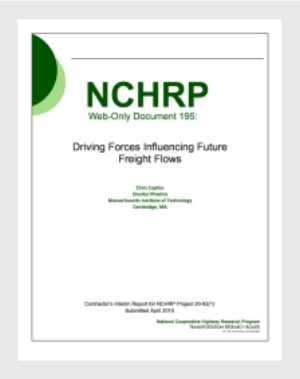

Driving Forces Influencing Future Freight Flows

DETAILS

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Section 1. Overview

This interim report summarizes the findings from the first phase of the NCHRP 20-83 (1) project. The objectives of phase 1 were to identify, categorize, and rank the driving forces and critical uncertainties that will influence the future freight transportation flows within the United States over the next 30 years. The results from phase 1 are to be used in phase 2 to help develop the set of future scenarios to utilize in the phase 3 workshops.

Phase 1 activities followed the process outlined in Figure 1 shown below.

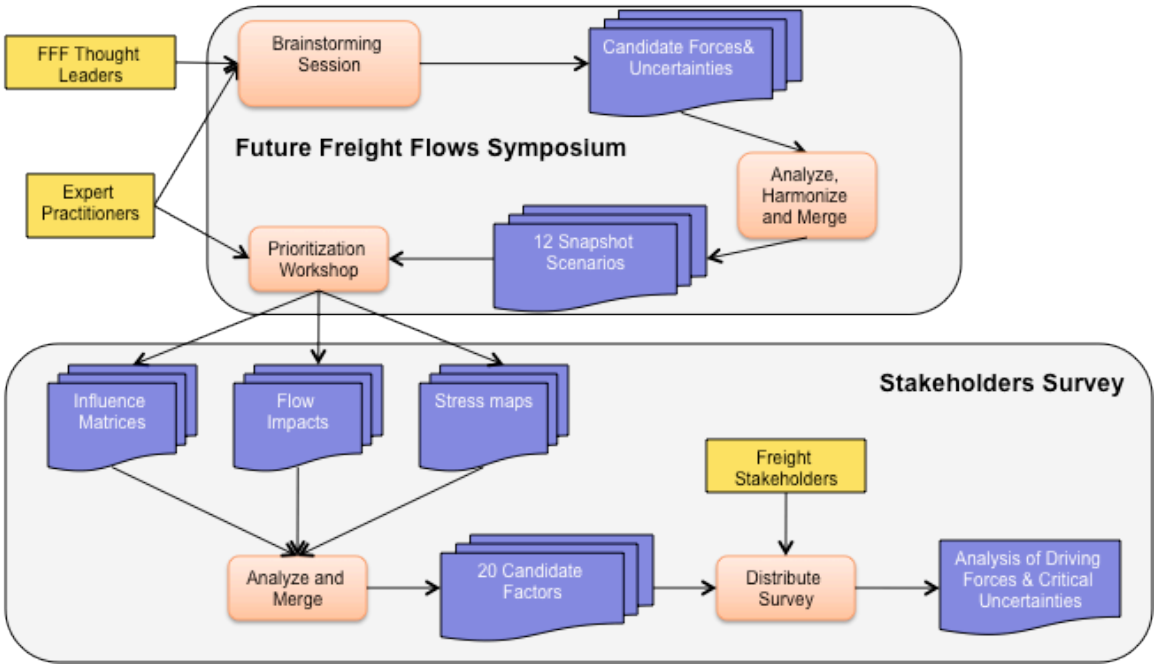


Figure 1 Process map of the Phase 1 activities.

The process started with the Future Freight Flows Symposium where thought leaders from five primary dimensions (Social, Technology, Environment, Economic, and Political) presented potential future trends to a hand picked group of expert practitioners. This led to a brainstorming session where the attendees generated potential driving forces and critical uncertainties. These were then analyzed, harmonized, and consolidated into twelve representative "Snapshot Scenarios". These Snapshot Scenarios were presented back to the practitioners in an interactive setting where they developed estimates of each force's influence over time, its impact on freight flows, and how it would stress the existing US infrastructure.

The results of these twelve analyses were analyzed and translated into twenty more detailed Driving Forces. The Driving Forces were incorporated into a survey that was distributed to a large set of freight stakeholders for further prioritization. The

survey respondents came from a diverse set of practitioners to include shippers, carriers, third party logistics providers, and governmental transportation planners at the federal, state, and local levels. The results of the survey were analyzed to determine the key dimensions or axes that should be used in the development of the future scenarios.

The remainder of the report is organized as follows. Section 2 provides details on the process and methodology used to uncover the driving forces and critical uncertainties. This includes a discussion of the Future Freight Flows Symposium, a review of the workshop materials tested, and a summary of the Stakeholders survey instrument. Section 3 presents the combined analysis of the results from these activities. Section 4 lays out the next steps by providing an update on Phase 2.

Section 2. Process and Methodology

As shown in Figure 1, above, the two major activities of Phase 1 were the Future Freight Flows Symposium and the Stakeholders Survey. Each is discussed in turn in terms of the process and steps involved. The combined results are presented and discussed in Section 3.

Future Freight Flow Symposium

The Future Freight Flows Symposium was held on 11-12 March 2010. The final agenda and attendance list is attached in Appendix 1. A total of sixty handpicked non-MIT professionals participated.

The symposium opened with a restatement of the objective of the project as a whole and the two-day symposium in particular. Additionally, the attendees were introduced to the concept of Flow Impacts. This was done in order to get the attendees to focus specifically on how any potential force or uncertainty would impact freight flows within a specified region. For the purpose of this symposium, we focused on the United States as a whole. However, all of the analysis and methods can be used on any pre-defined region or area.

Flow Impacts

There are an unlimited number of potential events, trends, or occurrences that can happen in the future. It is almost impossible to identify, much less plan for, all of these potential events. Instead, it is useful to translate these into a finite set of outcome types. We refer to these as Flow Impacts.

We created five Flow Impacts that capture the effect that any potential driving force or critical uncertainty might have on future freight flows. These are shown graphically in Figure 2 below.

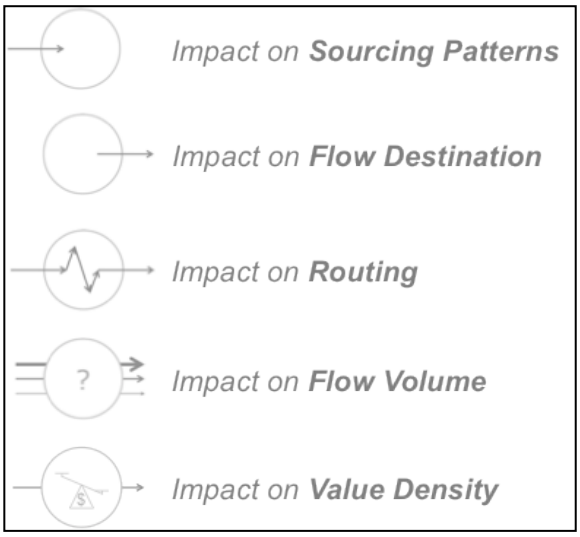


Figure 2 Descriptions of Flow Impacts.

Sourcing Patterns capture any changes in the location of the origins for most freight movements. This includes procurement of raw materials, manufacturing, and distribution. Changes to Flow Destinations capture any shifting in the locations of final demand – such as increased urbanization. Routing impacts capture any changes that affect the path that product will take to move from origin to destination. This could include, for example, changes in mode, for example, from over the road truck to intermodal or rail. Changes to a region's Flow Volume imply an increase or decrease to the amount of product moved in terms of shipments, tonnage, or volume. Finally, Value Density impacts capture events that change the characteristics of the freight being shipped. The value density is used as a proxy for all of the various changes that can occur since this ratio is a primary criterion for mode choice as well as supply chain network design. Products with a higher value density tend to be shipped by faster more expensive modes.

In order to illustrate how the Flow Impacts are used, consider the effect that containerization has had on business. Containerization has very strong Sourcing Pattern impact since it enabled the off shoring of manufacturing across the globe. This shifted the point of origin for most manufactured products from domestic locations distributed across the country to a handful of ports – mainly on the West coast. Containerization also has strong Routing impacts since this shifting increased the use of intermodal transportation to move the product inland to major metropolitan areas. There was minimal Flow Destination impact since containerization has not really changed location of the ultimate demand. There was strong Flow Volume impact as the number of containers moved through the United States increased dramatically. Finally, containerization has not significantly impacted the Value Density of the freight. Other technological innovations over the last thirty years have caused the Value Density to increase.

The remainder of the symposium followed a Diverge/Converge structure.

Thought Leader Presentations & Brainstorming Sessions

The first day (Thursday 11 March) was a diverging session where the participants were encouraged to brainstorm potential critical uncertainties and driving forces. The day consisted of seven speakers presented different visions of the future along various themes (demographics, environment, economy, technology, etc.). The participants were also asked to brainstorm their own potential driving forces during the sessions.

- A Nation Of Floridas: Aging, Changing Lifestyles & The Future Of Freight
  Dr. Joseph Coughlin, Director, MIT Agelab
- After The Storm: New Challenges For The Global Economy In 2010-2030
  Sara Johnson, IHS Global Insight
- Public Policy And Freight
  David Luberoff, Harvard University Kennedy School Of Government
- Transporting Bits And Atoms
  Professor Neil Gershenfeld, MIT Center For Atoms And Bits

- The New Age Of Sensing
  Prof. Sanjay Sarma, MIT Mechanical Engineering
- Wired For Innovation: How It Is Reshaping The Economy
  Prof. Erik Brynjolfsson, MIT Sloan School of Business
- Measuring And Managing Sustainability
  Dr. Jonathan Johnson, The Sustainability Consortium

Complete summaries of each of the thought leaders' presentations are in Appendix 2 while video and slides are posted at: http://ctl.mit.edu/FutureFreightFlows.

After each speaker, the attendees were asked to write down the three most critical drivers from that presentation that they thought might impact the future freight flows for the United States. Additionally, they were asked to classify which of the five Flow Impacts this force or uncertainty fit into. A sample sheet is shown below in Figure 3.

Driver	Impact on Freight Flows					Comments / Description
	Sourcing patterns	Flow destination	Routing	Volume	Value density	

Figure 3 Collection sheet for the potential driving forces and corresponding Flow Impacts from the Thursday brainstorming sessions.

The attendees were asked to complete a separate sheet after each of the seven speakers as well as an additional one at the end of the day to capture any factors that were missed. Over 1,200 individual drivers were collected.

The sheets were collected after each session and the team began harmonizing them. As expected, there was a fair amount of redundancy in the responses. Also, many of the responses tended to mirror the speakers' specific points. Beyond this, however, we were able to collect a large number of interesting and oftentimes unexpected responses. Unfortunately, we found that the respondents' classification of the

specific Flow Impacts for each driver was not worth capturing. In most cases, the attendees simply checked all of the boxes for each driver.

The team boiled the submitted drivers down into twelve representative Snapshot Scenarios. The Snapshot Scenarios were then used in Friday's workshop. The specifics on the Snapshot Scenarios will be discussed in Section 3.

Interactive Workshop

The objective of the Friday session was to converge all of the different ideas and concepts that came up in the previous day's discussions. The attendees were divided into six cross-industry groups and assigned two Snapshot Scenarios. Each team, facilitated by an MIT researcher, worked through a series of five tasks:

1. Definition – where the facilitator makes sure the team understands the Snapshot scenario they are assigned.
2. Adoption/Influence Matrix – where the team estimates when and if the specific driver will influence the market.
3. Flow Impacts – where the facilitator asks the team to provide insights into how the specific driver would impact the freight system: Sourcing Patterns, Destination Distribution, Routing, Flow Volume, and Value Density.
4. Stress Map – where the team allocated their assigned poker chips to a set of predetermined areas on an infrastructure map of the United States based on how it would be stressed under the given driving force.
5. Wrap Up – where the team can provide any detail on what was missed.

The facilitator's guide with instructions is shown in Figure 4 and Figure 5 below. The participants each had a worksheet outlining these steps as shown in Figure 6 and Figure 7.

For the Adoption Matrix, each participant had poker chips – one for each time frame – and they had to place them according to the level of adoption or influence of that driver by that time period. They did this individually and then after discussion, were allowed to change their "bets". We found very little change in the individual versus team based Influence Curves. For the Flow Impacts task, the participants wrote specific impacts for that scenario on sticky pads and classified them under the appropriate Flow Impact. This was not a very fruitful portion of the exercise as the attendees had a hard time clearly separating the flow classifications. Finally, on the Stress Map, each participant placed three chips on the communal map. This was very successful – the participants tended to discuss this with each other as they placed their chips. A refinement would be to have them set a benchmark or baseline level of stress prior to betting on the impact of the scenario under question. There were also recommendations on how to modify the Stress Map to include more and different investment options.

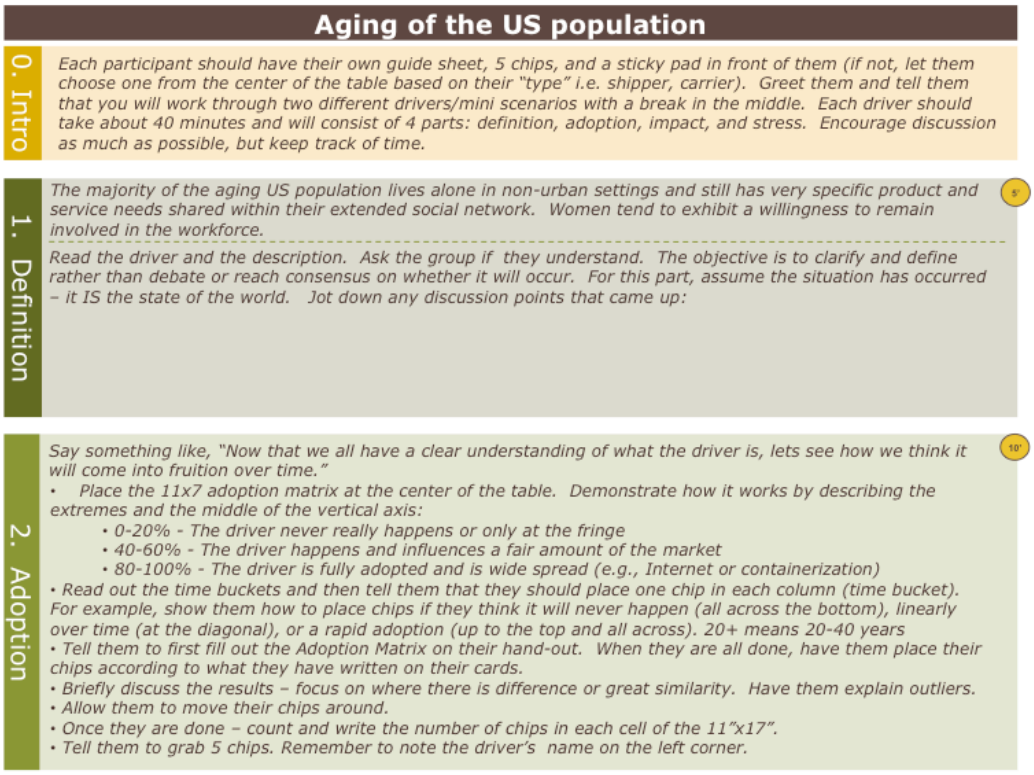


Figure 4 Facilitators guide to interactive workshop (part 1).

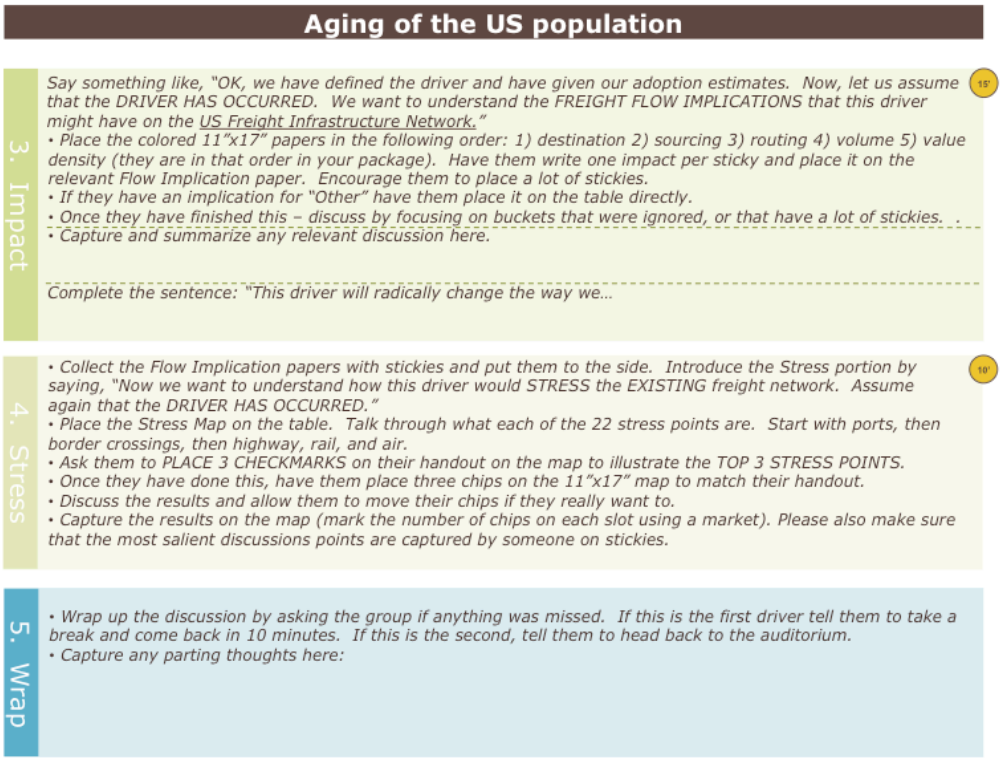


Figure 5 Facilitators guide to interactive workshop (part 2).

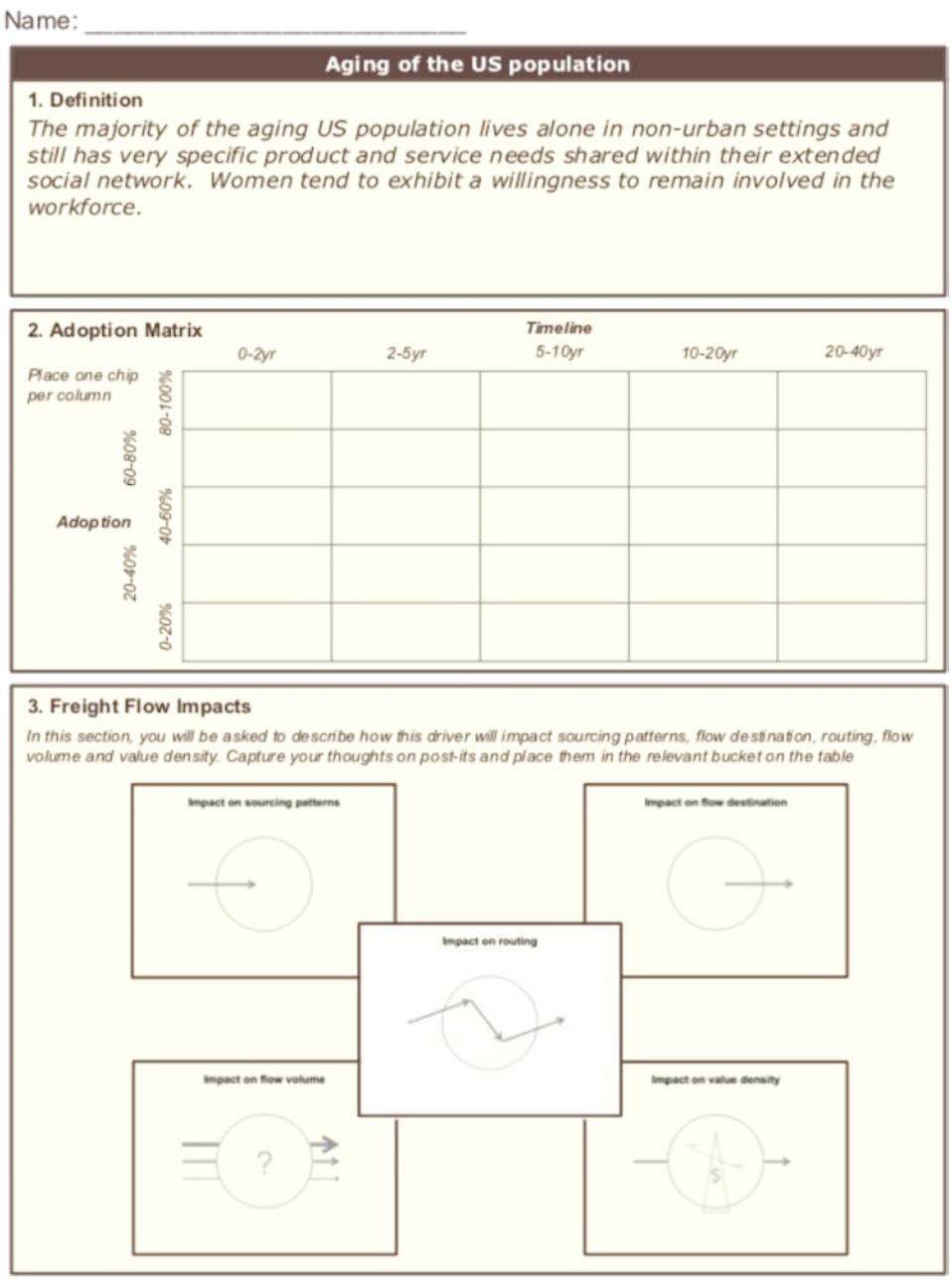


Figure 6 Front side of the participants sample form showing the Adoption Matrix and Flow Impacts.

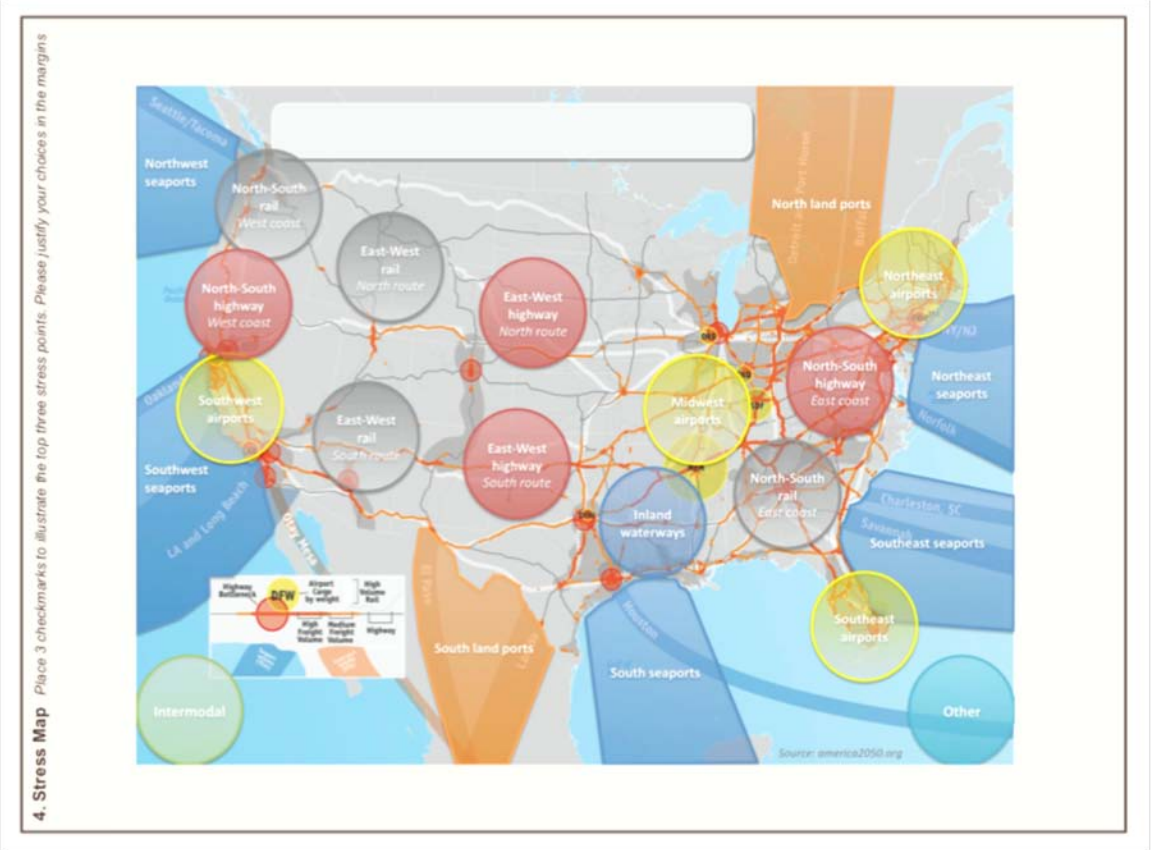


Figure 7 Back side of the participants sample form showing the Stress Map of the United States.

The Adoption/Impact Matrices and summaries of the Flow Implications for each of the twelve Snapshot scenarios are shown in Appendix 3. Additionally, a description of the discussion and debate arising from two of the Snapshot Scenarios is captured in Appendix 4. The analysis of the outcomes from interactive workshop is discussed in Section 3.

Stakeholders Survey

Following the workshop, the team created a web-based survey containing a set of representative Driving Forces that were culled from the analysis of the workshop results.

The objective of the survey was to prioritize the set of driving forces and critical uncertainties that were generated from our industry experts. A wider net was thrown to incorporate a larger set of perspectives. Because this was going out to a large number of individuals it had to be self-explanatory and short. Based on the twelve Snapshot Scenarios in combination with the feedback received from participants at the end of the March 11-12 Symposium, we developed twenty comprehensively described driving forces and asked each respondent to assess both the IMPACT (assuming it occurs) and the PROBABILITY of it even occurring. For the impact, they rated each force on a scale of 1 (No Impact At All) to 5 (Tremendous

Impact). For the probability, they indicated how widespread the factor will be over the next 10 to 20 years by selecting from the following choices (on a 1 to 5 scale):

1. Unlikely to Happen (0-20%)
2. Present at Fringes Only (20- 40%)
3. Generally Present (40-60%)
4. Widely Present (60- 80%)
5. Omnipresent (80-100%)

The survey also collected information on role, industry, company size, and other demographic information.

The survey instrument was completed and sent out in April 2010. A total of 264 complete and useable responses were collected from professionals across multiple industries and backgrounds. The survey itself is shown in Appendix 5 while the results of the survey are discussed in Section 3.

Section 3. Analysis of Driving Forces

While the initial brainstorming session yielded over 1,200 potential critical factors to consider, most of these were repetitive or obvious. It became apparent that both the specific speakers and their current situation at work heavily influenced most of the attendees. For example, Professor Gershenfeld's presentation on Personal Fabrication generated many suggestions of this having an impact – but, since we did not have a specific presentation on nanotechnology, no one mentioned it. Similarly, the rising and volatile cost of oil was another common submission – which is predominately a current concern.

However, several potential factors came out of the analysis of these responses. We harmonized the responses and generated twelve factors that we called Snapshot Scenarios. Each of the Snapshot Scenarios is essentially a bundle of common driving forces. It is worth noting that the Snapshot Scenarios were formulated as end states rather than trends. Indeed, our experience proves that people react better to a description of what the future may look like rather than a simple direction it may take.

Snapshot Scenarios

The twelve Snapshot Scenarios were:

Aging of the US Population

The majority of the aging US population lives alone in non-urban settings and still has very specific product and service needs shared within their extended social network. Women tend to exhibit a willingness to remain involved in the workforce.

Increase in Global Trade

Global trade has made the majority of the country strongly interdependent. This leads to higher volatility and extreme swings in GDP growth. Protectionism occurs but is only reactionary and is not permanent. The system is generally resilient with fluid trading blocks.

Rising Power of Emerging Markets

The dollar and the Euro have weakened. Emerging markets gained in affluence and purchasing power as well as political stability and financial strength. They are less focused on exporting as a means to grow and thus, importing more.

International Climate Regulation

Climate change proved to be a reality with rising sea levels and higher overall temperature. However, the major disruptions actually stemmed from the higher variability in weather systems leading to more extreme and abrupt manifestations. A sense of urgency shared across developing and developed countries led to the creation of a Global Environment Council redefining business rules and regulations globally in alignment with the WTO.

Rise of Protectionism

Following the COP15 debacle and a longer than anticipated recession, countries reacted by raising tariffs and duties to protect their own industries. While the US tried to save the WTO, internal debates between the states led to the US also adopting protectionist measures – sealing the fate of WTO.

New Technology: Personal Fabrication

Fueled by the innovative high-tech tools, personal fabrication has become a reality. Open-source design and social network platforms empower people with creating the products that best reflect their personal universe and needs. Although more manufacturing will be done locally in the US, automation limits the number of jobs created.

New Technology: The Senseable Network

Cheap wireless technology enables ubiquitous presence of sensors on products, vehicles and the infrastructure. This allows collection, transmission and analysis of multiple attributes such as temperature, humidity, location, etc.

Increase in Sustainability Regulations

Several layers of all encompassing regulations at the international, federal and state level are enacted. These regulations cover at varying degrees social responsibility, environmental emissions, resource usage, and trade practices. This results in a patchwork of often conflicting rules and penalties.

Increase in Sustainability Customer Demand

Consumer demand for sustainable products is a reality led by different segments of the population including aging baby-boomers, young mothers, etc. This is further fueled by innovative technology that enables consumers to make real-time decision at the point of purchase.

Rise in Global Security Concerns

Due to heightened security concerns, federal regulations now requires 100% scanning and tracking of all flows within and across the country. These procedures require state-of-the-art technology that is both time-consuming and costly.

Rise in Commodity Prices and Availability

Unreliable supply or unpredictable demand has led to dramatic increase in volatility and price of commodities to include oil, metals, grain, etc. Financial markets have further exacerbated the situation and new technologies have failed to solve the issue.

Additional Points of Entry Open Up

The Panama Canal is completed. The Northwest Passage is now open during summer. Manufacturing is no longer concentrated in the Pacific Rim as regions such as Africa have emerged as reliable suppliers for Europe and North America.

Impact Matrices / Influence Curves

As discussed in Section 2, the Influence Curve for each driving force is a graphical representation of how that factor will influence business (and thus potential freight flows) over time. We selected five time buckets (0-2 years, 2-5 years, 5-10 years, 10-20 years, and 20-40 years). The 0-2 years bucket can be considered current day while the 2-5 and 5-10 buckets are more short term and the 10+ year buckets are long term. A k-means cluster analysis was conducted on the Influence Curves to identify any patterns. We found that all of the driving forces followed one of four types of influence curves: Steady Growth, Rapid Growth, Peak & Crest, and Flat. These are shown in slightly stylized form in Figure 8, below.

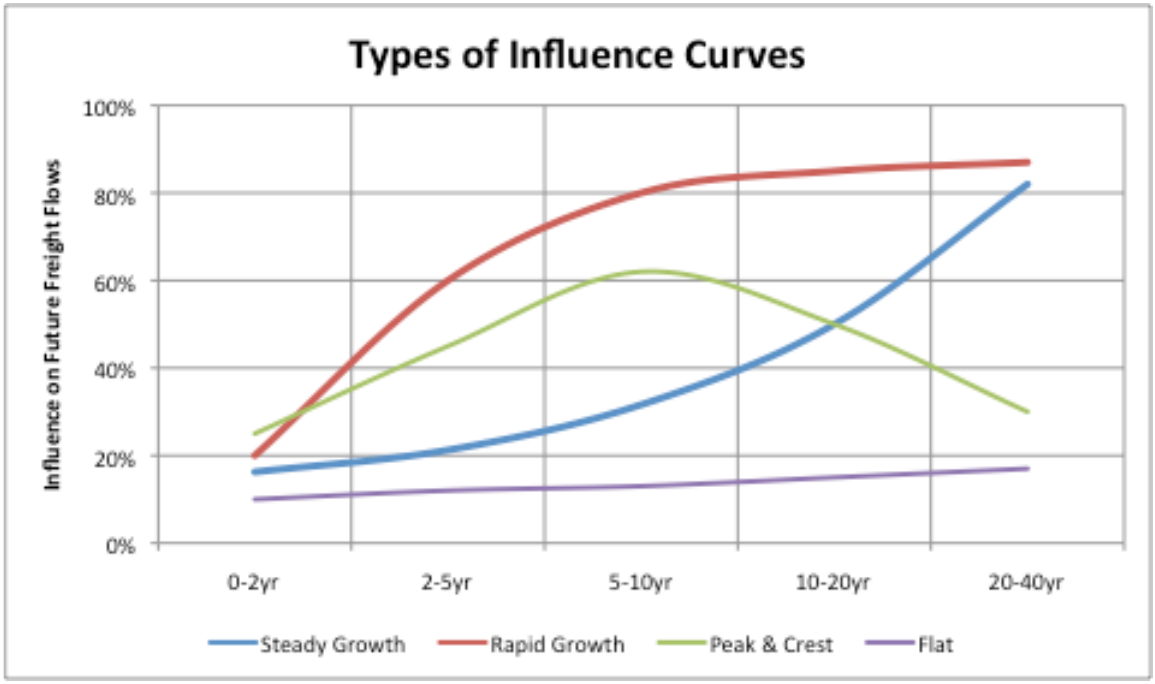


Figure 8 Types of Influence Curves.

The Steady Growth and Rapid Growth factors tend to start and end in the same places, but the path is very different. The Steady Growth forces tend to start out slowly but gather steam and eventually have widespread influence. The Rapid Growth forces have a more accelerated influence that reaches steady state. Peak & Crest forces exhibit a rising influence but at some point lose their influence. The idea is that as the factor becomes widespread, the businesses and the economy adapt to it, and it loses any of its individual influence. Finally, there are Flat forces that never really influence either thee freight patterns or business in general.

Analysis of Snapshot Scenarios

The detailed Impact Matrices for each Snapshot Scenario are shown in Appendix 3. Table 1, on the next page, provides a summary of the scenarios in terms of the general classification (Social, Technology, Economic, Environmental, and Political),

the Flow Impact (Sourcing, Destinations, Routing, Volume, and Value Density), and Influence Type (Steady Growth, Rapid Growth, Peak & Crest, and Flat).

	Classification					Flow Impact					Influence Type				
Driving Force	**Social**	**Technology**	**Economic**	**Environmental**	**Political**	**Sourcing**	**Destinations**	**Routing**	**Volume**	**Value Density**	**Steady Growth**	**Rapid Growth**	**Peak & Crest**	**Flat**	**Comment**
Aging of the US Population	X						X	X		⇑	X				Predetermined element
Increase in Global Trade			X			X		X	⇑	⇔		X			Tight consensus – potential blind spot
Rising Power of Emerging Markets			X		X		X	X	⇑	⇔	X				Tied to global trade
International Climate Regulation				X	X	X		X		⇓	X				Low uncertainty in short and mid term – high in long term
Rise of Protectionism			X			X	X	X	⇓				X		High uncertainty with decreasing impact
Personal Fabrication		X	X			X		X	⇓	⇓	X				High uncertainty in the long term
The Senseable Network		X						X				X			Predetermined element
Increase in Sustainability Regulations				X	X	X		X	⇓	⇑		X			Moderate levels of uncertainty
Increase in Sustainability Customer Demand	X			X		X		X	⇓	⇑	X				Uncertainty and impact increases with time
Rise in Global Security Concerns			X		X	X		X						X	Very low uncertainty and impact levels – potential blind spot
Rise in Commodity Prices and Availability			X			X	X			⇑		X			Too general for commodities – need to isolate fuel
Additional Points of Entry Open			X			X		X	⇑		X				Uncertainty and impact increases with time

Table 1 Classification of the 12 Single Shot Driving Forces. An X indicates the classification. For the flow impact, an up or down arrow indicates that that factor increases or decreases, respectively. A sideways arrow indicates a mix.

Note from the table above that the scenarios were a mix of Social, Technology, Economic, Environmental, and Political forces. The Flow Impact and the Influence Type ratings were culled from the workshop responses. Some key takeaways from this analysis are:

- The participants tended to be overly influenced by current events and situations. The Rise in Commodity Prices force included fuel along with other commodities. The influence of fuel on the transportation professionals overwhelmed the other commodity effects. We separated out fuel from other commodities going forward.
- The attendees classified the "Aging of the US Population" force as being a Steady Growth type. While this force will have tremendous impact on freight flows, it can be considered a predetermined element. That is, it is a force that is slow changing and will occur regardless of the scenario. The idea is that while this might be a driving force, it will occur in any and all futures and thus is not a defining or differentiating factor. We further refined the demographic forces for the Stakeholders Survey. Specifically, we focused on two of the more contentious aspect of demographic trends for the survey: life expectancy and urban density.
- The "Senseable Network" force, like the aging force was also seen to be a predetermined element. The presence of easily accessible sensor data will be included in all future scenarios.
- The "Increase in Global Trade" force was interesting in that it had tight consensus in the group for being Rapid Growth. This implies that there might be a blind spot in the participants' forecast of the future. This force is essentially an extension of the situation today – so it can be considered the "unofficial-official future." It was important to further refine this in the survey to understand the dimensions of global trade that might have severe implications.
- The "Rise in Protectionism" force was unique in that it was thought to have Peak & Crest type of influence. As protectionism increases, it has less of an effect over time. This was the only force that fit this pattern.
- The three Environmental forces (International Climate Regulation, Increase in Sustainability Regulations, and Increase in Sustainability Customer Demand) were designed to capture different aspects of the environment's impact on freight flows. The first captured the impact of international regulations and bureaucracy, the second captured the impact of domestic "top-down" green rules, and the last captured "bottom-up" or demand driven green practices. The top down forces were viewed as being more likely to occur and have more impact than the consumer driven force.
- The "Security Concerns" force was viewed as having little to no impact or influence on business. It was thought that this is more of the current situation and might be considered a predetermined element as well as a potential blind spot.

Stakeholder Survey

Based on the results of the Interactive Workshop, a set of twenty more refined Driving Forces were created as shown in Table 2 and Table 3, below.

Driving force	Description	Social	Technology	Economic	Environmental	Political	Sourcing	Destinations	Routing	Volume	Value Density
Re-domestication of manufacturing	Substantial re-domestication of manufacturing back to the United States			X			X	X	X		X
Reduction in global trade	Sustained reduction in global trade volume (both imports and exports) possibly due to rise of protectionism, pandemics, etc.			X			X			X	
Increased security threats	Large increase in both the number and magnitude of security threats (domestic and abroad)	X					X		X	X	
Green regulations	Stringent environmental and sustainability regulations adopted and strictly enforced by the United States and most other countries					X			X	X	X
High and volatile fuel prices	Dramatic increase in price and volatility of all oil based fuels			X			X	X	X	X	X
Rise of BRIC markets	Ascendancy of consumer markets in Brazil, Russia, India, China, and other countries leading to increased demand for products manufactured in the United States			X				X		X	X
Low-cost batch manufacturing	Widespread adoption of technologies enabling efficient and low-cost small batch manufacturing for most consumer goods		X				X			X	X
Online retailing	Dramatic shift towards online purchase and point-of-use delivery leading to reduction of physical retail stores		X	X				X	X	X	X
Senseable network	Widespread ability to capture and monetize real-time sensing data on all products, vehicles, and facilities across a supply chain at essentially no cost		X						X		
Recycling regulations	Omnipresent enforcement of regulations and rules requiring recycling and re-use of all manufactured products				X	X			X	X	
Average age of 100	Average life expectancy reaching 100 years in the United States	X						X			X

Table 2 Candidate Driving Forces for Stakeholders Survey, part 1.

Driving force	Description	Social	Technology	Economic	Environmental	Political	Sourcing	Destinations	Routing	Volume	Value Density
East coast ports	Shifting point of entry for a majority of imports to the East Coast (e.g. due to rise in manufacturing in Africa, more ships using the Panama Canal, etc.)			X			X		X	X	
New agriculture powerhouses	New countries (such as Russia or India) emerging as agricultural powerhouses supplanting the United States in some food commodities			X				X	X	X	X
Water scarcity	Pervasive water scarcity in some regions leading to a reduction in exporting products that either contain water (e.g. fruit) or require a water intensive manufacturing process (e.g., soda, electronic chips)				X		X		X		X
Green customer demand	The sustainability and environmental "friendliness" of a product becoming the dominant factor for consumer demand for most products supplanting cost	X			X		X	X	X		
Mega cities	Over 90% of the United States consumers living and working in mega-region cities and built up urban areas	X						X	X		X
Zero immigration	Immigration into the United States reduced essentially to zero					X		X	X		
Battery vehicles	New battery technologies dramatically reducing the cost and increasing the efficiency and range of electronic vehicles		X					X	X		X
Commodity price volatility	Shifting geo-politics and other factors leading to tremendous price volatility for almost all commodities such as wheat, copper, and lithium			X			X		X	X	
Increased value density	Advancements in manufacturing, materials, and other technologies increasing the average value per ton moved in the United States from ~$700 per ton (in 2008) to over $2000 per ton		X						X	X	X

Table 3 Candidate Driving Forces for Stakeholders Survey, part 2.

As shown in Table 4, there was a wide range of responses in terms of the expected Impact and Probability of occurrence.

	Impact of Driving Force						Probability of Driving Force					
Driving Force	Average Value	Standard Deviation	Coefficient of Variation	Avg Rank	StDev Rank	CV Rank	Average Value	Standard Deviation	Coefficient of Variation	Avg Rank	StDev Rank	CV Rank
Re-domestication of manufacturing	3.63	1.23	0.34	6	8	8	2.20	0.78	0.36	18	3	12
Reduction in global trade	3.70	1.23	0.33	4	9	7	2.20	0.84	0.38	19	7	17
Increased security threats	3.68	0.95	0.26	5	4	3	3.19	1.08	0.34	7	16	10
Green regulations	3.73	0.89	0.24	3	2	2	3.20	0.93	0.29	6	9	4
High and volatile fuel prices	4.44	0.67	0.15	1	1	1	3.94	0.83	0.21	1	6	1
Rise of BRIC markets	3.43	1.24	0.36	8	11	11	3.10	1.09	0.35	9	17	11
Low-cost batch manufacturing	3.22	1.31	0.41	14	15	13	2.79	1.04	0.37	12	12	15
Online retailing	3.26	1.54	0.47	12	18	16	3.21	1.07	0.33	4	15	9
Senseable networks	3.74	1.02	0.27	2	6	4	3.36	1.20	0.36	3	19	13
Recycling regulations	3.35	0.99	0.30	10	5	6	3.20	0.99	0.31	5	10	6
Average age of 100	3.05	1.30	0.43	15	14	15	2.39	1.27	0.53	17	20	20
East coast ports	3.02	1.27	0.42	16	12	14	2.63	0.83	0.31	15	5	7
New agriculture powerhouses	2.62	1.64	0.63	20	20	20	2.54	0.80	0.32	16	4	8
Water scarcity	2.92	1.57	0.54	18	19	18	2.80	1.04	0.37	11	14	14
Green customer demand	3.32	0.95	0.29	11	3	5	2.71	1.04	0.38	13	13	18
Mega cities	3.24	1.14	0.35	13	7	10	2.91	1.11	0.38	10	18	16
Zero immigration	2.72	1.50	0.55	19	17	19	1.58	0.70	0.44	20	1	19
Battery vehicles	2.93	1.39	0.48	17	16	17	3.43	1.00	0.29	2	11	5
Commodity price volatility	3.53	1.24	0.35	7	10	9	3.11	0.86	0.28	8	8	2
Increased value density	3.38	1.28	0.38	9	13	12	2.65	0.75	0.28	14	2	3

Table 4 Summary of impact and probability rankings from Stakeholders Survey.

The Average Value (for both Impact and Probability) is the average ranking from 1 (low) to 5 (high). The standard deviation is a measure of the dispersion around the mean or average value. The Coefficient of Variation is the ratio of the Standard Deviation to the Mean – it essentially normalizes the variability. The columns with the Rank are simply the ranking of each of the forces by average, standard deviation, and coefficient of variation, respectively – being #1 respectively means having the

highest Average, the lowest Standard Deviation and the lowest Coefficient of Variation.

Figure 9, below, plots the impact against the probability for each of the twenty driving forces. The driving force in the upper right corner (high impact and high probability) is the High and Volatile Fuel Price force.

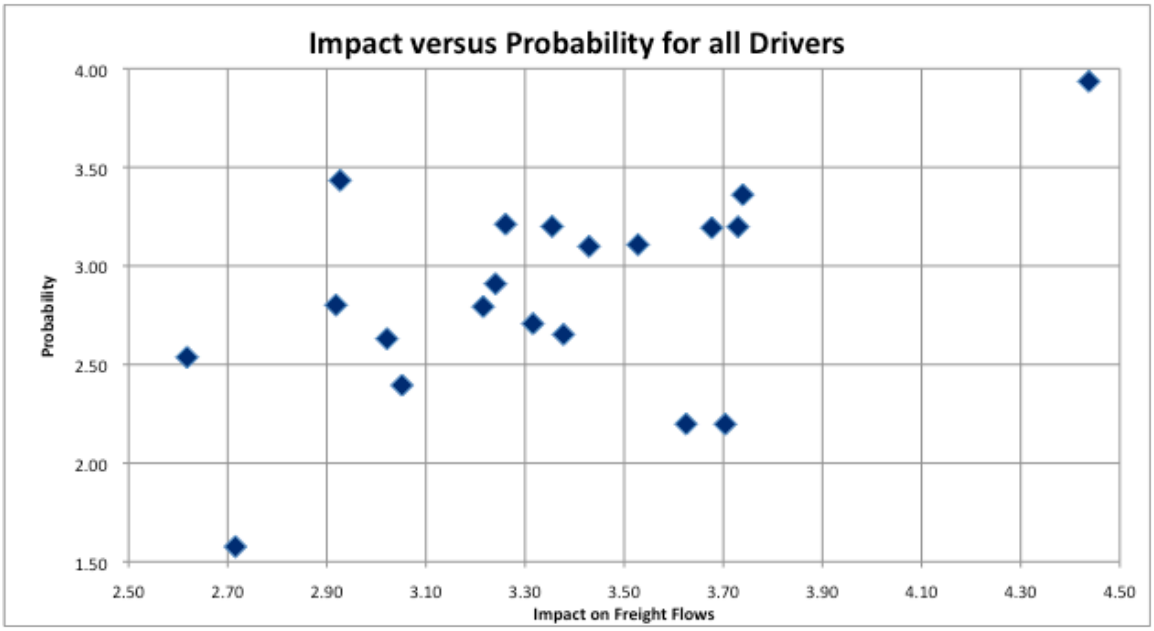


Figure 9 Plot of each driving force as the average impact versus the average probability.

Another way to look at the driving forces is to compare how they rank. Figure 10 plots the rankings of each of the driving forces for Impact versus Probability. Note that most of the forces have correlated probabilities and impacts. There are some anomalies, however.

Reducing Global Trade and the Re-domestication of Manufacturing are both viewed to be very impactful (ranked 4th and 6th respectively) but are viewed to be extremely unlikely to occur (ranked 25th and 24th respectively). This implies that these might be blind spots worth including in the potential scenarios. Conversely, the Recycling Regulations, Online Retailing, and Battery Vehicles forces are viewed as being very likely to happen (Ranked 5th, 4th, and 2nd, respectively) but will have next to no impact (ranked 10th, 12th, and 17th, respectively). These appear to be forces that are already having an effect today and should probably be considered as predetermined elements.

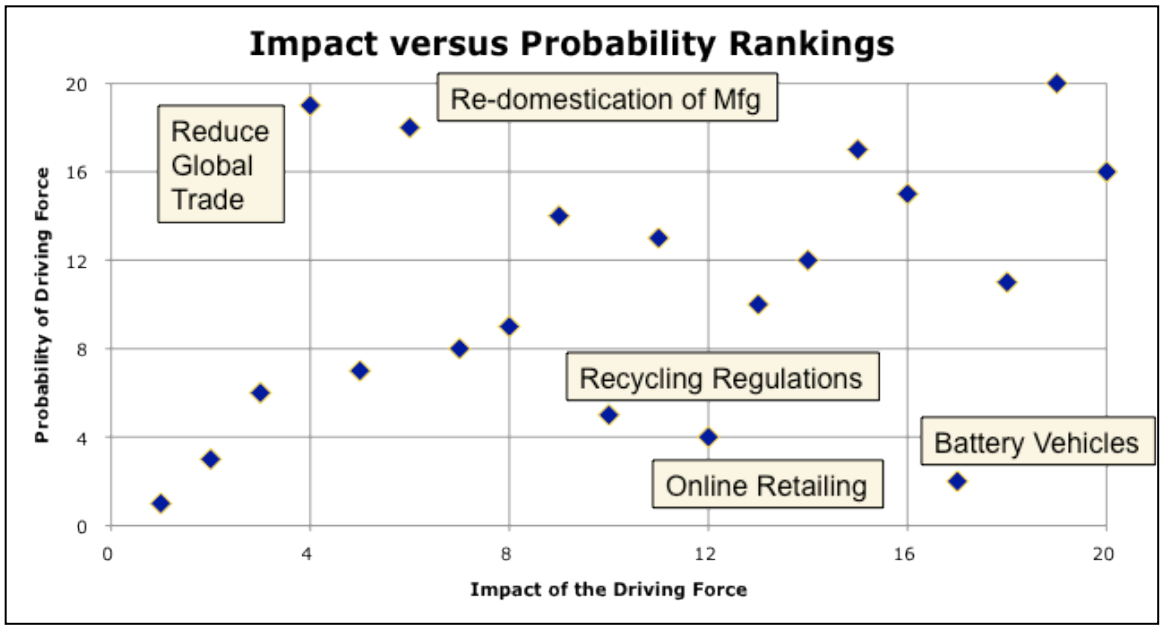
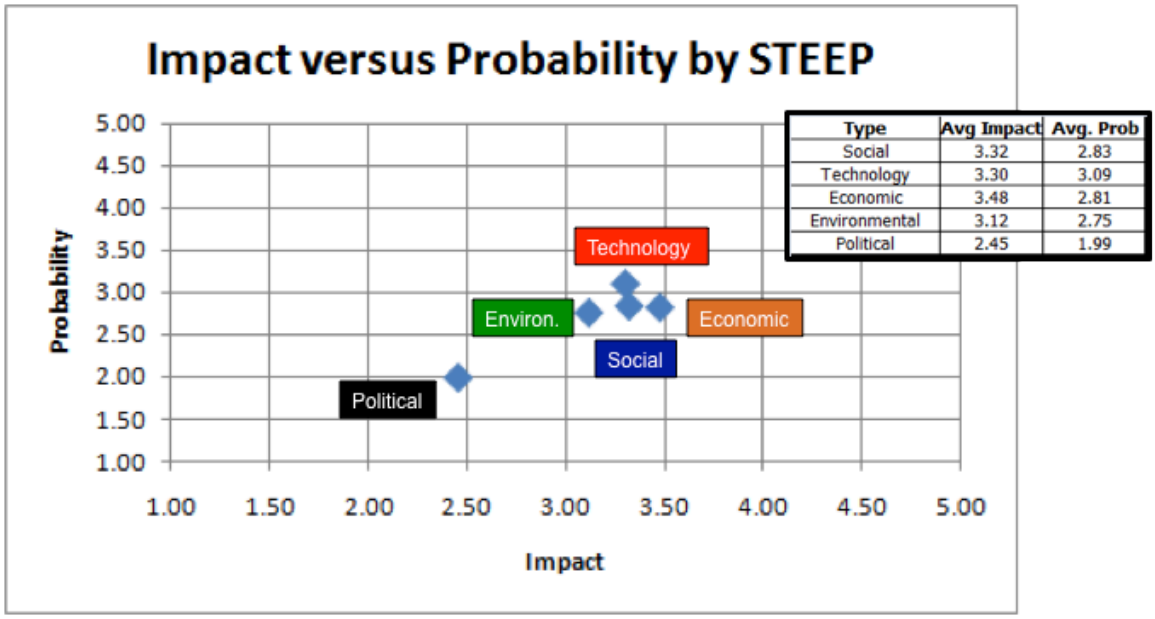


Figure 10 Plot of Impact rank (Rank=1 is the most important) versus Probability rank.

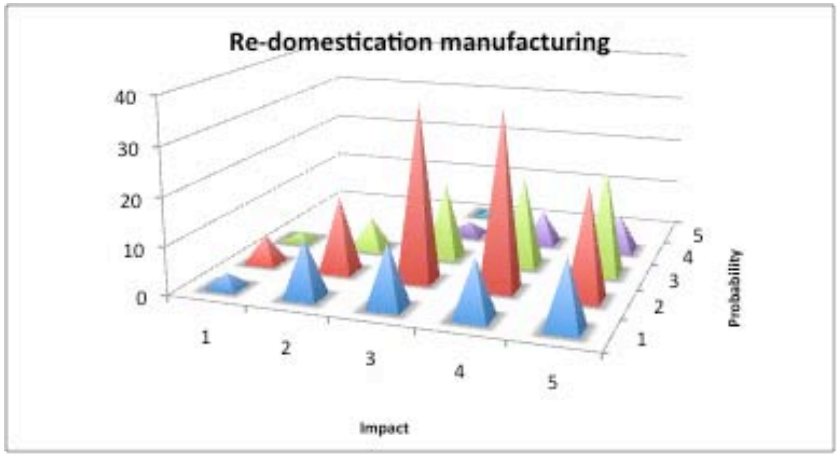
Figure 11 shows the driving forces grouped into their STEEP classifications and plotted for Impact versus Probability. Note that the political forces are both the least impactful, as a group, and the least likely to occur. The other four categories are fairly similar in location.

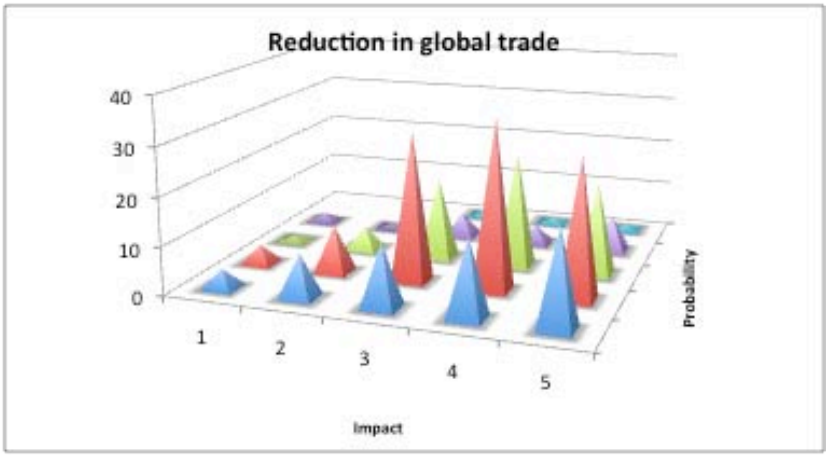


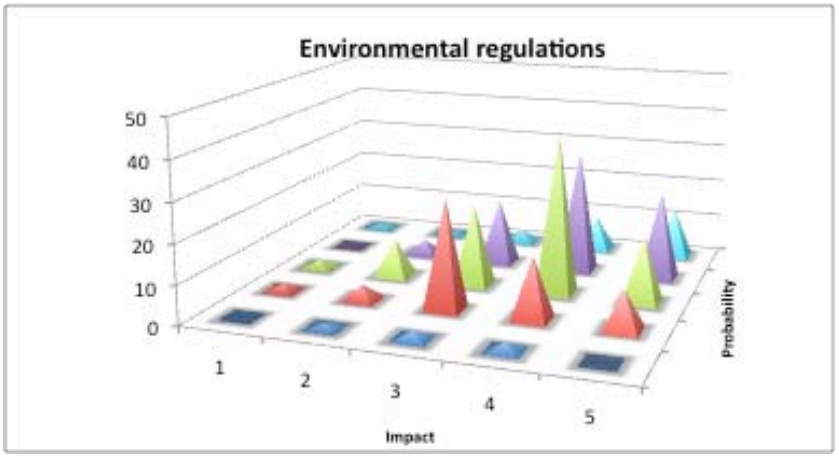
Type	Avg Impact	Avg. Prob
Social	3.32	2.83
Technology	3.30	3.09
Economic	3.48	2.81
Environmental	3.12	2.75
Political	2.45	1.99

Figure 11 Plot of STEEP factors for Impact versus Probability.

The full distributions and plots of the probability versus the impact for each driving force are shown on the following pages in Figure 12, Figure 13, Figure 14, Figure 15, and Figure 16.







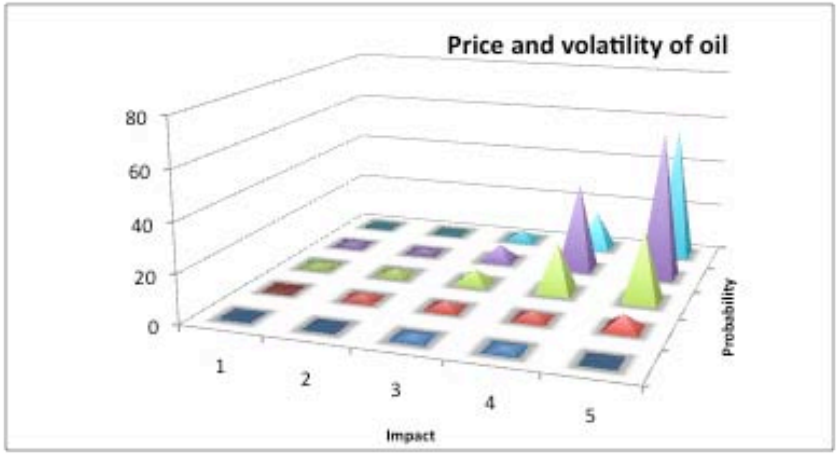


Figure 12 Histogram of candidate driving forces, part 1 of 5.

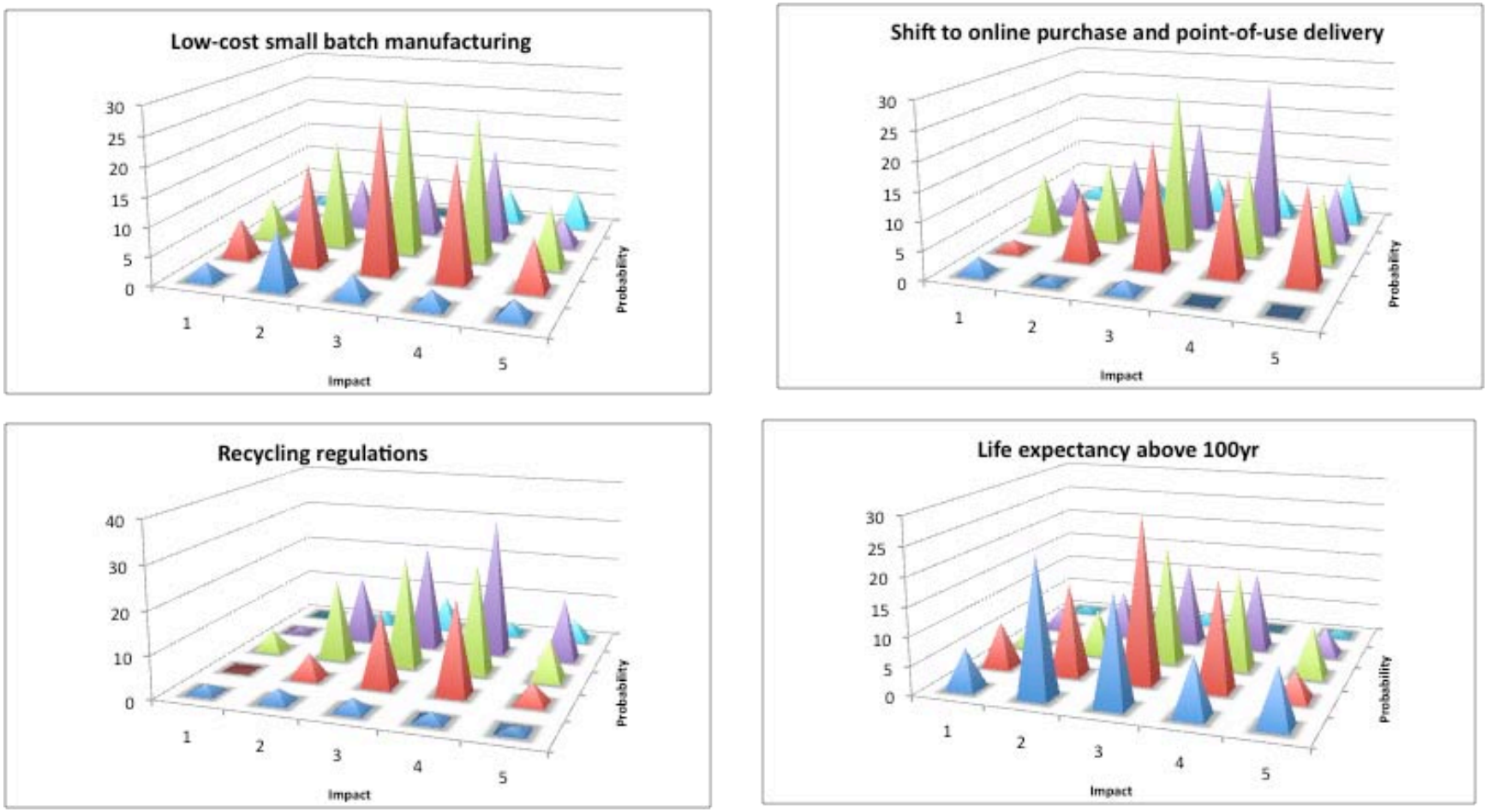
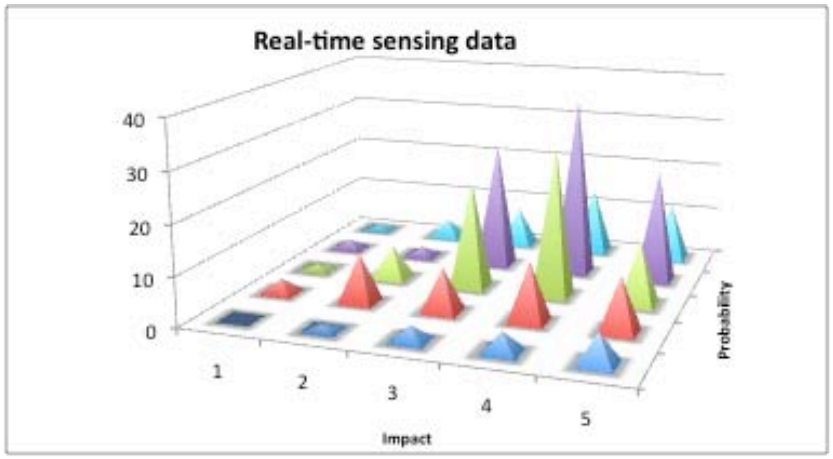
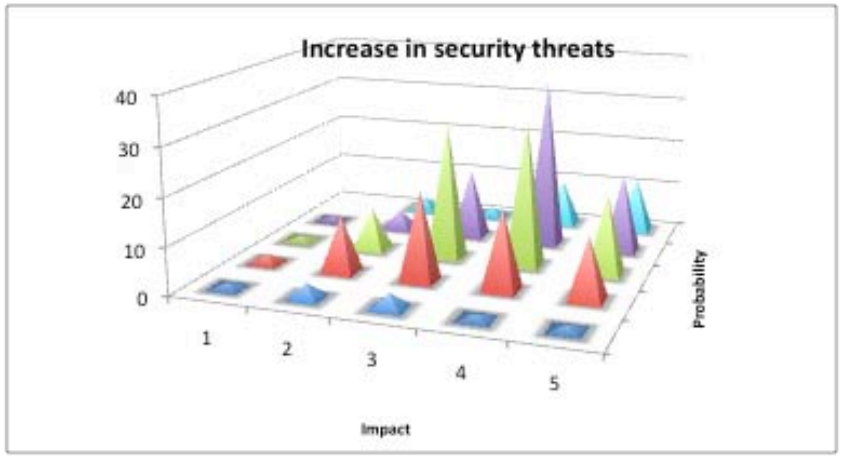
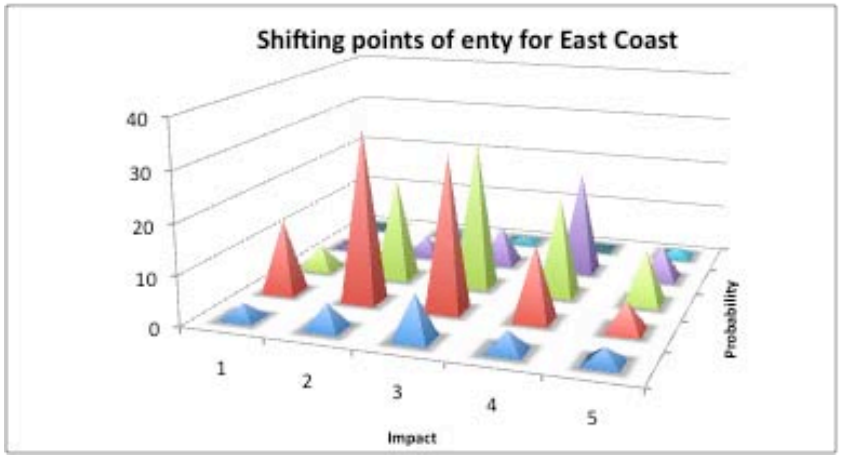


Figure 13 Histogram of candidate driving forces, part 2 of 5.







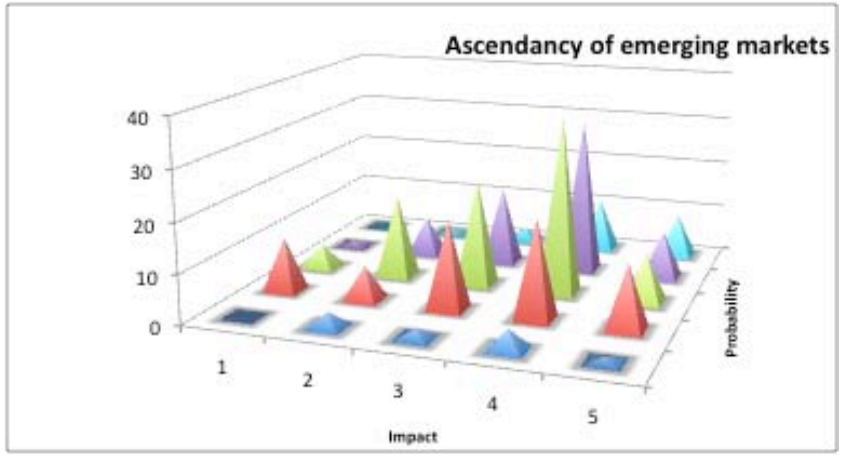
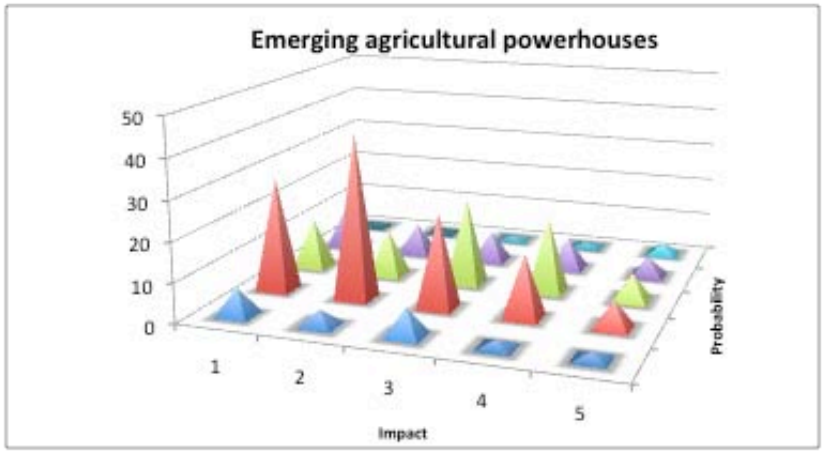
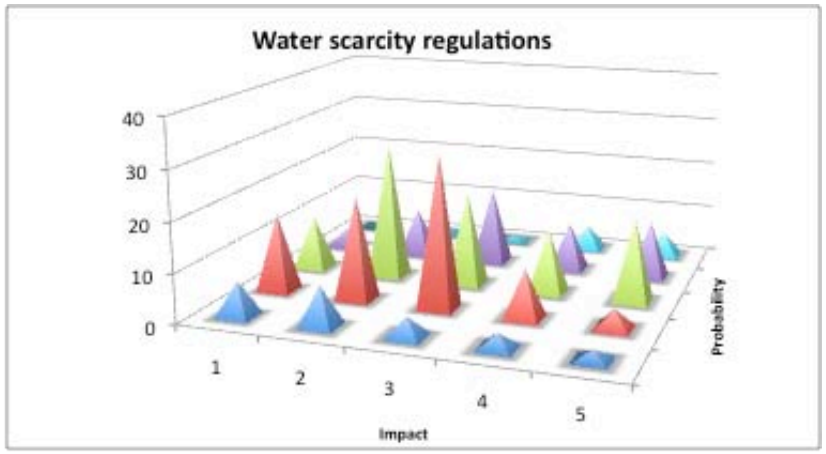
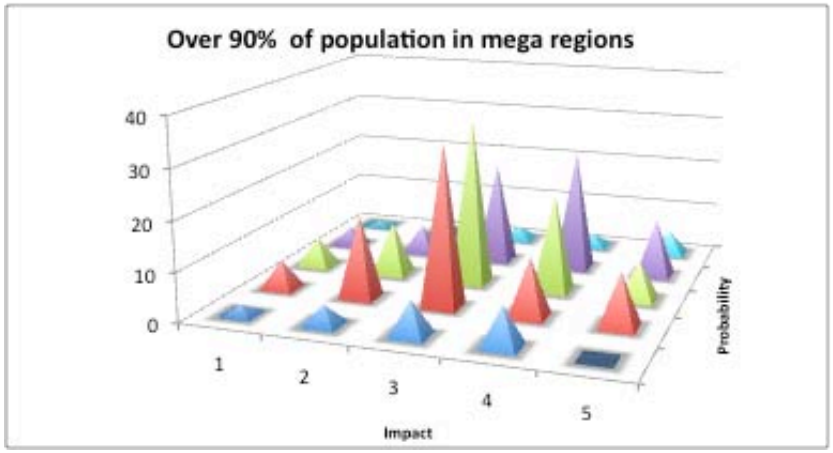


Figure 14 Histogram of candidate driving forces, part 3 of 5.







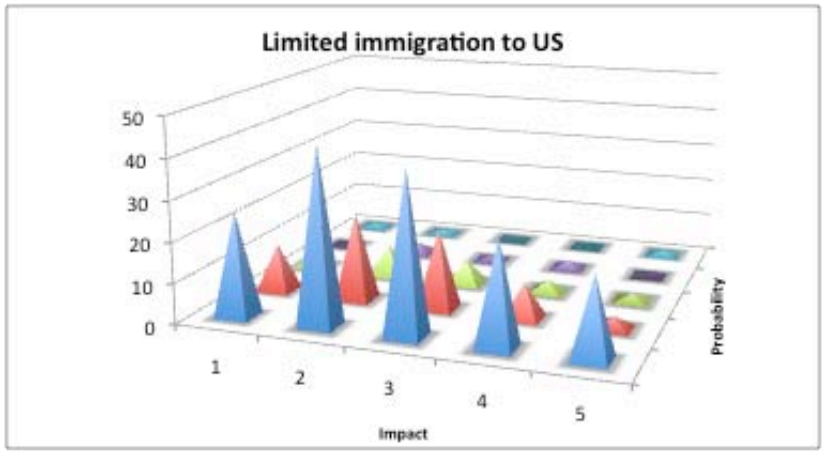


Figure 15 Histogram of candidate driving forces, part 4 of 5.

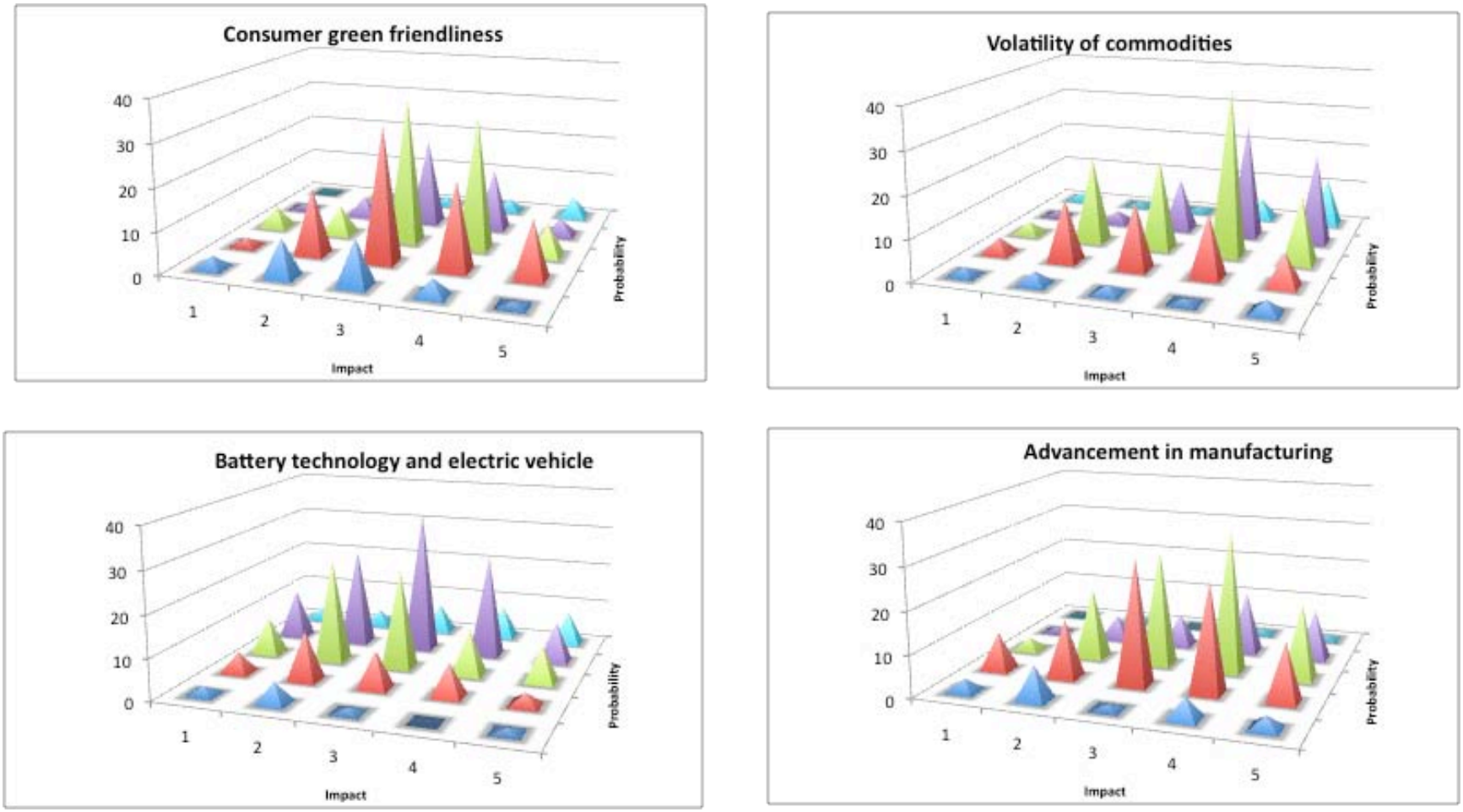


Figure 16 Histogram of candidate driving forces, part 5 of 5.

Further analysis of the driving forces did not reveal any significant correlations in the rating of probability and impact to background (shipper, carrier, government, etc.), position (C-level, vice president, Director, manager), sector, or firm size.

The following insights were gathered from the survey results:

- Most of the driving forces had highly correlated probabilities and impacts. This indicates that the survey respondents did not separate out the two different dimensions. The cases where there were anomalies stand out.
- The following forces appear to be predetermined and therefore will be included to some degree in each of the proposed scenarios: High and volatile fuel prices, Battery vehicles, Senseable networks, and Online retailing.
- The two forces that seemed to be the most impactful without the corresponding high probabilities are Reducing Global Trade and Re-domestication of Domestic Manufacturing. These are related in that they both signal a retreat from the global trading trends of the last half-century. These are wild cards that bear inclusion in the final scenarios.
- The coefficient of variation is a good indicator of uncertainty or variability. The driving forces with the most variability in the probability of occurring are: Average Age of 100, Zero Immigration, Green Customer Demand, and Reduction in Global Trade. The high CV numbers indicate a lot of disagreement over the potential outcome and while these forces might not define the different scenarios, they should be included.
- While forces previously identified as either predetermined or wild cards will constitute the main features of the future scenarios, the rest of the forces will not be overlooked but rather woven into the storyline to enrich the scenarios on a case by case basis.

Section 4. Next Steps

The next steps for the project are to use the insights as well as outputs from the workshop and the survey to craft a set of scenarios. This is the objective of Phase 2.

As demonstrated in table 5, Phase 2 is well underway and will be described in details in the Interim Report 2.

Building blocks	Action items	Status
Scenario Generation	Identification of scenario driving axes	*100%*
	Development of scenario storylines	*100%*
	Internal validation and testing of scenario storylines	*100%*
	Refining of scenario storylines	*75%*
	Writing of full length scenarios	*50%*
Scenario Quantification	Familiarization with FAF3	*100%*
	Identification of critical queries per scenario	*50%*
	Development of scenarios OD matrix	*0%**
	Network assignments for each scenario	*0%**
Designing the Scenario Planning Workshop	Identification of possible Policy and Management Strategies	*50%*
	Definition of workshop structure	*50%*
	Writing of facilitator/host guidelines	*25%*
	Development of other collaterals e.g. videos	*25%***

WIP: the completion of these tasks will be dependent on receiving the OD matrices from IHS Global Insight*
*WIP**: actual shooting will only begin after validation from the project board and will thus likely overlap into Phase 3*
Table 6 Phase 2 Update.

Appendix 1 – Future Freight Flows Agenda and Attendee List

MIT Center for Transportation & Logistics

Massachusetts Institute of Technology

MIT Future Freight Flows Symposium

Thursday, March 11, 2010 – MIT MediaLab Extension Building, Room E14-633

8:30	*Registration & Continental Breakfast*
9:00	***Welcome and Introduction*** Dr. Chris Caplice, MIT Center for Transportation & Logistics
9:15	***A Nation of Floridas: Aging, Changing Lifestyles & the New Future of Freight*** Dr. Joseph Coughlin, MIT AgeLab
10:00	*Break*
10:30	***After the Storm: New Challenges for the Global Economy in 2010-2030*** Sara Johnson, IHS Global Insight
11:15	***Public Policy and Freight: History, Trends, and Issues*** Dr. David Luberoff, Harvard University Kennedy School of Government
12:00	*Lunch*
1:00	***Transporting Bits and Atoms*** Professor Neil Gershenfeld, MIT Center for Bits and Atoms
1:45	***The New Age of Sensing*** Professor Sanjay Sarma, MIT Mechanical Engineering
2:30	*Break*
3:00	***Wired for Innovation: How IT is Reshaping the Economy*** Professor Erik Brynjolfsson, MIT Sloan School of Management
3:45	***Measuring and Managing Sustainability*** Professor Jonathan Johnson, The Sustainability Consortium
4:30	***Wrap Up*** Dr. Chris Caplice
5:00	*Adjourn*
5:30	*Social and Light Hors d'Oeuvres*

Friday, March 12, 2010 – MIT MediaLab Extension Building, Room E14-633

8:30	*Continental Breakfast*
9:00	***Synthesis of Thursday's Expert Sessions*** Dr. Chris Caplice
9:30	***Brainstorming Session: Key Driving Forces & Uncertainties*** All attendees and MIT facilitators
10:30	*Break*
10:45	***Translation and Mapping to Freight Flows*** All attendees and MIT facilitators
11:30	***Wrap Up and Preview of Next Steps*** Dr. Chris Caplice
12:00	*Lunch*

MIT Center for Transportation & Logistics

Future Freight Flows Symposium
March 11-12, 2010

AAFES
Maj. Gen. Keith Thurgood
Commander and CEO

Capt. DeShaunda Allen
CG Aide-de-Camp

adidas Group
Chris Peckham
Head of US Transportation

Anheuser-Busch InBev
Diana Orrego-Moore
Global Transport Manager

APL
Eric Mensing
President/CEO APL Maritime
and VP Gov't Trade/Affairs APL

Arkansas Best Corp.
Judy McReynolds
President and Chief Executive Officer

Armada Supply Chain Solutions/LXP
Paul Newbourne
Vice President & General Manager

BNSF Railway
Dean Wise
VP Network Strategy

California DOT
Michele Fell-Casele
Senior Transportation Planner

Chiquita
Deverl Maserang
VP North America Logistics
and Global Supply Chain Strategy

Con-way
Tom Nightingale
VP Communications and Chief Marketing Officer

Covidien
Robert Menard
Manager Global Transportation Contracts & Pricing

CSX
Dale Lewis
Strategic Analyst

D&M Holdings
Lalit Panda
CIO

Damco
Marc Heeren
Senior Director

Pyers Tucker
Global Head of Strategy

Dell
Bill Hutchinson
Director, Global Logistics and Fulfillment

EMC Corporation
Doug Deamaral
Senior Traffic Manager

John Manning
Project Manager - World Wide Logistics

Fairchild Semiconductor
Bob Scribner
Director, Global Logistics and Trade Compliance

FHWA
Tony Furst
Director, Office of Freight
Management & Operations

Fundacion LOGyCA
Rafael Florez
Director

Halcrow
Joe Bryan
Vice President

Heineken USA
Gregg Ramos
Senior Director, Supply Chain Management

Hewlett-Packard
Vincent Lafaix
HP Personal System Group Americas Logistics

Hutchison Port Holdings
Gary Gilbert
Senior Vice President

Illinois DOT
Keith Sherman
Bureau Chief, Urban Program Planning

J.B. Hunt Transport
Gary Whicker
SVP Engineering Services

Kornegay & Co.
Tom Kornegay
President

Kraft Foods
Harry Haney
Associate Director, Transportation Planning

Limited Brands
Kurt Kravchuk
AVP, Logistics

MeadWestvaco
Chris Osen
Vice President & General Manager

Michelin North America
William Jana
Director, Transportation & International Logistics

Michigan Technological University
Bruce Seely
Dean, College of Sciences and Arts

Minnesota DOT
Bill Gardner
Director, Freight, Rail & Waterways

Mississippi DOT
Juan Flores
Policy Manager

Mohawk Industries
Stan Brooks
Director of Transportation

Norfolk Southern Corporation
Michael Miller
General Manager

NxStage Medical
Judith Taylor
VP, Planning and Logistics

Orient Overseas Container Line
Rick Wen
VP Business Development

Penske Logistics
Frank Hazeltine
VP Global Markets

Pepsi Bottling Group
Jim Farrell
VP Transport

Paul Hamilton
VP Global Supply Chain Strategy

Port Authority of NY & NJ
Steve Brown
Manager, Freight Planning

RaceTrac Petroleum
Brett Connor
Logistics Manager

Schwan Food Company
Ron Siemers
Director, Supply Chain Operations

Starbucks
John Bauer
Director, Global Transportation,
Supply Chain Operations

Target
Steve Carter
Director, Transportation Strategy & Planning

The TJX Companies
Brian Lawson
VP Transportation

Transplace
Tom Sanderson
President and COO

Transportation Research Board
Bill Rogers
Senior Program Officer

UPS
David Adams
Strategic Planning Manager

USDOT/Volpe
Dr. David Damm-Luhr
Domain Leader, Organizational Systems Performance

Mike Dinning
Director, Freight Logistics and Transportation Systems

USTRANSCOM
Marc Sukolsky
Military (Civilian) Senior Fellow

Wal-Mart Transportation
Kelly Abney
VP Corporate Transportation

Mike Bright
Senior Director, Transportation Strategy

Washington State DOT
Barbara Ivanov
Co-Director, Freight Systems Division

Working Knowledge
Andrea & Dana Meyer
Senior Partners

MIT
Bruce Arntzen, Ph.D.
Research Associate, CTL

Chris Caplice, Ph.D.
Executive Director, CTL

Ken Cottrill
Global Communications Consultant, CTL

Tony Craig
Ph.D. Candidate, Engineering Systems Division

Tara Faulkner
Director of Communications, CTL

Francisco Jauffred, Ph.D.
Research Affiliate, CTL

Stephanie Jernigan, Ph.D.
Research Associate, CTL

Loïc Lagarde
Research Associate, CTL

Roberto Perez-Franco
Ph.D. Candidate, Engineering Systems Division

Shardul Phadnis
Ph.D. Candidate, Engineering Systems Division

Jim Rice
Deputy Director, CTL

David Riquier
Director, Corporate Outreach, CTL

Prof. Yossi Sheffi
Director, Engineering Systems Division & CTL

Mahender Singh, Ph.D.
Research Director SC2020

Prof. Joe Sussman
JR East Professor, Department of Civil & Environmental Engineering

Appendix 2. Summaries of Thought Leader Presentations

This appendix contains fairly detailed summaries of each of the thought leaders' presentations.

Symposium Introduction - Dr. Chris Caplice, Executive Director, MIT CTL

What should state-level transportation planners be thinking about 20 years from now? Dr. Chris Caplice, Executive Director of the MIT Center for Transportation and Logistics, opened the Future of Freight Flows Symposium with a question. How might future trends in the broader economy significantly change long-term future freight flows and thus affect the near-term patterns of investment in public and private transportation infrastructure? He illustrated this issue with an example from the past: how containerization affected sourcing, routing, and destinations of freight.

Containerization

Dr. Caplice described the history of an innovation – containerization – and its impact on freight. In the 1950s, Malcom McLean grew McLean Trucking into the second-largest trucking company in the US. McLean was trucking beer to Miami, but the cost of the transportation was eating into his profits. McClain thought, "What if I move beer by water instead of land?" In 1953, he developed plans to carry his trucks on ships. The trouble was that putting trucks on ships was inefficient because of the loss of potential cargo space. So, McLean originated the idea of simply loading the containers, not the chassis, on ships. The result: the cost per ton decreased from $6 per ton to 15 cents per ton in containers on ships.

Over time, containerization had significant second-order effects such as enabling offshore manufacturing and accelerating global trade. Ironically, containerization didn't help McLean avoid congestion delays -- congestion simply concentrated in ports. In short, containerization greatly reduced costs, changed sourcing patterns (enabling offshore sourcing) and created congestion at ports.

The Role of Scenarios

Decision-makers can use scenario planning to think about plausible future events and understand their impact before they occur. The goal of the scenarios is not to predict or forecast the future but to consider future outcomes or events and translate what their impacts would be on freight flows. Scenarios require stories to be plausible and relevant. Their end goal is to enable a more robust planning strategy. This symposium is part of a 21-month project that is developing scenarios focused specifically on freight planning.

Symposium Goals: Divergent and Convergent Thinking

The Future of Freight Flows symposium, a day-and-a-half event, is divided into two parts to foster divergent and then convergent thinking about freight flow scenarios.

The first day was devoted to divergent thinking – stimulating participants to think about a range of potential future events that might have significant direct or indirect effects on freight flows and stresses on logistics infrastructure. To do this, the first day featured seven talks by a range of thought leaders. The second day used breakout sessions for participants to discuss the adoption, implications, and stresses associated with twelve snapshot scenarios derived from the first day of the symposium.

A Nation of Floridas: Aging, Changing Lifestyles & the Future of Freight - Dr. Joseph Coughlin, Director, MIT AgeLab

Dr. Coughlin shared insights from the MIT AgeLab, of which he is the director. Whereas other presenters would talk about futures that may come to pass, Dr. Coughlin's message about the aging population was much more certain -- we are all getting older. And unless something drastic happens to death rates or immigration, the demographics of the US is readily predictable for the coming decades. Given the high predictability of the aging population, the questions Dr. Coughlin posed were: how will you live tomorrow? And what implications does that bring for the business of freight?

Demographic Trends

Demographic and economic trends will effect the composition of consumers and patterns of consumer demand that affect freight flows. Dr. Coughlin described four key trends that point toward these changes.

Aging in the US and Around the World

In the US, one person turns 64 years of age every 7 seconds. The fastest-growing demographic in the US is the over-85 age group. We're all becoming a nation of "Floridas" and more like Europe, where one-quarter of the population today is already over age 60. Some states have markedly older populations as well. Not only Florida but also Iowa, Pennsylvania and West Virginia had 15% of their populations over age 65 in 2000, with New York, Massachusetts, and the Rust Belt close behind.

Looking globally, the percentage of the population over age 60 in the year 2000 was already 16.5% in the US and former USSR, 14.3% in Asia, and 19.8% in Europe. By 2025, those figures will be 25% in the US and former USSR, 25.3% in Asia, and 28.8% in Europe.

Women

The future isn't about men, because women outlive men -- women outnumber men in nursing homes 8 to 1. Not only do women live longer, they also make a growing number of economic and consumer decisions. Women now are more educated than previous generations, and workforce participation by women is at an all-time high of 70 percent.

High Expectations of Activity

The boomers -- the generation that defined modern-day retailing -- are now getting older. The biggest challenge of meeting the needs of this group is brought by their

expectations. Boomers have very different expectations of old age compared to their parents. Boomers expect to work, volunteer, stay productive and stay connected. They won't just be retiring and staying home. Indeed, 79% plan to volunteer and 62% will be working part-time. The most telling areas of the poll show that 79% of boomers expect no serious limits on their activity until over age 70, and 50% expect to be active and going strong at age 80. How? 83% of them expect treatments for the ills of aging to improve.

Improved Health: Ill but not Sick

Boomers expectations of good health into old age aren't unfounded. There's been a decrease in disability among the "new elderly" in all income groups. People are enjoying longer periods of relative wellness into "old" age. That doesn't mean they are disease-free: 110 million Americans have a chronic illness, and 60 million have two or more chronic conditions. But they are managing these chronic conditions with medications and maintaining their lifestyles. Being ill no longer means being sick and disabled. These demographics of aging and health are already being disruptive. For example, the funeral industry is not meeting revenue projections because people are not dying fast enough -- they've living longer.

New Opportunities

These trends in aging, expectations, and behavior lead to new or increased opportunities for commerce that will affect freight flows. Aging boomers represent a significant business opportunity. About 20% of the population controls over 40% of all disposable income. Additionally, older adults control 77% of all assets and have $1.6 trillion in buying power in the US. This is expected to increase by 29% over the next five years.

'Smart' Spending

Boomers aren't looking just for prestige for the items they buy -- they want to get the good deal and show how smart they are. Costco parking lots have Porsches alongside Ford 150s as boomers look for ways to get brand-name products inexpensively. One issue yet in the early stages is: as boomers gray, will they also become greener? Boomers were the generation that gave birth to the EPA. Green issues do resonate the most with them, and they are starting to think about their legacy and their personal footprint.

The fastest-growing segment on the Internet is women 45+ who are seeking information on health, finance and auto purchases. They see the Internet and social media as a source of advice and to validate their choices. Women over age 59 are the fastest-growing segment on Facebook. Whereas kids use social media to talk with people they already know, boomers use it as a way to meet new friends.

Higher Education

The number of older adults with four or more years of college has doubled in the last 20 years, and there's an increasing demand for non-traditional learning. The most popular places to retire aren't golf courses but are college towns like Ann Arbor and Chapel Hill. Polls show that 89% of boomers expect to be learning, studying and traveling during their retirement years.

Women

Women manage the household and make 90% of the healthcare decisions, as companies like J&J and P&G already know. In fact, women make a surprising percentage of all purchasing decisions. Some 89% of consumer electronics sold per year -- $55 billion -- are sold to women. Even seemingly male-centric product categories have female-dominated purchasing patterns. For example, 80% of home improvement products and 80% of NFL products are sold to women. Women have made significant gains in affluence -- the number of women earning over $100,000 annually has tripled in the past 10 years, and 43% of people with assets over $500,000 are women. The point is that women are the Family CEO and are the primary caregivers for older adults.

Transportation & Caregiving

One in four families care for an older adult, and nearly 50% of US workers are more concerned about how they will care for a parent than a child. The oldest adult daughter typically guides the health and financial issues of older adults. Transportation is among the top five supports sought from friends and family. Just as boomers outsourced care of kids to daycare, their grown kids may outsource transportation and eldercare.

Four Future Scenarios

Dr. Coughlin enumerated four scenarios that are backed by current data.

Aging in Place

About 70% of Americans live in suburban and rural areas, and they plan to continue living there as they get older. Boomers are not likely to move to the city upon retirement. Their marriage and memories are tied to one place and most of them will be aging in place. The implications for transport and freight are clear: mass transit is unavailable in most of these areas, which means that driving is the only viable alternative. Transportation plans need to be put in place now if they're to be ready when needed.

Emerging Home Care Services: As people age in place rather than move into retirement homes, we'll see the emergence of virtual retirement communities like Beacon Hill Village. Community-based service providers will arrange for home delivery of food and medications. They'll also provide contract home repair and maintenance.

Intelligent Home Services: We'll see the integration of information technology (sensors) into clothing, appliances and bathroom fixtures. For example, next-generation toilets measure a person's weight, fat, heart rate, urine sugar, albumin and blood in urine, transmitting the information over the Internet to caregivers, doctors and pharmacists. This commode-and-communication combination is already a reality in Japan, where consumer electronics maker Panasonic has partnered with utility company Tokyo Electric Power to provide remote monitoring of older adults. These kinds of strategic partnerships will provide an array of branded home products combined with services. In the UK, a retailer is already using data from smart toilets to facilitate the food products you need based on your

"output." In the US, Philips and Comcast have partnered on a product that reminds you to take your medications and enables video discussions with clinicians using broadband. Another product for the home is a teddy bear tiger that sits quietly on the sofa and detects motion.

In summary, intelligent home services link multiple sensors in the home (kitchen appliances, bathroom, clothing, entertainment platforms) with physicians, emergency response services, health and wellness monitoring systems, food and nutrition and pharmaceuticals. Leading-edge companies like Partners Telemedicine, ADT, Healthways, Bank of America, Stop & Shop and Walgreens are already providing these branded services.

Home Alone

Single-person households are among the fast growing in the US, and the oldest old will be women living alone. The implications for business are smaller homes, smaller package sizes and smaller format stores with shopping carts that are friendly to those with diminished physical capacity. Boomers are willing to spend more for convenience -- they have never short-changed themselves. Even in a downturn, they have more discretionary income than their parents had. Home delivery of groceries will see a resurgence.

Personalize Me

Boomers experiencing midlife aches and pains will look for customized products that let them continue their active lifestyle. Personalization is the design and marketing response to older buyer needs and meeting their higher expectations. For example, boomers' disposable income lets them pay $20 more for a customized Nike ID shoe.

Wellness, Work & Older Workers

Older adults will work longer past retirement not only for the money but for the challenge, personal meaning and social benefits, an OECD study found. The implications for freight are a "graying" of the transportation workforce and an influx of women into the field. In US, 56% of women 55-64 are in workforce, an increase of nearly 10% in 10 years. This increased participation of older women in the workforce has implications for workplace design -- accommodating a 5'2" female driver rather than a 6' man.

Summary of the Implications of Aging on Business and Freight

Summary of Changes in Consumer-Side Logistics

- On-demand home logistics to meet personal needs will grow: store-shelf to home-shelf delivery.
- Overnight/day carriers blend as service operators (UPS meets Geek Squad).
- More home purchases made as needed rather than storing large quantities at home.
- More trips per household.

Summary of Changes in the Logistics Workplace

- Added focus on worker safety & health.

- Rethinking the current 'big' packaging & big-box store format.
- The "Feminization of Freight," meaning redesigning the workplace from vehicle to warehouse to accommodate older female fragility and safety.

Key Finding: Our future looks to be gray, small and female.

After the Storm: New Challenges for the Global Economy in 2010-2030 - Sara Johnson, IHS Global Insight

Sara Johnson, Managing Director of Global Macroeconomics at IHS Global Insight, presented forecasts for upcoming macroeconomic conditions. Work by IHS' Global Scenario Team tracks and forecasts a wide range of variables that affect freight flows. These factors include GDP, industrial production, trade, unemployment, interest rates, commodity prices, and currency exchange rates. Ms. Johnson offered a quick retrospective of the crisis, a commentary on near-term economic forces, and a discussion of longer-term trends in different regions of the globe.

Good News: No Depression 2.0

The good news is that the recent economic crisis was not another Great Depression. Although the world may have been staring into a financial abyss a year ago, resilience absorbed the shock. Concerted efforts by central bankers and governments prevented a deeper deflationary cycle, runs of banks, and other types of behaviors that contributed to the first Great Depression. Monetary stimulus stabilized the financial markets and fiscal stimulus limited the depths of the downturn. Now with the bottoming-out of the economic slide, people are becoming more confident or, at least, less fearful.

Globalization Continues

Despite some grumbling about greedy bankers, there was no significant backlash against free-market capitalism. By and large, governments rejected the siren call of protectionism that plagued the 1930s. Although world trade certainly suffered a big setback in 2009, trade is already rebounding. Although exports dropped 12% in 2009, they are expected to rebound 7% in 2010. In fact, charts of world imports as a fraction of GDP suggest that 2009 was more of a correction of over-exuberant levels of activity than a true setback. World imports were 24% of GDP in 2003, surged to 32% of GDP in 2008, retrenched to 27% in 2009, and are expected to climb back to 29% by 2011 and continue growing in the long-term to 37% by 2030.

Near-Term: Not a "V" Recovery

IHS does not expect a "V"-shaped recovery. Rather, growth will return slowly. Financial crises create more long-lasting economic damage than do normal business-cycle recessions. Banks still have more losses to absorb from commercial real estate; unemployment remains elevated; and many mortgages remain underwater. It takes time for banks, companies, and consumers to rebuild damaged balance sheets, access needed credit, and resume normal levels of economic activity.

Inventory Cycle Variations

Recent reports of very high growth (a 5.9% annual growth rate for the US in the last quarter of 2009) are not indicative of a sharp recovery. More than half of that growth figure reflects inventory cycle issues: companies ordered and produced extra goods at the end 2009 to replenish a year-long draw-down of inventories. Although this mini-surge of replenishment is unlikely to continue, it bodes well for the future. At the very least, companies are now regaining some confidence in holding inventory.

Pent-Up Demand, but Uneven Recovery Across Sectors

The next phase of the recovery will see a release of pent-up demand. In particular, IHS expects business equipment, especially high-tech, to lead the recovery. Consumers probably won't lead the recovery due to diminished appetites and capacities for borrowing and spending. Instead, consumers will be rebuilding decimated nest eggs by increasing their savings rates. Residential construction will rise from the extremely low current levels while non-resident construction will remain depressed due to aftermath of over-investment in construction during the last boom. The end of federal stimulus programs combined with budget pressures on state and local governments will mean low or negative growth in government spending. IHS expects healthy growth in exports as the US dollar weakens somewhat and world trade rebounds.

Prices and Currencies

Mostly Uninflated with a Chance of Price Bubbles

High unemployment and lingering financial damage should prevent any surge in inflation. Moreover, major central banks remain committed to controlling inflation. IHS expects an overall global rate of inflation of 2.5% annually over the next five years. That rate includes somewhat lower inflation in the advanced countries (less than 2%) and somewhat higher inflation in the emerging countries (4-5% inflation). Yet Ms. Johnson warned that the prevailing environment of ultra-low interest rates could spur speculation and over-investment in some areas. This might cause price bubbles in some assets or commodities.

The US Dollar Remains the Reserve Currency of World

Currency exchange rates affect the prices of imports vs. exports and thus affect the flow of international freight. During the crisis, the US dollar strengthened as investors sought safer refuge in the storm. IHS expects the US dollar to weaken slightly as the crisis unwinds.

As much as some might worry about the safety of the US dollar, no other currency seems capable of replacing it as a reserve currency used by many foreign exchange reserves and other global financial activities. The Euro's youth and the recent crisis with Greece (and similar debt issues with Portugal, Ireland, Italy, and Spain) make the European currency unattractive. The Chinese Yuan isn't freely inter-convertible and seems to be too much under the control of the Chinese government.

Future: A Multispeed World

Ms. Johnson's analysis of the various segments of the world economy revealed a multispeed future. Some economies will continue to grow quickly, while others will grow much more slowly. Whereas the advanced economies of the world will average about 2.5% annually over the next 10 years, emerging market economies will average 6% annual growth. Along with this spread of speeds is a further synchronization of business cycles and volatility. Greater globalization means increased tendencies for all economies to boom or bust at the same time, which means greater volatility of commodity prices and freight flow volumes.

Leading: Asian & Emerging Markets

Although the economic downturn certainly hit the export-dependent economies of Asia, they didn't suffer as much damage to their financial systems as did Europe or the US. An earlier financial crisis in Asia in 1998 led to reforms that helped those countries avoid deeper damage. Asian banks held higher surpluses at the beginning of the crisis than did their Western counterparts. Thus, Asia rebounded faster than other countries.

In the coming years, China, India and other emerging market countries will lead global economic growth. China, in particular, will grow rapidly and become a far larger fraction of the world economy. By 2020, China will surpass the US in GDP. China has reached the point where it is buying more light vehicles than the US. China, with its large population and aggressive economic development policies, will become one-quarter of the world economy. India will also continue to grow quickly, as will a range of emerging markets countries in other parts of Asia. Emerging markets countries in Latin America (e.g., Brazil) and emerging Eastern European countries will enjoy somewhat lower rates of annual growth in the 3-4% range.

USA/NAFTA

The US and NAFTA countries will probably take a middle road in economic growth of between 2.5% and 3% per annum in the coming two decades. The expected gradual decline of the US dollar in the post-crisis years will lead to growing export volumes in capital goods and basic machinery. The US also enjoys low-cost natural gas, which translates into a persistent cost advantage in many chemicals.

Lagging: EU/Japan

Although the financial crisis was centered in the U.S., banks in Europe actually suffered greater damage. European banks had higher leverage than did American banks. European banks also had significant exposure to Eastern European countries. Moreover, the EU faces internal economic challenges with Portugal, Italy, Ireland, Greece, and Spain. Differences in the competitiveness of different EU member countries will affect the rate of recovery of the region. Japan will also experience low rates of growth. Western Europe will average less that 2% annual GDP growth through 2030. The growth expectation for Japan averages less than 1% annually in the coming 20 years.

Long-Term Risks: Debts, Demographics, and Defaults

Despite the growing optimism, many risks remain on variety of time horizons. The withdrawal of government stimulus spending and premature tightening of interest rates could jeopardize the nascent recovery. Home prices may fall further, and commercial real estate will almost certainly deteriorate. Price volatility from commodity and asset price bubbles could further hurt weakened businesses or reduce confidence.

Demographics are also affecting long-term economic forecasts. Western Europe and Japan, especially, have much older populations, which generally means both less domestic production and less consumption. Some countries are actually expected to shrink in population, which will reduce total GDP growth.

In the long-term, high deficits and growing government debts threaten the futures of many advanced countries, including the US. Current U.S. Congressional Budget Office projections for the federal deficit suggest that it will decline from $1.4 trillion now down to $700 billion before rising to $1 trillion by 2020. Europe's challenges with Portugal, Italy, Ireland, Greece, and Spain also stem from high deficits and debts. Research by Reinhart and Rogoff suggests that countries with government debt in excess of 90% of GDP suffer from slower growth. As government debt grows, more and more economic activity becomes absorbed by repayment of debt rather than investment in growth. These high and unsustainable debt levels also raise the specter of sovereign defaults that could further damage the banking system, hinder economic growth, and reduce trading with the affected countries.

Public Policy and Freight - David Luberoff, Harvard University Kennedy School of Government

David Luberoff explored the issue of the seeming silence of freight interests in government transportation policy -- the proverbial dog that doesn't bark in the night. Freight policy is clearly important, but it doesn't get much attention today. For example, in the Testimony on Current and Future Investment in Infrastructure May 2008, CBO Director Peter Orzag only mentioned to word "freight" nine times in 43 pages. Of these nine mentions, seven were on simple charts, one discussed changes to truck weights and travel distances to reduce highway wear, and the last mentioned freight in the context of public-private partnerships (PPPs) such as the Alameda corridor.

Freight Policy in U.S. History

Historically, US transportation policy was dominated by freight. In the 1700s, ports were the key to the first American cities. In the early 1800s, the freight policy centered on internal improvements: waterways, railroads and some roads. Developing a rapidly-expanding frontier and mobilizing the natural resources of a nation meant an emphasis on moving goods from the hinterland to cities, factories, and markets. Later, the policy shifted to one of moving people more so than moving freight.

The Canal Era

The Erie Canal was built to move cargo, not people. Indeed, the Erie Canal cemented New York City as the dominant city because it was more freight-competitive than Philadelphia or Boston. Other localities also tried to build their own canals, but most of them failed economically. As a result, state governments began to put debt restrictions on such projects and put authorities in charge of them. The early 1800s also saw the first effort to have federal plan for freight, but the idea failed.

The Railroad Era

In the mid- to late-1800s, freight policy focused on the promotion of transcontinental railroads. States provided free land to the railroads and city leaders vied to attract railroads to their areas. Railroad companies had the leverage to tell cities, "if you don't give us what we want, we'll go to a different city." Chicago leaders opened up their city to railroads and gained prominence.

Farm-to-Market Roads

Whereas the major federal policy of the late 1800s focused on the transcontinental railroad, in the early 1900s policy shifted toward creating a network of farm-to-market roads. Next, early aviation systems focused on airmail -- a low-volume, high-value product. Airplanes moved money between banks and documents between companies. Localities lobbied to get airports using federal government subsidies. When Atlanta became a southern air hub over Birmingham, localities began to see the importance of aviation as part of their economic strategy.

From Interstate Highways to Suburban Congestion

The 1950s saw the emergence of trucking and the pressure to build highways. Freight was a big part of that, and the federal government created the interstate highway system. A shift was beginning, however, because highways were also about moving people. The federal highway system represented a transitional moment in which moving people around became a priority at the national and state level. Although interstate highways still primarily moved fright, highways in urban areas were about moving people. The rise of the suburbs brought the rise of commuters. Moreover, popular support came not from freight but from solving traffic problems.

Freight Policy Today

Today, few projects are freight-focused and high profile. The Alameda corridor is the exception: a corridor to connect Long Beach and LA by means of a below-grade railroad. Only a handful of projects, such as the fast corridor in Seattle, focus on making freight flow better. Freight today faces the problem of conflicting uses: older working waterfronts are being redesigned into public spaces with restaurants -- but where is the freight? It disappears. Boston is one of the few cities to have a working port as well as a redevelopment project. In California, San Francisco focused on the tourist redesign and all the freight went to Oakland.

The Modern-Day Politics of Freight

Mr. Luberoff explored three hypotheses for the seeming absence of freight-related discussions in the government transportation policy discourse:

- freight isn't important
- freight interests do effect policy but do so quietly
- freight interests don't affect policy due to some sort of strategic, political, or structural disadvantage

Is Freight Still Important?

Perhaps the reason why freight policy has disappeared from public discourse is due to the declining linkage of freight to the economies of most population centers. For example, consider the Port of New Orleans in the post-Katrina rebuilding effort. The number of people employed at the port is miniscule, thereby decoupling the importance of the port in the rebuilding. The declining cost of moving goods also reduces the salience of freight-related issues. The cost to move a ton of freight one mile has dropped dramatically. When the cost of moving goods goes down, it's less important where the freight nodes are located. As a result, the economic fate of Boston is no longer tied to being a freight hub.

Yet other facts prove that freight still plays a key role in the US economy:

- The value of freight shipments was $14.9 billion in 2006 and $16.7 in 2008
- The value of freight shipments is expected to rise in value by 3.1 to 3.5 percent a year
- There were about than 200,000 transportation and warehousing establishments in 2002
- These establishments employed more than 3 million people
- Total payroll was over $115 billion

Is Public Policy Aligned with Freight Interests?

In terms of lobbying, freight interests do lobby. By sector, transportation spent $2.07 billion on lobbying from 1998-2009, compared to the highest spender (Finance, Insurance and Real Estate at $3.9 billion and Health at $3.8 billion). In comparison, Labor was a low spender at $392 million. [Source: OpenSecrets.org] This leads to the question of alignment of freight's use of transportation modes versus government spending on different modes. Looking at a pie chart of which modes freight uses, we see:

- Trucks: 65%
- Intermodal: 14%
- Pipeline and unknown: 10%
- Air, air & truck: 7%
- Rail: 3%
- Water: 1%

In comparison, the amount spent by private and public sources on transportation ($106 billion in 2004) was apportioned into the following infrastructure segments:

- Highways: 63%
- Mass Transit: 15%

- Aviation: 14%
- Freight/Railroads: 6%
- Water Transportation: 2%
- Passenger Railroads: 1%

Allocation of Government Spending by Mode

But the real test is the allocation of public spending to modes and how that compares to freight activity by mode. States spend more money than the federal government does on all modes (highways, mass transit, aviation, water transportation) except on freight railroads (which are all private spending) and passenger railroads, which is all federal (Amtrak). In general, the share of public spending on freight by mode aligns with the share of freight traveling by that mode, with some exceptions. For example, the share of freight (by value) traveling on trucks is 65% and the share of public spending on highways is 68%. The ratio for rail is 3% with zero public spending; water is 1% with 2% public spending; air and air/truck is 7% with 13% public spending; pipeline and unknown is 10% with zero public spending. Public spending on transit is 16% (which of course carries no freight). Thus, there is some variance but not large disparities in spending being allocated to the most-used freight modes.

Transportation Politics 101

Debates about how public spending will be allocated focus on four interrelated questions:

- how much will be spent
- who will pay for it
- what will it be spent on
- where will it be spent

People want to know how much benefit will go to their state or district or how much their department will get from it. In the case of transportation, much of the money comes from the gas tax, which is paid by the public and truckers.

Transportation Politics 102

The deeper issues in the current debate require an understanding of the nature and importance of coalitions, government structures, funding mechanisms and regulatory politics. First, coalitions arise not because people all agree, but because if they work together they will get more things accomplished. In freight politics, weaker interests can block legislation but they can't push any legislation through without help. Thus, powerful interests go to weaker interests to stop them from blocking, and weaker ones join stronger ones to get something that they want in return. In transportation, there's always a fight between mass transit interests and highway interests. Mass transit is important to a concentrated set of politically powerful cities. Even though transit only moves 2% of the population, it gets 20% of the funding.

Second, government structures evaluate issues based on what is in it for their geographies, which increases the focus on locally-targeted projects. That makes

freight, which by definition spans geographies, weaker politically than highly-local, city-focused transportation projects. Third, funding mechanisms -- such as dedicated user fees and taxes -- generally change the political dynamics. Finally, regulatory politics may have a different structure and issues. Consider the Big Dig in Boston, which was funded by the 1987 Surface Transportation Act but vetoed by President Reagan as pork. It was tied to a jobs bill on regulation of billboards and speed limits on highways. Because of the speed limit issue, the state of Nevada voted with a coalition to override the veto.

Freight Politics in the 21st Century

Freight will have continued economic significance in the new century, and we need to ensure that freight interests aren't ignored. Freight will, however, have a weaker connection to local economies, which weakens political clout. Conflicts with other uses and values, such as waterfront developments, may also weaken the political clout of freight interests. Finally, less visible regulatory policy makers may be more sensitive to freight issues.

In summary, freight is clearly important, but its influence on policy is less than its impact on the economy.

Transporting Bits and Atoms - Professor Neil Gershenfeld, MIT Center for Atoms and Bits

Prof. Neil Gershenfeld from the Center for Bits and Atoms (CBA) discussed the future of fabrication and the changing relationship between the world of physical goods and information. Research at CBA spans chemistry, biology, engineering, computer science, math, design, and many other disciplines. In many ways, the goal of CBA is to create a device similar to Star Trek's replicator that can be commanded to make any product at any time for anyone. Prof. Gershenfeld suggested that CBA is already one-third of the way to a replicator and that people can be inventing the future now, rather than waiting 20 years for it.

Goal: Generalize to All Scales

One of CBA's goals is to learn how to design and build anything of any size. That is, CBA would like to be able to design some object or functionality and then implement it in any scale. The problem is that it currently takes a lifetime to learn to use all the different tools. CBA is trying to change that. The work at CBA spans many orders of magnitude in scale, and Prof. Gershenfeld described three specific examples that span a range of scales.

Macroscopic Digital Fabrication

The macroscopic scale contains the familiar world of mechanical components, factory machine tools, and electronic circuit boards. Much of the work at CBA concerns a pivotal shift in macroscopic manufacturing technologies embodied in what CBA calls a FabLab. A FabLab is a collection of versatile computer-controlled tools that enable almost anyone to make almost anything. The goal is to both increase the capabilities of the tools and to broaden their use.

Microscopic Digital Fabrication

A range of technologies, such as those used in semiconductor chip-making, enable manufacturing on a microscopic scale. One crucial example of these devices is microfluidic systems. Etching tiny channels, pipes, chambers, etc. provides a small-scale environment for doing chemistry and chemical synthesis. One can even make microfluidic computer circuits in which bubbles in the pipes take the place of the information bits in a wire and specialized channel features automatically perform computer-logical operations with the bubbles.

Nanoscopic Digital Fabrication

Biology has already solved the problem of manufacturing shapes at the molecular level. Ribosomes are the tiny nanofactories that cells use to fabricate physical proteins and enzymes from information that is encoded in DNA and transcribed into RNA. Prof. Gershenfeld outlined DARPA research on growing engineered materials. He described the workflow for designing a wrench that living cells could mass produce. The work starts with computational models that let one design a shape, convert that shape into an amino acid sequence, and then convert the amino acid sequence into a DNA sequence. Then one can confirm the quality of the work by simulating the folding of the DNA-encoded amino acid sequence back into the original goal design. Finally, one can upload the DNA into a bacteria, plant or animal that will mass-produce copies of the design.

Goal: Embedded Computation in Objects and Materials

CBA is blurring the line between atoms and bits by trying to merge "it" with "bit." The result brings the advantage of digital systems to the normally analog world of atoms. The effort also radically increases the features and flexibility of physical systems.

The Digital Advantage

CBA seeks to make physical devices be digital in the same the way that communications were made digital. Digital communications can be readily copied and transmitted without error. Whereas analog systems degrade over time, and noise steadily accumulates in the signal, digital systems can be robust to noise. Digital fabrication and digital objects could be more robust than their analog ancestors.

Microfabs

Prof. Gershenfeld provided an in-depth look at FabLabs, which are a network of small labs that let virtually anyone build virtually anything. The core of the FabLab is a set of computer-controlled fabrication tools for extremely high versatility. These tools include various computer-controlled machines such as a laser cutter, large milling machine, small precision milling machine, and a sign cutter. The combination lets people easily make a wide range of 2-D and 3-D parts in a wide range of materials including plastic, wood, metal, and even food. The FabLab also includes a programming toolkit for creating software for small RISC processor boards so that people's projects can respond to commands over a network, read sensor values, gather data, and control motors, valves, etc. Only a few years ago, these tools cost

more than $100,000. Now a complete lab setup is half that price, and the prices continue to fall.

A Global Network of FabLabs

Although one FabLab is good, the key to changing the world is to get FabLabs located around the world. Thus, MIT and others have encouraged the deployment of local FabLabs worldwide. There are now more than 40 FabLabs located in countries such as Afghanistan, Iceland, Kenya, Ghana, Russia, and India. These labs not only provide an opportunity for more people to learn about the technology, but they also allow people to create low-cost solutions to suit local needs.

For example, the FabLab in Jalalabad, Afghanistan helps solve the city's telecommunications problems. Like many Third-World and war-torn areas, Jalalabad suffers from degraded infrastructure. The local FabLab designed a point-to-point wireless networking system called FabFi. They used the FabLab to build low-cost, high-gain antennas that would extend the range of simple WiFi routers over multiple miles in urban Jalalabad. Rather than import expensive telecommunications equipment from distant Western technology firms, the Afghanis could design, build, install, and maintain their own equipment at lower overall cost.

Other FabLabs have designed other low-cost products that can be replicated by a FabLab. For example, one lab created a disposable thermometer for healthcare applications. The device uses microfluidic design principles and only costs 1 cent. Another FabLab developed an Internet terminal that costs only $10.

Parallels in History

The development of low-cost tools such as those used in the FabLabs parallels the development of computers. As computers declined in cost, they transitioned from the mainframe, minicomputer, and PC eras. Each drop in cost led to an increase in adoption and an increase in the range of applications. And when computers became cheap enough for the home hobbyist, then applications and usage exploded and a massive new array of businesses was born. Inexpensive technology enables entrepreneurship by lowering the cost barriers to finding new applications and new businesses based on the technology.

Open-Source Model Leads to Viral Adoption

FabLab has an open-source mentality. People share ideas, problems, and solutions. People can see the interesting things that others can do with a FabLab and create their own new variants and new ideas. The result is a growing portfolio of ideas, solutions, and designs. Rather than re-invent the wheel, someone can download the design for a wheel off the network, add or remove features, and contribute their modified design to others. A national network of FabLabs could do for the US what Andrew Carnegie's network of public lending libraries did at the turn of the 20th century.

The result is a viral adoption model in which the more people that hear about FabLab, the more FabLabs get created. And the more people that can use the equipment, the more applications people will discover, design and create for the

technology. And the more applications for a technology, the more valuable that technology becomes. And the more FabLabs that get created around the world, the more people hear about FabLab. Prof. Gershenfeld suggested that low-cost FabLab could become a lightweight alternative to big costly National Labs in unlocking a new wave of creativity and discovery.

Implications for Economies and Freight

Example: Scream Body

Prof. Gershenfeld founded a course, "How to Make Almost Anything," with a twofold purpose: a) to teach students how to use these new fabrication technologies and b) to learn how people might use FabLab-style technologies. The star pupil of the first class, Kelly Dobson, illustrates what is possible. This non-engineering student designed and made a plush bag with shoulder straps that's worn on the chest like a backpack switched to the front. When the wearer becomes mad, frustrated, or just wants to blow off some steam, she (or he) can scream into the bag and be as loud and foul-mouthed as they want. The bag's circuitry both muffles the scream so no one else can hear it and also records the scream. Later, the wearer can replay the scream out loud. Needless to say, it's a very idiosyncratic product. No one expects the Scream Body to dominate the shelves of Wal-Mart as the holiday's hottest product. Instead, the product illustrates how one non-technical individual can make one highly-individualized product that would have, in the recent past, required a team of engineers with a fat R&D budget.

Mass Production Still Has a Role

The technologies being developed by CBA and the FabLab network don't replace mass production. If a large number of people all want the same product with the same features, then traditional mass production may be more efficient. And some specialized manufacturing processes and products might well remain in the domain of mass production. But if some people want something special with added features, then a local FabLab-style lot-size-of-one may be better. Or, if some people want a simple, stripped-down version of a product, then local FabLab-style lot-size-of-one may be better. Moreover, the expanding database of FabLab designs could easily provide the seeds for mass-produced products.

Reprogrammable Matter Means Less Reverse Logistics

The concept of programmable matter also implies that matter might be reprogrammed. Instead of discarding obsolete or damaged end-of-life objects, people would reprogram the material for other uses, reprogram it to self-degrade or feed the object back into the fabricator. The result is a reduced waste stream and less reverse logistics.

From Finished Goods to Finished Ideas and From Global Production to Local Production

The FabLab concept radically changes the flow of freight in two important ways. First, it replaces the flow of finished goods with a flow of information to microfabricators. Second, production of finished goods shifts from global to local. That is, the end-consumer or a local FabLab sources the design globally and downloads it over the Internet.

But FabLabs don't mean an end of freight. Instead of delivering finished goods, one delivers the raw commodity materials and components used by the FabLab for local or even home-based production. The materials include plastics, sheet materials, small RISC processors, MOSFETs, sensors, buttons, motors, etc. The point is that a relatively small number of high-tech consumable SKUs replace a virtually unlimited range of finished-goods SKUs.

From Scarcity to Plenty in a Post-Industrial Digital Fabrication World

In the context of manufacturing, this trend overturns the economics of traditional industrial-era capitalism. The past was a time of scarcity in manufacturing. Only big companies had the capital needed for investing in the means of production. Companies controlled those factories and made products based on mass-produced economies of scale. But if anyone can buy a versatile FabLab-style microfactory for less than the price of car, then the means of production becomes extremely cheap. Any home hobbyist or small business can afford the equipment and make anything. The point is that the technology changes the manufacturing world from one of scarcity into a world of plenty.

The New Age of Sensing - Prof. Sanjay Sarma, MIT Mechanical Engineering

Dr. Sanjay Sarma, Associate Professor of Mechanical Engineering at MIT and cofounder of the Auto-ID Labs at MIT, spoke of the evolution of sensors. Prof. Sarma used the history of RFID tags and other sensor platforms as examples. As Prof. Sarma sees it, the world is changing from very sparse and expensive sensors to a world of mobs of ubiquitous sensors.

Technology Trends: Progression of Sensor Networks

In tracing the history of RFID, Prof. Sarma sees a common pattern in the progression of technologies. This pattern plays out in a 3-dimensional space composed of features, cost, and ubiquity.

Heavy

In the beginning, RFID chips were expensive and heavy. To justify their high cost, the chips needed to have a lot of functionality. High cost also meant low production volumes. This meant that one RFID tag design needed to serve many applications, which also meant lots of functionality. On a 3D cube -- with axes Features, Inexpensiveness, Ubiquity – early RFID occupied the high-features, high-cost, and low-ubiquity corner of 3D cube.

The world of sensors sees a similar pattern. Early sensors tend to be expensive and heavy. The cost motivates designers toward very rugged, long-lasting systems, but that further increases cost and mass. Such early-generation sensors are manufactured in very low volumes with stringent performance specs. These do-everything sensors and systems cost tens to hundreds of thousands of dollars. Only the military, government, and large corporations can afford these heavy sensors. Even then, they buy very few of them. Thus, early-generation sensors also tend to occupy the high-features, low-inexpensiveness, and low-ubiquity corner of the 3-D cube.

Medium

Over time, some people realize that certain applications only need a subset of features. Engineers design somewhat simpler, lower-performance versions that provide lower cost and expand the market for the technology. This creates a trend toward medium-performance, medium- inexpensiveness sensors that find increasing applications. This trend begins the movement of the technology out of the high-features, low-inexpensiveness, and low-ubiquity corner of the 3-D cube.

Mob

In the ultimate end-point of technology development, the sensors become so inexpensive that they become ubiquitous. That is, people can afford to deploy a mob of sensors. Each sensor may have limited functionality, limited performance, and limited life, but the ability to deploy hundreds or thousands of sensors compensates for the weakness of each sensor. Rather than insist on high reliability from a limited number of sensors, a mob of sensors can provide robust coverage even if some sensors fail.

In the RFID world, tags became simpler and simpler until the simplest only contain the minimum number of bits to uniquely identify the tag. All of the data that would have been stored in tags of yore are now stored in the network. This trend, which can be seen in the sensor world as well, is that as the sensor becomes cheaper, smaller, and dumber, the intelligence and functionality moves into the network.

The evolution of sensing is leading to mobile sensing. Lightweight sensors are just around the corner. Some organizations are using lightweight sensors for monitoring the temperature of food in transport, such as ice cream. One possible low-cost version of this could be simply two RFID tags stuck together with one of them having an antenna that melts if the temperature rises above freezing. If the tag is put on ice cream, it is easy to tell if the ice cream melted. Similar two-tag sensor designs could be used to detect moisture, physical shock, and even pests such as termites.

From Government to Corporate to Consumer Networks

Whereas early expensive sensors were the purview of the military, civilian government (e.g., weather satellites and oceanographic buoys) and high-end commercial applications, cheap sensors move into the realm of consumer devices. For example, iPhones and many smartphones contain a microphone, camera, accelerometer, and GPS and that enables them to sense sound, light, motion, and location.

Technology Trends: From Wired to Wireless

Another major technology trend concerns the connectivity of sensors. Decision-makers must somehow get the data from the sensor so that they can processes the data and act upon it. Over time, these connection technologies have changed to reduce the costs of connections, increase the flexibility of connections, and support increasing numbers of connections.

Wired Circuits

In the past, sensors were physically wired to data collection and information management systems. Wires suffer from three disadvantages. First, wire is expensive to install and run, especially over longer distances. Second, wires are prone to damage from errant backhoes and falling trees. Third, wires generally require forethought on placement and incur additional high costs if they have to be moved. Prof. Sarma gave the example of controlling the lights in a room. With current technology, the light switch (which is a type of sensor that detects whether people want the light on or off) is physically wired to the light. Moving the lights or the switch requires significant expense in rewiring.

IP and Early Wireless

The next step in connection technology uses wired IP or wireless technologies in which sensors and other devices communicate to some type of home-base or central receiver. This technology eliminates the costs of routing long wires from point to point and makes it much easier to relocate systems. In wired IP networks, a simple reprogramming allows any switch to control any light without rewiring. People can easily modify wireless networks, as long as the sensors, controls, and devices remain in range of the home-base receiver. That central wireless receiver then becomes a limiting factor in the design, because each device must have enough power to provide the range to reach that receiver. The central receiver may also pose a reliability problem -- if the control center has a fault, then the entire system stops working.

Mesh Wireless

The latest in wireless technology, such as Zigbee, uses mesh networks in which each sensor or device in an area talks to its neighbors, and each neighbor steadily routes the data from neighbor to neighbor until it reaches the destination. Mesh networks have two major advantages. First, each device can have much lower power because it only needs to talk to other nearby devices (i.e., a range of dozens of feet rather than hundreds of feet). Second, the network is incredibly robust to damage. A temperature sensor can route data directly to a refrigeration unit or alarm without going through any central controller.

Wireless technologies continue to diminish in size and grow in ubiquity. Prof. Sarma asked if anyone was aware of the smallest cell phone in common use. The answer: the tiny circuit inside the Amazon's Kindle that lets Kindle users download books at anytime.

Example Sensor Networks

Prof. Sarma presented several examples of the evolution of sensors from heavy-sparse networks to mob-style networks.

Traffic Monitoring

The heavy-sensor version of traffic monitoring uses rugged traffic cameras and in-road loops to measure traffic flow and velocity at key locations. These sensors connect to Operations Centers via dedicated communications networks linking

traffic monitoring to the operations centers. But these sensor networks are costly and can't cover every road, intersection, or even every stretch of highway.

But, now, a mob of sensors does cover every road, intersection, and highway – it is the "mob" of cell phones that drivers carry. Cell phone-derived data potentially includes the motions of each phone from cell-tower to cell-tower, GPS data, and accelerometer data. Such data can detect velocity, stopped traffic, and even rapid braking. Moreover, cell phone-derived traffic data can be used to redirect traffic: people and freight can flow more smoothly through rapidly-changing traffic patterns by receiving updated route recommendations via their cell phone.

German Haus

In the past, energy consumption wasn't measured with fine granularity -- a single high-cost meter provided only monthly data on energy consumed for an entire facility. But low-cost sensors and connection technology now support much finer-grained, real-time monitoring of power consumption.

German Haus is freshman undergraduate dormitory that was instrumented with power strips that measured students' electricity consumption in every room. The goal was to monitor the levels of power use and transmit the data to a web server over Zigbee. By viewing the power loads, experimenters could be see whether some students left the lights on all the time, for example.

Implications

The move from heavy sensors to mob sensors provides significant opportunities for new applications and better decision-making.

Creating Behavior Change

The traffic and power-strip examples raise the issue of behavior in future freight flow scenarios. Just because we have the capability to measure resource use doesn't imply that we have control over that use. Will people listen to the data and will they change their behavior?

The key issue is one of behavior change. Prof. Sarma cited the work of Dan Ariely and his recent book, *Predictably Irrational*. He summarized Ariely's point, which is that the right messaging is required to change human behavior. For example, a study by Arizona State Professor Robert Cialdini explored how to get occupants of a hotel room to agree to re-use their towels rather than getting new towels each day of their stay. Cialdini used four slightly-different messages and tabulated the change in response. The first sign used the traditional motivation of "do it for the environment." The second sign asked guests to be the hotel's partner in this cause. (This sign had 12% less compliance the than environmental sign did.) The third sign stated that the majority of guests in the hotel reused towels at least once during their stay. (This message was 18% more effective than the traditional environmental one.) Finally, the fourth variation said that the 85% of guests "in this room" had reused their towels. This message produced a 33% increase in compliance over the traditional message.

Democratizing Sensors and Information

When sensors are inexpensive, consumers and start-up entrepreneurs can easily afford them. This leads to wide range of personal, commercial, and public applications. Cheap sensors can help solve modern problems such as detecting automotive reliability problems such as Toyota's stuck accelerators, detecting mass movements of people such as stampedes, and mapping emissions from vehicles. The declining costs of sensors threaten specialized companies. For example, smartphones with embedded GPS (such as Google's Android) threaten specialized navigation device makers such as TomTom and Garmin.

Behind many of today's top stories is a growing role of cell phone video and cell phone networks. These range from the Iranian political demonstrations to the Chilean earthquake. The growing mobs of interconnected sensors of all types give more people more data for more applications.

Wired for Innovation: How IT is Reshaping the Economy - Prof. Erik Brynjolfsson, MIT Sloan

Prof. Erik Brynjolfsson is the Schussel Family Professor at the MIT Sloan School of Management, the Director of the MIT Center for Digital Business, and Research Associate at the National Bureau of Economic Research. An economist by training, Prof. Brynjolfsson presented research on the impact of information technology on productivity. In particular, his work found that companies must invest in much more that just hardware and software to gain the benefits of technology. In fact, investments in complementary organizational capital may need to be four to ten times higher than investments in technology in order to gain the full benefits of technology. Prof. Brynjolfsson's presentation summarized some of the ideas from his recent book, *Wired for Innovation*, which was included in the participants' conference materials.

Does IT Catalyze Productivity?

Prof. Brynjolfsson's research was driven by a productivity paradox. In the early decades of the computer revolution, economists couldn't find evidence they expected to find: that information technology was actually making companies more productive. Although it was easy to see why computers should help companies perform much better, the actual evidence didn't show that IT was helping much. Then, after 1995, the data started to show increasing evidence that IT was actually helping. Prof. Brynjolfsson's work looked at explaining this change and why some companies benefit from IT and others do not.

IT Investment Does Help, But It's Not the Whole Story

One analysis looked at the relative productivity of companies as a function of relative levels of IT investments. That is, were companies more productive than their peers if they invested in more IT than their peers? The answer was a modest yes, but there was a lot of scatter in the data -- some companies invested a lot but got little.

Leader vs. Laggards

All industries have leaders and laggards -- the top 25% of firms enjoy higher profit margins than do the bottom 25% of firms. But how has this spread varied in time and among firms that use or don't use IT? Among companies that don't use much IT, the spread between the most profitable and least profitable firms has remained relatively constant for decades. But the picture for companies that intensively use IT (not just those that make IT) is quite different. In recent years since 1995, the gap is up 45% -- the leading firms have profit margins that are 50 points higher than lagging firms. This means that some companies are using IT effectiveness to out-compete and out-profit others.

Complements: The Other 90% of the IT Investment Story

Next, Prof. Brynjolfsson looked at why some companies enjoyed more productivity bang for their IT buck. He analyzed 1167 companies' financial statements and surveyed those companies to understand their practices and other investments. The result uncovered an interlocking set of investments and practices that create coherent performance from computerization.

Organizational Capital Investment

The first finding was that IT investments are only the tip of the iceberg in converting technology into productivity. Companies that gain the most from IT investments complement IT with very substantive investments in what Prof. Brynjolfsson calls *organizational capital*. That is, the leading firms invest heavily in people and processes, not just in computer hardware and software. In fact, for each $1 spent on IT, high-performing companies spend another $9 on these complements. Unfortunately, these complementary investments are not well measured by traditional accounting standards and economics. People may be a company's most important asset, but they appear nowhere on the company's balance sheets.

The Invisible Assets on an Empty Factory Floor

An anecdote serves to illustrate the power of these unmeasured complements. When Prof. Brynjolfsson visited Dell's Round Rock computer factory, he noticed that the factory was half empty. That seemed inefficient. His host explained that Dell had recently redesigned its manufacturing operations to reduce work-in-process, accelerate cycle times, and employ much more aggressive just-in-time practices with a 4-hour delivery lead-time. The result was the factory now churned out 30% more computers using 40% less floor space. Six months later, Dell had filled the factory and was producing twice as many computers as before the reorganization.

Another company, if faced with a potential doubling of production, would have bought another factory. Dell invested in reorganization instead. In essence, Dell got a free factory out of its investments in better processes. Working smarter meant that Dell could produce more without more factory space. That reorganization represented a very valuable asset that is equivalent to having another factory. And yet current-day accounting and economics does not recognize the tremendous value. This illustrates not only the value of investing in organizational capital but also how two companies might have similar levels of assets on their balance sheets

(i.e., the same level of investment in physical plants, IT, etc.) and yet one company produces much more than the other.

Seven Practices of Digital Organizations

Overall, Prof. Brynjolfsson found seven key practices to what he calls digital organizations. Companies that invested in IT *and* used most of these seven practices had superior performance relative to companies that only invested in IT, that only used these practices, or that neither invested in IT nor used these practices. These practices complement IT investments in the sense that, together, they lead to significantly higher productivity and profits than they would if adopted individually. The seven practices are:

- Move from analog to digital processes
- Open information access
- Empower employees
- Use performance-based incentives
- Invest in corporate culture
- Recruit the right people
- Invest in human capital

Coherence is Key: Partial Adoption Is Worse than No Adoption

These seven practices also complement each other. The audience noticed an interesting dip in the plot of company performance as a function of IT investment and the adoption of digital organization practices. Companies that adopted some -- but not many -- of the digital organization practices did worse than those than companies who didn't adopt any digital organization practices. This dip speaks to the crucial role of complementarities -- some practices really need other practices to work well. This dip also illustrates the curse of best practices: just because some practice works really well in one leading organization doesn't mean it will work well in another company if the adopting organization doesn't copy all of the complementary practices of that leading organization.

Productivity Isn't Everything, but Almost

Productivity is the Future

Productivity defines future growth and future affluence. Over the long-term, productivity accumulates to make massive differences in economic activity and standards of living. A 1% rate productivity growth for 70 years means a doubling of the standard of living. In contrast, 4% productivity growth for 70 years means 16 times higher standard of living. A 16-times increase takes a $2,500/year Third-World worker to a $40,000/year Western life style and takes a $40,000/year Western worker to $320,000 per year life of opulence. Concerns about how society might pay for healthcare disappear in the face of such long-term improvements in total earning power.

Total Factor Productivity: Measuring True Improvement

Prof. Brynjolfsson focuses on total factor productivity to control for all the tricks that might make productivity look higher than it really is. Productivity is defined by the total amount of all inputs needed to make some output. Questions from the audience led to a clarification of what doesn't count as a true productivity improvement. For example, productivity doesn't mean just working longer hours; longer hours mean more inputs. And finding cheap labor doesn't count because someone is still putting in the hours to make the product. Outsourcing doesn't always improve productivity -- substituting external purchased services for internal labor simply shifts the labor from the company to the contract manufacturer or service provider. Outsourcing only improves productivity if the service provider really does have better processes and methods that result in less labor and money to create the same or greater outputs. The point is that true productivity means working smarter, not just worker more, working for less, or having someone else do the work.

Productivity: More and Less Freight

Productivity improvements lead to both more and less freight for two reasons. First, productivity means doing more with less, which generally means more finished goods coming out per unit of raw material coming in. It also means a rising standard of living, which generally means more consumption and more freight. Productivity increases affluence, which enables consumers to buy more finished goods.

The Great Restructuring, not the Great Recession

The trends behind these studies go far beyond just economic effects; they also affect the futures of workers and companies. The past couple of years haven't been too good for the economy as unemployment has risen sharply. Worse, six million people have been out of work for more than six months. Many of these six million people represent jobs that are gone and won't come back due to changing patterns of economic activity. For those reasons, Prof. Brynjolfsson said the Great Recession will ultimately become known as the Great Restructuring.

Measuring and Managing Sustainability - Prof. Jonathan Johnson, The Sustainability Consortium

Jonathan Johnson, Professor of Management at the Sam M. Walton College of Business, University of Arkansas, led the establishment of the Sustainability Consortium in July 2009. The Sustainability Consortium seeks practical solutions for improving the sustainability of corporate business practices. Consortium members include Wal-Mart, Best Buy, Safeway, Dell, Clorox, Colgate, Disney, General Mills, Pepsi, P&G and Monsanto. Prof. Johnson is seeking some transportation companies to be members as well.

The Sustainability Consortium and Responsible Reporting

Managing the New Anthropocene Epoch

The Consortium represents a cross-industry effort to have sustainability reporting and to get people to think long-term about how to drive sustainability reporting. A

primary driver for the Consortium is the evolution of earth history from the Holocene to Anthropocene epochs, namely the shift to an air, land, and sea environment dominated by a large human population and human activities. As the population increases and the levels of affluence increase around the world, we will see increased consumption that will stress ecosystems even more. The Consortium seeks to mitigate those impacts.

Multi-Metric Lifecycle Analysis

Prof. Johnson advocated a multidimensional, full lifecycle approach to sustainability. For example, incandescent lights have a smaller footprint at the store shelf when compared to CFLs but when one adds in the entire life, including the consumer's energy footprint in using the light, then CFLs beat incandescent. Some counter that CFLs represent a serious risk from toxic mercury during disposal, but mercury emissions from the coal fired electricity plants that make incandescent lamps are a more serious source of mercury. The point is that one needs to understand the entire lifecycle and all dimensions.

Avoiding Uni-dimensional Mandates

Prof. Johnson cautioned against simplistic approaches to sustainability, because they miss real opportunities to improve sustainable and can stifle innovation. For example many now advocate an "eat local" ethos on the basis that it reduces the footprint of transportation. But transportation may be a small fraction of the total footprint. An analysis of the CO2 emissions from US milk production found that only one-quarter (27%) of the footprint comes from transportation. Even if the cow were in the consumer's backyard, milk would still have a significant footprint. In fact, other factors such as inefficient production could make local milk less sustainable than milk transported from more efficient producers.

Multiple Interlocking Natural Cycles

The need for responsible metrics and reporting is due to the interrelated nature of nature. That is, we can't look just at the carbon footprint impacts without also considering water and the nitrogen cycle. The different dimensions are all interrelated, and we can't make decisions on just one dimension. We need rigorous information to drive innovations at every point -- not just in manufacturing but in consumer behavior as well. The information has to be at a sufficiently good level of granularity so that all decision-makers -- both consumers and buyers -- can make informed decisions.

Social Dimensions

The Consortium's sustainability reporting metrics include an explicit social component. In contrast to the environmental movements of the past, modern sustainability takes a balanced approach to look not just at resource depletion in the environment but also the social and environmental aspects like human rights and safety. The quantification of social metrics is currently at an earlier stage compared to environmental impact metrics.

Guiding Principles

Science-Based and Outcome-Focused

The Consortium wants to combat a tower of ecobabble -- some 350 different possible green labels -- with solid information and consistent methods for assessing sustainability. The competing green labels, some of which are blatant frauds, contributed to distrust of certifications and labels. Objective and transparent analysis methods that are based in science rather than ideology will help companies, consumers, and policy makers understand the true impact of their choices and will motivate more sustainable decisions.

To accomplish its aim, the Consortium borrows technologies from the virtual world of the Internet. The technology of ontology mapping enables developers of online worlds to define the components and properties of an object such as a chair. That same approach lets one map the components of real-world objects and aggregate lifecycle sustainability properties to understand the net impacts of real world objects.

Understand the Uncertainty

The Consortium also wants to avoid an artificial sense of certainty in sustainability assessment. Adding another digit after the decimal point to a rating doesn't necessarily imply the rating is more accurate. Acknowledging and tracking what we don't know about the sustainability of products and processes will help guide improvements in methods and data-gathering.

Use Information to Drive Innovation and Adoption

Although the tools are still in their infancy, Prof. Johnson advocates a much greater use of information technology to guide decision-making. Without a clear understanding of why a product has the sustainability rating that it does, managers can have no basis for improving the product's sustainability. That is, the rating by itself isn't very useful because managers need to understand the basis and components of the rating if they are to make changes to improve the rating. These tools are in development. For example, SAP announced the forthcoming release of a sustainability performance management module. Prof. Johnson noted that open-source teams are creating low-cost tools, too.

To be adopted by businesses, a sustainability methodology must provide value without excessive costs or risks. The four business imperatives for a good assessment include:

- integrated and interpretable decision tools
- credible, transparent metrics
- cost-effective reporting
- intellectual property protection (e.g., for proprietary formulas and methods)

Tools might also extend to the consumer. For example, GoodGuide is an iPhone app that lets consumers scan the bar code of a product, such as Cheerios. The service provides an overall product rating that combines some 15 dimensions related to health, environment, and society.

Benefits of Good Environmental Practices

Measuring and managing sustainability will bring benefits beyond the environment and social benefits. Prof. Michael Porter of the Harvard Business School examined the potential innovation benefits of companies who were leaders in environmental management in the mid 1990s. He looked at the country level: countries that regulated environmental externalities more strictly received innovation benefits. For example, regulating tailpipe emissions not only reduced the emissions but also enabled a host of other innovations.

Driving Adoption

The Sustainability Consortium is only eight months old as of March 2010, but symposium participants asked what will drive adoption of the reporting metrics. A range of forces will contribute to the growing adoption of sustainability.

Consumer Demand

Currently, consumers say they care about the environment, but they are not making those decisions at the transaction level. Some demographics will pay more for sustainable products, but due to greenwashing practices there's also a distrust in the claims. Consumers don't have enough information to make a sound decision. Young mothers and millennials have shown a willingness to pay a premium for sustainable products, and all Whole Foods shoppers pay a premium, but most consumers are not making those decisions.

Sensible -- Not Premature -- Government Standards

Another participant asked about the role of government in mandating sustainability metrics. For example, France is mandating environmental labeling starting in 2011. The question remains, however, how to meaningfully measure the carbon footprint in a consistent way. And, it is important to look at the whole lifecycle and across dimensions. For example, the local-food movement reduces "food miles" of trucking, but misses the bigger costs, such as trying to grow lettuce in Arizona. We have to look at the bigger picture of total environmental cost.

Retailer and Producer Sensitivity

Retailers are becoming more interested in labeling. Retailers see labeling as an important new competitive space. And, their customers are expecting some level of prescreening before a product makes it onto store shelves. No one wants to discover that their store carries a product with 12% child labor. It is a portfolio of drivers among industry, consumers and perhaps government that will make this happen.

Attendee Comments and Discussions

At the end of day one, Dr. Caplice asked the audience to share their key takeaways from the presentations. He then asked people if they were certain about any particular future events on a 10-year timeframe and then a 20-year timeframe. Below are the participants' responses.

Participants' Key Takeaways

Technology

- We're on the verge of the next industrial revolution. The Star-Trek-like replicator (i.e., the personal fab) Prof. Gershenfeld mentioned is disruptive technology squared.
- Technology continues to be a driver across any topic -- analytics, sensing, computing, microelectronics. Computing power drives it all.
- Integrate technology with business processes to get productivity gains. (Don't just automate bad processes.) Evaluate carriers and help them get better.
- There's a digital gap between the creation of new technology and the adoption of it by organizations. For example, we have remote sensing technologies but truck drivers fill out paper logs.

Big Economic Changes

- Demographics are changing.
- The price and availability of commodities: there is volatility in prices, but the spikes up can't be passed along to consumers.
- Geopolitical insight into China and India and the global economic shift: There'll be a change in the wealth patterns if China's population becomes wealthy. (Americans may have "a great future behind us.")
- Will the current great recession affect future generations? The Great Depression affected a whole generation. Will we see changes in buying and saving patterns from those scarred by the current downturn?

Role of Government

- Government interest in infrastructure: what the government can/should do: the government has a role to play.
- There's a gap between government and business in managing disruptive technology. There are biologic products that the government doesn't understand.
- Sustainability and environmental concerns will be more important and will be driven by both consumers and government.

Changing Supply Chains

- Seeing more customization/personalization and a lot size of one.
- Freight/supply chain matters can make a significant difference in performance, sustainability, cost, etc.
- Safety and freight: using new technology to create a safer environment.

How to Learn About the Future

- The difference between individual insights and research-based insights.
- "Me guessing what is important to someone else is not as powerful as seeing what is important to them, watching them do it." (In reference to seeing the products which people have built using personal fabs.)

Participants' 10-Year, High-Confidence Predictions

Changing Citizenry and Consumers

- The numbers of older people will be increasing: aging demographics.
- Healthcare delivery will change: receiving more care through the home.
- The customer rules, and customization has good implications for reducing inventory. When we try to guess what the customer wants, we get it right 40% of the time. But with customization, we can get it right 100% of the time. There will be a better focus on customers, which will bring increased efficiency.
- What are the chances of a welfare state, if 50% of the population pays no taxes and 20% of the population pays 80% of the taxes?

Overall Increase in Freight

- Equation: Population x Affluence = Greater Freight. This increase will bring a lot of implications (especially environmental impact) which may bring the shift to intermodal.
- Globalization will continue: trade barriers won't go up, and there will be more global freight. On the downside, the US will have network failures due to congestion.

Supply Chains in 10 Years

- Trucks will still move the majority of the freight because that mode is more time-definite than intermodal.
- We will not see an improvement in miles per gallon (MPG) in trucks. No significant breakthroughs appear to be on the horizon.
- We want to see a more efficient transportation system and we're spending a reasonable amount of money (based on David Luberoff's chart) but it's not clear how we can best influence the process to get that efficiency. Where should investment go? How do we go about the investment process as a group, to influence a comprehensive plan?
- The carbon footprint of air freight vs. ocean and rail vs. truck, as well as lower costs, will drive an increase toward those more socially-conscious modes.
- New Department of Transportation requirements, such as testing for sleep apnea, combined with aging of truck drivers, will force more intermodal use because of a lack of truck drivers.
- Public-Private Partnerships (PPP) will arrive given the reality of transportation funding. The partnerships could be a way for the private sector to get what they want and increase highway capacity.

Paradox of Better Decisions and More Uncertainty

- Disruptive technology will come faster, but almost certainly our predictions about what that technology is will be wrong. "Something disruptive this way comes."
- A lot of technological capacity depends of social, political and economic factors to be successful, as Prof. Brynolfsson showed. We over-promise the near-term and underestimate the long-term impacts because of the unknown-unknowns. There's a

deep-rooted enthusiasm about disruptive technology, but it's not likely in the 10-year window. (Don't be seduced by the enthusiasm for the IT and sensing technologies we see now because it takes longer for the social pieces to evolve.)

- On-time decision-making will improve. We'll have more real-time data, more sensing, and faster processing, which will help make better decisions.
- The rise of smart sensing is de-skilling and increasing access to what previously required an army of engineers to do (such as route planning for UPS). Now route planning can be done for free on the Internet, Google maps, etc. This is true not only of sensing and data: there is a proliferation of analytics that are becoming easy to use and widely available. (On the other hand, this can also increase information overload.)
- We need transparency and good science around sustainability.

Participants' 20-Year, High-Confidence Predictions

- An increasing focus on the environment.
- A shift in global wealth from developed markets to emerging markets (from west to east).
- Aging of the population.
- Adaptability: people will age, but their ability to keep working will increase, and their health will be better so they won't be idle.
- There will be wars and rumors of wars.

Appendix 3 – Snapshot Scenario Output

Out of the input collected during day one of the symposium, the following "single-shot" drivers were developed. These are meant to be individual critical driving forces that were to be analyzed in isolation. Twelve were selected and two were rejected for use at the symposium.

Aging of the US Population

The majority of the aging US population lives alone in non-urban settings and still has very specific product and service needs shared within their extended social network. Women tend to exhibit a willingness to remain involved in the workforce.

Aging of the US population

Adoption matrix - initial

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%					
60-80%			25%	38%	50%
40-60%		25%	25%	38%	50%
20-40%	25%	13%	25%	25%	
0-20%	75%	63%	25%		

Adoption matrix - final

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%					
60-80%			13%	38%	63%
40-60%		13%	25%	38%	38%
20-40%	25%	38%	38%	25%	
0-20%	75%	50%	25%		

Flow Implications

Sourcing patterns

Minimal impact with some closer or localized sourcing

Flow destination

More frequent, smaller deliveries to more locations

Increased need for quality "last mile" distribution

Routing

Increased use of hubs and complex routing

Increased added value services - white and grey glove

Flow volume

More volume in the last mile

Minimal change on inbound moves

Value density

Much higher value density ratio

Smaller products due to miniaturization

Increase in Global Trade

Global trade has made the majority of the country strongly interdependent. This leads to higher volatility and extreme swings in GDP growth. Protectionism occurs but is only reactionary and is not permanent. The system is generally resilient with fluid trading blocks.

Increase in global trade

Adoption matrix - initial

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%				13%	25%
60-80%	13%	13%	25%	63%	63%
40-60%	25%	50%	75%	25%	13%
20-40%	50%	38%			
0-20%	13%				

Adoption matrix - final

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%				0%	0%
60-80%				38%	50%
40-60%	13%	25%	63%	63%	50%
20-40%	75%	75%	38%		
0-20%	13%				

Flow Implications

Sourcing patterns

More points of entry due to large imports/exports

Flow destination

Minimal impact

Routing

Increased use of transload hubs from ports

Flow volume

Increase especially at ports and natural choke points

Value density

High value density imports

Exports might expand with lower value density ratio

Rising Power of Emerging Markets

The dollar and the Euro have weakened. Emerging markets gained in affluence and purchasing power as well as political stability and financial strength. They are less focused on exporting as a means to grow and thus, importing more.

Rising power of emerging markets

Adoption matrix - initial

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%					
60-80%		13%	13%		25%
40-60%	13%			63%	63%
20-40%		13%	63%	38%	13%
0-20%	88%	75%	25%		

Adoption matrix - final

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%					
60-80%		13%	13%		13%
40-60%	13%			63%	75%
20-40%		13%	63%	38%	13%
0-20%	88%	75%	25%		

Flow Implications

Sourcing patterns
Balance in imports and exports
Increase in domestic sourcing from interior points (midwest)
Flow destination
Dramatic increase in exports -
Ports as primary destinations
Increase in specialized ports
Routing
Increase in entry and exit points will be required
Rise of inland (dry) ports
More freight corridors to handle mix of import/exports
Flow volume
Potentially more air freight volume
Increased overall flow as trade increases
Value density
Value density goes down on exports but remain the same on imports

International Climate Regulation

Climate change proved to be a reality with rising sea levels and higher overall temperature. However, the major disruptions actually stemmed from the higher variability in weather systems leading to more extreme and abrupt manifestations. A sense of urgency shared across developing and developed countries led to the creation of a Global Environment Council redefining business rules and regulations globally in alignment with the WTO.

International climate regulation

Adoption matrix - initial

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%					14%
60-80%					14%
40-60%				57%	57%
20-40%			57%	43%	14%
0-20%	100%	100%	43%		

Adoption matrix - final

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%					14%
60-80%					14%
40-60%				57%	57%
20-40%			57%	43%	14%
0-20%	100%	100%	43%		

Flow Implications

Sourcing patterns
Reduce sourcing options for greener suppliers
Increase in local sourcing (relative to international)
Flow destination
No changes
Routing
Significant impact on complexity of routing
More routing via greener options - intermodal, inland waterways
Flow volume
Limited volume in and out of region (national)
More shipment moves within region
Value density
Impacted to reduce wasted materials and miles

Rise of Protectionism

Following the COP15 debacle and a longer than anticipated recession, countries reacted by raising tariffs and duties to protect their own industries. While the US tried to save the WTO, internal debates between the states led to the US also adopting protectionist measures – sealing the fate of WTO.

Rise of protectionism

Adoption matrix - initial

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%		13%	13%		13%
60-80%	13%		13%	50%	13%
40-60%	13%	38%	25%		
20-40%	75%	38%	38%	38%	38%
0-20%		13%	13%	13%	38%

Adoption matrix - final

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%		13%	13%		
60-80%	13%		13%	38%	13%
40-60%	13%	38%	25%	13%	13%
20-40%	75%	38%	38%	38%	38%
0-20%		13%	13%	13%	38%

Flow Impacts

Sourcing patterns
Reduction in both exports and imports
Revival of domestic sourcing
Flow destination
Significant drop in exports
More bi-national agreements and regional trading blocks
Reduction in US trade with Asia
Routing
More distributed routing with less port movements
Flow volume
Less in and out of region
Increase within region
Value density
Minimal impact

New Technology: Personal Fabrication

Fueled by the innovative high-tech tools, personal fabrication has become a reality. Open-source design and social network platforms empower people with creating the products that best reflect their personal universe and needs. Although more manufacturing will be done locally in the US, automation limits the number of jobs created.

New technology: personal fabrication

Adoption matrix - initial

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%				13%	38%
60-80%			13%		25%
40-60%				38%	13%
20-40%		38%	50%	38%	25%
0-20%	100%	63%	38%	13%	

Adoption matrix - final

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%				13%	38%
60-80%			13%		13%
40-60%				25%	25%
20-40%		38%	50%	50%	25%
0-20%	100%	63%	38%	13%	

Flow Impacts

Sourcing patterns
Increase in raw material sourcing
Increase in local sourcing of components
Flow destination
Local or regional distribution will become more prevalent
Routing
More bulk routing of raw materials
Reduction in amoiuntof last mile delivery
Flow volume
Overall reduction in shipments
Value density
Much lower value density ratio

New Technology: The Senseable Network

Cheap wireless technology enables ubiquitous presence of sensors on products, vehicles and the infrastructure. This allows collection, transmission and analysis of multiple attributes such as temperature, humidity, location, etc.

New technology: the Senseable Network

Adoption matrix - initial

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%				38%	75%
60-80%			38%	25%	25%
40-60%		50%	25%	38%	
20-40%	75%	25%	38%		
0-20%	25%	25%			

Adoption matrix - final

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%				50%	75%
60-80%			50%	38%	25%
40-60%		63%	38%	13%	
20-40%	75%	25%	13%		
0-20%	25%	13%			

Flow Impacts

Sourcing patterns
Greater efficiences can be gained with sensing
No major impacts
Flow destination
Greater efficiencies in deliveries
No major impacts
Routing
Dramatic efficiency improvements
Potential reduction in congestion
Flow volume
No dramatic overall change
Shift to off-peak times
Value density
No impact

Increase in Sustainability Regulations

Several layers of all encompassing regulations at the international, federal and state level are enacted. These regulations cover at varying degrees social responsibility, environmental emissions, resource usage, and trade practices. This results in a patchwork of often conflicting rules and penalties.

Increase in sustainability regulations

Adoption matrix - initial

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%			13%	25%	50%
60-80%		13%	38%	38%	13%
40-60%	25%	38%	25%	38%	25%
20-40%	13%	25%	25%		13%
0-20%	63%	25%			

Adoption matrix - final

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%			13%	25%	50%
60-80%		25%	25%	38%	13%
40-60%	13%	25%	38%	13%	25%
20-40%	25%	38%	38%		13%
0-20%	63%	25%			

Flow Impacts

Sourcing patterns
Increase in local or regional sourcing
Flow destination
Increased intermodal and water modes used
Increased restrictions and costs for urban delivery
Routing
Complex routing to reduce overall environmental footprint
Lower service levels due to consolidation
Flow volume
Reduction in truck and local delivery
Increase in greener modes
Value density
Increase in value density as waste is reduced
Cost of transport increases - driviiiing value increase

Increase in Sustainability Customer Demand

Consumer demand for sustainable products is a reality led by different segments of the population including aging baby-boomers, young mothers, etc. This is further fueled by innovative technology that enables consumers to make real-time decision at the point of purchase.

Increase in sustainability customer demand

Adoption matrix - initial

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%				13%	13%
60-80%			13%		38%
40-60%			13%	50%	25%
20-40%	13%	38%	50%	25%	13%
0-20%	88%	63%	25%	13%	13%

Adoption matrix - final

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%				13%	13%
60-80%			13%		38%
40-60%			13%	38%	25%
20-40%	13%	38%	50%	13%	
0-20%	88%	63%	25%	25%	25%

Flow Impactss

Sourcing patterns
Increase in local and regional sourcing
Flow destination
Consumers demand more local distribution
Increase in last mile delivery
Routing
Increased complexity to reduce green footprint
Flow volume
Reduction in total miles
Value density
Increase in value density ratio as waste is removed

Rise in Global Security Concerns

Due to heightened security concerns, federal regulations now requires 100% scanning and tracking of all flows within and across the country. These procedures require state-of-the-art technology that is both time consuming and costly.

Rise in global security concerns

Adoption matrix - initial

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%					
60-80%					20%
40-60%				20%	
20-40%			40%	20%	60%
0-20%	100%	100%	60%	60%	20%

Adoption matrix - final

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%					
60-80%					
40-60%					13%
20-40%			25%	38%	63%
0-20%	100%	100%	75%	63%	25%

Flow Impacts

Sourcing patterns
Increase regional sourcing
Concentrated port entry and exit points
Increase in NA trading blocks
Flow destination
Minimal impact
Routing
Significant impact as transit takes longer
Flow volume
Reduction in shipments in and out
More intra-regional moves
Value density
No significant change

Rise in Commodity Prices and Availability

Unreliable supply or unpredictable demand has led to dramatic increase in volatility and price of commodities to include oil, metals, grain, etc. Financial markets have further exacerbated the situation and new technologies have failed to solve the issue.

Rise in commodity prices and availability

Adoption matrix - initial

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%					
60-80%		14%	14%	29%	29%
40-60%	43%	29%	43%	29%	43%
20-40%	14%	43%	14%	43%	29%
0-20%	43%	14%	29%		

Adoption matrix - final

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%					
60-80%		14%	29%	29%	29%
40-60%	43%	29%	43%	57%	71%
20-40%	14%	57%	14%	29%	14%
0-20%	57%	14%	29%		

Flow Impacts

Sourcing patterns

Increase in near shoring

Commodity scarcity drives to more remote sourcing

Flow destination

Reduction in local delivery

Routing

More complex to reduce fuel usage

Shift to more efficient modes

Flow volume

Increase on more efficient modes

Value density

Higher value density as efficiency become critical

Additional Points of Entry Open Up

The Panama Canal is completed. The Northwest passage is now open during summer. Manufacturing is no longer concentrated in the Pacific Rim as regions such as Africa have emerged as reliable suppliers for Europe and North America.

Additional points of entry open up

Adoption matrix - initial

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%					14%
60-80%				14%	57%
40-60%				14%	14%
20-40%			57%	71%	14%
0-20%	100%	100%	43%		

Adoption matrix - final

	0-2yr	2-5yr	5-10yr	10-20yr	20-40yr
80-100%					14%
60-80%				14%	57%
40-60%				14%	14%
20-40%			57%	71%	14%
0-20%	100%	100%	43%		

Flow Impacts

Sourcing patterns

New points of entry into region

Balance of flow from various coasts

Flow destination

No significant changes

Routing

More complexity as sourcing entry points will change

More transhipments and other intermediate points

Flexibility in routing is critical

Flow volume

Increase in all volume of flows

Value density

No significant changes

Appendix 4. Description of Interactive Workshop Session

In order to get a feel for the dynamics of the interactive sessions, this Appendix summarizes the discussion and debate involved in one of the six breakout groups. It is important to remember that one of the objectives of this exercise was to test drive the hands-on process involving poker chips and playing boards.

Snapshot: New Technology: Personal Fabrication

The Scenario

In this scenario, low-cost, computer-controlled FabLab-style tools, open-source designs, and social networks let anyone create their own unique personal products locally. Although more manufacturing would be done in the US, the high level of automation means limited job creation. The group wondered about key aspects of this scenario, such as the cost of the personal fabricators and the skill-set. For purposes of the exercise, the devices were assumed to cost $2,000 - $3,000 and require no special skills. The groups also got clarification that the scenario didn't include Prof. Gershenfeld's more futuristic notions of programmable matter.

Adoption Trends

Overall, the group expected no adoption for at least 2 years and then a steady increase in adoption. Yet even on the 20-40 year horizon, adoption might only be 50%. The group also varied in their adoption estimates, spanning the entire 0% to 100% adoption range in the 10-20 year time frame.

One issue was that some group members thought that many people would eschew the technology because they were too busy to want to spend time on personal fabrication. That is, people who are cash-rich and time-poor wouldn't use the technology. This led to the discussions that local businesses or individuals might act as "Personal Fabricators" analogous to the notion of hiring a "Personal Shopper." This issue also implied that adoption might also have a strong generational component with both extremes of the age spectrum adopting the technology. On the youth-end, kids personalize everything and don't mind spending untold hours playing with technology. At the other end, the technology may find a following among retirees: grandpa could be puttering in the basement with his personal fabrication workshop.

Freight Flow Implications

The biggest change would be a shift in sourcing. More bulk commodities would be coming from countries that provide raw materials. And less sourcing would occur in low-cost labor countries. This is part of a larger trend of self-service that includes self-checkout in stores and IKEA assemble-it-yourself furniture. Developing world labor can't compete with a customer who donates their labor for free to save money, ensure quality, or because they enjoy the do-it-yourself ethos.

In particular, the US would probably reroute more domestically-extracted raw materials to internal local production rather than export. The shift from concentrated centers of finished goods production and distribution would change routing from hierarchical paths to a mesh of cross-deliveries.

Stress Map

The decline in sourcing of finished goods from Asia would reduce freight flows on the West Coast. Rising local production and personal production would mean more flows and more stress on urban infrastructure and areas with high population density, such as the East Coast. The group recommended adding a 23rd bubble to the stress map – a bubble for Urban Congestion.

Snapshot: Rising Protectionism

The Scenario

What if the WTO dies under a rising tide of protectionism fueled by a longer-than-anticipated recession? Countries would enact higher tariffs and duties to protect local industries. The group saw this as a self-fulfilling prophecy in which countries progressively retaliate against each other. One group member with extensive experience in international trade noted that protectionists have an arsenal of techniques to manipulate international trade.

Adoption Trends

The group's aggregate voting patterns showed a rise and then fall of protectionism over time. Rather than see protectionism rise steadily into the future, the group expected a cyclic process tied to the broader macroeconomic challenges of the Great Recession. Governments might become more protectionist for several years, but then the cycle would reverse under pressures to take advantage of foreign trade opportunities, access inexpensive imports, and create reciprocal agreements to improve trade relations. Overall, the group expected protectionism to peak at 50% adoption in 10 years and then decline to 20% adoption in the 20-40 year time frame.

Freight Flow Implications

Overall, protectionism would mean a significant change in sourcing. Domestic sources would supplant foreign sources. Protectionism would also change destinations in the sense that lower exports mean less freight destined for seaports and land ports.

Stress Map

This would lead to a decline in seaport activity and a marked increase in domestic freight movements. In particular, the group voted strongly for high stresses on West Coast highways, East Coast highways, and the South route of the East-West highways. And yet, the group also anticipated much lower GDP due to economic damage of protectionism. Depressed imports, exports, and overall demand mean less total freight flows.

The group discussion revealed a second major type of economic stress for freight infrastructure. Whereas the most common type of stress comes from over-utilization, freight infrastructure can also suffer economic stress and demand for investment due to underutilization. In the case of rising protectionism, US seaports would experience significant declines in freight volume. The problem is that these asset-intensive entities often require some minimum volume of business to support high debt payments and labor. If freight volume drops, then the ports might suffer from debt defaults, bankruptcies, and massive layoffs that would disrupt the viability of the seaports. Ironically, a decline in freight volume may necessitate some form of investment or government support to maintain operations.

Appendix 5. Stakeholder Survey

The following pages contain a printed version of the stakeholder survey. The actual survey was web-based.

Introduction

Hello,

As part of a multi-year research project sponsored by the Transportation Research Board of the National Academies, the MIT Center for Transportation and Logistics is looking to identify the main driving forces that could potentially shape future freight flows and supply chains within the United States. This project will help decision makers at the federal, state, and local levels make more informed decisions concerning freight transportation infrastructure investments.

The survey itself looks at TWENTY potential driving forces or future outcomes, previously identified during the MIT CTL Future Freight Flow Symposium held on March 11 - 12, 2010 (view the symposium presentations and videos at http://ctl.mit.edu/futurefreightflows). We ask you to give your best estimate as to HOW strongly and WHEN (if at all) this force might impact YOUR business and supply chain operations in the United States. We will use your input to develop a set of potential future scenarios.

This survey should not take you more than 5 or 10 minutes to complete and it is completely anonymous. All collected information is completely confidential and no individual respondents will be personally identified in any reports. This survey is, of course, totally voluntary.

Thank you in advance for your participation.

Dr. Chris Caplice
MIT CTL Executive Director

Importance and Probability of Potential Driving Forces

This page asks two questions about the twenty proposed driving forces. For each of the driving forces, we would like you to assess the IMPACT (assuming it occurs) and the PROBABILITY of it even occurring.

For each of the following potential driving forces, please indicate its IMPACT on your business and supply chain operations as if it has come to pass. For the purpose of this question, assume that the driving force HAS occurred.

	No Impact At All	-	Moderate Impact	-	Tremendous Impact
Shifting geo-politics and other factors leading to tremendous price volatility for almost all commodities such as wheat, copper, and lithium.	○	○	○	○	○
Over 90% of the United States consumers living and working in mega-region cities and built up urban areas	○	○	○	○	○
Shifting point of entry for a majority of imports to the East Coast (e.g. due to rise in manufacturing in Africa, more ships using the Panama Canal, etc.)	○	○	○	○	○
New countries (such as Russia or India) emerging as agricultural powerhouses supplanting the United States in some food commodities	○	○	○	○	○
Ascendancy of consumer markets in Brazil, Russia, India, China, and other countries leading to increased demand for products manufactured in the United States	○	○	○	○	○
New battery technologies dramatically reducing the cost and increasing the efficiency and range of electronic vehicles	○	○	○	○	○
Sustained reduction in global trade volume (both imports and exports) possibly due to rise of protectionism, pandemics, etc.	○	○	○	○	○
Large increase in both the number and magnitude of security threats (domestic and abroad)	○	○	○	○	○
Dramatic shift towards online purchase and point-of-use delivery leading to reduction of physical retail stores	○	○	○	○	○
Omnipresent enforcement of regulations and	○	○	○	○	○

rules requiring recycling and re-use of all manufactured products					
Widespread ability to capture and monetize real-time sensing data on all products, vehicles, and facilities across a supply chain at essentially no cost	◯	◯	◯	◯	◯
Advancements in manufacturing, materials, and other technologies increasing the average value per ton moved in the United States from ~$700 per ton (in 2008) to over $2000 per ton.	◯	◯	◯	◯	◯
Average life expectancy reaching 100 years in the United States	◯	◯	◯	◯	◯
Substantial re-domestication of manufacturing back to the United States	◯	◯	◯	◯	◯
The sustainability and environmental “friendliness” of a product becoming the dominant factor for consumer demand for most products supplanting cost	◯	◯	◯	◯	◯
Widespread adoption of technologies enabling efficient and low-cost small batch manufacturing for most consumer goods	◯	◯	◯	◯	◯
Stringent environmental and sustainability regulations adopted and strictly enforced by the United States and most other countries	◯	◯	◯	◯	◯
Dramatic increase in price and volatility of all oil based fuels	◯	◯	◯	◯	◯
Pervasive water scarcity in some regions leading to a reduction in exporting products that either contain water (e.g. fruit) or require a water intensive manufacturing process (e.g., soda, electronic chips)	◯	◯	◯	◯	◯
Immigration into the United States reduced essentially to zero	◯	◯	◯	◯	◯

Any comments?

For the same list of twenty potential driving forces, please indicate how widespread you think it will occur within the next 10 to 20 years.

	Unlikely to Happen (0-20%)	Present at Fringes Only (20-40%)	Generally Present (40-60%)	Widely Present (60-80%)	Omnipresent (80-100%)
Dramatic shift towards online purchase and point-of-use delivery leading to reduction of physical retail stores	○	○	○	○	○
Shifting point of entry for a majority of imports to the East Coast (e.g. due to rise in manufacturing in Africa, more ships using the Panama Canal, etc.)	○	○	○	○	○
Pervasive water scarcity in some regions leading to a reduction in exporting products that either contain water (e.g. fruit) or require a water intensive manufacturing process (e.g., soda, electronic chips)	○	○	○	○	○
Immigration into the United States reduced essentially to zero	○	○	○	○	○
Large increase in both the number and magnitude of security threats (domestic and abroad)	○	○	○	○	○
Advancements in manufacturing, materials, and other technologies increasing the average value per ton moved in the United States from ~$700 per ton (in 2008) to over $2000 per ton.	○	○	○	○	○
Shifting geo-politics and other factors leading to tremendous price volatility for almost all commodities such as wheat, copper, and lithium.	○	○	○	○	○
Substantial re-domestication of manufacturing back to the United States	○	○	○	○	○
The sustainability and environmental “friendliness” of a product becoming the dominant factor for consumer demand for most products supplanting cost	○	○	○	○	○
Widespread ability to capture and monetize real-time sensing data on all products, vehicles, and facilities across a supply chain at essentially no cost	○	○	○	○	○
Ascendancy of consumer markets in Brazil, Russia, India, China, and other countries	○	○	○	○	○

leading to increased demand for products manufactured in the United States					
New battery technologies dramatically reducing the cost and increasing the efficiency and range of electronic vehicles	○	○	○	○	○
Widespread adoption of technologies enabling efficient and low-cost small batch manufacturing for most consumer goods	○	○	○	○	○
Over 90% of the United States consumers living and working in mega-region cities and built up urban areas	○	○	○	○	○
Dramatic increase in price and volatility of all oil based fuels	○	○	○	○	○
Average life expectancy reaching 100 years in the United States	○	○	○	○	○
Stringent environmental and sustainability regulations adopted and strictly enforced by the United States and most other countries	○	○	○	○	○
Omnipresent enforcement of regulations and rules requiring recycling and re-use of all manufactured products	○	○	○	○	○
New countries (such as Russia or India) emerging as agricultural powerhouses supplanting the United States in some food commodities	○	○	○	○	○
Sustained reduction in global trade volume (both imports and exports) possibly due to rise of protectionism, pandemics, etc.	○	○	○	○	○

Any comments?

What critical driving forces that will influence business and supply chain operations over the next 10 to 20 years did we miss?

Participant profile information

In order to understand the perspective of each respondent, we need to collect some basic information on your company and industry. All of this information is completely confidential and cannot be used to identify an individual respondent.

Which category would best apply to your organization?

- ◯ Shipper
- ◯ Carrier
- ◯ 3PL
- ◯ Academic/Researcher
- ◯ Other (please specify)

What is your current position within your organization?

- ◯ C-level
- ◯ Vice President
- ◯ Director
- ◯ Manager
- ◯ Other (please specify)

Which category would best describe your industry?

- ◯ Academia
- ◯ Aerospace
- ◯ Apparel
- ◯ Automotive
- ◯ Chemicals
- ◯ Computers
- ◯ Consumer Products
- ◯ Consulting
- ◯ Energy
- ◯ Food & Beverage
- ◯ Government
- ◯ Logistics
- ◯ Pharmaceutical
- ◯ Retail
- ◯ Software
- ◯ Telecommunications
- ◯ Transportation

Other (please specify)

What is the approximate size of your firm in terms of annual revenue?

- ◯ Less than $1M
- ◯ Greater than $1M and Less than $10M
- ◯ Greater than $10M and Less than $100M
- ◯ Greater than $100M and Less than $500M
- ◯ Greater than $500M and Less than $1B
- ◯ Greater than $1B and Less than $10B
- ◯ Greater than $10B and Less than $25B
- ◯ Greater than $25B

If you are you interested in participating in more research along these lines, please provide us with the following information. By providing your email address you are allowing MIT to contact you, if needed, to voluntarily clarify or further explain your responses.

First Name

Last Name

Email Address

Company