
# Be lean to be resilient:

## *Setting capabilities for turbulent times*

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EDIM is run by a consortium consisting of the industrial management departments of three institutions:

- KTH Royal Institute of Technology, Stockholm, Sweden
- Politecnico de Milano, POLIMI, Milan, Italy
- Universidad Politécnica de Madrid, UPM, Madrid, Spain

## Abstract

Businesses globally are challenged to innovate their operations strategies and practices towards tighter delivery times, better quality and cheaper prices to remain profitable in addition to managing unpredictable circumstances well in today's turbulent business environment. They often have to deal with the apparent paradox of advancing efficiency-fostering approaches such as lean production, and enhancing operational resilience against unanticipated disruptions. The purpose of this study is to investigate whether and how practices in seemingly contradicting paradigms in operations management can be utilised to attain a better competitive position in the face of uncertainties.

This thesis is comprised of 'modules' of studies designed to systematically address the three research questions. This was necessary due to the different maturity level of the concepts brought together. Predominantly qualitative mixed-method approach was used for the overall research with some quantitative analysis included. The critical incident technique, case study and Bayesian inference were used in the different studies (papers).

Operational resilience is characterised in terms of five core functions: sense, build, reconfigure, re-enhance, and sustain (RQ1). Resilience is also operationalised using routine practices that are bundled into internal/external, proactive/reactive dimensions of capabilities that positively influence performance upon recovery from disruption. An analysis showing that lean practice bundles lead to better operational performance under high uncertainty context is also done in this thesis (RQ2). Finally, operational resilience (based on routine practices that form the core functions) was found to have stronger synergies than trade-off with lean (based on practice bundles) in times of turbulence (RQ3).

This thesis extends the resource-based view to high uncertainty contexts through empirical evidence and shows that resilience (dynamic) capabilities can be built from practices that firms normally employ; the capabilities are sources of better performance and competitive advantages in turbulent business environments. The thesis contributes to the discussion on the paradox of lean and operational resilience based approaches in the same context; lean practices bundles lend themselves to synergy with resilience capabilities, and leverage competitive gains in turbulent times.

Practically, findings of this thesis suggest that companies need not abandon their lean implementation to become more resilient. In fact, it shows that lean implementation should be extended to address value chain processes beyond the shop floor for integrative removal of wastes, while being able to flexibly mitigate disruptions.



### Keywords

Resilience, lean production, synergy, supply chain disruption, dynamic capabilities, mixed method approach, uncertainties

# Abstract (Italiano)

La sfida della competitività nei mercati globali dipende in larga parte dalla capacità delle imprese di innovare le loro *operations* per ottenere termini di consegna sempre più stretti, maggior qualità a prezzi sempre più competitivi; tutto questo in un contesto industriale e socio-economico sempre più incerto e turbolento. Oggi le imprese sono chiamate a prendere decisioni e ad adottare dei modelli di business dagli effetti contrastanti, come ad esempio l'adozione di pratiche che enfatizzano risultati di efficienza produttiva (i.e. *lean production*) a fianco di strategie e soluzioni che mirano ad accrescere la capacità del sistema di adattarsi dinamicamente ad eventi perturbanti (resilienza), esterni o interni all'organizzazione. Lo scopo di questa ricerca è quello di investigare se e come l'adozione di pratiche potenzialmente contrastanti nell'ambito della gestione delle *operations*, possono essere utilizzate per mantenere e migliorare la propria posizione competitiva in contesti di forte incertezza e turbolenza dei mercati.

La ricerca si compone di una serie di "moduli", ovvero di singoli studi progettati per affrontare sistematicamente e organicamente le tre domande di ricerca fondamentali, la cui risposta conduce alla proposta di tesi. Questa impostazione si è rivelata necessaria a causa del diverso livello di maturità dei concetti studiati e sviluppati nella tesi. Anche la metodologia di ricerca rispecchia le diverse esigenze e peculiarità dei vari aspetti studiati e per questo è stata definita seguendo un approccio misto, in cui metodi di tipo qualitativo sono affiancati da analisi quantitative che implementano tecniche statistiche. In particolare, nei diversi "moduli" (*paper*) si utilizzano: la *critical incident technique*, diverse metodiche di studi di caso, e inferenza Bayesiana.

La resilienza operativa è stata caratterizzata secondo cinque funzioni principali (*core functions*): *sense, build, reconfigure, re-enhance,* e *sustain* (RQ1). Ciascuna di queste è tradotta a livello operativo attraverso procedure e pratiche stabili (*routine*) - interne/esterne, proattive/reattive - che sono in grado di influenzare positivamente le prestazioni a seguito di un evento perturbante. Attraverso la ricerca, viene analizzato l'effetto positivo che differenti pratiche lean (*lean practice bundles*) inducono sulle prestazioni operative in condizioni di incertezza (RQ2). Infine, un'analisi bayesiana sui parametri tipici di un campione selezionato di eventi incidentali a carico di organizzazioni e supply chain globali ha rivelato che tra resilienza operativa (implementata attraverso specifiche *routine*) e lean production (implementata attraverso specifiche *lean practice bundles*) esistono fenomeni sinergici più forti dei meccanismi di *trade-off*, quando valutati in contesti turbolenti (RQ3).

I risultati della tesi contribuiscono ad ampliare e rafforzare un approccio teorico *contingent resource-based view* all'analisi delle organizzazioni che operano in regimi di forte incertezza (complessità e dinamicità); il contributo originale si concentra in particolar modo nel fornire evidenza empirica che le capacità di resilienza di una organizzazione (*dynamic capabilities*) possono essere costruite su processi e *routine* normalmente eseguite dalle imprese. Ove disponibili, queste capacità sono usate come fonte di miglioramento prestazionale e per l'ottenimento di un vantaggio competitivo in contesti turbolenti. Ulteriori evidenze supportano la tesi che un'ampia gamma di *lean practices* possono essere usate in maniera sinergica per un ulteriore rafforzamento della resilienza operativa.

Dal punto di vista pratico e in contrasto con parte della letteratura esistente, la tesi offre ai manager industriali solidi argomenti per non abbandonare la propria strategia *lean* o limitare i propri obiettivi di efficienza allo scopo di conseguire una maggiore resilienza operativa. Si dimostra infatti che quando l'adozione di partiche lean viene estesa ad una porzione sempre più ampia della *value chain*, alla conseguente riduzione degli sprechi si associa anche una maggior flessibilità nella gestione di eventi perturbanti o distruttivi.

# Sammanfattning

I dagens turbulenta affärsklimat står företag världen över inför utmaningen att på ett effektivt sätt hantera oförutsägbara händelser och samtidigt förnya sina verksamheter med syfte att uppnå kortare leveranstider, bättre kvalitet och ökad lönsamhet. I dessa ansträngningar möter företagen ofta det skenbara dilemmat av att vissa arbetssätt såsom *lean produktion* ställs i kontrast mot aktiviteter syftande till att skapa *återhämtningsförmåga, dvs* angreppssätt och rutiner för att hantera oväntade störningar (operational resilience). Syftet med denna avhandling är att undersöka om och hur dessa två olika arbetssätt, med till synes motstridiga paradigm, kan användas för att uppnå ökad konkurrenskraft för företag verksamma under osäkra marknadsförhållanden.

Avhandlingen består av fem artiklar och syftar till att, på ett systematiskt sätt, avhandla tre övergripande forskningsfrågor. Uppdelningen i artiklar motiveras av olikheter i mognadsgrad hos de båda grundbegreppen. En kombination av forskningsmetoder har använts. Den övergripande forskningsstrategin har varit kvalitativ och fallstudiebaserad. Även kritiska händelse metoden, (Critical Incident Technique, CIT) och kvantitativa metoder såsom statistisk analys och Bayesiansk inferens har använts som komplement i några av artiklarna.

Resultaten visar att operativ återhämtningsförmåga kan beskrivas i termer av fem *kärnfunktioner*: uppfatta, formera, konfigurera, återförbättra och bibehålla (RQ1). Resultaten visar även att återhämtningsförmågan kan operationaliseras såsom kombinationer av *sammansatta organisatoriska rutiner* (practice bundles) vilka kan karaktäriseras i termer av interna/externa och proaktiva/reaktiva dimensioner. Kombinationer av dessa sammansatta organisatoriska rutiner har identifierats vilka både samverkar och förstärker varandra i situationer av störning och efterföljande återhämtning. Vidare visas att implementering av lean rutiner leder till ökad effektivitet i situationer karakteriserade av hög osäkerhet (RQ2). Avslutningsvis visar resultaten att återhämtningsförmåga och lean, operationaliserade som kärnfunktioner respektive sammansatta organisatoriska rutiner, har stark samverkan då det gäller att hantera störningar. Några sammansatta organisatoriska rutiner har dock en trade-off relation till vissa kärnfunktioner (RQ3)

Ur ett teoretiskt perspektiv utökar avhandlingen det resursbaserade synsättet till att även inkludera företag som verkar under osäkra marknadsförhållanden. Resultaten visar att (dynamisk) återhämtningsförmåga kan byggas med hjälp av metoder som företagen normalt använder idag (sammansatta organisatoriska rutiner). Genom att omkonfigurera existerande förmågor och rutiner skapas en källa till ökad produktivitet och ökad konkurrenskraft. Således bidrar avhandlingen till diskussionen om det skenbara dilemmat av att en samtidig användning av strategier baserade på *lean production* och strategier fokuserande på *återhämtningsförmåga* (operational resilience) samverkar och förstärker varandra snarare än motverkar varandra. Avhandlingens praktiska implikation är att företag inte behöver överge sitt lean arbetssätt för att öka sin återhämtningsförmåga (operational resilience). I själva verket, bör företag utgå ifrån existerande lean arbetssätt och utvidga dessa till att även omfatta processer utanför den direkta tillverkningen.

*In loving memory,*
*To my dad*

*Without his determination I would*
*have not gone to school at all.*

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I am indebted to my wife Embafresu Teklay for selflessly supporting me and taking care of our daughters Fikir and Johana all by herself throughout my PhD study. Thank you.

Being part of EDIM has been an enjoyable experience most importantly because of the wonderful people I met and the multi-cultural research context I experienced. I learned a lot from the EDIM scientific committee, the PhD candidates, the academic and administrative staffs at the Department of Management, Economics and Industrial Engineering (Politecnico di Milano) and the Department of Industrial Economics and Management (KTH). Andres Ramirez, Emrah Karakaya, Maxim Miterev, Yasmin Hassan, Sudipa Sarkar, and all other EDIM candidates, thank you for sharing your life experiences and skills.

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Stockholm, December 2015
Seyoum Eshetu Birkie

## List of appended papers

This thesis is based on the work reported in the following papers, referred to by roman numerals in the cover essay.

Cover essay
*Be lean to be resilient: Setting capabilities for turbulent times*

**Paper I**

Birkie, S.E., Trucco, P., and Kaulio M., (2014). "Disentangling core functions of operational resilience: A critical review of extant literature", *International Journal of Supply Chain and Operations Resilience,* Vol. 1, No. 1, pp.76–103.

*An earlier version of this paper was presented at the APMS conference, Rhodes, Greece, 24—26 September 2012.*

**Paper II**

Dabhilkar, M. Birkie, S. E., & Kaulio, M. (2015). "Supply side resilience capabilities as practice bundles: A critical incident study". (Under third round of review in an international journal)

*An earlier version entitled 'Developing resilience capability: Statistical evidence from a critical incident study' was presented at the 20th EurOMA Conference, Dublin, Ireland, 7—12 June 2013.*

**Paper III**

Birkie, S. E., & Trucco, P. (2015). "Understanding dynamism and complexity factors in engineer-to-order and their influence on lean implementation strategy" (Under third round of review in an international journal)

**Paper IV**

Birkie, S. E., Trucco, P., & Kaulio, M. (2015). "Sustaining performance under operational turbulence: the role of lean in engineer-to-order companies" (Submitted to an international journal)

*An earlier version entitled: 'Lean implementation in the face of uncertainty and complexity: Operational performance implications in ETO' was presented at the 21th EurOMA Conference, Palermo, Italy, 20—25 June 2014.*

**Paper V**

Birkie, S. E. (2015). "Operational resilience and lean: In search of synergies and trade-offs", *Journal of Manufacturing Technology Management*, Vol. 27, No. 2, (forthcoming)

*An earlier version entitled 'Too lean to be resilient? The dilemma of leveraging from synergetic practices in the event of disruption' was presented at the 22nd EurOMA Conference, Neuchâtel, Switzerland, 26 June — 1 July 2015.*

Selected additional publication

Birkie, S. E., Trucco, P., & Kaulio, M. (2013). "State-of-the-art review on operational resilience: concept, scope and gaps", in Emmanouilidis, C., Taisch, M., & Kiritsis, D. (eds.), *Advances in Production Management Systems. Competitive Manufacturing for Innovative Products and Services IFIP Advances in Information and Communication Technology*, Vol. 398, pp 273-280.

# Contents

# 1 Introduction

*'In quest for lower costs, companies have stretched supply chains globally and made them more efficient. However, many now question whether they have gone too far, and ask how they could restore flexibility, transparency and redundancy—without loading up on inventory'*

(Shill et al., 2012)

*This chapter provides a brief account of the background to the study, research aim, and scope. It also provides the overall thesis structure.*

## 1.1 Setting the scene

*The Japanese automaker Nissan has been affected by the severe flooding in Thailand in October 2011. While its Thai plants were not severely damaged, production has been suspended in different locations due to acute shortage of parts from suppliers in Thailand. Lost production has been estimated to 40,000 vehicles by November 2011[a].*

*Nissan managers described that their strong collaboration with suppliers and good visibility along their value chain enabled them to reduce the impact of this disruption from affecting European and North American production. They used the March 2011 Japan disaster that affected many global supply chains as a lesson to reduce the operation suspension periods and undue impact on other plants. Despite a number of difficulties beyond control, Nissan's sales hit an all-time high in fiscal 2011, 15% increase from previous year [b]. The report reads: 'We were put to the test, but we fulfilled our potential and surmounted the challenges. This success has not made us complacent, the business environment remains volatile, and global competition is intensifying every day'.*

*Nissan's philosophy based on lean production approach, the Nissan Way, states that the power comes from inside. It has been fostered as guiding principle for all employees through their business operations. It proved its worth in addressing such challenges as the strengthening yen and flooding in Thailand and helping to lessen their impacts on the business and increase their competitive edge, as described in their annual report [b]. continues prevention counter measures have been developed and continuously exercised to manage risks associated with the three elements of production, as Nissan refers to, the human resource, purchased parts, machinery and equipment for diverse risk factor categories (scenarios).*

*The company stressed that strong cooperation with suppliers made the recovery from the natural disasters in 2011 smoother. The fruits of such collaboration included supporting affected suppliers and early information sharing on sustained damage and recovery efforts so that supply of components starts as soon as possible for the mutual benefit.*

***Notes:***

*[a] Nissan's press release about effects of Thai flooding, 04 Nov. 2011*

*[b] Nissan, Annual Report Fiscal year 2011*

A strong implementer of lean production, Nissan claimed that it had been able to lessen the negative impacts from the multiple disruptions they had encountered. Can we find similar cases of lean implementation fostering resilience against disruptive circumstances elsewhere? Different media reported that lean-based approaches left global supply chains that were strongly tied to Japan highly vulnerable after the triple disaster in 2011. Similar debates in academic literature are not uncommon. This thesis tries to address this and similar issues.

The global business environment has experienced several incidents that have had unfavourable consequences far beyond what had been anticipated. From labour strikes, factory fires, IT failures to large scale natural disasters such as floods and tsunamis, disruptive circumstances made companies wonder what to do and which are the best ways to avoid the *a priori* unmeasurable consequences that they might have to face. Such incidents make companies vulnerable to failures or disruptions that can originate from anywhere in their business environments and have direct or indirect consequences on their operations. According to Business Continuity Institute (BCI), 85% of the companies surveyed in 2011 reported that they had had at least one incident disruptive to their organisations in the past 12 months, and roughly 30% of them had had more than five such incidents in the same period (BCI, 2011).

While companies need to be well prepared to address adversities that affect their business operations, such efforts often entail high levels of investments. Furthermore, regardless of what happens in the business environment, businesses need to be able to fulfil the (minimum) customer requirements in terms of quality-based, time-based and cost-based competitive priorities (Corbett and van Wassenhove, 1993). Therefore, 'how can companies accommodate these issues and remain viable in turbulent circumstances?' is an intriguing question in operations management in recent years. This thesis is an attempt to provide an alternative analysis and explanation in the aforementioned line of research.

## 1.2 Research gap and positioning

Many companies try to manage disruptions in operations and supply chain with the use of asset buffering and redundancy in the system. Dominant forms of doing so include pilling inventory and spare or duplicate capacity maintenance. The

problem is that these approaches consume big investment; they also tend to reduce operational efficiencies and profit margins. Other ways of forming capabilities to mitigate disruptions are related to establishing flexibilities (e.g. Talluri et al., 2013). Disruption refers to any discontinuity in information, materials or financial flow due to man-made or natural causes of unanticipated scale, timing and location, and that can hinder fulfilment of the firm's operational goals (Craighead et al., 2007; Durowoju et al., 2012; Hendricks and Singhal, 2005). A question then follows as to whether it is possible to create resilience capability starting with a company's existing physical assets and practices without significantly penalising efficiency. That is, if firms can be both efficient and resilient in turbulent times.

Capability refers to the firm's ability to integrate, build and reconfigure internal and external competences (Teece et al., 1997). It can be formed from a cluster of inter-related distinct routines that help to manipulate resources in order to gain competitive advantages (Amit and Schoemaker, 1993; Peng et al., 2008; Prahalad and Hamel, 1990).

Analogous arguments about efficiency and flexibility were discussed as early as 1999 (Adler et al., 1999). Lean production is one of the dominant paradigms with regard to efficiency improvement in enterprises (Narasimhan et al., 2006). If a company implements lean, would this entail having lower resilience in managing unanticipated disruptions? Two arguments have been discussed in literature about this. The first argument says that companies implementing lean could be too efficiency-focused to be resilient in sustaining operations and re-attaining their earlier or a better state after disruptions occur (e.g. Christopher and Peck, 2004; Christopher and Rutherford, 2004).

The second (and the counter-) argument is that since the underlying notion and motive of lean production is to satisfy customer requirements flexibly, it must ideally provide elements for increasing agility for the firm to manage disruptions (Spear and Bowen, 1999). Agile and lean systems can co-exist within an organisation without contradicting intentions that a well-designed lean system should also provide faster response and better efficiency in complex environments (Adler et al., 1999; Flumerfelt et al., 2012). It follows from this argument that if a company claiming to be lean is not resilient against disruptions, it is possible that

the issue is more of practical than theoretical in nature. While both the arguments have been mentioned in operations management literature, empirical investigation of the issues is fairly limited.

Unlike lean, the development of the resilience concept in business and management is fairly recent. The concept of resilience was developed in ecological studies (Holling, 1973). Later, the concept has been migrated to business and management studies where the metaphor of resilient ecosystems recovering to resume their previous situation after being severely affected has been further developed and applied to business organisations (e.g. Ponomarov and Holcomb, 2009).

Some authors contend that lean approaches are against spare capacity, redundancies and contingencies (e.g. Christopher and Peck, 2004) to be used in cases of unexpected shifts affecting business—and thus in opposition to resilience approaches. Whereas others say that there are possibilities to embrace both paradigms and sustain high levels of operational performance. Some anecdotal evidence of this has been presented (e.g. Sheffi, 2007), but more empirical investigation is needed to provide stronger evidence.

In short, the following are identified as points of interest for this study:

- Given the pressing global financial conditions and turbulent business environment, it is worth investigating ways of utilising capabilities both for managing uncertainties and for improving operational efficiencies. To this end, an analysis of efficiency-based (e.g. lean) and disruption risk management approaches (i.e. resilience) is timely and vital;
- Consideration of uncertainties during investigation of lean-performance relation is becoming an important research focus;
- Only little is discussed in academic literature regarding operationalisation and measurement of operational resilience, particularly in relation to operational performance metrics;

In this thesis the main concepts under discussion are resilience and lean (see chapter 2 for discussion). The way this thesis approaches the two concepts differs in two major ways from what has been done before. First, resilience in supply

chain has dominantly been seen as a function of accumulating flexibilities through extra resources and capacity. This research, while recognising that those approaches could be valid, aspires to determine how firms might be able to achieve competitive gains that would be retained with changing forms even when unanticipated events unfold in the internal and external business environment. This is one reason for choosing the resource-based view as a reference frame in contingent situations (see discussion in Section 2.1). Second, the concept of resilience has entered into the supply chain and operations risk management discourse as metaphor, and has lately been criticised for being not more than a vacuous buzzword. There is a strong need to transform the metaphor into a measurable construct and subsequently compare it with other paradigms in managing business operations (in the context of this thesis, lean production).

This theoretical positioning requires the adoption of a multitude of methods in order to jointly address concepts at different levels of maturity that are presumed to be valid in differing contexts (see Chapter 3 for methodological discussion). The thesis can be seen as theory extension and testing research that adds to the resource-based view on how firms can, by adopting routine practices, both survive and progress to having better operational capabilities for turbulent times.

### 1.3 Research aim, relevance and delimitations

The general objective of this study is to investigate if practices in seemingly contradicting paradigms in operations management can be utilised to attain better operational performance and competitive position in face of uncertainties. This objective is addressed through the analysis of the relationship between lean and operational resilience with respect to operational performance objectives in the face of unexpected disruptive events.

The relevance of this study stems from the strong pressure in businesses globally to meet tighter delivery schedules, better quality and cheaper prices while addressing unpredictable events in the global business arena. Businesses are faced with tough choices on which direction to follow: improve performance at the expense of what (bad) might take place in the uncertain future, or increase flexibilities with profit eroding increases in investment and tied up capital. I

believe this thesis will provide insightful discussions on how to assist their decision making.

In this research, it is assumed that business firms can acquire different capabilities through collaboration and partnership with other businesses. However, their resilience towards unanticipated events will only be as good as the extent of embeddedness of the approach in their internal organisation and operations. Also to be noted is that in developing theoretical relationship between variables, the study considers that lean and resilience constructs take some form of 'capabilities' which affect some 'performance' parameters at firm level.

Considering the time limitations for the study period, an extensive longitudinal study to compare lean and resilience practices in a single firm across multiple time periods was not conducted, although it would have been expected to provide more controllable and reliable comparisons.

The study is not a solution for a particular kind of operation in a specific sector. Therefore, there may be particular aspects of some sub-sectors or industries that, by design, the research cannot exhaustively address. This is also why the approach of bundling inter-related practices is used for both lean and resilience concepts as discussed in Chapter 2 as well in the specific papers (see Paper II, Paper IV, and Paper V).

### 1.4 Research questions

Based on the background and the identified research gaps, the overall research question of this study is stated as follows:

*RQ: How are operational resilience and lean practices related in enhancing performance and competitive advantages in face of turbulent business conditions?*

I intend to answer this research question through the investigation of the following sub-questions:

**RQ1.** What are constituents of operational resilience that businesses can utilise in times of unanticipated disruptions?

**RQ2.** Whether and how can lean practices provide a possible competitive edge for businesses operating in high uncertainty environments in terms of operational performance?

**RQ3.** What are the relationships and drivers for synergies/trade-offs between lean and operational resilience (and their constituents) in face of uncertainty?

## 1.5 History of the research journey

I carried out this research as a PhD candidate in the European Doctorate in Industrial Management (EDIM) programme. EDIM is a joint doctoral programme funded by the European Commission under the Erasmus Mundus Action 1 (2011-2015). It is run by a consortium of three European universities: KTH Royal Institute of Technology, Sweden, Politecnico di Milano (POLIMI), Italy, and Universidad Politécnica de Madrid, Spain.

As part of the programme requirement on mobility, I spent three years at my home institution POLIMI for the periods October 2011 – September 2012 and October 2013– end of study). I spent one year (October 2012 – September 2013) at my host institution KTH. This mobility differed from exchange programmes in that, throughout the programme and regardless of where I was physically located, I was working under the close joint supervision of my supervisors from both home and host institutions.

The practicalities of mobility had their implications on the nature and sequencing of studies for this thesis. For example, during my stay in Stockholm, I had a chance to extensively collaborate with Prof. Mandar Dabhilkar (the first author of Paper II) from Stockholm University. This was a great opportunity as I had access to data that would have been very difficult to collect with my only one year stay in Stockholm. Similarly, my stay in Milan enabled me to engage in detailed case investigations of engineer-to-order firms in the area.

Here is information regarding the authorship and my contribution in the development of Paper II for the sake of completeness. The collaboration started when I was presenting my research Progress at KTH and Prof. Dabhilkar was my

discussant. He was interested in the research framework I had and we started discussing how to work together to make empirical analyses. By the time I moved to KTH in the second year of the programme he had provided with the detailed collected data. I have carried out detailed qualitative and quantitative data analyses and interpretation based on my framework. We had many face-to-face discussions on how to develop the paper for conference presentation as well as for submission to a top level journal, with agreed sequence of authorship. I worked very closely with prof. Dabhilkar throughout the development and subsequent revisions of the paper asked by the reviewers from the journal the paper is submitted to.

### 1.6 Structure of the thesis

The thesis consists of this cover essay and five adjoining papers that address the main concepts of the thesis (lean and resilience) first separately, and then bringing them together.

Operational resilience and lean were essentially developed with their own distinct motives in operations management. Broadly speaking operational resilience focuses on finding better ways of dealing with situations that have unwanted consequences and are difficult to anticipate. It is recent in development (and is evolving) within the supply chain and operations risk management domain. Lean production on the other hand has been employed for decades and thus relevant literature is more readily available. Given the above, the cover essay focuses on areas that have not been well addressed so far. One pertinent issue is the use of different methods for addressing the two concepts which are at different stages of development.

The five appended papers in this dissertation provide research findings in relation to operational resilience, lean or a combination of both in relation to operational performance in the face of uncertain circumstances. Figure 1 illustrates the relationship of the appended papers among themselves and with this cover essay.

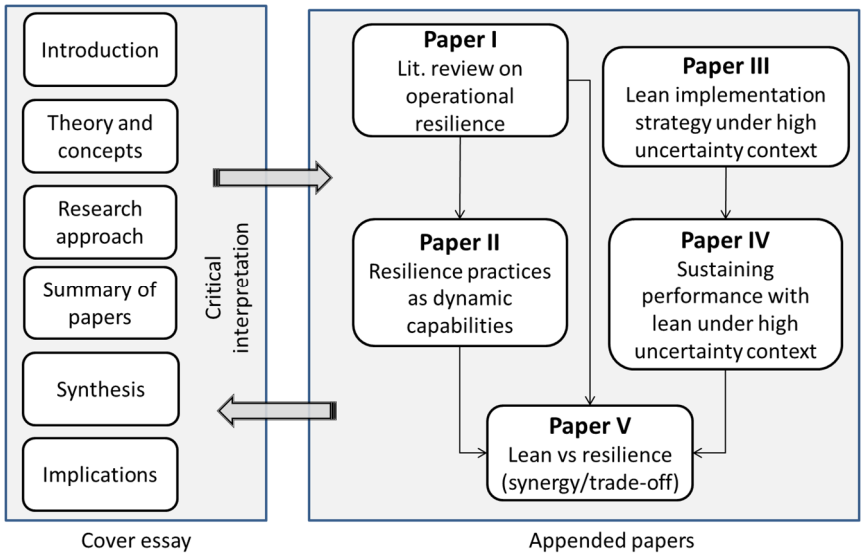


Figure 1. Structure of cover essay and appended papers

**Paper I** (2011-2013) is the starting paper where the research gap and agenda for the whole research are identified. It is mainly a literature review of resilience perspectives to define operational resilience core functions. It provides two case examples and proposes practices that can be used in practically assessing resilience in business firms.

**Paper II** (2012-2015) discusses resilience practices in term of dynamic capabilities. It is an empirical investigation of how firms use (routine) practices for building resilience capabilities to air recovery of operational performance in the wake of disruptive incidents.

**Paper III** (2013-2015) is dedicated to the discussion of the complexity and dynamism uncertainty factors that characterise engineer-to-order business context and their implication on lean implementation strategy. It is advisable to read this paper before Paper IV as it provides characterisation of complexity and dynamism context factors that are referred to in Paper IV.

**Paper IV** (2013-2015) focuses on lean production as a set of practices implemented in a sector of high complexity and dynamism. Through comparative

case studies it investigates how lean practices can be leveraged to obtain better flexibility in such high uncertainty business environments. lean implementation in ETO is discussed with regard to type, extent and locus of lean practices implementation to sustain performance gains.

**Paper V** (2014-2015) is a paper that, using a Bayesian inference approach, discusses the synergy/trade-off relations between lean and resilience practices upon disruption.

All of the five papers have been submitted to peer-reviewed international journals. Paper I has already been published; Paper V is accepted for publication, and the other three are in different rounds of the peer review process at the time of writing this cover essay.

# 2 Theoretical background and concepts

*'The real sources of advantage are to be found in management's ability to consolidate corporate wide technologies and production skills into competencies that empower individual businesses to adapt quickly to changing opportunities'*

(Prahalad and Hamel, 1990)

*This chapter briefly presents the theoretical lens as well as the theoretical understanding concerning the concepts used. Each of the four papers contains specific research frameworks necessary for analysis in the respective papers. The presentation in this section focuses on general theoretical concepts in line with the overall thesis questions.*

## 2.1 Theoretical frame of reference

The detail theoretical frameworks used in the development of the publications are discussed in the respective publications. In a broader sense, the major theoretical underpinning used in this study is the resource-based view (Barney, 1991), and more specifically the dynamic capabilities perspective, as a variant of the resource-based view (Ambrosini et al., 2009; Teece, 2007). Resource-based view (RBV) argues that firms consist of bundles of productive resources and capabilities that help to achieve competitive heterogeneity with heterogeneous resources over time (Hoopes et al., 2003; Penrose, 1952). RBV, at least in its original form, assumes that the development of resources over time is path-dependent and that the environment in which firms compete remains fairly stable. The dynamic capabilities perspective has been developed to explain how and why some firms show competitive advantages in unpredictable and rapidly changing business environments (Teece et al., 1997); it discusses more explicitly the non-tangible elements of differentiation in addition to possession of unique productive tangible assets. In fact there have been consistent calls to include

contingency perspective in RBV (e.g. Aragón-Correa and Sharma, 2003; Barney, 2001).

Some examples of the resilience literature using RBV as a theoretical frame include, Ponomarov and Holcomb (2009) and Ismail et al. (2011) among others (see Paper I). Several supply chain risk management papers also use contingency theory as the underlying theory (Grötsch et al., 2013). Contingency theory susggests that measures and actions for optimal results require an understanding of the prevailing internal external business environment (Sousa and Voss, 2008). Contingency theory views firms as open systems. In the context of this input-process-output system issues from the business environment act as 'inputs', organisational actions or strategies as 'processes', and performance results reflect 'outputs'. Contingency theory provides a convenient way of explaining how proactive measures are developed in operations risk management (Grötsch et al., 2013). This theory suitably addresses inter-organisational issues pertainting to unanticipated circumstances affecting business operations. It explains how organisations adapt structures to remain robust with changing contexts (Sousa and Voss, 2008).

Through combining RBV (e.g. Barney, 1991) and contingency theory (e.g. Duncan, 1972), the dynamic capabilities (Ambrosini et al., 2009; Eisenhardt and Martin, 2000) perspective helps address issues of competitive advantage and better performance in unanticipated dynamic and complex contexts (Conner and Prahalad, 1996). From both RBV and contingency theory it is learnt that actions and strategies are influenced by how the management perceives the general business environment (Aragón-Correa and Sharma, 2003).

Dynamic capabilities consist of main processes namely: reconfiguration, learning, integration, (Teece, 2007), and leveraging (Ambrosini et al., 2009). Reconfiguration is about the transformation and recombination of resources to suit prevailing situations. Learning helps tasks to be performed more effectively and efficiently, and is often achieved through small scale experimentation. Integration as a dynamic capability process is the ability to integrate and coordinate resources internally and externally to regenerate a new resource base. The dynamic capabilities can be seen as functioning at different hierarchical levels

to renew and generate lower level capabilities. Leveraging refers to replicating and extending a (sub-)system, or a process, proven useful in one area to another.

The dynamic capabilities perspective advances the argument of RBV further, saying that firms (should) possess capabilities that enable them to reconfigure, refresh, or integrate resources to meet operational and business needs in turbulent environments. In this research, this perspective is considered in relation to the implementation of the resilience concept based on interrelated practices and routines (Paper II) which, at higher levels of abstraction, form practice bundles that reflect dynamic capabilities (Peng et al., 2008). A similar pattern is valid for lean implementation since lean is a reflection of appropriate implementation of practices (Paper IV) in bundles (Shah and Ward, 2007) that cascade from strategic principles and core values. Using combinations of theoretical frames, this thesis argues that resilience can be viewed as a capability, and that a firm's action routines are the micro-foundations (Teece et al., 1997) to create proactive and reactive capabilities that span from internal operations to external connections (Paper II). Consideration of uncertainties, as is done in here by focusing on contingent RBV, is important because it is difficult to *a priori* determine the resources needed to enable enhanced performance in turbulent environments (Aragón-Correa and Sharma, 2003). Both lean thinking and operational resilience features in firms can be seen as sources of valued capabilities to deliver competitive advantages. For the purpose of this study, competitive advantage is defined as the result of a firm being differentiated in its business offering and/or excelling at doing its business (i.e. doing better than the competition) (Eisenhardt and Martin, 2000; Lewis, 2000) given the prevailing context. This implies that the firm may have to adjust the resources and processes for generating such advantages in the long term and as situations change (e.g. Reeves and Deimler, 2011). The concepts operational resilience and lean, and how they theoretically relate in high uncertainty contexts in enabling firms attain better competitive performance is illustrated in Figure 2.

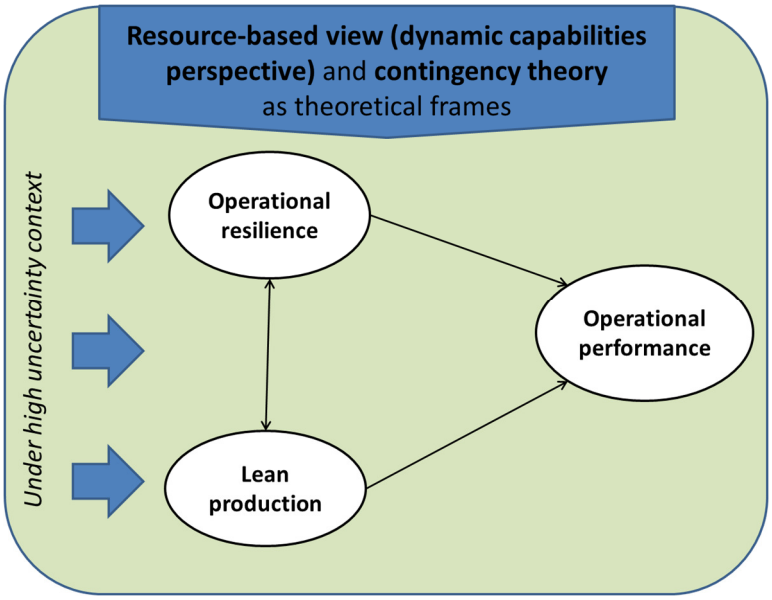


Figure 2. Concepts and proposed relationships under the selected theoretical frames

## 2.2 Changing business environments and uncertainties

The current business environment is acknowledged to change rapidly and unpredictably, posing challenges for firms and supply chains. Sources of uncertainty and environmental turbulence may arise from within the business or the supply chain of concern, or may emanate from the external environment that is directly or indirectly connected to the business of concern. Furthermore, the strong inter-dependence of businesses globally is causing chain or unwanted consequences to develop from sources previously considered to be minor or not considered at all (Trkman and McCormack, 2009).

Environmental turbulence and sources of uncertainty could be related to supply-side, demand-side or internal operations including control processes (Childerhouse and Towill, 2004; Mason-Jones and Towill, 1998). However, the type and extent of change considered as part of uncertainty may vary from time to time. A supplier going bankrupt or an unanticipated disruption of sources as well as extended delays can be mentioned as typical examples. Changing customer

tastes and preferences, technological shifts and new regulatory requirements are typical sources of demand-side turbulences. Internal processes can also be sources of, or be affected by, uncertainties of demand disruptions (e.g. quality problem) or supply-disruptions (e.g. causing over utilisation or the bankruptcy of suppliers). In addition to those turbulences directly related to the business, any adversities in the overall business arena such as financial crises or terrorist action could have devastating consequences on business operations.

Uncertainty is a state that ranges from some lack of certainty to nearly complete lack of knowledge about a phenomenon or its consequences (Paté-Cornell, 2012), prohibiting the decision makers from making definitive decisions. The potential of unwanted negative consequence of an event or activity associated with uncertainties is referred to as risk. According to decision theorists, risk is not just a downside but an issue of uncontrollability that can also include the 'upside' of potential performance changes and opportunities (Frost et al., 2000; Rao and Goldsby, 2009). The sources of uncertainty could affect a few elements or may trigger a chain of events with propagating effects along value chains (Bode and Wagner, 2015; Frost et al., 2000; Jüttner and Maklan, 2011). As such, despite the classification of triggers, the firm is not immune to risky implications.

Previously, business environments were considered to be fairly stable with manageable amounts of variations. Methods such as forecasting were developed under this assumption. Such tools are still utilised but their effectiveness can be questioned when the variations become unpredictable. Current business problem solving approaches should therefore take into account such unavoidable causes for uncertainty and business turbulence.

The concept of uncertainty is evolutionary concept derived in relation to risk management approaches. As such, it is well integrated with the concept of resilience concept. Introducing the idea of changing environments and uncertainties to lean production is a different path because it requires reconsideration of tools and practices which are often discussed with fairly stable business conditions in mind. It requires extending the consideration of routine and predictable (yet unavoidable) variations to abrupt changes and turbulences.

Turbulence or environmental uncertainty can be classified as complexity and dynamism dimensions (Duncan, 1972). Complexity refers to the number of

factors (and similarities among them) involved in decision making. Dynamism refers to the predictability of the factors over time.

Different uncertain environments may in different ways influence lean practices implementation and their effect on performance (Browning and Heath, 2009; Chavez et al., 2013, 2015). Investigation of uncertainty context factors complexity and dynamism with lean production has been fairly limited apart from a few recent studies (Azadegan et al., 2013; Browning and Heath, 2009; Chavez et al., 2013, 2015; Marley and Ward, 2013). This classification of uncertainties is used in Paper III and Paper IV with the engineer-to-order business environment as mentioned before.

Using two dimensions, Figure 3 shows a different representation of uncertainties that potentially affect operations in a turbulent business environment. The uncertainties can be seen as variations that occur routinely or non-routinely (horizontal axis). Routine uncertainties are those accepted to commonly occur in the sector or the way of doing business. Non-routine uncertainties are those that are external to the ordinary variations. On the vertical dimension we see that routine or non-routine uncertainties can be predictable (largely known) or unpredictable (largely unknown). Predictability implies that consequences and/or probabilities of occurrence can be somehow estimated. The classification forms four scenarios as indicated by the quadrants. An example of the uncertainty situation in quadrant I is day-to-day and seasonal demand variations in a mass production environment. Quadrant II represents a typical situation in highly customised ETO manufacturing. ETO is used as an empirical setting for Paper III and Paper IV (this empirical setting is used to extend the lean concept into the high uncertainty context, as shall be seen in subsequent chapters). Supply chain disruptions such as the one caused by the Japan triple disaster in 2011, or the flooding in Thailand described in the introductory Nissan case are examples that belong in quadrant III. Quadrant IV represents uncertainties pertaining to, for example, a work place accident that can be addressed by established risk management processes.

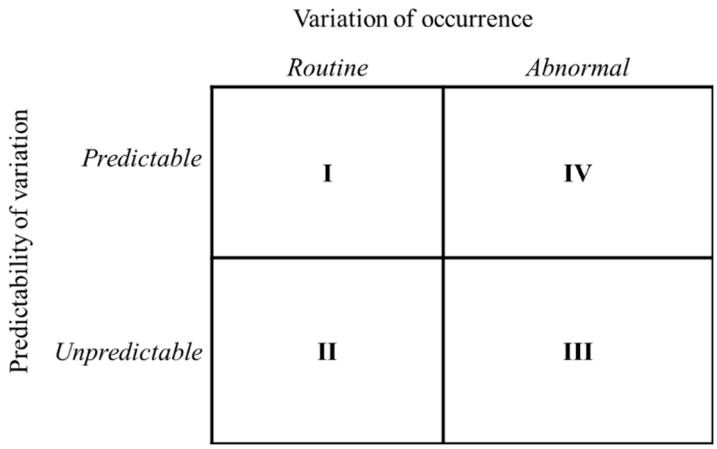


Figure 3. Characterisation of operational uncertainties as variation

## 2.3 Lean Practices

Lean production has existed, and was evolving, for decades. Therefore, relevant literature on it is readily available even though its consideration in uncertain environments is scarce (Azadegan et al., 2013). For this study lean is characterised as a socio-technical system of multiple managerial practices. It can be defined as 'an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimising supplier, customer, and internal variability' (Shah and Ward, 2007, p. 791). Lean is based on principles that focus on processes, people and partners, as well as problem solving and long-term thinking philosophy (Alves et al., 2012; Liker, 2004). The ultimate goal of lean production is creating better value for the customer. Lessening wasteful activities in processes, understanding e customer requirements, and subsequently offering a value proposition for which the customer is willing and able to pay for is how lean can be described at an aggregated level (Hines et al., 2004).

Lean has been dominantly implemented on the production shop floor where it is easier to observe wastes and eliminate them. Many firms start with lean experimentation pilot projects on the shop floor, and then proceed to other processes to create an integrated management system as advocated by the proponents of lean production. One of the challenges in implementing lean is to focus too much on localised optima that do not lead to firm-level improvements.

Wasteful activities in non-shop floor activities can erode what could have been achieved using lean implementation at an aggregate level (Paper III and Paper IV present findings in this regard).

Literature suggests that lean production can be employed in different sectors and with diverse product configurations (Modig and Ahlstrom, 2012; Womack and Jones, 2003). However, empirical investigations on lean implementation are dominantly reported from large companies, with fewer product varieties and large production volumes. A possible justification for this are the possibilities for large companies to have large volume production, with dedicated production lines which tend to require less work-in-progress inventories (Demeter and Matyusz, 2011). In other words, it is easier to implement some lean practices under these conditions. In general, however, for lean production to be as flexible as possible with reduced numbers of flow units while also improving resource utilisation, cellular manufacturing is suggested. Other elements associated with lean include just-in-time production, standardisation of work procedures, and diligent waste (*muda*) reduction. While the early formulations of manufacturing waste considers the 'seven wastes' mainly on the manufacturing shop floor, recent conceptualisation encompasses several other forms of waste including the waste of 'lost opportunity' and underutilised employee skills (e.g. Alves et al., 2012).

Organisational learning derived from waste removal and continuous improvement is a crucial element for companies implementing lean in their striving to create and retain competitive advantages by crafting their own implementation paths suitable to their business environments. Through the years, lean has evolved from having a solely shop-floor based approach to an overall system of delivering value to the customer (Hines et al., 2004). Therefore, lean based managerial practices can be found extending throughout an enterprise's value chain. thus evolved, lean can now be thought of as a work organisation model where the worker takes the position of a thinker (Alves et al., 2012) for better agility.

Lean production is a multi-faceted concept. Systematic study of lean production becomes difficult when so many diverse tools and practices can be implemented by different firms pursuing similar principles and goals for their lean production. One approach to alleviate this problem is the grouping of

interrelated practices together. Such an approach has been popularised through the notion of lean practice bundles introduced by Shah and Ward (2003, 2007). In this study, this notion of bundles of lean practices is used in operationalising lean. Further details and additional references are included in Paper III and Paper IV.

A review of relevant literature on lean reveals that the number and specification of the lean practice bundles differs. The most representative practice bundles discussed in literature are (1) total quality management, (2) just-in-time and flow, (3) lean purchasing, (4) total productive maintenance, (5) human resources management for lean, (6) customer involvement and partnership, and (7) supplier involvement and development. Standardisation can also be added to the above list when it is of particular interest for making comparisons. A detail description and presentation of practices included in each of these bundles can be found in Paper III and Paper IV.

Some practice bundles such as total quality management (TQM), total productive maintenance (TPM), human resources management (HRM) and just-in-time/flow are focused on operations within the business firm, and are termed as internal lean practices (Azadegan et al., 2013; Chavez et al., 2013). Others are externally focused, with examples including lean purchasing, customer- and supplier-related practice bundles. Furthermore, as described in Paper III, some of the lean practices could be more targeted on shop floor activities (e.g. TPM) while others can span broad ranges of functions in the value chain (e.g. TQM or HRM).

## 2.4 Operational resilience

As discussed in detail in Paper I, the ultimate goal of operational resilience is to create an enterprise that can continue delivering its targets with minimum possible adversities from unanticipated circumstances affecting its core operations (Caralli et al., 2010). Therefore, one can say that operational resilience is an emergent property of operational risk management. For the purpose of this study, the definition of resilience suggested by Ponomarov and Holcomb (2009) has been adopted. Resilience is obviously more than just recovery. It implies having the anticipative and flexible capabilities required to address the positive and negative influences of the environment so as to keep the business delivering

value and remaining viable in a competitive business environment (Ponomarov and Holcomb, 2009). The fulfilment of these goals by an operationally resilient company calls for the presence of five core functions (Paper I). These core functions are: sense, build, reconfigure, re-enhance, and sustain.

The sense core function is related to how firms try to improve visibility and early detection of unanticipated events. Indicative patterns and proxies help detect influential changes and their potential influence. It also incorporates scenario-based analysis to improve expertise, experience and asset base for possible future shocks.

The build core function signifies a set of activities carried out proactively. Usually these are executed prior to encountering changing circumstances or starting immediately after the encounter (Sheffi and Rice, 2005). The build core function has to do with broadening asset and capabilities bases through the use of uncommitted resources as much as possible (Weick and Sutcliffe, 2007).

Reconfigure refers to a higher and integrative form of capability to adapt in responding to unanticipated circumstances that have an important impact on the firm's business operations. The essence of adapting or reconfiguring is to sustain the attainment of business objectives (i.e., delivery function). Continuing to deliver business operations is an important feature in reducing lingering consequences.

The re-enhance core function is concerned with retaining competitive performance levels once the effects of shocks or pressures are felt through recovery and enhancing. Recovery is mainly concerned with disruptive events (Christopher and Peck, 2004; Sheffi, 2007). Firms try to enhance gains from opportunities before they turn into threats (Hamel and Välikangas, 2003).

Different resilience perspectives adopted in business firms (e.g. organisational, strategic, systems engineering and so on) contribute to forming operational resilience. Based on review of relevant literature, a detail presentation of how the different perspectives contribute to the operational resilience core functions is discussed in Paper I. The literature on supply chain resilience concentrates on resilience aspects related to velocity, flexibility, visibility and collaboration in efforts to recover from disruptions (Jüttner and Maklan, 2011). The organisational resilience literature is mainly concerned with learning and

with dynamism in humans as collective decision makers (e.g. Välikangas, 2010). When resilience is viewed from a strategic perspective, reconfigurations and enforcing changes occur before changes force a business to unwillingly change something at a greater expense (Hamel and Välikangas, 2003; Välikangas, 2010). The idea of maintaining the continuous fulfilment of objectives stems mainly from the business continuity line of thought (Caralli et al., 2010).

A particular point of interest in operational resilience in relation to what is discussed in the supply chain resilience literature is the 'inward looking' focus of the former. With the dynamic capabilities perspective, operational resilience is conceptualised to primarily establish and initiate embedding of relevant capabilities and resources by asking the question 'what can I do to be in a better operational and competitive position against unanticipated events?' This implies that the different mechanisms for building better resilience in supply chains are not excluded. Besides, the utilisation of opportunistic circumstances is given equal priority as events that are considered disruptive *prima facie* because uncertainties always entail both threats and opportunities (Frost et al., 2000; Hamel and Välikangas, 2003). Consistent with this, the definition of risk as 'a situation or event where something of human value (including humans themselves) is at stake and where the outcome is uncertain' (Rosa, 1998) is used in this thesis. Accordingly, knowledge of probabilities or expected values is not required for the study of uncertainties with possibly desirable or undesirable outcomes (opportunities and threats).

# 3 Research approach

*'Data is of course important in manufacturing, but I place the greatest emphasis on facts'*

*(Taiichi Ohno)*

*This section presents the overall research approach of the dissertation.*

## 3.1 Overall research design

On and off, issues related to the selection and justification of logical analysis in scientific research is under strong debate particularly in management research. Logical process in scientific inquiry coarsely refers to a set of normative standards used for judging the process of testing scientific theories (Simon, 1973). In the realm of scientific explanation or analysis, an important element is the presupposition of tentative theory (based on limitations in previous theories) that needs to be rigorously tested (Chalmers, 1999). In view of management research, then, rigor and relevance are important in explaining and testing these tentative theories. Relevance can be described in terms of creating insights that practitioners consider useful for the better understanding of the phenomenon of concern. Rigor describes how consistent the various elements of a theory are, how logically derived the hypotheses are, how unbiased data collection is, and reliable measures are (Eisenhardt and Graebner, 2007; Vermeulen, 2007).

The studies in this thesis predominantly use qualitative approach and the tentative theories for observing and explaining the phenomenon of concern are proposed based on received knowledge. However, specific methods of data collection and analysis vary depending on the aims and context of the specific study which are explained in Section 3.3.

## 3.2 Research context

The unit of analysis in this research is the single firm. In cases where the legal entity firm consists of multiple and diverse business units, a particular business

unit is considered as the unit of analysis, inheriting common features from the parent firm.

Medium and large sized firms are preferred in the studies for a few reasons. First, multinational firms are assumed to be more representative of the global business context than small local firms; and multinational firms are often large or medium sized. Second, larger firms are more likely to implement structured management systems of practices such as lean and risk management (e.g. Shah and Ward, 2003). Besides, idiosyncratic applications of implemented practices that lend themselves for richer explanations are more likely to be observed in larger firms.

This thesis is comprised of 'modules' of studies that are designed to address the overall research questions systematically. This was chiefly necessary due to the different maturity level of the concepts brought together, as well as the limited access—due to the thesis timeframe— to study objects fulfilling the study setting. As such, we can talk about different levels of generalisability and representativeness. At each study level, the findings are relevant to the particular domain of investigation and subject to the advantages and limitations of methods applied. At an overall level, the general framework is applicable to a broader domain since at least one study was conducted taking this into account.

### 3.3 Multimethod approach

On an aggregate level, the main methodological approach used to address the three research questions of the dissertation has been to combine the critical incident approach, multiple case studies and Bayesian inference. Generally speaking, the approach can be regarded as qualitative, with quantitative analysis embedded when deemed necessary and appropriate. Use of various combinations of methods for addressing research questions in single studies or complex programmes of continuous research is becoming a research style in itself (Brewer and Hunter, 2006). It is considered to have so developed due to the complex nature of contemporary social science research problems that are best addressed using multi-method approach. This approach provides distinctive advantages of coordination and comparison of different methods and findings.

The respective methods used in each paper along with their respective research questions are shown in Table 1.

### 3.3.1 Critical incident technique

The critical incident technique (CIT) was first developed by Flanagan (1954) in the field of industrial and organisational psychology. It is an approach where informants are asked to recall incident(s) that challenged the fulfilment of an important objective, or deviation(s) from some work process that had noticeable consequences or implications. An incident is an observable human activity that should be complete enough to allow inferences and predictions to be made about it. The informant is free to describe it, without prior judgment of what is important, as long as response is aligned with the overall research framework. The context is thus developed from the respondent's perspective (Chell, 1998). A critical incident consists of at least: (1) description of the specific event that actually occurred, as well as what made it interesting/critical (Chell, 1998); (2) an account of behaviours or actions in association with the event (Flanagan, 1954); (3) specific (potential) outcomes and implications that differ from what could routinely have been expected (Edvardsson and Roos, 2001); (4) description of the environment and time in which the incident occurred and progressed (Edvardsson and Roos, 2001; Hughes, 2012).

Table 1. Summary of methods in adjoining papers

| Paper | Paper I | Paper II | Paper III | Paper IV | Paper V |
|---|---|---|---|---|---|
| **Topic** | Operational resilience core functions | Identification of practices forming resilience capabilities | Lean implementation strategy under high uncertainty context | Improving and sustaining performance with lean in a high uncertainty context | Lean- resilience synergy/trade-offs |
| **Method of data collection and analysis** | Structured literature review | Qualitative interview with structured survey instrument; qualitative and statistical analyses | Case study (a primary detail one and a brief additional case) | Multiple (comparative) case study; data collected with interviews, reports and field observation | Secondary data from public sources; Bayesian Network (probabilistic) analysis |
| **Source of data** | 41 papers reviewed; two cases based on secondary data | 22 manufacturing firms in Sweden | (Two multinational firms with ETO manufacturing in the capital goods sector) | (Two multinational firms with ETO manufacturing in capital goods sector) | (Secondary data from media and company sources of 40 multinational firms) |
| **Unit of analysis** | | One manufacturing firm | ETO manufacturing business unit of a multinational firm | ETO manufacturing business unit of a multinational firm | A firm (a business unit in case of multiple ones) |
| **Participants** | -- | Managers in supply chain related positions | Managers of (production, quality, procurement, operations strategy) positions | Managers of (production, quality, procurement, operations strategy) positions | Senior managers (through publicly available official reports and interviews) |
| **Research Questions in paper** | **Q1**. What are the core functions of operational resilience? | **Q1**. How can resilience capabilities be developed as typology?<br><br>**Q2.** What is the impact of the resilience capabilities on operations performance? | **Q1:** What are the peculiarities of complexity and dynamism factors for ETO firms in capital goods manufacturing?<br>**Q2:** How do complexity and dynamism affect lean implementation strategy in ETO capital goods manufacturing firms? | **Q1**: Does lean practices implementation differ in ETO capital goods manufacturing compared to widely established literature in repetitive manufacturing?<br>**Q2:** What is the implication of lean implementation on performance gains in ETO capital goods manufacturing firms? | **Q1**: Are there evident synergies or trade-offs between lean and resilience in reducing operations performance loss upon disruption?<br>**Q2:** How do the underlying elements of lean and resilience relate in forming synergy or trade-off among the two? |
| **Related thesis RQ** | **RQ1** | **RQ1; RQ3** | **RQ2** | **RQ2; RQ3** | **RQ3** |

Through developments over the years the method has come to have important features of (1) focusing on critical events or incidents that are marked by enhancement or hindrance of effective performance of activity or situation (2) data collection is mainly done with face-to-face or telephone interviews, (3) analysis based on a reference frame that emerges from the data for generating categories (Butterfield, 2005).

When applied in management studies, CIT has often been combined with other approaches and methods of data collection and analysis (Gremler, 2004). For example, it is commonly used within case study design (Åhlström, 1997; Blackhurst et al., 2005; Craighead et al., 2007); Flanagan (1954) himself used the frequency of mentioned incidents for analysis; the relevance of augmenting time series analysis and historical considerations with the incidents has been suggested as a way of improving CIT method (Edvardsson and Roos, 2001). Researchers have also used reliability and validity tests other than those suggested in the original CIT (e.g. retranslation, standard deviation test, drawing different samples to generate critical incidents) (Butterfield, 2005). The CIT approach has been used in supply chain risk and resilience studies due to its suitability for retrospective investigate 'out-of-the-routine' incidents (Craighead et al., 2007; Klibi et al., 2010).

In paper II, the CIT method was extensively used with two sequential steps. In the first stage, a sample of 14 incidents were collected to extract critical incidents related to supply side disruptions, and to see what actions have been taken to achieve better and faster recovery. The process finally resulted in a shortlist of 14 action routines that, based on to the informants' comments, were found to have resulted faster and better recovery. These practices (actions) were used in the second step to question other firms about a disruptive incident they have experienced and how well the shortlisted practices were then employed. The process has enabled more reliable data collection, relationship building among resilience capabilities and performance, and further quantitative analysis.

The use of CIT in Paper II, along with Paper I, paved the way for encoding the data in Paper V; the data collection used the idea of CIT, with a novel encoding approach being subsequently applied.

### 3.3.2 Case study

Detailed explanatory discussion of phenomena in their real-life settings makes case study a suitable qualitative method (Yin, 2003). The case study method is often considered appropriate in the search for a better understanding of phenomena in a single setting, with the added possibility of extending to multiple cases to improve generalisability (Meredith, 1998). Case study enables the use of multitude of data types and sources with greater depth of investigation of the phenomenon of interest in its natural setting (Meredith, 1998; Yin, 2003).

Paper III and Paper IV used multiple case study methodology. Shop floor observations, participation in meetings, multiple interview sessions and collection of written documentation have been used in combination. This methodology was used in investigating how the extension of lean practices implementation to multiple value chain processes could help to better address uncertainties and consequently sustain operational performance in the ETO setting. Paper IV discusses how lean practices can be useful for extending flexibilities in highly uncertain environments. This is subsequently extended to the investigation of the potential relationship of lean and operational resilience (analysed in Paper V) in difficult to anticipate circumstances.

### 3.3.3 Bayesian inference

A Bayesian network is a graphical approach used to represent relationships among variables. It is a Bayesian theory-based approach that enables the analysis of conditional relationships between random variables. It is a statistical inference approach distinguished from the frequentist approach by the use of probabilities to express information uncertainty. A major benefit of the Bayesian network (BN) approach is that it enables to describe back propagation of causality when sufficient information is not available (Charniak, 1991; Speigelhalter et al., 1993). That is, one can consider as if a child node (effect) has actually occurred, and then calculate posterior probabilities for other variables. Even though BN is quantitative primarily analysis, the way the inferences are used in this thesis to identify synergetic/trade-off relationships makes it qualitative because the focus is on signs of a relationship rather than on its magnitude (Wellman and Henrion, 1993).

The findings of Paper II were part of the pre-established encoding scheme used in Paper V. The BN approach is used in Paper V to develop conditional probabilities from encoded data. It was consequently employed to analyse the synergy/trade-off relationship between resilience and lean upon disruption with reference to changes in operational performance.

### 3.4 Methodological quality assessment

The main issues of concern in assessing the quality of a research method are reliability and external validity, construct validity, and internal validity.

Construct validity expresses how well variables and constructs illustrate reality within the scope of the study (Yin, 2003). In Paper II relevant practices were identified through empirical investigation before using them to collect further empirical evidence in order to address issues of construct validity. Further, the respondents in the second stage had the possibility to ask for clarification from the interviewers as to what the questions or specific terms were referring to. The review of the relevant literature strengthened the construct validity of the study (e.g. Paper I). In Paper III and Paper IV, the semi-structured interviews and follow-up discussions with the respondents helped ensure proper representation of the phenomenon. The use of multi-item constructs for lean practices improves the reliability of analysis. The constructs so validated were carried over to Paper V where the collected secondary data (on incidents such as the Nissan situation in the introductory case) were compared against the pre-established variables in the coding process.

Internal validity addresses the question of whether the causal relationships identified between variables or constructs actually reflect the relationships in reality (Yin, 2003). Triangulation of both qualitative and statistical analyses (e.g. Paper II) and causal relationship from qualitative case studies (e.g. Paper IV) are used in this thesis to bring about better internal validity.

External validity and reliability concern the issue of replicability of the findings in a different sample and at different point in time. This thesis attempted to improve external validity and reliability through formal tests when possible (e.g. Paper II). The results are expected to be replicable in circumstances of similar nature as the studies in this thesis. However, due to the diversity of

possible causes for uncertainties, differences may be observed. Following the line of argument from the contingency theory, my argument for such observations would be to proceed with further investigation to explain why the differences materialise, leading to further rectification of proposed relationships in this thesis.

### 3.5 Research limitations

This thesis, as any other research undertaking, is not without limitations. The research limitations in this thesis emanate from the limitations of individual studies not addressed by one of the other studies.

For example, the small sample size of the statistical analysis part in Paper II could be mentioned as one limitation even though consistent results were obtained from both the qualitative and statistical analyses with the same sample size. The same paper also has some limitation related to possible 'filtering' of recalled information, even though the authors tried to reduce this with the use of data from the pre-study coupled with face-to-face interviews in an effort to guide informants in the main study.

Limitations in Paper III are related to the identification of the configuration and the moderation roles of complexity and dynamism context factors on lean implementation strategy. These limitations are not addressed in Paper IV since resolving this limitation along with generalisation to a broad sector of industry would normally require large-scale surveys. In Paper V, there are possibilities for bias due to provision of selective information or differences in the presentation of details for public consumption by different managers and media. While the presence of such biases is undeniable, it appears to be limited due to reputation issues as well as to the regulatory requirements put on corporate managements to provide correct information. The study (Paper V) did not rely on just news media; performance data and confirmation of the incidents in all cases came from company reports. For the sake of argument, presence of these biases would have favoured contrary results in the opposite direction (i.e., more trade-off than synergy between lean and resilience). See Paper V for details.

# 4 Summary of the appended papers

*This chapter briefly presents summaries of the appended five papers.*

## 4.1 Overview

The summaries presented here are intended as a help to the reader on how each paper contributes to the overall discussion Chapter five. Readers may refer to Figure 1, which illustrates the outline of the thesis and the connection among the appended papers. Though the summaries are provided here, the appended papers are stand-alone texts.

## 4.2 Paper I

Birkie, S.E., Trucco, P., and Kaulio M., (2014). "*Disentangling core functions of operational resilience: A critical review of extant literature*"

This paper systematically reviews literature on different perspectives and definitions of resilience in order to identify the core functions of operational resilience. It starts with pioneer resilience conceptualisation from ecosystem studies (Holling, 1973) and engineering (Walker et al., 2004), and proceeds with resilience perspectives in business resilience to characterise operational resilience with its core functions.

The study uses literature review based on keyword searches in mainly Scopus and Web of Knowledge databases. Relevant publications were further shortlisted after the abstracts were. References of the selected papers were checked to search for relevant material not indexed in these databases. 41 publications (35 articles, five books and one book chapter) in a final list were reviewed in detail. Five of the 41 had extensive literature reviews in them, and 25 gave formal definitions of resilience in their study contexts.

Two case examples (Dell and Manganese Bronze) were included in this paper to scrutinise the identified core functions. The different resilience perspectives (engineering, supply chain, organisational and strategic) contribute to characterise operational resilience in businesses. Accordingly, five operational

resilience core functions were identified. They are: (1) sense, (2) build, (3) reconfigure, (4) re-enhance, and (5) sustain.

*Sense* refers to the ability of the firm to anticipate possible future uncertainties and ways-out. It includes aspects such as improving visibility, scanning the business environment for early detection and prompt collection of information at the incident site. The analysis of near misses is also seen as a part of the *sense* core function. The b*uild* core function is concerned with the establishment of proactive capabilities and learning to take action. It has to do with regenerating and broadening the asset and capability bases (Ambrosini et al., 2009) through the use of uncommitted resources as much as possible. *Reconfigure*, as the name implies, is about adapting and reconfiguring organisational arrangements and resources to align them with prevailing and upcoming uncertainties (both threats and opportunities). The r*e-enhance* core function concerns retaining competitive performance levels after the effects of shocks or perturbations are felt. It includes efforts to recover from deteriorating performance (e.g. Christopher and Peck, 2004; Sheffi, 2007), and enhance business performance utilising windows of opportunity (e.g. Sheffi, 2007). *Sustain* is about continuing to deliver value to the customer regardless of changing circumstances.

The main contribution of Paper I is that it broadens the scope of resilience in businesses beyond the earlier scope of redundancy and slack in physical resources for resilience. It redefines operational resilience in terms of the five core functions. Therefore it addresses the limitations of earlier research that discussed indicative mechanisms of building better resilience, which are difficult to exhaustively present. It also points to future directions of research such as how resilience capabilities could be practically achieved in firms. Additionally, the paper tries to connect operational resilience with the dynamic capabilities perspective (Teece, 2007) thus further paving the way for future research. It links the identified core functions of operational resilience to the four functions of dynamic capabilities (learning, integration/coordination, reconfiguration, delivery).The paper concludes by pointing to possible future directions of research to address debates and paradoxical issues including the relationship between lean and resilience towards better operational performance.

### 4.3 Paper II

Dabhilkar, M. Birkie, S. E., & Kaulio, M. (2015). "*Supply side resilience capabilities as practice bundles: A critical incident study*"

Paper II conceptualises a typology of resilience capabilities for supply-side disruptions. It seeks to validate how and why practice bundles form and relate to operational performance through empirical analysis.

The study uses the critical incident technique to collect data on disruptive events that manufacturing firms face. The study was done in two steps; the first step was dedicated to identifying relevant practices that firms adopted upon disruption (incidents from 14 firms), and the second step used the identified practices to develop and validate the typology by collecting critical incident data from a set of other 22 firms. The study is primarily qualitative with contains a frequency of occurrences included. A minor statistical section of factor and regression analyses was also included to provide methodological triangulation. Both methodologies reveal consistent evidence of bundle formation, correlation between the adoption of bundles of practices and recovered operational performance after an upstream supply chain disruption.

The value of using a mixed method approach in this study was that it helped to ascertain that the practice bundles really caused operational performance recover (internal validity through qualitative research), as well as estimating the strength of these relationships (external validity through quantitative research).

Supply-side resilience is conceptualised as four capabilities in the two dichotomous dimensions 'proactive/reactive' and 'internal/external' as proactive-internal, proactive-external, reactive-internal and reactive-external resilience capabilities. The empirical findings support the conceptualised typology. Bundles of specific practices that can be associated to each capability are identified. These practice bundles are collections of specific practices employed prior to, and after encounters with disruptive supply chain incidents. The bundles were found to help firms recover their manufacturing operations performance after supply-side disruptions. This claim is supported by a thorough qualitative investigation and methodological triangulation using quantitative analysis.

The paper identifies the practices that lead to recovered operational performance in the event of supply chain disruptions. It contributes to current resilience literature by adding a practice-based view (Ketokivi and Schroeder, 2004). In particular, it advances current theory by showing how resilience can be operationalised as a set of dynamic capabilities in terms of practice bundles that restore operational performance. This study has shown through conceptual work and empirical validation which practices are most relevant, how they bundle, and how these bundles lead to improved operational performance in the event of an upstream supply chain disruption. The study helps solve an important managerial problem of managing unforeseen supply-side disruptions. The study demonstrates that all mitigation is not just reactive; many valuable actions should be taken proactively, that is, before and in anticipation of the disruptive event.

Paper II gives an alternative presentation and empirical extension of the resilience core functions conceptually discussed in Paper I. It advances current theory by operationalising resilience as a set of dynamic capabilities in terms of practice bundles that aid in recovering operational performance upon disruptions.

### 4.4 Paper III

Birkie, S. E., & Trucco, P. (2014). "*Understanding dynamism and complexity factors in engineer-to-order and their influence on lean implementation strategy*"

The paper seeks to extend the limited consideration of lean practices in an engineer-to-order (ETO) environment. It aims to understand in more detail whether the complexity and dynamism factors discussed in a general business context (Duncan, 1972) also apply as they are to ETO firms or if different sub-factors can be identified. It also aims to explore and better understand how these context factors affect implementation of lean practices in these ETO firms.

The methodological approach used for this study is case study (Yin, 2003) as it provides better internal validity and the opportunity to work with details in order to investigate contextual factors, whereas replication and sampling frames are its challenges (Eisenhardt, 1989). Two case companies were investigated in this study: a primary case, where detailed investigation has been conducted, and a

secondary case, where the application of similar context patterns for lean implementation is discussed using secondary data. For the primary case, data were collected through 7.5 hours interview sessions with managers from production planning, quality management, engineering, procurement functional areas, and several hours of field observation at the shop floor, as well as 10 hours of participation in cross functional meetings. Copies of documents concerning e.g. lean implementation on shop floor, problem identification and analysis, progress of different initiatives were also collected.

In this study, we observed that most of the identified complexity and dynamism sub-factors are relevant for characterising the two context factors in the ETO mode of production in the capital goods sector. The findings strengthen previous studies on complexity and dynamism factors by demonstrating that these two context factors encompass much more elements than just the market concentration index or factors beyond the control of the firm. Unanticipated uncertainty issues that are reflected in the form of complexity and dynamism in ETO can be managed by leveraging lean practice bundles to derive value from them. Paper III proposes a framework of two forms of influence (configuration and moderation) from dynamism and complexity context factors on lean implementation strategy. Previous studies had limited contribution to the discussion of the configuration role, and those discussing the mediation influences are sparse too. The configuration influence is observed when sub-factors in the context factors foster or hinder the implementation of the lean practices themselves. Moderation influence of the context factors depicted on the extent of operational performance obtained from the lean practices implementation.

The findings suggest that several complexity and dynamism sub-factors provide opportunities for strong value enrichment to customers as well as experimenting with different ways of implementing practices in the specific ETO context. At practice bundle level, the context factors do not seem to restrict lean implementation strategy, even though a few specific practices might be challenged. Once lean is implemented, the uncertainty context factors seem to foster performance gains from the lean strategy despite differences in implementation details. However, it was not possible to separate configuration

and moderation influences of the context at this level of this study. Large scale investigation is required to verify the proposed framework, and to analyse the magnitude of individual as well as combined influences of the context factors in the ETO environment.

The high uncertainty context in ETO seems to favour gains from lean strategy. Therefore, the study implies that firms implementing lean and facing unanticipated high uncertainty contexts, such as supply chain disruptions, may exhibit similar patterns (which relates to the aim of Paper V). In practice, lean implementation strategy in ETO capital goods helps to structure diverse activities that would otherwise remain cumbersome.

### 4.5 Paper IV

Birkie, S. E., Trucco, P., & Kaulio, M. (2015). "*Sustaining performance under operational turbulence: the role of lean in engineer-to-order companies"*

While there is consensus that lean practices provide better performance, it is generally predicated on a stable business environment. There is only limited information on how lean practices in uncertain environments may influence performance gains. This study investigates how the implementation of lean practices within and beyond the shop floor can improve and sustain performance in uncertain environments.

The study draws on an in-depth investigation and comparison of two engineer-to-order (ETO) cases that represent a highly uncertain (high complexity and high dynamism) context (Duncan, 1972). Characterisation of complexity and dynamism sub-factors in the ETO mode of production provided in Paper III is used as input. The case companies in this study are part of multinational firms that engineer and manufacture capital goods. Using the lean implementation framework proposed by Bhamu and Sangwan (2014), differences in performance gains between the two case companies are discussed in relation to the type and the extent of lean practices implementation over multiple processes in the value chain.

The study shows how lean is applicable to ETO firms using the proposed implementation framework. It discusses that, in ETO environments under high

uncertainty, performance gains need to capture not only the improvement but also the sustenance of achieved operational performance levels. It then provides a possible explanation as to why ETO capital goods manufacturing firms implementing lean might show differences in their performance sustenance. Findings of the study indicate that (the greater extent of) lean practices implementation in transactional processes appears to further enhance shop floor level performance achievements, which leads to performance sustenance. The study also extends the leveraging of lean practices implementation in transactional processes for building capabilities to flexibly and proactively managing the uncertainties which are common business features in ETO business. This suggests that managers need to apply lean practices not only in shop floor processes, but also in transactional processes covering broader range of the value chain to obtain real, long lasting gains from their lean implementation in dynamic and complex situations.

Based on these observations, the paper argues that in the ETO context performance gains are a result of certain multiple effects of lean practices in transactional processes and shop floor practices. This may not be so common in make-to-stock (MTS) modes because most of the service components and expensive activities requiring strong interactions with customers, suppliers and other actors are often concentrated at the beginning of the company value chain. By simultaneously implementing lean to a higher extent in both shop floor and transactional processes, more opportunities for exploiting capabilities to meet customer requirements with increased flexibility at the different levels can be captured.

Recent papers described how complexity and dynamism affect the relationship between lean practices and performance in MTS (e.g. Azadegan et al., 2013). This paper provides an in-depth investigation as to how and why this relationship works in the ETO setting where empirical evidence is sparse. By viewing the complexity and dynamism factors as opportunities to attract a more fruitful exploitation of lean implementation efforts, it provides relevant practical insights.

### 4.6 Paper V

Birkie, S. E. (2015). "*Operational resilience and lean: in search of synergies and trade-offs*"

This paper investigates the synergy/trade-off relationships of lean and resilience in mitigating performance degradation due to disruptions starting with the paradoxical discussion of the relationship in extant literature. It also aims to investigate how the lean practice bundles (discussed in Paper III and Paper IV) and resilience core functions (discussed in Paper I) contribute to the synergy/trade-off relationship. The study uses secondary data from multinational firms that have recently faced disruptions. A disruption scenario type variable with three levels is introduced to weigh the performance reduction avoided by the firm. Details in this publicly available data regarding disruption incidents, practices implemented by the affected firm, and operational performance changes are encoded using pre-set constructs from other studies reported in this thesis. Bayesian network (BN) approach is used for inference analysis of the empirical data.

The findings show that firms with higher usage of resilience and lean practices are more likely reduce operational performance losses due to disruptions compared to all other cases. Thais is to say that, the study suggests that the synergy between lean and resilience outweighs the trade-offs. The results are shown to be robust by means of sensitivity analysis.

The study contributes to previous research that conceptually discussed the relationship of lean and resilience based approaches (e.g. Carvalho et al., 2011). It also shows that lean would be a suitable approach, not only in stable but also in disruptive environments. The paper further argues that lean implementing firms have a greater chance of leveraging (flexible) resilience capabilities to manage disruptions (e.g. Talluri et al., 2013) without necessarily requiring huge investments on redundancies.

The paper further investigates sources of synergy by considering a pair of lean practice bundles at a time and comparing with a resilience core function. It shows that most lean practice bundles contribute to the outweighing synergy. Among the lean practice bundles considered, the ones that showed the strongest trade-off on

resilience are JIT-Flow and TPM. Lean purchasing, HRM, customer and supplier related practice bundles showed synergetic effects on all, or on most, of the five resilience core functions.

From the findings of this study we understand that firms need not necessarily abandon all their lean practices in order to be resilient in managing unanticipated disruptive incidents. However, enhancing or augmenting practices that provide anticipative capabilities are necessary to engender better operational resilience. The implication of the findings is that companies need not lose their competitive edges in their operations in order to have better resilience against unanticipated disruptions. In practice, the implication is that managers, rather than abandoning lean altogether, need to pay strict attention to adjusting their lean practices implementation so as to leverage it in building better resilience against unanticipated events.

# 5 Setting operational capabilities to compete in turbulent times

*'Rather than looking for causes we should look for concurrences, and rather than seeing concurrences as exceptions we should see them as normal and therefore also as inevitable.'*

*(Hollnagel, 2006)*

*This section discusses the research results drawn from the appended papers.*

## 5.1 Uncertainty conditions for this study

Recall Figure 3 in section 2.2 that characterises uncertainties in the form of two dimensional variations. It describes that variation occurrence can be routine or non-routine in one dimension, and fairly or barely predictable on the other. Consider now Figure 4 showing common approaches to addressing the different uncertainty conditions shown in Figure 3. In the traditional sense, the implementation of lean practice bundles is a possible way to address routine and predictable uncertainties (i.e. quadrant I which represents the relatively stable business environment). Usually, structured risk management processes are applied for largely known or knowable non-routine uncertainties (quadrant IV). Scholars and practitioners in operations and supply chain management agree that resilience approaches are applicable for largely unpredictable non-routine uncertainties (quadrant III).

Paper IV discusses indications of leveraging resilience capabilities from proper lean implementation while keeping track of better and sustained operational performance using ETO as empirical setting (quadrant II) in the search for leveraging capabilities. It argues that lean practice bundles implementation benefits are not limited to stable environments. Continuing with these results, Paper V also gives us an idea of how lean and resilience can synergistically provide protection against performance reduction in unpredictable and non-routine uncertainty conditions.

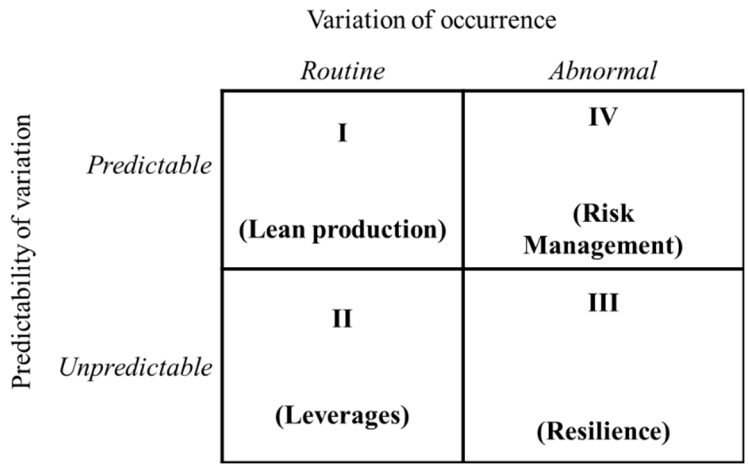


Figure 4. Lean and resilience under different conditions of uncertainty

This synergetic relationship is also a source of competitive gain when the firm is not facing extreme conditions (i.e. leverages to routine variability situations). Therefore, this thesis ultimately argues that by carefully arranging lean practice bundles and resilience core functions that use essentially the same available resources, it is possible to be in a better position against unpredictable situations. Those same capabilities can be utilised for bringing higher operational performance in different uncertainty conditions according to the dynamic capabilities perspective.

The subsequent three sections discuss issues addressed by the appended papers in reference to the three quadrants (I, II, III) of Figure 3 and Figure 4, which also represent the areas of the three thesis research questions. Section 5.2 deals with operational resilience (lower right quadrant) without consideration of lean; Section 5.3 deals with lean production as extended to a high unpredictability environment (left column). Section 5.4 then extends lean to the lower right quadrant (with resilience) by means of synergy/trade-off analysis.

## 5.2 Operational resilience in face of turbulent environments

The first research question set for the overall thesis asks 'What are constituents of operational resilience that businesses can utilise use of in times of unanticipated disruptions?' Answering this research question requires: (1) characterising what operational resilience is, (2) developing a practical measure for it, and (3) relating the identified measure with some performance index in order to evaluate if the implementation of those operational resilience measures have resulted in 'better performance'. The first and second papers have been devoted to fulfil those points in answering the first research question. The following paragraphs discuss each of the above points.

Through the combination of papers I and II, the first research question of this thesis has been fully addressed. The specific practices, their categorisation into bundles following the dynamic capabilities perspective, as well as the resilience core functions have been identified. Using the insights gathered in this study, business firms can better arrange their routinely undertaken practices so as to survive and excel in times of shocks or disorders. The practices can be used to seize opportunities faster than competitors, and to reduce the unwanted consequences of disruptions in sustaining their operational goals.

Based on a critical literature review, operational resilience was characterised in terms of five core functions: sense, build, reconfigure, re-enhance, and sustain (Paper I). By so doing, the concept of resilience has been in terms of the core functions that firms should achieve independently of specific mechanisms. Resilience is treated as a system property. There is therefore a need to describe how this property makes the system behave in certain way. This kind of specification not only avoids the need to enumerate specific mechanisms, but also helps to broaden the scope of resilience features responsible for utilising opportunistic shocks.

The concept of resilience is essentially linked to some disorder or shock that affects the normal functioning of the entity under consideration. A business enterprise exhibits operational resilience if it is able to maintain the value delivery process regardless of unanticipated turbulences. The capabilities it has developed prior to such incidents and the measures it takes upon the occurrence of the event provide the levers to retain its performance and remain economically viable.

From an RBV and dynamic capabilities point of view, resilience is a capability, and that it is intended to be utilised as a set of productive capabilities during normal operations and as protective capabilities during shocks. Since the profile and arrangement of each practice cannot be prescribed for an infinite number of uncertain occurrences, the dynamic capabilities perspective provides a suitable lens for accommodating unanticipated sources of risk with the emergent application of practices constituting operational resilience (Paper I).

Paper II takes the second argument of defining a practical measure for resilience further by identifying measures of resilience based on what companies actually did when they faced disruptions. There are few points worth mentioning about paper II in light of Paper I. First, from the literature review in paper I we know that there are several routinely used practices mentioned here and there in resilience literature, but there has not been a systematic study empirically investigating whether these practices are the only ones that have been employed by manufacturing firms. This has therefore been addressed by paper II. Second, investigating such measures empirically meant that we had to rely on predominantly occurring and recallable incidents. This is one of the reasons why Paper II puts strong emphasis on the supply-side disruptions. However, it was seen that if the manufacturing firms were able to have resilience capabilities for different forms of supply-side disruptions, they also had the possibility to extend those practices in leveraging capabilities to deal with demand-side or internally oriented threats and opportunities. This is in line with the arguments of dynamic capabilities perspective. Third, Paper II also provides an alternative framing of resilience capabilities in-terms of internal/external (from the buying firm's perspective), and proactive/reactive (before/after the event) dimensions. If a firm is to have better operational resilience, it needs to have some practices from each category. Having one category alone is not seen to be satisfactory. Having only reactive resilience capabilities may hinder performance in long term as well. Another way of saying this is that the firms need to have practices belonging to the different core functions. Having practices only for reconfiguration or re-enhance alone may not enable the firm suitably exploit turbulent environments unless the sense and build core functions also feed relevant inputs.

The operationalised resilience capabilities have been discussed in relation to the five performance objectives: quality, speed, flexibility, dependability, and cost. These five objectives have been aggregated into one measure by taking into account the priority assigned to the objectives by each firm and how the objectives changed before and after an incident. Both the qualitative and quantitative analyses (Paper II) show that regardless of the level of performance before the incident, firms with higher resilience capabilities tended to have better performance after recovery.

### 5.3 Lean practices in environments of high uncertainty

The second research question in the thesis sought to discuss how and if lean lends itself to acquisition and preservation of competitive advantages in high uncertainty environments. In discussing this the approach followed was to first identify measures for lean in terms of practice bundles as suggested in the established literature (e.g. Shah and Ward, 2003). I then proceeded to the discussion of these lean practice bundles in situations of high uncertainty (e.g. ETO). This is done to address the gap of literature in connecting the theory of lean production with uncertain business context, and explain how lean could be a suitable part of production management system in the same situation. The characterisation of the uncertainty context in ETO manufacturing and their roles influence on lean strategy is provided in Paper III; the empirical investigation of how lean leads to sustained performance in an ETO context is discussed in Paper IV.

The two papers discussed how that lean practices can be systematically arranged to enable them to be used for extending competitive advantages in routinely uncertain business environments, such as the case is with ETO. The second research question of the thesis is addressed for the most part with these investigations. The remaining part (i.e. lean in non-routine unpredictable circumstances) is addressed along with the third research question while analysing synergy/trade-off issue.

As discussed in Chapter 2 of this cover essay and in Paper III, the ETO environment can be classified as a high uncertainty environment with high complexity and dynamism. This provides an extreme case situation for the

investigation of lean implementation in complex environments (Chavez et al., 2015). It is to be noted, however, that the nature of uncertainty in an ETO environment may be slightly different in terms of the unpredictability of shocks in business environment for which resilience has been traditionally sought. In an ETO environment the uncertainty drivers are part of the routine business. Change requests from your customers are 'expected to be unexpected'. Nevertheless, I take the position that if the practice bundles in lean production can be useful in driving competitiveness in the 'routinely' uncertain ETO business, then it is indicative of plausible leverages of competitive advantages even in overall (disruptive or otherwise) turbulences. From the study findings in Paper IV we can see that companies implementing lean in a broader range of value chain processes tend to show better signs of sustaining enhanced operational performance.

Recent studies have shown how lean practices may have helped improve performance in repetitive manufacturing. The study in Paper IV reports a comparison between two firms of engineer-to-order manufacturing so that it extends the definition of high uncertainty context, and tries to identify sources of difference between two implementers of lean in the same environment. The implication is that lean practices that cover a greater range of processes than just the shop-floor activities are actually the real differentiators in highly uncertain environments. As reported in Paper III, the influence of uncertainty context factors can be looked at from two directions: first the effect of the context factors in implementing the lean practices (configuration influence), and the effect of the context factors on the relationship between implemented lean practices and operational performance (moderation influence). That he working environment in ETO is more complex and dynamic means that, at least at the initial stages, the implementation of lean practices can be really challenging. However, complexities and dynamism are part of the business. Therefore it is a reasonable attempt to implement lean practices so that their correct implementation can reduce part of complexities and dynamism. This in turn can lead to less possibility of performance disruptions occurring (Marley and Ward, 2013). From the findings of the study reported in Paper IV, along with the recognition of the characterisation of ETO as a high uncertainty context in Paper III, we observe that ETO manufacturers rigorously implementing lean practices both in shop-floor

and transactional processes have more possibilities to leverage competitive gains compared to those implementers in the same environment that focused too much on implementation on the shop-floor.

The follow-up question to these results is if the lean practices can better operational capabilities in unanticipated business circumstances together with operational resilience core functions as is discussed in Section 5.4.

### 5.4 Synergies and trade-offs between lean and operational resilience

The third thesis research question concerns the identification of synergetic/trade-off relationships between lean and resilience in highly unpredictable conditions. At this stage, we know that operational resilience can be treated as a set of capabilities (Paper II) consisting of five core functions (Paper I) following RBV and dynamic capabilities formulations. Likewise, lean also can be treated as a set of practice bundles (Paper III). Stronger implementation of lean practices in broader processes of the value chain is seen to indicate improving competitive priorities in highly uncertain environments (Paper IV).

As seen in Paper III and Paper IV, the use of lean approaches in in the high the uncertainty context of ETO provides an argument for lean practices to be used in high uncertainty contexts (as described in section 5.1 and illustrated in Figure 4). Thus in Paper V, the use of lean practices already discussed to apply in quadrant II (of Figure 4) is extended to quadrant III. Using the same argument that lean applies to high uncertainty contexts, Paper V simply extends the argument by expanding the extent of uncertainty to the unpredictable and non-routine. Therefore, we do not directly observe the presence of an ETO environment in Paper V.

Then, bringing the concepts of lean and operational resilience together in non-routine, unpredictable conditions and by using Bayesian inference analysis, Paper V finds that better operational performance upon disruptions implies that higher resilience and higher lean are more likely, rather than just one of them (or lower likelihood for both). So the answer to the question whether lean and operational resilience are in synergy in high uncertainty contexts is yes, but not completely. The synergies between the two outweigh the trade-off.

Comparing the relationships between a pair of lean practice bundles and a resilience core functions at a time revealed that most of the lean practice bundles actually contribute to the dominating synergy at aggregate level. More specifically, total quality management, human resources management for lean, supplier involvement and development, customer involvement and partnership, and lean purchasing practice bundles have stronger synergetic effects on the operational resilience core functions. Total productive maintenance and JIT-flow bundles contributed more to trade-off than synergy on core functions. Referring to the synergetic effects received by the resilience core functions, the sense core function received the least synergy. In fact, majority of the lean practice bundle pairs have trade-off with the anticipate core function of sense. Reconfigure acquired marginally higher trade-off effects. Sustain has marginally higher synergetic effects. Build and re-enhance got much stronger synergetic effects from lean practice bundle pairs.

The practical interpretation of these results is that lean practice bundles could well be implemented to exploit synergetic gains from resilience capabilities in the face of unpredictable (disruptive) turbulences. It is also possible that the evolution of lean practices implementation to also address eventual changes in the business environment might have added to the identified synergistic relationships. However, lean bundles seem to have very limited leverage for improving the anticipative capabilities of operational resilience, and that companies need to consider how they can compensate for this shortcoming. As seen in the results of Paper IV, the lean practice bundles that are mainly focused on shop-floor practices (e.g. JIT-flow, total productive maintenance) fail to provide synergies for resilience upon uncertainty. Companies may consider how these bundles can be enhanced to gain better synergies.

The quest for cumulative and trade-off capabilities and performance objectives dates to the late 80's with the study of Ferdows and de Meyer (1990) who have investigated cumulatively building one capability on top of another. These discussions appear to have continued until recent years with enhancements and the introduction of variations. A common trait of these studies is that they all treat the investigated capabilities as outcomes received and perceived by the customer.

This thesis is concerned with the search for synergy or trade-off among paradigms and their underlying constructs as enablers in effecting performance outcomes. In essence, therefore, it assumes that the performance objectives or outcomes are implicitly cumulative (Ferdows and de Meyer, 1990) but with no specific hierarchy or sequence implied. However such hierarchy reflects itself in terms of values assigned to the relevant parameters in the data.

Competitive advantages are argued to have limited life-cycles (Corbett and van Wassenhove, 1993) that companies need to search for sources of such competitive priorities. Taking this into consideration, this thesis argues that when faced with turbulent business environments, high forms of flexibility can be a source of such competitive advantages since value of flexibility increases with uncertainty (Christopher and Holweg, 2011).

Companies may shift trade-offs between efficiency and flexibility and induce ambidexterity through the use of what Adler calls metaheuristics (Adler et al., 1999). Such metaheuristics (or 'meta' routines as in Peng et al. (2008)) are sources of better utilising routine and non-routine tasks. By the same logic, it is plausible for companies to be ambidextrous on lean and operations resilience because several mechanisms for shifting trade-offs towards better synergy with operational resilience can be enriched from within the lean production system.

## 5.5 Synthesis

Using multimethod studies, this research attempted to provide an alternative explanation to the 'efficiency-robustness' debate in the era of turbulence (Christopher and Holweg, 2011) how far lean practices can be utilised alongside operational resilience functions for exploiting synergies that also add to the competitive advantages for the implementing firm.

Starting with Paper I that reports a critical review of literature, Paper II, Paper III, Paper IV and Paper V describe findings in relation to the specific research questions posed in them. In aggregation, they help to synthesise answers to the overall research questions of the dissertation. As shown in Table 2.

Table 2. Synthesis of main research findings from appended papers

| Research contribution issue | RQ1 | RQ2 | RQ3 | Synthesis |
|---|---|---|---|---|
| **Operationalising the concept of operational resilience** | Paper I<br>Paper II | | | Efficiency based paradigms like lean can be employed together with operational risk reduction (resilience) strategies in the current turbulent business environment to provide competitive gains without overly compromising operational performance. |
| **Extending lean practices into turbulent business context** | | Paper III<br>Paper IV | Paper III<br>Paper V | |
| **Search of synergetic elements** | Paper V | Paper V | Paper V | |
| **Drive for performance and competitiveness** | Paper II | Paper IV | Paper V | |

The implementation of lean practices in an appropriate manner entails that it starts small in areas of easiest application (Paper IV), and proceeds by expanding the pilot projects. It involves small scale experimentation to test and bring in new ideas. The lean production paradigm encourages employees to continuously think of improvements and flexibly accommodate changes (while keeping customer requirements and prevailing business conditions in mind), i.e. it promotes thinkers (Alves et al., 2012). This is also an important aspect for building better operational resilience.

If thinkers are developed through the implementation of lean practice bundles (Alves et al., 2012) such as HRM and TQM, then there is a strong possibility that these thinkers will leverage the lessons of lean implementation for enhancing operational flexibilities for better resilience (Paper V). The arrangement of practice bundles and exactly how the practices are applied to routine and non-routine tasks varies from company to company (owing to competitive advantages). By bringing in proactive capabilities through learning from previous (disruptive) incidents and near misses (Paper II), the lessons can help push

competitive frontiers further, while keeping an eye on challenges presented by business environment turbulences of unanticipated nature.

We can discuss the leveraging of competitive and performance priorities obtained from the synergetic relationships between lean practice bundles and operational resilience core functions for two major lines of business uncertainty as follows. The points of discussions are synthesised from a combination of results in Paper II, Paper IV, and Paper V.

While the use of redundancies and extra resources to increase flexibility and resilience is a possible approach, in this thesis I argue that they do not necessarily provide 'protection' against all kinds of unpredictable abnormalities. Findings of Paper V indicate that firms that kept big pile of inventories did not perform better than those claimed to have 'no redundancies to spare' during disruptions. Furthermore, they come with very high investment costs, which significantly erode productivity and competitiveness. With the resource-based view that takes into account the contingent perspective, I would suggest developing dynamic capabilities with relatively lower investments (as compared to redundant or extra assets keeping), and making use of those capabilities to devise mechanisms to embed such redundancies at strategic positions of the value chain only. Better compromises can be struck using this approach.

All in all, the five papers have addressed the thee research questions of the thesis, and subsequently addressed the overall research question that practices taken to establish lean production in the management system and action routines for building resilience capabilities against unanticipated disruptions can be used synergistically not only for survival in turbulent times, but also to competitively excel in operational performance. This can be used as input in designing operations strategies in business firms.

# 6 Implications

*'For every enterprise, the challenge is twofold: First, protect the value you already have, and second, create new value. To create value, enterprises must be able to identify and seize opportunities …'*

(Funston and Wagner, 2010)

*In this chapter the theoretical and practical implications of the thesis are presented followed by limitations and suggestions for further research.*

## 6.1 Implications to theory

The findings of this thesis contribute to resource-based view and dynamic capabilities perspective by: (1) extending the application of lean practices in high uncertainty business environments, (2) operationalising operational resilience in terms of specific practices that are sources of competitive advantages and improved operational performance, (3) discussing synergetic relationships which imply that resilience and lean are not necessarily alternatives but can be complementary if well managed.

Returning to the theoretical antecedents of this thesis, it is largely documented that dynamic capabilities provide competitive advantages to firms as they lend themselves to unique configuration and renewal of assets and routines (Ambrosini et al., 2009). It is also documented in operations management literature that such dynamic capabilities can be built from practices and routines (Ketokivi and Schroeder, 2004; Peng et al., 2008). With this thesis, this theoretical line of thought is extended by discussing empirical evidence that resilience (dynamic) capabilities can be built from practices that firms normally use (Paper II). It is not the individual routine practices that are unique, but instead their application as bundles in the particular application context is. The capabilities are sources of better performance and competitive advantage in turbulent business environments (Paper II and Paper V). Furthermore, the application of lean practices for better operational performance is extended to

environments of high uncertainty (Paper IV), and they lend themselves to synergetic relationships with resilience core functions (Paper V) to survive and excel in uncertain circumstances. To the best of my knowledge this issue of excellence in turbulent times has previously not been well addressed in literature.

There are arguments that best practices and competitive advantages have limited life-cycles (Sousa and Voss, 2008). Should this be true, the thesis provides an explanation that perhaps the use of the dynamic capabilities in ways discussed here is a possible approach to generate and excel with new competitive advantages when old ones whither. The dynamic capabilities can reconfigure or refresh resources and other capabilities to deliver those advantages (Ambrosini et al., 2009); the routine practices along with the resources provide a competitive weapon. This is consistent with what is given as a 'resource based' explanation to competitive heterogeneity by Hoopes et al. (2003).

Moreover, the methodological aspect of developing typologies and a systematic measurement of resilience capabilities using low-level practices is in itself a relevant theoretical contribution. I can now argue that resilience is not just a vacuous buzzword (Henry and Ramirez-Marquez, 2012; Rose, 2007), but a set of capabilities that businesses can embed in their systems and use beginning by making use of their current tangible and intangible assets. It is therefore possible to argue that resilience at supply chain level is a hypothetical construct that can only be realised when firms in the supply chain own and develop their internal capabilities. In doing so, they also add to the capabilities of the greater supply chain.

The findings of the studies in this thesis are in line with recent arguments that flexibility based approaches for resilience provide superior results when compared to redundancy based ones (Park, 2011; Talluri et al., 2013); perhaps, it is possible to create redundant capacities as a by-product of flexibility based approaches.

## 6.2 Implications to practice

From a practical stand point, it means that companies need not abandon their lean implementation in order to become resilient against disruptions. In fact, they will benefit from joint implementation.

The study suggests how companies can engender resilience by utilising routine practices. Additional (marginal) investments on resilience building can be routinely utilised in productive manner, and thus justified regardless of whether unanticipated shocks occur or not. Contrary to arguments and suggestions put forward in several recent studies (e.g. Park, 2011), this thesis argues that operational resilience capabilities do not have to depend on the type of uncertainty or trigger events.

According to the perspectives in this thesis, resilience should not just be concerned with surviving disruptions, but also about excelling in those turbulent situations. The combination of lean and resilience practices can provide a better efficiency frontier by taking into account the needs of flexible proactiveness towards unavoidable as well as unknowable uncertainties. The same is true for those sectors that were deemed to be operating in stable environments. Regardless of the nature of the uncertainty (as shown in Figure 3) they can leverage from the synergetic effects of resilience (dynamic) capabilities and lean practice bundles.

However, all lean practice bundles do not provide synergetic effects to all resilience core functions. Consequently, pragmatic approaches are needed to compensate for theses short comings. Once again, the firms can take into account that these pragmatic arrangements add to the competitive excellences provided by the synergetic effects.

The thesis additionally provides 'gauging' for lean implementing firms so as to see if they are implementing lean practices as correctly as they ought to. In a general sense, it has demonstrated that lean practice bundles implementation should not be limited to only shop-floor processes. They have to be extended to other (transactional) value chain processes so as to benefit from the integrative removal of waste from all processes while concurrently trying to embed flexibilities.

### 6.3 Avenues for further research

This thesis has provided some exploratory and theory building undertakings. There is still much to be understood and discussed regarding the practical measurement of operational resilience capabilities, relationships with lean

practice bundles as well as the influence of uncertainty on plausible competitive performance gains from lean and resilience.

One possible avenue to follow in future research is to conduct large-scale analyses of the relationships between lean and resilience in different uncertainty scenarios. This is a hotly debated domain lacking a strong empirical basis. Perhaps, in an attempt of better understanding about these relationships, we may have to unveil significantly more interesting issues of practical and theoretical relevance not addressed in this thesis. The detailed mechanisms of the synergistic relationship could also be investigated using, for example, detailed (and longitudinal) case studies.

The methodological approaches proposed and used in this thesis may also be further strengthened and improved in future research undertakings.

Another avenue for advancing future research in line with this thesis could be re-evaluation and redefinition of competitive advantages in this era of turbulence.

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