-20 dBm = 0.00001 W	0.71	2.83	5.24
-27 dBm = 0.000002 W	0.14	0.56	1.05
-30 dBm = 0.000001 W	0.07	0.28	0.523
-37 dBm = 0.0000002 W	0.014	0.056	0.104
-40 dBm = 0.0000001 W	0.007	0.028	0.052

Using the measured values in Field 7, a very rough estimation could be calculated on the RF-EMF radiation power density (W/m2) for the area and rough proximity calculation to a cellular ARD transmitter. Both rough estimate values can be used for the development of a heat map in fulfilment of public interest research question five (5).

4.13 RF-EMF radiation range and channel re-use

4.13.1 Range

The working range of an ARD site, the range within which mobile devices connect reliably to the ARD site ('hand-shake'), is not a fixed figure. It will depend on several factors, including, but not limited to:

- Line-of-sight propagation dependent on the height of the ARD antenna over surrounding topography.
- Frequency signal utilized.
- Timing limitations in technologies. Example, cellular GSM is limited to 35 km.
- ARD transmitter rated power.
- Network communication uplink/downlink protocol required of the data rate from the subscriber's device (Andrews et al., 2007:43).
- Azimuth characteristics of the ARD antenna array.
- Reflection and absorption of radio energy by buildings or vegetation.
- Imposed limitation by local geographical, regulatory factors and weather conditions.

Urban environments generally hold a web array of ARD transmitter cellular sites to cover a wide area with the ARD sphere configuration of each site set to:

1. Adequate overlap for 'handover' to/from other sites. The transfer ARD base station responsibility from one site to another with greater signal efficiency, typically encountered while in a car, train, bus, building, elevator or bad weather.
2. Maintaining minimal buffer overlap in an effort to minimize interference problems with other ARDs.

Due to the above interference constraints and competition for telecommunication market share, ARD cellular sites are grouped in areas of high population density to gain access to the greatest number of potential users. Increasing to range constraint, an ARD site data traffic handling capability is finite in the number of users it can handle at once, resulting in a space limiting factor between ARD sites (Rappaport, 1996). In residential areas cellular ARD masts are historically two to three kilometers (2–3 km) apart with dense urban areas having a spacing of four hundred to eight hundred meters (400–800 m) apart. Through increased population densification and evolution of higher frequency ARD transmitters, these distances are rapidly decreasing (CCPTM, 2015).

Transmission network 'hand-shake' protocols play a major role in range. When not limited by interference with other ARDs nearby, the maximum range of a Cellular GSM ARD transmitter mast is limited to a maximum range of thirty-five kilometers (35 km). CDMA and IDEN ARD transport protocols have no built-in limit except for the 'hand-shake' with the corresponding ARD device such as a cell phone limited factor power capability to generate an ARD back to the ARD base transmitter. For example, illustrated in two scenarios (1) a tall ARD mast in flat terrain can generate a successful 'hand-shake' between fifty and seventy (50-70 km). (2) in hilly terrain (including buildings), a successful 'hand-shake' can be limited to five to eight kilometers (5-8km) due to an encroachment of intermediate objects into the wide center Fresnel zone of the signal (Xia et al., 1993).

In the RF-EMF 2Ghz range for WiFi, 3G and LTE as a general rule of thumb in home networking by Mitchel (2016) estimates that domestic WiFi routers operating on the traditional 2.4 GHz band reach up to 46 m indoors and 92 m outdoors in establishing the 'hand-shake' protocol. However, Tengyuen's (2016) review of WiFi devices, demonstrates how WiFi coverage distances can drastically change depending on the antenna attachment, i.e. TP-Link TL-ANT2409A (9dBi) has an approximate 'hand-shake' range of *1.77km*/1km/140m at 1/11/54Mbps respectively, and the TP-Link TL-ANT2424B 56km/31.5km/4.44km at 1/11/54Mbps respectively.

The narrower RF-EMF radiation amplitude for 5G delivers faster data transfer speeds but due to the law of physics, is more subjective to physical obstructions in homes, i.e., brick walls, metal frames and organic matter (including humans) reduce the range of a 5G Wi-Fi network by 25% or more (Mitchel, 2016). Additional 'hand-shake' obstacles result in interference from other electrical equipment such as microwave ovens, DECT (cordless) phones, Bluetooth devices and wireless baby monitors.

4.13.2 Channel reuse

Cellular and WiFi base stations are configured to transmit different RF-EMF radiation signals in each of their coverage sectors so that more operators and devices can emit within the same area on different channels and avoid 'hand-shake' interference clashes with each other on the similar spectrum. With wireless devices being a ubiquitous commodity, especially in 2.4 and 5 GHz RF-EMF frequency modulation, the RF-EMF radiation emissions from base stations and devices are twenty-four seven (Rajasthan, 2012; Suzuki, 2014; Mitchel, 2016). Shown in Figure 4.5 is a typical indoor WiFi router setup. The RF-EMF radiation can reach the distance of the device and beyond (Figure 4.4) but due to interference from other RF-EMF radiation emitting devices signal interference contaminates the 'hand-shake' protocol. This type of interference scenario may result in an ARD transmitter with a higher RF-EMF radiation power output or additional network boosters or repeaters to be installed to increase the success rate of the 'hand-shake'. Resulting in an increase in ambient RF-EMF radiation levels and incidence of localized RF-EMF radiation hotspots.

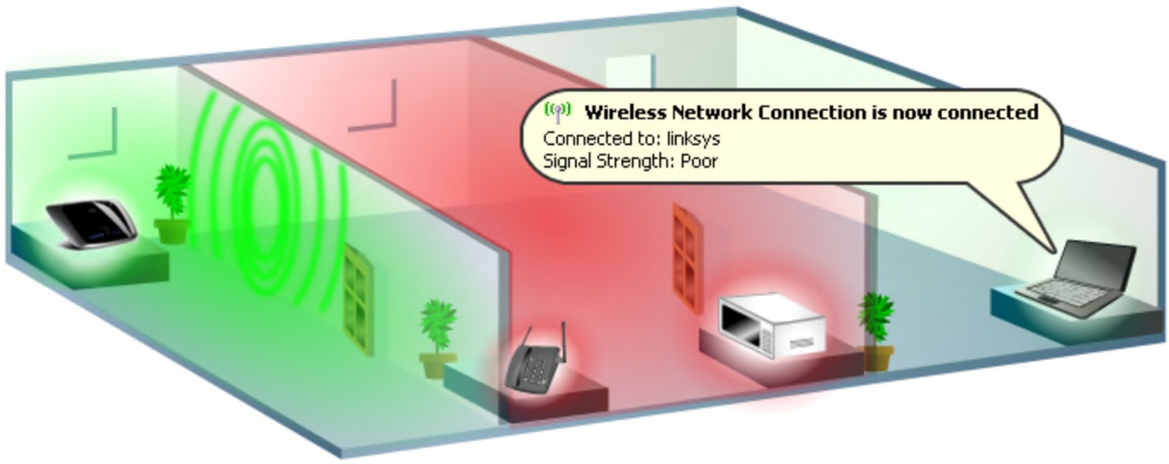


Figure 4.5 RF-EMF 'hand-shake' protocol interference between devices (Linksys, 2016)

4.14 ELF and RF-EMF radiation mitigation options

4.14.1 RF-EMF radiation mitigation options

Historically efforts have been underway to explore possibilities of how RF-EMF radiation pollution in wireless networks could be reduced. The reasoning for a patent filed by the telecommunications company SWISS-COM AG (2004) explicitly quotes RF-EMF radiation capable of having a detrimental effect on human well-being and evidence of damage in human DNA (WHO, 2006a; WHO, 2006b; WHO, 2016e).

The potential detrimental effect on human well-being is not only from RF-EMF radiation infrastructures but the ELF EMF radiation magnetic field component as well. Transformation of RF-EMF radiation (microwave) into ELF and ULF EMF magnetic fields occurs when entering water, resulting in a high magnetic flux density that has the potential to affect human health (Bärtels & Mosler, 2008).

Another example, is the frequent complaint from the public, when a cellular ARD transmitter is installed on the side or on top of a building and the potential effect the RF-EMF radiation would have on the close proximity to residents. Chapter Two (2) and Four (4) illustrated the various site points of interest of how an RF-EMF radiation measurement are to be conducted per the STEP model protocols in such a scenario.

Most cellular ARD transmitters are directional and therefore the brunt of the radiation is pointed outwards from the building resulting in a minimal RF-EMF radiation level in comparison (Kumar, 2010).

Higher RF-EMF radiation levels would be encountered due to reflection propagation by bouncing off other surfaces (localised hotspots). In instances, where this is not the case, some residents of the building still exhibit EMF radiation complaints despite the measured relatively low levels of RF-EMF radiation. However, as discovered in the selective context in the STEP model rationale in Chapter Two (2), the RF-EMF radiation site measurements may not have conducted magnetic flux measurements as a result of the RF-EMF radiation near-field and or the ELF EMF radiation from the cellular ARD device, transformer or power cables themselves. RF-EMF radiation field intensity may be shielded by walls, but magnetic fields are not (XcelEnergy, 2012; Belyaev et al. 2016).

Life on earth has become extremely dependant on specific ULF EMF radiation (Schumann, 1952). Modern medicine takes advantage the Schumann resonance through science-based authorized programmable medical devices, that emit a specific low intensity pulsed ULF ELF EMF radiation, used to improve microcirculation thereby improving the body's ability to contribute in alleviating conditions and support the body's own self-healing regenerative process (BEMER, 2006; Bärtels & Mosler, 2008).

Another advertised non-shielding RF-EMF technology is absorbing/transformation materials that are attached to RF-EMF radiation sources capable of altering the structure of the ELF EMF radiation magnetic flux density (Waveex, 2016; SafestCellPhone, 2016). The EMF radiation absorbing technology has a diamagnetic effect (levels/regulates/aligns) on magnetic field gradients (ELF EMF) and near field EMF radiation without corrupting the quality of the far field RF-EMF radiation used in establishing a 'hand-shake' protocol between ARD devices (Medinger, 2015). The advertised result is an EMF radiation device that is more tolerable to the body's biological system of adaptability because the incongruous magnetic flux density is reduced and harmonized (Bärtels & Mosler, 2008).

A strategy adopted by some countries in employing the LTCEP model and ALARA Principle while still enabling close proximity between the public and EMF radiation infrastructure sources is the improvement of technologies and quality parameters thereby decreasing negative EMF radiation capabilities toward public health (WHO, 2016c).

The technologies listed above may sound like science fiction and 'snake skins sales oil' gimmicks but when referencing back to Chapter Two (2) on RF-EMF radiation spurious emissions standards, the science is plausible on the potential influencing effects these technology types may have on EMF radiation and human well-being.

STEP model endorsing agencies argue against limiting STEP model EMF radiation reference levels further and imposing environmental restrictions because the adopted LTCEP model limits would restrict new technologies entering the market (WHO, 2006). However, this is contradictory in the Climate Change Framework because historically, environmental restriction on pollutant emissions are capable of leveraging funding and innovation development into technologies that are safer, more energy efficient, productive toward society and an economy stimulus.

For example, Light Fidelity (LiFi) is a bi-directional, high-speed and fully networked wireless communication technology similar to Wi-Fi. A form of visible light communication and a subset of optical wireless communications is a potential complement to RF-EMF radiation WiFi and cellular communication or even a replacement in contexts of data broadcasting. LiFi offers astronomical data connection speeds over and above WiFi by carrying much more information. It is a potential complementing solution to the RF-EMF radiation bandwidth limitation dilemma for spectrum regulators. LiFi can use existing infrastructure technologies, i.e., an off the shelf LED light transmitting data to a standard solar panel that acts as a modem but without the reported RF-EMF radiation health complaints (Tsonev et al., 2013; Haas, 2015).

Following a STEP model, market-driven approach, by its nature, may restrict technology progression because technological advancements can be staggered into the market thereby enabling further individualism benefits, i.e., varying model technology releases of patented technology over the years demonstrated in mobile technology and other products, i.e., iPhone x and Samsung X.

4.14.2 ELF EMF mitigation options

This public interest research identified many potential ELF EMF radiation LTCEP model violations, as well as a trend of increasing proximity of ELF EMF radiation infrastructure sources to the public. EMF radiation is composed of both electric (V/m) and magnetic (mG) fields which are strongest in levels close to their emitting source. However, when coupled in close proximity to other HVAC sources, the magnetic (mG) field can significantly increase the distance of dissipation. Magnetic field flux densities and levels are a concern in the LTCEP model because unlike electric fields, i.e., V/m, wireless RF-EMF radiation, most objects such a walls, insulation, window UV tinting and trees can reduce, absorb or block electric fields. Magnetic fields cannot easily be shielded and therefore will penetrate structures (XcelEnergy, 2012).

There is strong public concern regarding exposure to EMF radiation from HVAC power lines but within microenvironments, many appliances, when in operation and close proximity, can emit the same or more ELF EMF radiation as a HVAC powerline at a specified distance.

For example, the Toronto Telephone Commission (1907) investigated a mysterious illness that was first reported by the telegraph line installers and the telephone switchboard operators. The symptoms of the illness included neurasthenia (nerve disorders), depression, extreme anxiety, exhaustion, convulsions, unconsciousness, rashes, and a whole host of other malaise (Schliephake, 1932; Havas, 2014; Belyaev et al., 2016). In support of the LTCEP model, the EMF radiation complaints reached a tipping point, resulting in the Bell Telephone company switchboard operators in Toronto, Canada to strike. The employees demanded substantially reduced working hours and better-working conditions (Havas, 2014).

Typically, within microenvironments, the public has the voluntary choice of the proximity to exposure of an ELF EMF radiation source, i.e., switch on the kettle or oven and go into another room to attend to other duties, resulting in a decreased ELF EMF radiation exposure.

However, some microenvironments may have macro EMF radiation exposure sources, termed as chronic overexposure to EMF radiation. In the telephone switchboard operator case, personnel would manually operate the switchboard panel to connect one telephone caller to another individual by the use of a switchboard cable. The personnel proximity to the ELF EMF radiation source (switchboard), per the LTCEP model, resulted in chronic ELF EMF radiation exposure as a result of hundreds of cumulative live telephone connections, for up to eight (8) hours each. Additionally, operator headsets emitted high levels of ELF EMF radiation that re-radiated when coming into contact with the user voltage switching the phone terminal connections when connecting calls (Havas, 2014).

Even, with the advancement of technology a century later, there is still an array of environmental scenarios where members of the public are exposed to chronic levels of ELF EMF radiation within microenvironments. For example, industrial sewing machines or within offices and residential complexes that contain unshielded HVAC transformers and sub-stations (WHO, 2015a).

Shielding ELF EMF radiation in these microenvironments is achieved through Passive and Active Magnetic shielding solutions. Both shielding approaches are employed in STEP, LTCEP model endorsing countries, either for occupational protective purposes or public protection legislative purposes.

Passive shielding employs the installation of metal sheets commonly used in single rooms, while Active shielding is a practical approach to HVAC power line mitigation at the whole building level. Unlike Passive shield, Active shielding is not able to completely block ELF EMF radiation. In Active shielding, fundamental principles of physics are applied in the real world to solve a problem where a magnetic field can be thought of as a force that has both strength and direction (EMF Services, 2015). If it is met with an equal force of exactly opposite direction, the forces will cancel and the net force will be zero.

Identified in Chapter Four (4), ELF EMF radiation shielding is complicated in practical achievement because the strength of a magnetic field varies greatly across a given area, and the invisible lines of magnetic flux that constitute a magnetic field are at inconvenient angles relative to the earth's plane (EMF Services, 2015). If the angle of the Active shielding counter field does not closely match the angle of the undesired field, it does not matter how much power is pumped into the Active shielding system, the desired ELF EMF radiation shielding is not achieved. Due to the advancements of computer modeling, software can dynamically adapt fundamental physical concepts to each set of unique site conditions.

Regulator6 explained the mitigation of HVAC powerlines underground as a Passive shielding strategy is too cost prohibitive, time-consuming and requires additional land space for the installation of a substation enabling the transition from above ground to underground.

However, installation in counties that employ Active shielding such as the USA, Canada, Israel, Sweden and Switzerland have all demonstrated Active shielding as a resource efficient mitigation alternative. Shown Figure 4.6 and Figure 4.7, is a visual demonstration of non-invasive Active shielding in an urban environment and the effect it has on mitigating ELF EMF radiation levels.

Figure 4.6 ELF EMF radiation Active shielding installation EMF Services, 2015)

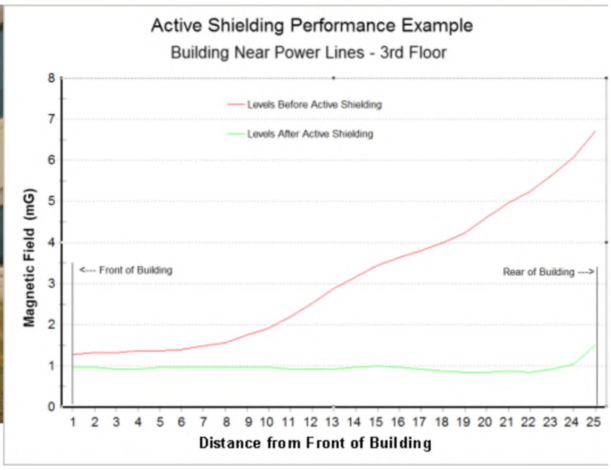


Figure 4.7 Comparison of ELF EMF radiation levels with Active shielding (EMF Services, 2015)

4.15 Social fabric and economic attributes

This section discusses the purpose and financial scope of ‘economic costs', ‘accounting costs' and dematerialization in relation to the STEP and LTCEP model.

Technological advancements using the medium and byproduct of EMF radiation has brought about economic prosperity, increased security and efficiency through the application of dynamically evolving ‘economic costs', ‘accounting costs' and dematerialization (doing more with less) (Herman et al., 1990; Mobile Manufacturers Forum, 2010; Frakt & Piper, 2014; Willard, 2014). However, the design and calculation of accounting and economic costs between the STEP and LTCEP model are very different.

Accounting costs: A company/municipality/province/country's (CMPC) ‘accounting costs' are all the financial costs it incurs to produce output. Thereby, the ‘accounting profit' or loss, is equal to the CMPC’s revenue, minus the CMPC 's accounting costs (Frakt & Piper, 2014).

Economic costs: The analysis of significant influence is ‘economic costs' (Frakt & Piper, 2014; Willard, 2014). A CMPC's ‘economic costs' include the CMPC's ‘accounting costs' as well as opportunity costs. Thereby, the CMPC's ‘economic profit' or loss, is equal to the CMPC's revenue, minus the CMPC's economic costs. ‘Economic profit' is crucial because a CMPC derives decisions based on ‘economic profits' rather than ‘accounting profits'. That is, a CMPC desires to maximize their economic profits rather than accounting profits (Frakt & Piper, 2014).

Dematerialization: Improved ‘economic costs' and ‘economic profits' is derived through the dematerialization of business processes and operations. Dematerialization refers to the absolute or relative reduction in the quantity of materials required to serve economic functions in society, in common terms doing more with less (Herman et al., 1990).

This research’s EMF radiation public interest and Values Risk Threshold Limits business case is organized around bottom-line benefits that align with current evidence about the most significant sustainability-related contributors to company/municipality/province/country's profit (UNFCC, 2006, Willard, 2014; UNFCC, 2014).

Social accounting scenario modeling (economic costs and profits) is achieved by running simulation models of designed adaptation strategies to aid in developing a clearer understanding of the tradeoffs that are made concerning the substitutability of the services investigated (Boumans et al., 2015). Proposing the investigation of EMF radiation within the MIMES Framework mandates the incorporation of the Anthroposphere and the computation of dynamic terrestrial processes on EMF radiation infrastructures, and their influence on potential EMF radiation-related health effects and public health, a direct computation of ecosystem services (Boumans et al., 2015). Computation of ecosystem services is achieved through the Ecosystem Service Evaluation tool explained in the next section.

4.16 Input-Output Analysis and Social Accounting Matrices

Input-Output Analysis (IOA) including Social Accounting Matrices (SAM). IOA is a method that systematically quantifies the mutual interrelationships between various sectors of an economy (Policy Design Lab [PDL], 2006). Combining economic empirical facts and the theoretical mathematical formulation of problems to describe inter-industry relationships within the investigated area, but only providing reliable results at the macro level (PDL, 2006). Coupling between ecosystem services is described by a set of linear equations expressing the balances between the total input and the aggregate output of each commodity and service produced and consumed over a defined period of time. SAM is used for revealing the structure and its role in ecosystem services analysis is limited to monitoring and benchmarking of developments, not to the analysis of scenarios (PDL, 2006). IOA does have some limitations in modelling the inherent nature of diversified environmental impacts, particularly Anthrosphere consequences of technological change (EMF radiation devices) in the system unless a more complex model is built. A limitation addressed in the HYGEIA Model in building lots of smaller models (Boumans et al, 2014a).

4.17 Benefit transfer method continued

The BTM could be applied for making gross estimates of recreational values. The more similar the sites and the recreational experiences based on science-based standards, the fewer biases will result (King and Mazzotta, 2000). King and Mazzotta (2000) caution BTM values to be only as accurate as the initial study. Section 'weighted studies', in Chapter Two (2), is an illustration of the applied systematic literature approach and comparison between epidemiological studies and extracting metric values for a BTM.

Application of the benefit transfer method involves several steps (King and Mazzotta, 2000):

(1) identify existing studies, values and policies that can be used for the transfer. There are many valuation databases that can be useful, i.e. EMF-portal.org, Google Scholar, National and Provincial databases;

(2) evaluate the existing studies, values and policies to determine whether they are appropriately transferable. King and Mazzotta (2000) recommend considering whether the service being valued is comparable to the service valued in the existing studies, including the determination whether the features and qualities of sites or ecosystems are similar, including the availability of substitutes. Additionally, examine if the characteristics of the relevant population are comparable. This includes determining whether the demographics and population preferences and value risk system are similar between the area where the existing study was conducted and the area being valued;

(3) evaluate the quality of studies to be transferred. High-quality initial studies provide more accurate and reliable transferrable values to the new study model. King and Mazzotta (2000) warns this step requires professional judgment and interdisciplinary understanding of the researcher;

(4) adjust the existing values from studies and policies to better reflect the values for the site under consideration, using whatever information is available and relevant. King and Mazzotta (2000) advised that the researcher may need to collect supplemental data to ensure gathering reliable context data. For example, the researcher might consult key informants, talk to the investigators of the original studies, get the original data sets, or collect some primary data at the study site to use for future adjustments;

(5) estimate the total value by multiplying the transferred values by the number of affected people.

4.18 Starr's Law and De Minimis risk thresholds

4.18.1 Starr's law

Mazar (1998) recommends utilizing quantitative laws in EMF radiation guideline research in analyzing and modeling societal and risk concerns, exploring the potential EMF radiation infrastructure hazards and ambient radiation levels.

LTCEP models include in their accounting the cost of societal concern (WHO, 1999). Results from Ball & Boehmer-Christiansen (2002) showed the decoupling of issues invoking societal concerns from considerations of cost and practicality should be avoided.

Slovic (2000) explained the calculation of acceptable risk for a new technology is that level of safety associated with ongoing activities having a similar benefit to society. Conflicts in defining this calculation for the public interest research were encountered when reviewing the CCPTM (2015) Telecommunication Infrastructure Policy values and priorities of the Regulator4 (2016), Regulator5 (2016) and Regulator2 (2016).

The CCPTM (2015) Telecommunication Infrastructure Policy endorses the STEP model in prioritizing economic development and visual appeal over EMF radiation public health concerns, while the CCPTM Regulators[2,3,4,5] (2016) endorse the LTCEP model in prioritizing public health concerns provided there is supported evidence to the EMF radiation public health complaints.

Due to the conflicting endorsed models the researcher chose to evaluate using Starr's (1969) three tentative laws, providing a quantitative instrument examining the relationship between risk and benefit across a number of joint activities:

1. The public is willing to accept voluntary risks (example: lifestyle disease of type 2 diabetes, hypertension or mobile/tablet EMF radiation exposure) about 1,000 times greater than involuntary risk (example, natural disasters, cellular transmitter EMF radiation, HVAC powerlines) that provide the same benefit. However, Slovic's (2000) data identified negative support for the quantitative formulation, that people are willing to accept high involuntary risks with large benefits.
2. The acceptability of risks appears to be roughly proportional to the real and perceived benefits, to the cube of the benefits.
3. The acceptability level of risk is inversely related to the number of persons exposed to that risk (example, more than four billion cellular subscribers). Starr's law disconnected between imposed risks and those accepted voluntarily.

Starr et al. (1976) proposed the following numerical measurements in disconnecting between imposed risks and those accepted voluntarily (these numbers may be accepted as philosophical assumptions and speculations). A numerical upper bound of 10^{-2} for disease, mortality rate; and lower bound of 10^{-6} for natural hazards representing the public's acceptance of involuntary risks.

4.18.2 De Minimis and thresholds

Examining EMF radiation infrastructure sources thresholds requires the calculation of "No-Observed-Effect-Level (NOEL), as this will affect the power function used, the size of a test run, which exposure-response model is employed and where the burden of proof is placed (Mazar, 2009). With there being numerous STEP and LTCEP model variations a de minimis dilemma is encountered (negligible risk EMF radiation infrastructure sources). Per Webler et al. (2001), society may declare a certain threshold, below which a hazard is judged to be negligible with quantitative safety criteria established subjectively and politically biased, with rational-based methods not solving problems such as the level of unacceptable risk.

APPENDIX TO CHAPTER 5
EMF Radiation HYGEIA Framework

5.1 No content for appendix

APPENDIX TO CHAPTER 6
EMF Radiation HYGEIA Model

6.1 No content for appendix

APPENDIX TO CHAPTER 7
Research Methodology

7.1 PAIA (2000) data sources

Table 7.1 HYGEIA Model Knowledge base requirements - Pollutant attributes

EMF Infrastructure	Source	Data file type received	Date acquired
ELF EMF			
11kV – 400kV	EMFDS1	PAIA application ignored	
Sub-stations	EMFDS1	PAIA application ignored	
Compact sub-stations	EMFDS1	PAIA application ignored	
11kV – 400kV	EMFDS2	Data vector file	September 2016
Sub-stations	EMFDS2	Data vector file	September 2016
Compact sub-stations	EMFDS2	Data vector file	September 2016
RF-EMF			
Public WiFi	EMFDS11	Excel export of co-ordinates.	May 2016
	EMFDS10	Excel export of co-ordinates and status.	May 2016
	EMFDS5	Email of location names.	May 2016
	EMFDS6	Excel export of location names only.	September 2016
	FindFreeWifi	KML data vector export.	August 2016
Radiobroadcast towers	EMFDS7	Excel export of co-ordinates and power output levels.	August 2016
Cellular Transmitters	EMFDS8	Excel export of lease agreement table of cellular property rentals on public land.	November 2012
	EMFDS8	Scanned pdf of renewal lease	May 2016

		agreements table on public land. Only Property ERF No. provided.	
	EMFDS9	Excel export of addresses of permits approved of cellular transmitters.	June 2014 – August 2016
	EMFDS10	Excel export of site street addresses only.	September 2016
	EMFDS11	PAIA application denied.	2016
	EMFDS12	PAIA application denied.	2016
	EMFDS13	PAIA application denied.	2016
	EMFDS14	PAIA application ignored.	2016
	EMFDS15	Signed agreement but data never received.	2016
SMART Meters	EMFDS1	PAIA application ignored.	
SMART Meters	EMFDS2	Data not available yet.	September 2016
Historical Radiofrequency EMF measurements			
Cellular transmitters	EMFDS16	EMF site measurement reports.	
	OpenCellid.org	CSV file of cell tower and measurements conducted by volunteer user cell phones.	August 2016
	Regulator4	Awaiting equipment availability since June 2016.	No equipment to date.

Table 7.2 HYGEIA Model Knowledge base requirements - Spatial attributes

Source	Data file type	Date range
Practitioner16	Excel export of school details, learner numbers per grade, latitude and longitude.	May 2016
StatsSA	Data vector file of population statistics.	April 2013
EMFDS9	Data vector file of city parks, fire stations, land parcels,	May 2016

	official suburbs, sports grounds, stadiums, swimming pools, wards, 2011 census, clinics, community centres, hospitals, places of worship, police stations, post officers, railways, railway stations, IBRT bus network, schools, street names, LIDAR, Raster Images of 8cm aerial photographs	
GoogleMaps	Children homes, day care, hospice, juvenile prisons, orphanages, retirement homes, prisons, sports fields, tennis courts.	August 2016

The study, Table 1.1, can be reviewed for supportive data of consulted 'practitioners' (experts) as directed by the MIMES framework, tier 1, data acquisition methodology (Study, Table 4.1).

7.2 Far-Field power density evaluation

A Far-Field Power Density evaluation is permissible when the total power fed into an ARD transmitter is known as is the antenna gain, it is possible to calculate the power density in the boresight of the main beam by assuming an Inverse Square Law dependence upon distance at all distances from the ARD transmitter, for a single operator. Utilizing Equation 10 below for RF-EMF radiation power density P_d, at a distance R is given by:

Equation 10 Far-Field power density (Mann et al., 2000; Kumar, 2010, FCC, 1997)

$$P_d = \left(\frac{P_t \times G_t}{4\pi R^2} \right) \quad \text{Watt/m}^2$$

Where:

P_t = Transmitter power in Watts

G_t = Gain of transmitting antenna

R = Distance from the antenna in meters

Equation 10 above is only valid for Free Space calculations and does not represent real world modeling covered in Section 'localized hotspots" in the literature review because Free Space calculations do not incorporate Maxwell's set of partial differential equations to account for reflection propagation (Houndou et al., 2006). A single ARD transmitter array in a real world densely populated scenario would have multiple RF-EMF radiation exposure measurement locations shown in Figure 7.1, including inside the buildings themselves (Houndou et al., 2006).

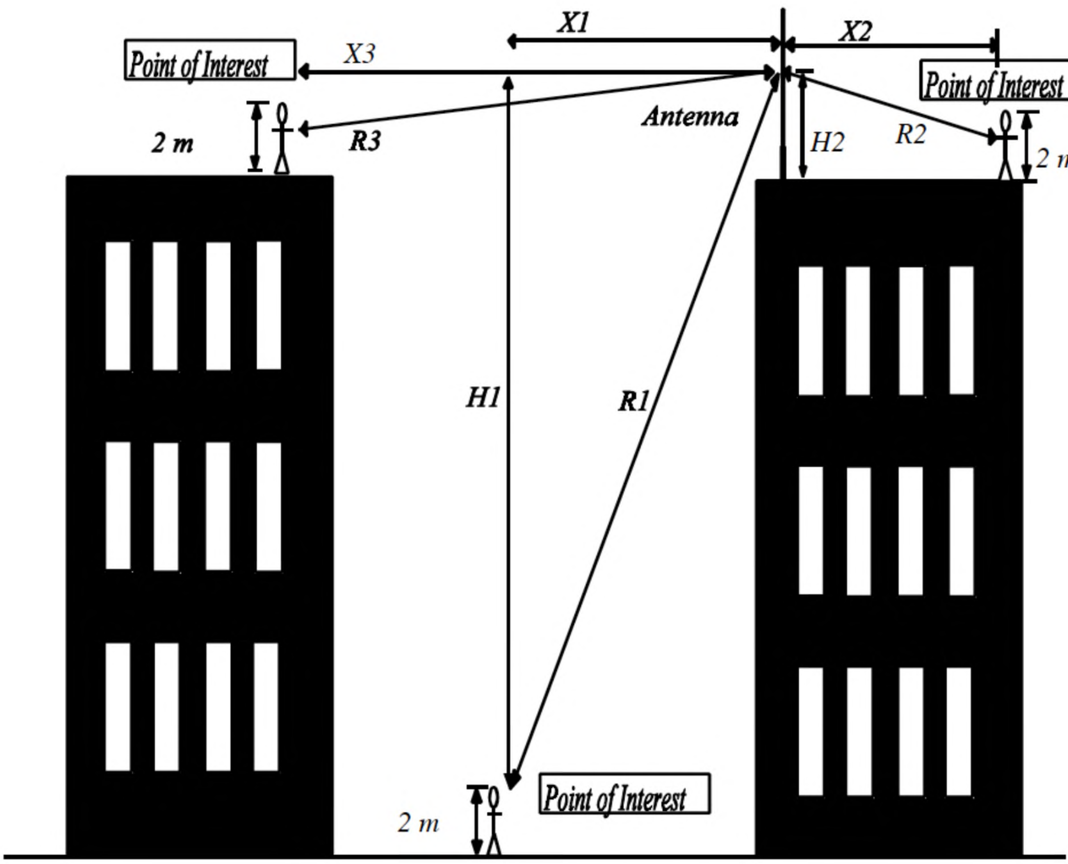


Figure 7.1 Single roof-top antenna, various exposure locations (FCC, 1997)

Mann et al. (2000), disclaimed the use of Equation 10 will overestimate RF-EMF radiation power density in directions other than the main beam because the antenna gain is effectively less in these directions. Additionally, it will also overestimate RF-EMF radiation power density at short distances, generally within 10 m of cellular ARD transmitters.

Far-Field RF-EMF radiation calculations, in the real world, would need to account for multiple ARD transmitters and operators, on a single structure (**Error! Reference source not found.**), and or multiple ARD transmitters and operators (Figure 7.3), spaced apart, contributing to the RF-EMF radiation exposure at a point of interest.

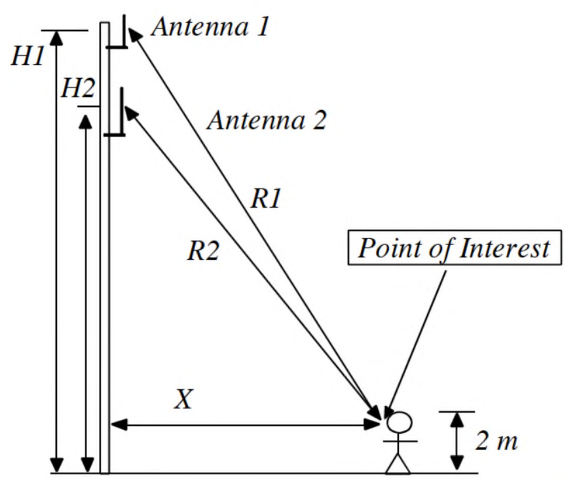


Figure 7.2 Single structure, co-located ARD transmitters, ground-level exposure at 2 meters (FCC, 1997)

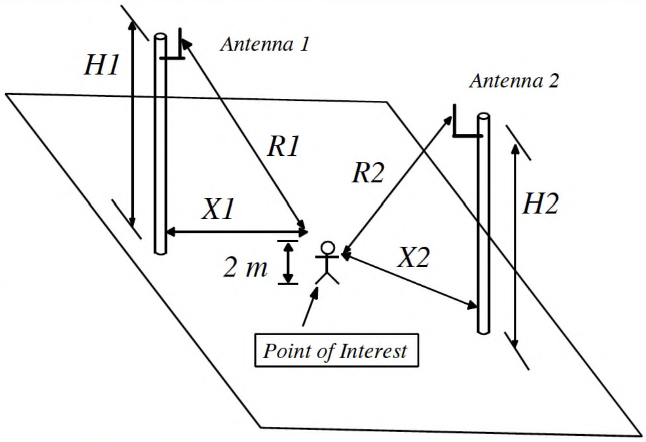


Figure 7.3 ARD trasnmitters on multiple structures contributing to RF-EMF radiation exposure at point of intersection (FCC, 1997)

Calculating the RF-EMF radiation power densities, in the scenarios of Figure 7.2**.** to Figure 7., would require detailed technical specifications from the telecommunications suppliers, as well as topographical data processed and modelled through 3D GIS that has 3rd party commercial software plug-ins. GIS simulation models are able to process the spatial fluctuation of the RF-EMF radiation intensity of electromagnetism, in which the phases of RF-EMF radiation waves coming from an infinite number of paths in a 3D space, interfere with each other resulting in localised hotspots, where the RF-EMF radiation power density is expected to increase (Mann et al., 2000; Houndou et al., 2006).

The lack in access to accurate technical specifications from EMF radiation infrastructure data sources requires the use of generic data from literature. A generic scenario of a 100 Watts cellular ARD transmitter with a gain of 17 dB shall be used per site. For Pt = 100W, Gt = 17 dB = 50, Pd various values of R are given in Table 7.3 below.

A single cellular ARD transmitter Pt can range between 1W – 80W (Mann et al, 2000, Kumar, 2010). The value of 100W for Pt was selected because a site would typically have multiple ARD transmitters and the selected value is conservative enough, in light of some sites, with three to four (3-4) operators could have a total Pt of 300 – 400Watts (Kumar, 2010).

The distance (R) in Table 7.3 is the minimum compliance distance from an ARD transmitter with the above specifications using the Inverse Square Law, for each RF-EMF radiation guideline. Distance in meters in Table 6 is calculated by the use of an isotropic antennae with

17 dB gain. The Far-Field calculation (Equation 9) with the above input values for the output at 100m from the ARD transmitter in Table 7.3 is expressed as:

$$100000\text{mW} / (4\Pi(100\text{m})^2) * 10^{\wedge}(17/10) = 0.08*50 \approx 40 \text{ mW/m}^2 = 0.04 \text{ W/m}^2$$

Table 7.3 International RF-EMF radiation power density limits for GSM 1800

Distance	Power Density	Field Intensity	RF-EMF radiation guideline	
P_t = 100W	W/m2	V/m	Description	Countries
6.3	10	61	FCC	USA, JAPAN, Canada
300			Some districts around schools in USA and Canada, Nelson Mandela Bay Municipality*	USA, SA, NMBM
6.6	9.2	59	ICNIRP 1998	EU, Australia, SA -recommended only
5000			KwaDukuza Municipality around schools	KwaDukuza Municipality, KZN, SA
11.6	3	34	Canada Safety Code 6, 1997)	Canada
14.1	2	27	Australia, New Zealand	
20	1	19	India and not on vulnerable area facilities	India
520	1	19	India, Rajasthan State (1W/m2 + 500m buffer from hospital, places of children)	
28.3	0.5	14		New Zealand
40.7	0.24	10		CSSR, Belgium, Luxembourg
63	0.1	6.14	China, Poland	Slovenia, Poland, China, Italy, Paris
64.5	0.095	5.98	Limit in areas with duration > 4hrs	Italy
64.5	0.095	5.98	Switzerland per site	Switzerland
66.5	0.09	5.82	ECOLOG 1998 Precaution recommended only	Germany
115	0.03	3.36		Italy
126	0.025	3.07	Exposure limit in Italy in Vulnerable areas	Italy
141	0.02	2.75	Exposure limit in Russia (since 1970), Bulgaria, Hungary	Russia, Bulgaria, Hungary
630	0.001	0.61	Precautionary limit in Austria, Salzburg City only (New Salzburg Precautionary limit (2001), STOA	Salzburg, Austria, EU Council resolution

665	0.0009	0.58	BUND 1997 (Germany) Precaution recommendation only	Germany
6200	0.00001	0.06140	New South Wales, Australia	New South Wales Australia

The RF-EMF radiation power density values given in Table 7.3 above are for a *single* carrier array and a *single* operator. If *multiple* carriers are being used and *multiple* operators are present on the same roof top or structure, then the above RF-EMF radiation values will *increase manifold* (Kumar, 2010).

Practioner5 (2016) warned on the misleading complexity of RF-EMF radiation compliance applications because the PEAK ERP value could be five (5x) to ten times (10X) greater.

For example, an ERP value of 5kW (100W including 17gain) for a cellular ARD transmitter could have peak power transmission levels that are 25kW (5X). In the interest of accuracy and calming speculative concerns, the RF-EMF radiation density will be much lower in the direction away from the main beam of the ARD transmitter.

Obtaining the technical specifications in a successful PAIA (2000) application will enable the calculation of the actual RF-EMF radiation pattern of the ARD transmitter, thereby, calculating the exact RF-EMF radiation density at a point on interest.

7.3 Calculation of Radio broadcast spatial proximity buffer

Shown in Figure 7.4 Far-Field power density exposure radial density based on Salzburg 2001 EMF radiation guideline and epidemiology study by Ha et al. (2007), is the buffer zones based on the kW ERP output of the radio broadcast RF-EMF radiation transmitter. The buffer zones are based on the Salzburg 2001 EMF radiation guideline and correlated epidemiological findings by Ha et al. (2007).

Figure 7.4 Far-Field power density exposure radial density based on Salzburg 2001 EMF radiation guideline and epidemiology study by Ha et al. (2007)

The epidemiological study Ha et al. (2007) was an extensive and detailed study of AM radio RF-EMF radiation. The number of childhood cancer patients in this study was sufficient to produce moderate statistical power for detecting an effect of RF-EMF radiation exposure from AM transmitters. The study identified that children living within two (2) kilometers of an AM transmitter (20 kW or more ERP power) had more than twice the potential risk of developing leukemia, compared to those living more than twenty (20) kilometers away.

An interesting finding in the study was the potential biological effect association of Peak to ambient RF-EMF radiation levels, compared to base station studies. In Ha et al. (2007) study, total RF-EMF radiation exposure seemed more likely to be associated with childhood leukemia than Peak RF-EMF radiation exposure. Ha et al. (2007) suggesting that RF-EMF radiation exposure in the AM broadcasting modulation possibly acts as a *promoter* rather than an *initiator* of the carcinogenic process.

Ha et al. (2007) estimated the electric field at approximately two (2) kilometers from the AM transmitters ranged from 1 V/m to 3 V/m. Ha et al. (2007) dose-relationship correlation of high EMF radiation exposure classification for biological effects correlates with Edger &

Jahn (2010) in Section 'weighted studies' in Chapter Two (2). In contrast STEP model endorser RF-EMF radiation reference levels for AM frequencies are:

FCC field intensity of 614 V/m or power density 1000 W/m^2

ICNIRP field intensity of 87 V/m or 20 W/m^2

Attempting to model potential RF-EMF radiation violations against STEP model reference levels in this study is unlikely to be identified. The highest ERP transmitter level received by Sentech in CPT is 50kW:

- at 50 meters, the field intensity is 27 V/m or power density of 2 W/m^2;
- at 20 meters, the field intensity is 68.6 V/m or power density of 12.5 W/m^2

The above values are well below the STEP model reference levels and therefore no potential RF-EMF radiation violations for radio broadcast antennas *based on the data received* are identifiable.

7.4 EMF radiation spectrum analyser measurement uncertainties

EMF radiation site measurements bring about several sources of uncertainty:

(1) electrical factors associated with the calibration of the EMF radiation spectrum analyzer and ARD transmitters;

(2) factors arising from surveying practices, i.e. effective positioning and handling of the EMF radiation spectrum analyzer, covered in the EMF radiation spectrum analyzer instruction hand book.

Uncertainties linked to point (1) are readily obtained from the relevant calibration certificates that come with the EMF radiation spectrum analyzer. Mann et al. (2000) reported uncertainty in the calibration of EMF radiation spectrum analyzers of values between 0.8 dB and 2 dB.

Uncertainties linked to point (2) are reported as challenging to quantify (Mann et al, 2000). Mann et al. (2000) cautioned that the most significant source of EMF radiation spectrum analyzer imprecision measurements is likely to arise from the disturbance of the EMF radiation spectrum analyzer factor during measurements. The EMF radiation spectrum analyzer factor is quantitatively described as the coupling between an EMF radiation spectrum analyzer and a uniform field.

A uniform field is one in which the electric field is constant at every point, achieved when the EMF radiation spectrum analyzer is a long distance from conducting and dielectric objects, such that mutual coupling is negligible (Mann et al, 2000). For example, this is achieved by mounting the EMF radiation spectrum analyzer onto a tripod. When the EMF radiation spectrum analyzer is manipulated by hand, it can potentially cause significant coupling of the EMF radiation spectrum analyzer with the operator's body, and with other nearby structures such as building or structure fabrics. Mann et al. (2000) reported typical disturbance values to EMF radiation spectrum analyzer factors of 2 to 6 dB depending on the accessory EMF radiation spectrum analyzer measuring accessory attachment i.e. bi-conical, log-periodic or ridge guide.

In conducting site measurements, the surveyor will need to refer to the EMF radiation spectrum analyzer and accessories handbook in obtaining overall uncertainty multipliers in EMF radiation power density associated with the use of each EMF radiation spectrum analyzer accessory, shown in Table 7.4 Overall EMF radiation spectrum analyzer accessories affecting EMF radiation power density measurements (Mann et al, 2000) below. The uncertainty multiplier (EMF radiation power factor correction) is the multiplication of the measurement on the EMF radiation spectrum analyzer to reach a final EMF radiation power density value.

Table 7.4 Overall EMF radiation spectrum analyzer accessories affecting EMF radiation power density measurements (Mann et al, 2000)

		Power density multiplier	
Frequency range	Uncertainty (dB)	Minimum	Maximum
30–300 MHz	±6.4	0.23	4.3
300–1000 MHz	±4.5	0.35	2.8
1–2.9 GHz	±2.9	0.51	2.0

Table 7.4 reflects the actual RF-EMF radiation power densities as a result of the different EMF radiation spectrum analyzer accessories, may have differed from the reported values by factors which are bounded to a 95% degree of confidence by the limits tabulated in the two right-hand columns of Table 7 (Mann et al, 2000). For example, the accessory measurement frequency range 300 – 1000 MHz, identified a 95% certainty that the true maximum RF-EMF

radiation Power Density was not greater than 2.8 times the reported measurement value on the EMF radiation spectrum analyzer.

7.5 Data processing and treatment/analysis for GIS datasets

7.5.1 Geodatabase

A spatial database, also referred to as a geodatabase, is a database that is optimized to store and query data that represents objects defined in a geometric space. Spatial databases allow representing simple geometric objects (feature class) such as points, lines, polygons and relationship data tables (ESRI, 2016). The study created a Geodatabase that housed all data, raster and vector files for the public interest EMF radiation HYGEIA Model. A Geodatabase enables easier migration capacity of the public interest research to another platform or user for potential future research studies.

7.5.2 Projections

A map projection is a mathematical procedure method used to represent the 3D sphere surface of the earth onto a 2D plane in cartography (Dempsey, 2002). Using the 'Project Coverage' tool in ArcMap GIS data vector files from data sources were converted into the 'GCS_WGS_1984' geographic co-ordinate system. Generating a uniform co-ordinate mapping system for the data results in a reduction in alignment errors on the map during the analysis phase (ESRI, 2016).

7.5.3 Mosaic dataset

The 8cm resolution aerial photographs received from the EMFDS9 are in the format of raster image files. Each raster image is taken from an airplane at an angle at different co-coordinates and projections of the earth. A mosaic dataset was created and the 'add raster' tool in ArcMap was used to store, manage, view, and query vast collections of raster and image data supplied by EMFDS9. In summary, it is a data model within the geodatabase used to manage a collection of raster datasets (images) stitched together on a cartographic map and viewed as a mosaicked image shown in Figure 7.5 on the next page (ESRI, 2016).

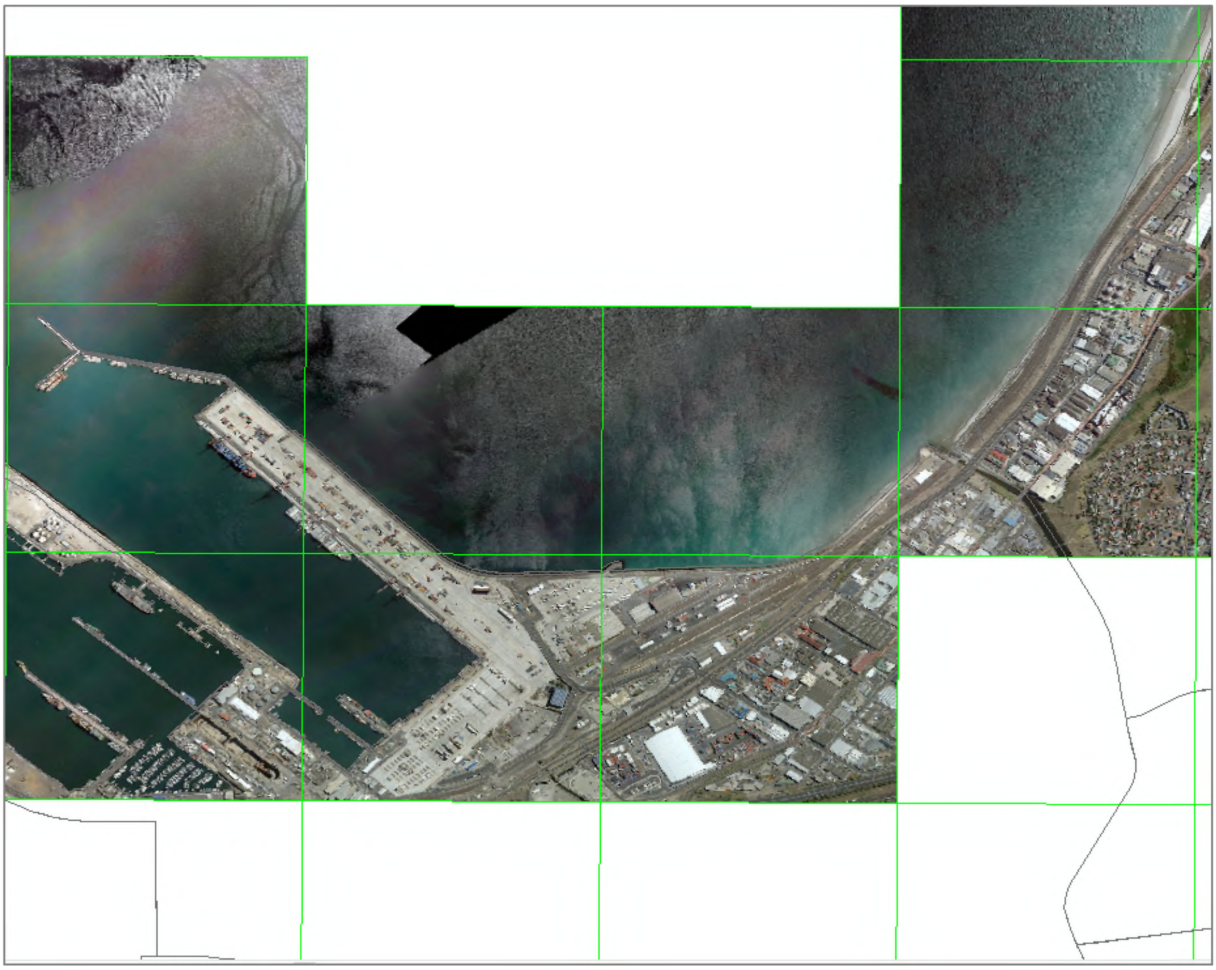


Figure 7.5 8cm resolution aerial Mosaic dataset of City of Cape Town Municipality, SA

7.5.4 Feature dataset

A feature dataset is a collection of related feature classes that share a common coordinate system. A feature class is a collection of geographic features with the same geometry type (such as point, line, or polygon), the same attributes, and the same spatial reference (ESRI, 2016). Feature classes allow homogeneous features to be grouped into a single unit for data storage purposes. For example, highways, primary roads, and secondary roads can be grouped into a line feature class named ‘roads’. Feature datasets are used to spatially or thematically integrate related feature classes (ESRI, 2016).

GIS data vector files received from data sources are feature classes. Data from the literature review, spreadsheets and scanned documents from the data sources were extracted and programmed into the GIS as feature classes. The researcher created feature datasets based on categories for analysis. For example, an RF-EMF dataset would consist of feature classes (geometry type points) of public WiFi hotspots in CPT, SA.

7.5.5 Vulnerable areas feature class buffer zones

The vulnerable areas feature classes supplied by the data sources were 'points' of the feature and not 'polygons' covering the land feature. The researcher attempted to create a new polygon feature of each point feature to generate an accurate geographic buffer representation of the vulnerable area. For some of the features this was done in ArcMap by (1) using the 'selection SQL, select by location tool'; (2) EMFDS9 'land parcel ERF' polygon features were selected that intersected with the vulnerable area point feature class shown in Figure 7.6.

Figure 7.6 Hospital: vulnerable area polygon feature class by land parcel polygon intersection with hospital school point feature class

Unfortunately, while processing the land parcel buffer tool, errors were encountered with the EMFDS9 land parcel ERF feature class. The land parcel feature class had overlapping polygons with other isolated polygons and some of the land parcel areas were incomplete, resulting in vulnerable areas intersected features not to be recognized and or a selected area was much greater than the representing vulnerable facility land coverage area. The encountered matching land parcel buffer error was for a large percentage of the feature classes. To manually correct and re-create the correct land parcel ERF feature classes per site would have been too resource intensive for this research. The errors should rather be rectified by the data source in the interest of potential future research studies and accurate public information that other service providers are dependent upon.

Overcoming the encountered land parcel buffer mismatch errors required problematic vulnerable areas to be measured using the ArcMap 'measurement tool' on the aerial photographs. Different areas were sampled and an average approximation was calculated for each vulnerable area feature. The 'buffer analysis' tool was used to create polygon buffer feature classes shown in Figure 7.7. Illustrated in Figure 7.7, the applied 'work-around' method does not fully cover the land parcel as identified in the top two pink rings of the tennis courts and community hall, along with the large ring for the sports field with only half of the sports field land features being covered.

Figure 7.7 Vulnerable areas buffer feature class

The methodology scope of this public interest research is a public interest demonstration data modelling exercise and absolute accuracy for the entire investigation area of CPT, SA is not a requirement because in fulfilling public interest research question five (5), potential future studies will be able to request correct and updated data from data sources through the successful PAIA (2000) Public Interest Override applications.

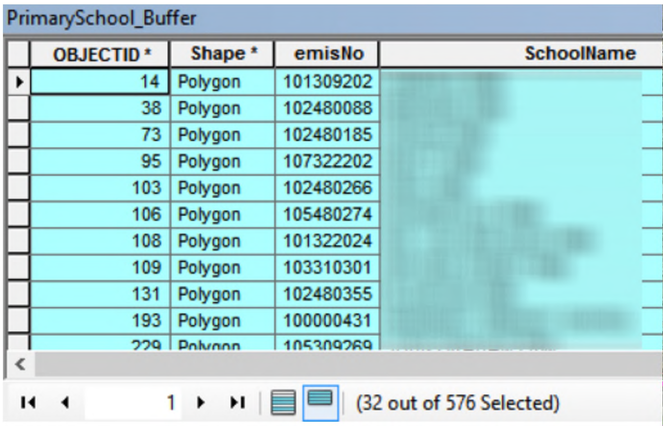
7.5.6 Identifying potential EMF radiation guidelines violations

Public interest research question four (4) and five (5) aimed to identify the number of potential STEP and LTCEP EMF radiation violations on the defined vulnerable population areas.

Per each STEP and LTCEP model mitigation option, a recursive SQL analysis query would be performed of 1….n, querying, for each vulnerable area feature classes intersected with the different EMF radiation feature classes.

For example, thirty-two (32) primary schools were identified to have WiFi RF-EMF radiation exposure shown in Figure 7.8, a screenshot of the search results table from the SQL query.

Shown in Figure 7.9 is a zoomed aerial photograph showing the outdoor public WiFi ARD transmitters installed on the classified vulnerable area feature class, primary schools'. For example, per Israel and French National Assembly (2015) policies, this would be considered a potential EMF radiation protection violation (Haifa municipality, 2016).



PrimarySchool_Buffer

OBJECTID *	Shape *	emisNo	SchoolName
14	Polygon	101309202	
38	Polygon	102480088	
73	Polygon	102480185	
95	Polygon	107322202	
103	Polygon	102480266	
106	Polygon	105480274	
108	Polygon	101322024	
109	Polygon	103310301	
131	Polygon	102480355	
193	Polygon	100000431	
229	Polygon	105309269	

1 (32 out of 576 Selected)

Figure 7.8 Search results of SQL query for public WiFi feature class that intersects with the primary school feature class

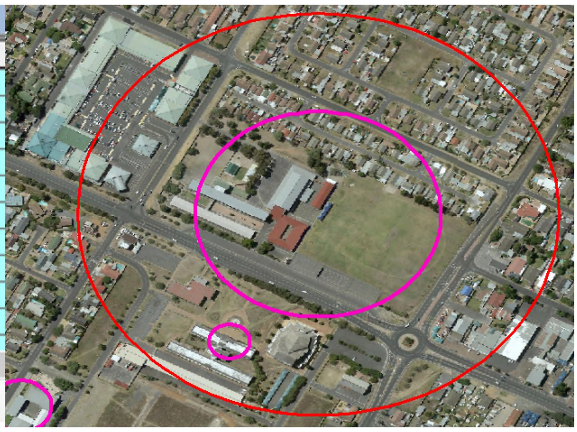


Figure 7.9 Visual representation of public WiFi feature class (red) intersecting with the primary school feature class (large pink)

Shown in Figure 7.10 is the intersection of the RF-EMF and ELF EMF radiation feature classes with the tennis courts, library, sports field and community center vulnerable areas feature classes. All three vulnerable area facilities house 'sensitive occupants' for temporal periods that match the LTCEP model criteria. The EMF radiation HYGEIA Model simulated hazard conditions for input ELF and RF-EMF radiation exposure levels are within reported potential biological associated health effects (Impact Predictors) per the LTCEP model.

Figure 7.10 Cellular transmitter and HVAC power lines EMF radiation exposure intersecting with tennis courts, library, sports field and community center.

Appendix to CHAPTER 8
Potential ELF and RF-EMF violation
Data analysis and results

8.1 Potential RF-EMF radiation violations per the STEP and LTCEP model

Shown in Table 8.1, is a RF-EMF radiation policy reference table for the STEP model reference levels and LTCEP model limits. Each RF-EMF radiation policy was assigned a chart reference label, i.e., ‘A’, ‘B’, correlated to each RF-EMF radiation policy. STEP model reference levels are in ‘red’ and LTCEP model limits are in ‘green’.

Table 8.1 STEP and LTCEP model spatial propagation model

Field Intensity V/m	Policy	RF-EMF radiation guideline description
61	A	FCC: USA, JAPAN, Canada
	B	Some districts around schools in USA and Canada, Australia, Nelson Mandela Bay Municipality, SA*
59	C	ICNIRP 1998, EU, Australia, DHSA -recommended only
	D	KwaDukuza Municipality, KZN, SA
34	E	Canada Safety Code 6, 1997)
27	F	Australia, New Zealand
19	G	India and not on vulnerable area facilities
19	H	India, Rajasthan State
14	I	New Zealand
10	J	CSSR, Belgium, Luxembourg
6	K	China, Poland, Italy, Paris, Slovenia
5.98	L	Limit in areas with duration > 4hrs, Italy
5.98		Switzerland per site
5.82	M	ECOLOG 1998 Precaution recommended only, Germany
5		Paris
3.36	N	Italy
3.07	O	Exposure limit in Italy in Vulnerable areas, Italy
2.75	P	Exposure limit in Russia (since 1970), Bulgaria, Hungary in vulnerable areas
0.61	Q	Precautionary limit in Austria, Salzburg City only (New Salzburg Precautionary limit (2001), EU Council resolution, EU Parliament Scientific & Technological Options Assessment (STOA)
0.58	R	BUND 1997 (Germany) Precaution recommendation only
0.06140	S	New South Wales, Australia

Some EMF radiation exposure policies utilize the STEP model reference level but impose spatial proximity restrictions to vulnerable area facilities rendering the policy an LTCEP model limit. The field intensity (V/m) value is displayed instead of the power flux density (W/m^2) because of the implementation of an EMF radiation HYGEIA Model. The construction of a public health model forecasting potential biological effects must reference the appropriate unit of measurement per literature standards, being V/m because W/m^2 can output misleading values as discussed in Chapter 4 and 7.

STEP and LTCEP model geospatial propagation model demonstration runs were simulated through the EMF radiation HYGEIA Model. The results of potential STEP and LTCEP model RF-EMF radiation violations is shown in Figure 8.1 to Figure 8.17 below.

In the GIS, SQL queries were used to identify the potential STEP and LTCEP model RF-EMF radiation violations. The results in Figure 8.1 to Figure 8.17, revealed a pattern of the lower the EMF radiation policy values risk tolerance threshold limit, the greater the number of identified potential RF-EMF radiation violations.

Due to the small sample of cellular ARD transmitters and small spatial buffer variances between some of the policies, the results were grouped together to save illustration space, i.e., 'A,C'. However, in potential future studies. a larger sample size and detailed operating log files per cellular ARD site, more accurate identification of potential RF-EMF radiation violations per site and policy would be identifiable.

Concerning policy 'S', in Australia, EMF radiation exposure reference levels per the STEP model ICNIRP guidelines were implemented in March 2003. At the local level, the most stringent RF-EMF radiation LTCEP model limit was set in New South Wales with a power density limit of 0.01 mW/m2. The New South Wales RF-EMF radiation limit is based on science-based findings published in the BioInitiative Reports (2007, 2012).

Available in the Appendix, Section 2.1.1 EMF radiation guidelines, exposure and effects of RF-EMF, is (1) a table graph spatial representation of RF-EMF STEP model reference levels and LTCEP model limits; (2) the Inverse Square Law of dissipation per RF-EMF radiation devices and potential reported EMF radiation-related health effects per the BioInitiative Reports (2007, 2012).

However, in recent applications by individual facilities filed in court against policy 'S', the favor was granted toward the national limits (Bärtels & Haak-Nebbe, 2015). From a 2D GIS model analysis, almost all the vulnerable areas facilities in this public interest research were in potential violation of policy ‘S’. However, given CPT’s dynamic topography, Anthroposphere and vegetation cover, a 3D GIS model analysis may reveal different results.

8.2 Potential RF-EMF radiation violations per the STEP and LTCEP model results charts

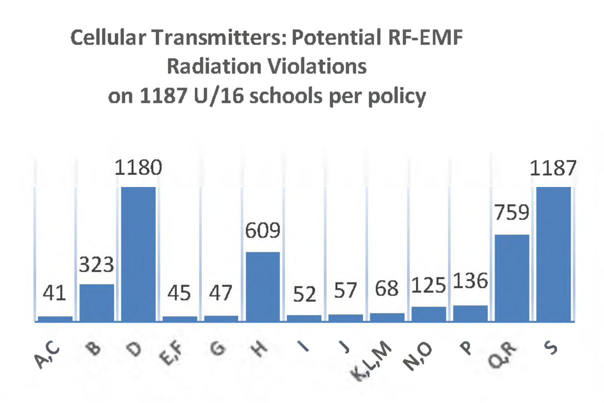


Figure 8.1 Cellular Transmitters: Potential RF-EMF Radiation Violations on 1187 U/16 schools per policy

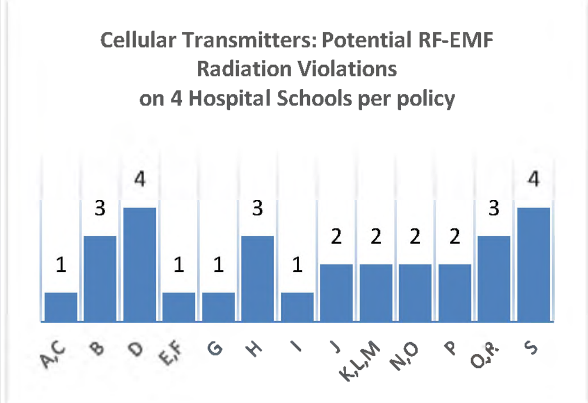


Figure 8.2 Cellular Transmitters: Potential RF-EMF Radiation Violations on 4 Hospital Schools per policy

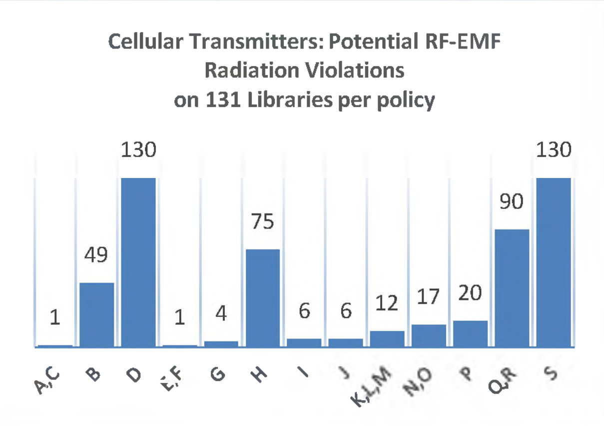


Figure 8.3 Cellular Transmitters: Potential RF-EMF Radiation Violations on 131 Libraries per policy

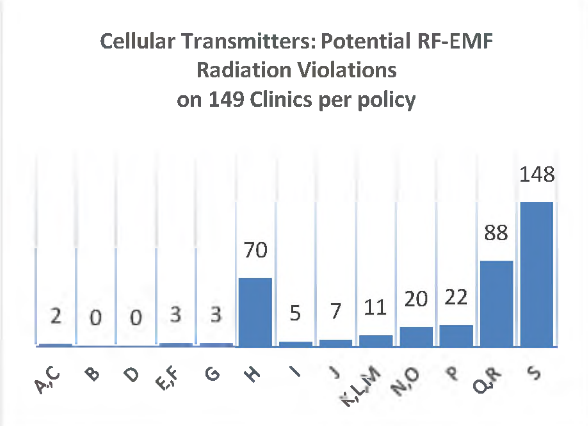


Figure 8.4 Cellular Transmitters: Potential RF-EMF Radiation Violations on 149 Clinics per policy

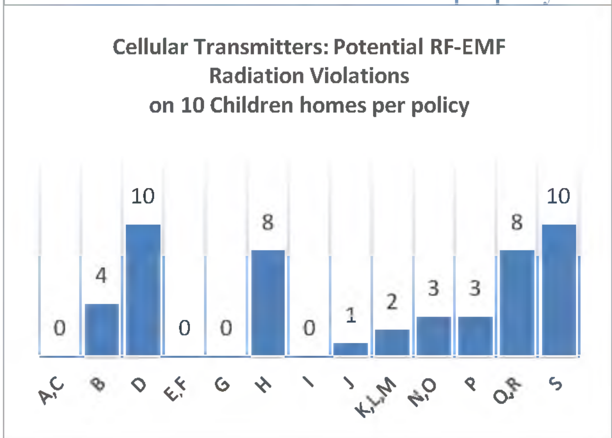


Figure 8.5 Cellular Transmitters: Potential RF-EMF Radiation Violations on 10 Children homes per policy

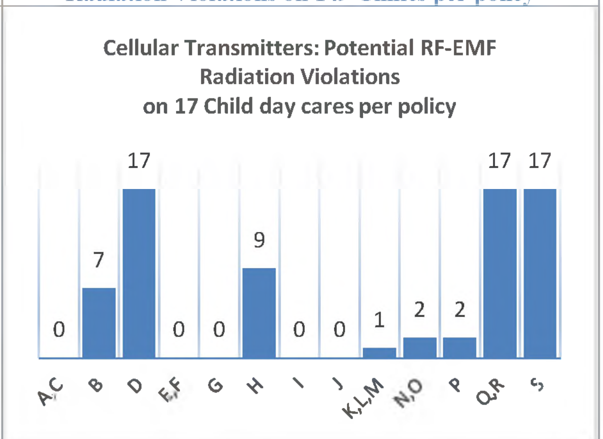


Figure 8.6 Cellular Transmitters: Potential RF-EMF Radiation Violations on 17 Child day cares per policy

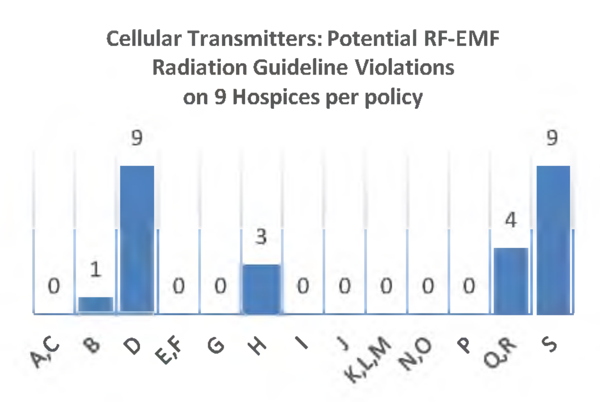


Figure 8.7 Cellular Transmitters: Potential RF-EMF Radiation Violations on 9 Hospices per policy

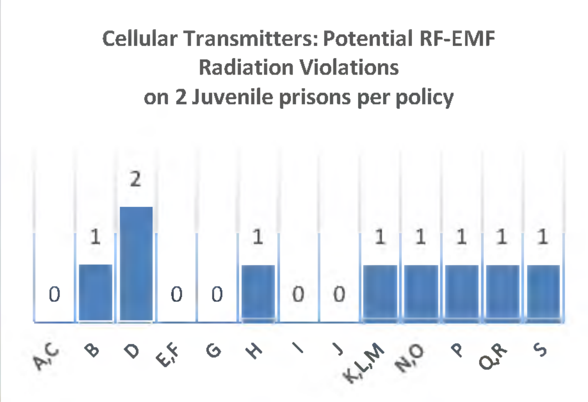


Figure 8.8 Cellular Transmitters: Potential RF-EMF Radiation Violations on 2 Juvenile prisons per policy

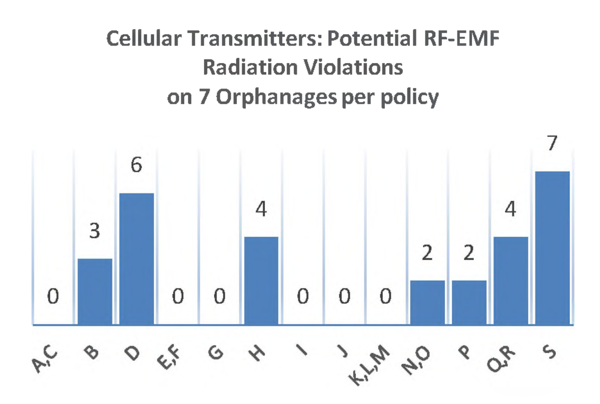


Figure 8.9 Cellular Transmitters: Potential RF-EMF Radiation Violations on 7 Orphanages per policy

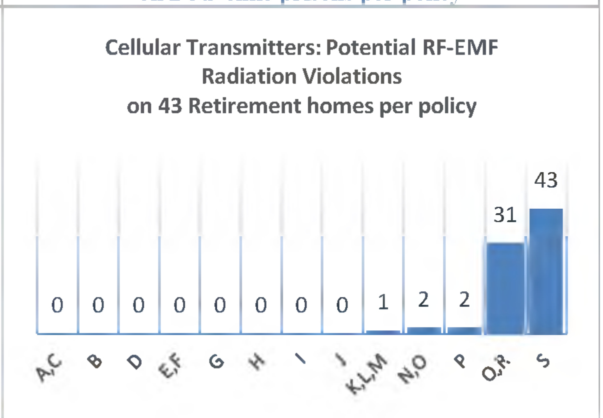


Figure 8.10 Cellular Transmitters: Potential RF-EMF Radiation Violations on 43 Retirement homes per policy

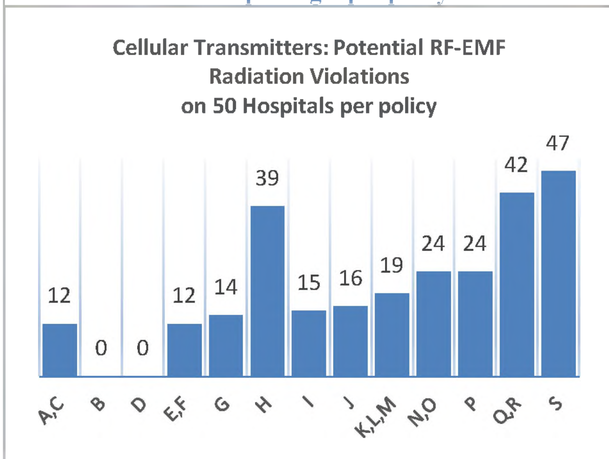


Figure 8.11 Cellular Transmitters: Potential RF-EMF Radiation Violations on 50 Hospitals per policy

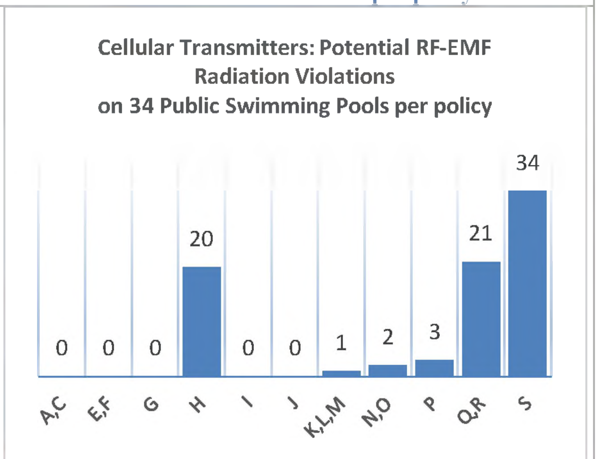


Figure 8.12 Cellular Transmitters: Potential RF-EMF Radiation Violations on 34 Public Swimming Pools per policy

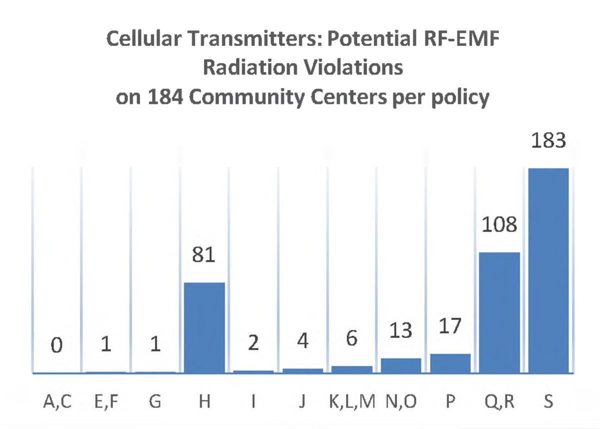


Figure 8.13 Cellular Transmitters: Potential RF-EMF Radiation Violations on 184 Community Centers per policy

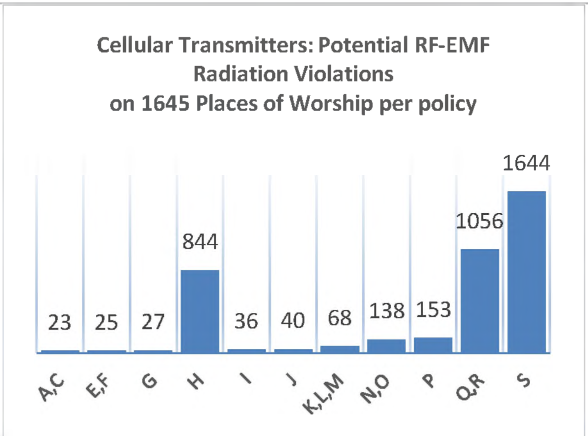


Figure 8.14 Cellular Transmitters: Potential RF-EMF Radiation Violations on 1645 Places of Worship per policy

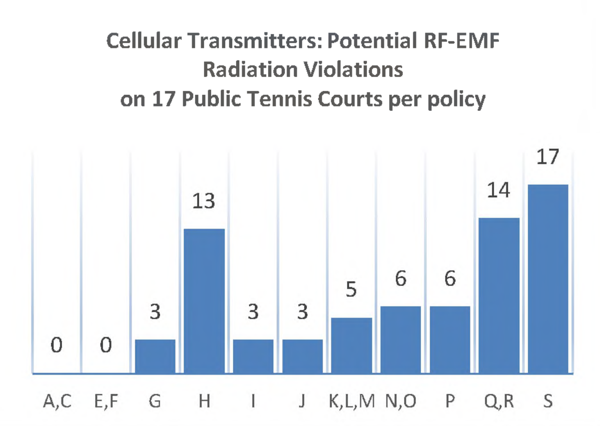


Figure 8.15 Cellular Transmitters: Potential RF-EMF Radiation Violations on 17 Public Tennis Courts per policy

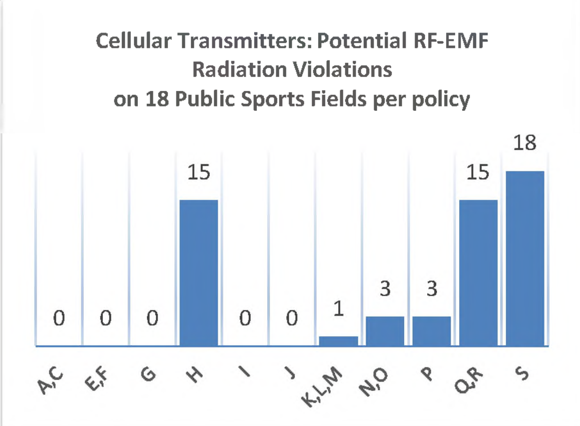


Figure 8.16 Cellular Transmitters: Potential RF-EMF Radiation Violations on 18 Public Sports Fields per policy

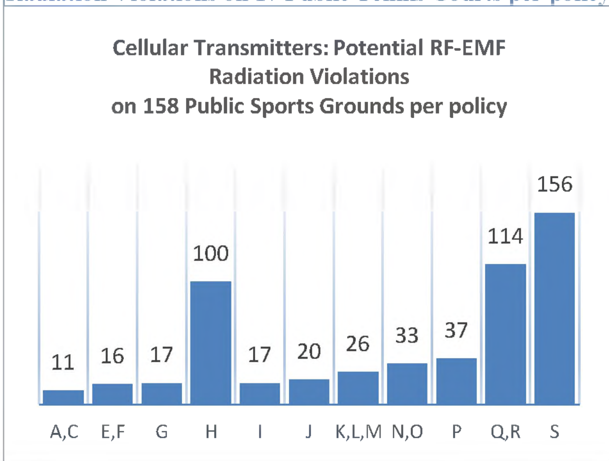


Figure 8.17 Cellular Transmitters: Potential RF-EMF Radiation Violations on 158 Public Sports Grounds per policy

APPENDIX TO CHAPTER 9
Public Interest Override function Data analysis and results

9.1 No content for appendix

APPENDIX TO CHAPTER 10
Conclusions and contributions

10.1 No content for appendix