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Business Continuity Planning

and

Semiconductor Manufacturing

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Business Continuity Planning

And

Semiconductor Manufacturing

by

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DEDICATION

This thesis is dedicated to my family, my partner, classmates and my friends who supported me through this entire program.

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Business Continuity Planning

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The University of Texas at Austin, 2010

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In the current era of globalization in supply chain, business continuity planning should play an even more important role than previously. Business continuity planning provides company with an analysis of potential business threatening situations, everything from natural disasters to supply shortages, and ensures that actions are taken in order to mitigate the probability that those risks will become reality. Business continuity planning does not come without a cost, since companies will in some cases have to spend money in actions like redundancies (e.g. supplier).

In the Semiconductor industry, supply chains might are extremely complex and globalized. These supply chains can go from having suppliers in the United States, to frond-end manufacturing in Europe, to back-end manufacturing and packaging in Asia. Raw materials for semiconductor manufacturing, for example raw wafers, can be found for above $500 per wafer. It is due to not only the complexity of the supply chain in semiconductors, but also due to the high costs of raw materials and manufacturing, that it is crucial for companies in this particular industry to ensure business continuity planning is taken seriously, and adequate measures are taken to mitigate as many risks to their supply chain as possible.

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I. INTRODUCTION

In everyday life, people constantly face uncertainty. This uncertainty can be presented in many forms, such as the possibility of being robbed, of losing a job or a family member, of spraining an ankle or of having a car accident. In some of these instances, such as losing a job or losing a family member, there might not be too much that an individual can do to mitigate or eliminate the risk of that possibility happening. One might lose a sibling in an accident, and may have been no way that person could have foreseen the accident to prevent it from ever happening, or from at least limiting the effect if it happens (injury versus death of the sibling.) In other cases, such as the possibility of being robbed, one could argue that one could do several things: avoid dangerous situations, avoid dangerous locations, or even carry a handgun for protection, all of which provide some ability to either eliminate the possibility of the robbery from happening or to mitigate the impact to oneself from the robbery.

In other cases, such as a car accident, there is something else that can be done to mitigate the effect of the accident if it was to occur: pay for car insurance. A study conducted by the American Automobile Association (AAA) found that the average yearly cost of a typical insurance policy (collision and comprehensive coverage) for a sedan was of approximately $1,031[1]. An insurance policy provides the driver of the vehicle a sense of security, since if an accident were to happen, it would mean that the driver would be covered (depending on the policy) and the insurance company would be responsible for paying not only the costs to repair the vehicle(s), but might also cover medical costs. Insurance policies are required by all states in the United States, with specific guidelines with regards to minimum bodily injury liability and property damages; an example of this being the state of Texas, which has a 20/40/15[2] minimum, which means in case of an accident, each injured person could receive up to $20,000, with the maximum for the event of the accident for bodily injury being $40,000, while the property damages (e.g. vehicle damage) would be covered up to $15,000. This is the minimum requirement, which implies that each person seeking insurance can opt for more on any category based on their own preference and their desire to minimize the impact to themselves, in this case with financial liability, if an accident were to occur. As mentioned earlier, this is all in case of an accident, yet an accident might never occur for an individual who pays insurance each month. This, however, does not mean that the money spent is wasted, since it is a requirement and it provides financial back-up in case an accident was ever to occur.

Business Continuity Planning (BCP) could be, by oversimplifying, equated to having car insurance. BCP is a growing trend in today's world by which companies plan for possible eventualities based on a careful analysis of the major risks that the company could face, the probability of facing them, and the impact it would have on the company if they were to be happen. BCP is being required of companies by their customers, just like drivers are required to have insurance, in order to give a sense of security to them that in case something happened to one of their suppliers, the impact to their own profitability would be minimized thanks to appropriate planning.

This paper plans to address the importance of Business Continuity Planning, specifically targeting its importance in the Semiconductor Industry, while focusing on this industry's supply chain operations.

II. BUSINESS CONTINUITY PLANNING

What is Business Continuity Planning?

Business Continuity Planning, or BCP, is defined by the National Fire Protection Association (NFPA) as "an ongoing process supported by senior management and funded to ensure the necessary steps are taken to identify the impact of potential losses, maintain viable recovery strategies, recovery plans, and continuity of services"[3]. There are several key elements to this description that need to be examined:

1. It is an ongoing process: the world changes, and with its changes come new risks that need to be taken into consideration every year, hence this plan needs to be a living plan;
2. It needs management support: without management support, and the adequate funding to support the actions that results from this plan, BCP will fail;
3. It needs to focus on the impact itself of the potential losses: some losses might not have an impact worth the investment, some might;
4. Its strategies must be viable, provide recovery plans and ensure the continuity of services: a business continuity plan that is not feasible or that does not ensure the ability of the company to withstand the impact of the occurrence of the identified risk is not a good plan.

There are several standards and certifications for BCP. Two of them worthy of notice are the British Standards Institute's BS 25999-1[4] and the NFPA's 1600 standard[5]. Both of these standards provide detailed information on the creation and management of a business continuity plan, including execution and the restoration of operations for a company which has been impacted by the realization of an identified risk. We will now, however, focus on the description of the steps necessary to create an effective business continuity plan, according to a training course provided by Freescale[6].

Steps to Create a Business Continuity Plan

Identifying a team

As mentioned earlier, senior management support plays an important role in BCP, not only through providing funding and championing the program, but also because they should be responsible for creating an initial risk assessment for the company. A risk can be defined as a "chance of something happening, measured in terms of probability and consequence"[7]. It is important to note that a risk can be of "positive or negative" consequence[8]. This is important because in some people, a risk of something happening might carry a negative connotation. The risk of having a customer increase demand without notice could be considered a positive risk, since if we are able to accommodate the extra demand, it will mean profits not previously forecasted for the company.

This initial assessment should include a high level identification of potential risks to the company, and it should assign a priority to each one of these risks. This priority should be based on the perception of senior management of the impact of the risk were it to occur. Senior management should also be responsible to hire (if a large company) or designate (if a small company) one person to be BCP Program Coordinator, who would be responsible for the development and continuous improvement of the business continuity plan for the company.

This BCP plan should include not only a careful analysis, which we will discuss on future steps, but also develop all procedures to respond to all identified and evaluated risks.

The program coordinator should also serve as the team's liaison with other groups within the company, whom with she will have to work with, in conjunction with senior management, to help identify a BCP team, which will be a "group of individuals functionally responsible for directing the development and execution"[9] of the business continuity plan. After helping identify the BCP team, the program coordinator will continue to work as a liaison with other groups through the creation, implementation and continuous life of the BCP plan.

Conducting a Risk Assessment

As stated before, an initial Risk Assessment should be conducted by senior management and provided to the BCP program coordinator to understand the priorities of the company. A Risk Assessment is defined as the "overall process of risk identification, analysis and evaluation"[10]. Different companies will identify and worry about different risks, depending on what kind of business they are in, where they do business, whom they do business with, etc. It is up to the BCP program coordinator and the BCP team to work on identifying all possible risks to the company, thus expanding the initial risk assessment provided to the team. Some examples of categories of these risks can be taken from surveys, which will be provided later on, and include economic risks (e.g. market crash, supplier going out of business), weather risks (e.g. earthquakes, hurricanes) or even social risks (e.g. terrorist attack).

Each of the risks identified need to be realistic and well documented in order to be evaluated. For example, a local business in Austin, Texas would not have the risk of being hit by a typhoon. Considering this as a risk for this particular company would not only be unproductive, but it would diminish the validity of the business continuity planning process. It is important also to mention that when identifying the risks, it is recommended to consider various different types of risks (as stated above under categories), and the possible disruptions they might have to business operations.

After all risks have been identified, each risk must be categorized with an estimate of the probability of happening to the organization based on a scale of three values: high, medium, or low probability. Table 1 shows a simple example of a potential risk analysis for a local Austin caterer.

Risk Number	Risk Name	Probability
1	Delivery van problems	High
2	Event Cancellations	High
3	Power outages (office/kitchen)	Medium
4	Flu epidemic	Medium
5	Employee strike	Low
6	Tornado	Low

Table 1: Risk Analysis for sample Austin caterer

In this case, we can see that all risks have been identified and have been assigned probabilities of occurrence from high to low. The caterer in this case considers that having delivery van difficulties is a very high probability, while she considers that a tornado hitting Austin is very low probability. After the Risk Assessment is completed by the BCP team, the next step is to generate a Business Impact Analysis.

iii. Generating a Business Impact Analysis

The basis for the Business Impact Analysis (BIA) is the Risk Assessment completed in the previous step. The BIA can be defined as an "analysis by which an organization assesses the quantitative (financial) and qualitative (non-financial) impacts, effects and loss that might result if the organization were to suffer"[11] of the realization of a risk. The BCP team will review the assessment, and then determine what the impact would be of the risk if it were to materialize. Examples of things to consider during the evaluation of each risk is the impact it could have on the health/safety of employees during and after the event, on health of responding personnel, on continuity of business operations, on company facilities, on the environment, on customers, and so on. It is up to each BCP to take into consideration as many variables as possible to determine an "accurate" level of impact per risk identified.

Each risk must then have an impact level assigned, which should also follow the approach we used for the probability of the event, which is assigning an impact level of high, medium or low. Following the sample risk assessment created for an Austin-area caterer, Table 2 below shows a tabular approach to the Business Impact Analysis.

Risk Number	Risk Name	Probability	Impact
1	Delivery van problems	High	High
2	Event Cancellations	High	Medium
3	Power outages (office/kitchen)	Medium	Low
4	Flu epidemic	Medium	Medium
5	Employee strike	Low	Medium
6	Tornado	Low	High

Table 2: Tabular Business Impact Analysis for sample Austin caterer

After assigning an impact level to each risk, this tabular form does not really give us an easy way to identify the highest threats to the company. Creating a visual representation (Figure 1) of this table will give us an easier way to identify the threats to the company.

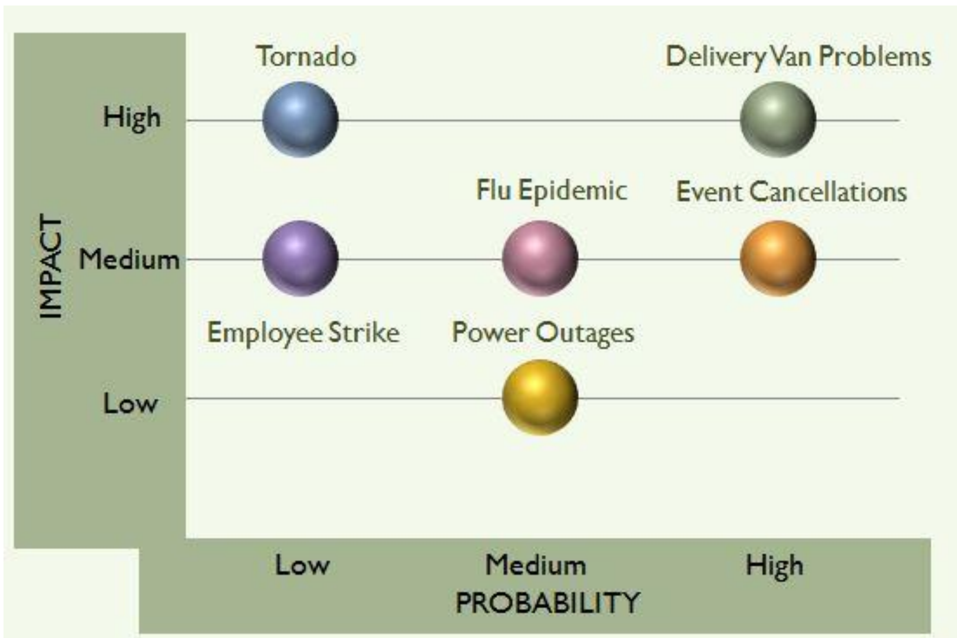

Figure 1: Visual Business Impact Analysis for sample Austin caterer

Seeing the data in graphical display allows us to understand that the BIA is telling us the order of importance that needs to be assigned to the risks are:

1. Delivery Van Problems
2. Event Cancellations
3. Flu Epidemic
4. Power Outages
5. Tornado
6. Employee Strike

Now that we have a BIA, thanks to which we know the ranking of the issues the BCP team needs to address in the BCP plan, we must move to the phase in which a Strategic Plan needs to be developed.

iv. Preparing a Strategic Plan

A Strategic Plan uses inputs from the Risk Assessment and the Business Impact Analysis as its basis. This plan is used to create a strategy to reduce the potential disruptions that might occur to business operations in the event of a crisis. There might be more than one strategic plan within one business continuity plan; this is all dependent on the risks analyzed in the Risk Assessment / BIA. The factors that should be considered when creating a Strategic Plan are:

1. Building construction standards: this is if the plan includes recommendations about building new construction, thus eliminating possible future issues with the facility;
2. Avoidance of hazard through land-use practices: possibly building on a hill of there are risks of flooding, storing inventory in higher locations;
3. Relocation/removal of structures at risk: if the structures themselves can be removed without major impacting to operations;
4. Removal of the hazard: identify if a way exists to completely remove the hazard;
5. Reduction or limitation of the size of the hazard: this is if the hazard cannot be eliminated through actions;
6. Separation of hazard from vulnerable parties: possibility of moving staff, systems;

7. Modification of basic characteristics of the hazard: if we know a particular impact of a hazard, we can find a way to nullify the impact (e.g. power outage: ability to quickly find a new source of energy);
8. Control the rate of release of the hazard: if possible, for example if the risk is a risk of an oil leakage;
9. Provision of protective systems or equipment: in the case of IT systems, appropriate firewalls or antivirus programs, or helmets and protective gear for employees;
10. Establish effective hazard warnings and communication strategies: this will help diminish the impact if followed correctly, which should include training;
11. Redundancy in personnel, systems, equipment and others: redundancy allows for effective mitigation of risks effects.

Just like any of the previous steps, each Strategic Plan prepared must be a feasible and attainable; it should also be verifiable through tests (which can be conducted before implementation) and be cost effective. A plan that is not cost effective is a plan that will fail, since the point of a BCP is to provide a company with the ability to withstand the effects of a risk if it were to occur, and not being cost effective would mean that the company would also be spending a lot of money to put a plan in place which would end up hurting their bottom line.

An example of a simple strategic plan for the example used above would be to target one of the risks and analyze it. The prepared BIA identified “Delivery Van Problems” as the number 1 risk for the caterer. Table 3 shows a simple analysis of the hazard with four possible ways to tackle the risk.

Risk	Delivery Van Problems	
Priority	Option	Factor considered
1	Buy second van	Modify basic characteristics of hazard Reduction of hazard Redundancy
2	Rent second van as needed	Modify basic characteristics of hazard Redundancy
3	Keep mechanic on staff	Modify basic characteristics of hazard Reduction of the size of the hazard
4	Train delivery staff on potential car problems and how to fix them	Reduction of the size of the hazard

Table 3: Strategic Plan for sample Austin caterer

Assuming the caterer has the money to be able to do all these if needed, we have a feasible plan. Each option has pros and con, which need to be considered by the caterer when deciding. Delivery van problems are almost impossible to prevent, since they could take multiple forms. Buying a second van would modify the basic characteristics, since we would have a different source of mobility for the caterer. It also reduces effect of the hazard on the caterer, since it would be easy enough for the caterer to request his second van to help with the delivery while the first van is being repaired. This brings redundancy into the equation, since we have two vans now, when only one might be used, the other van might sit unused, or the van usage might be split between the vans. This could be considered by some as a waste of money, but just like insurance, it will help in case of an eventuality. The last option, which would be to train the delivery staff on car mechanics would help reduce the size of the hazard, but this would only tackle one portion of the possible issues which might be experienced with the delivery van, hence its lower priority.

Compiling the Business Continuity Plan

Once all strategic plans are finalized, the business continuity plan needs to be put together, and it should include:

1. Risk Assessment;
2. Business Impact Analysis;
3. Strategic Plan(s);
4. Trigger Strategy: when to use the BCP, how to use, and who will begin the execution;
5. Communication strategy: how and who will be notified;
6. Responsibilities: define responsibilities for senior management, BCP Program Coordinator, BCP team and others, and;
7. Contact information: who to contact and names of the team.

After the business continuity plan is completed and before it is implemented, it is recommended to test the plan to ensure the plan is valid. Other benefits of testing the plan are: it heightens the awareness of the BCP team and the employees with respect to their duties; it clarifies their roles and; it identifies weaknesses of the plan to be addresses before the plan is implemented.

Implementing a Business Continuity Plan

After the business continuity plan is completed, it is time to implement it. Every employee who is somehow affected by it will need to be trained. It is critical that people who have responsibilities assigned to them within the plan know about these responsibilities in order to be successful. Training of the plan should then include:

1. BCP responsibilities: who does what, from implementation to execution;
2. Communication methods and contact points in case of emergencies;
3. Information on conditions and scenarios which could trigger the implementation of BCP;
4. Alternates in case of unavailability of identified BCP people.

As with any training, it is crucial to either make sure the people who are trained either use the knowledge in their daily jobs, or that training is regularly provided to ensure the knowledge is retained by the employees.

As mentioned earlier, the implementation of the business continuity plan is not the end. The BCP team is responsible for ensuring that this living document stays relevant through the life of the business. One of the things to do to keep this document up to date is something done throughout project management: documenting lessons learned. Not only should there be a schedule set to review the business continuity plan to ensure its continuous validity, but after every crisis event, the lessons learned should be documented and the plan should be modified if needed.

What Drives Business Continuity Planning?

In a 2009 Business Resilience Survey conducted by iJET Intelligent Risk Systems, in which they surveyed more than 350 companies, each with revenues of above $1 billion, iJET found that the main drivers of BCP are Senior Management, with 74% of respondents' agreement[12], and

Customers, with 49% of respondents' agreement[13]. These results show that the definition provided by the NFPA holds true: it is critical to have management support, and have management be the driving force behind the implementation of a business continuity plan, and also that the continuity of services of the company is critical, and this is of interest not only for the company itself, but for all customers of the company which also wish to minimize risk for their own operations.

This survey also asked respondents to identify the major sources of disruption to their operations. The results are not surprising, considering the environment the world is currently in: 53% agree on the economic environment, while 41% and 32% agree on the world's weather/environment and geopolitical unrest/terrorism respectively[14]. The current financial crisis can be traced to have started in 2007 when the Federal Home Loan Mortgage Corporation (Freedie Mac) announced it would "no longer buy the most risky subprime mortgages and mortgage-related securities"[15], and the world watched while the Lehman Brothers Holding Inc. filed Chapter 11 in September of 2008[16]. This crisis had several effects, one of which was to increase the importance of BCP, but it also had another effect, which we will be discussing later in this analysis when we focus on the semiconductor industry.

In terms of the other main drivers, such as the environment and geopolitical unrest, we can clearly understand why: in 2008, the world experienced 656 natural disasters, ranging from droughts to earthquakes. These disasters impacted over 224 million people, killing over 240 thousand of those impacted, and represented over $190 billion in estimated damages[17]. In 2009, the Economist.com presented a geopolitical unrest map (Figure 2) which qualifies each area with a range of their risk of social unrest from "Very High" to Low.

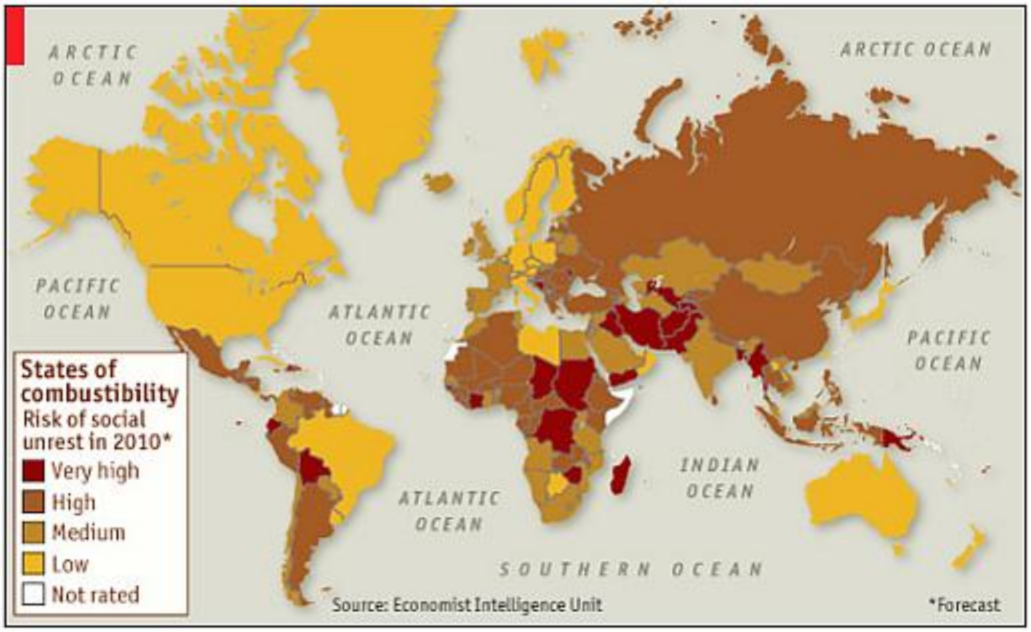

Figure 2: States of Combustibility. *Source*: Economist.com, December 29, 2009

This analysis substantiates fears from senior leadership about geopolitical issues, considering most of the world is classified as an area of "High." Even though this paints a bleak picture of the state of the world, it highlights the importance of BCP for companies, and this is clearly visible in the fact that as of the 2009 iJET survey, 73% of respondents identified that the investment in BCP is ongoing within their companies, and 82% of them indicated they currently have a business continuity plan[18]. These statistics show us the importance of BCP for big corporations, but again, BCP is for all companies who have an interest in being able to survive a catastrophe. The U.S. Department of Labor conducted a study in which they were able to estimate that more than 40% of businesses that are struck by a catastrophe never re-open[19]. It also estimates that of those companies that remain, at least 25% will close within two years of the catastrophe[20].

Overall, it is easy to understand the importance of Business Continuity Planning for any company that wishes to remain in business in the long run. It is an investment that requires senior management sponsorship, and employee involvement to be successful. It is also important for senior management to understand that this investment might not always be measurable, just like having car insurance is not always measurable, and in some cases it might seem like a waste of money. In reality, BCP is an investment which should give not only the company's senior management peace of mind, but it will also give the company's customers peace of mind that in case of a catastrophe, their supplier will be able to deliver.

III. SEMICONDUCTOR MANUFACTURING AND FREESCALE SEMICONDUCTOR

What is a Semiconductor?

The word “semiconductor” is sometimes used interchangeably with the world “microchip” to refer to a semiconductor device. A semiconductor, however, is “a substance as germanium or silicon whose electrical conductivity is intermediate between that of a metal and an insulator; its conductivity increases with temperature and in the presence of impurities”[21].The previous definition refers to a semiconductor material. A semiconductor device, which is the same as a microprocessor chip and what the semiconductor industry manufactures, is a “electronic equipment consisting of a small crystal of a silicon semiconductor fabricated to carry out a number of electronic functions in an integrated circuit”[22].

Semiconductors are components of a large variety of products, such as personal media players or vehicles. Figure 3, shows the end-use segments for the semiconductor industry as of 2007.

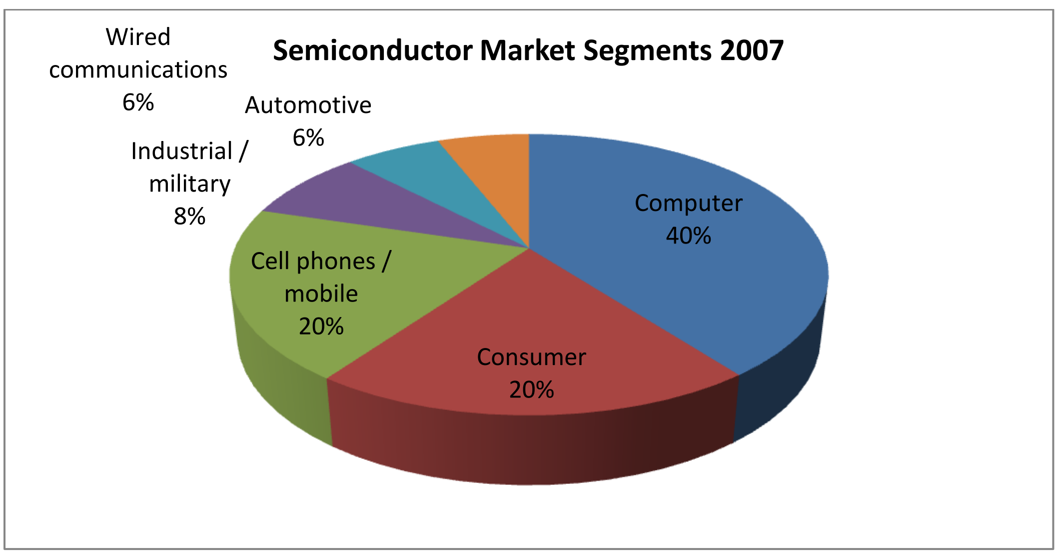

Figure 3: Semiconductor Market Segments 2007.
Source: Semiconductor International Webcast December 2007.

As can be seen in Figure 3, while the largest segment is the computer market (40%), there are several other end-use industries of semiconductors. The second largest segment is consumer products (20.5%), an example of which is a toaster oven. The third segment in rank is the cell phone one with 20% of market, while the rest of the semiconductor end-use market is composed of the industrial/military segment (8.2%), the automotive segment with 6.3% and finally wired communications with the remaining 6% of the market.

In 2009, the semiconductor industry (excluding foundries) posted revenues of over $229 billion dollars[23], with the highest market share belonging to the Intel Corporation with $32.4 billion dollars in sales, representing approximately 14.1% of the market[24]. Other important companies include Samsung Electronics, Toshiba and Texas Instruments, which hold 7.6%, 4.5% and 4.2% of the market, respectively[25]. Table 4 shows the top 10 semiconductor companies of 2009, based on rankings from the iSupply Corporation.

2008 Ranking	2009 Ranking	Company Name	2008 Revenue	2009 Revenue	Percent Change	Percent of Total
1	1	Intel	33,767	32,410	-4.00%	14.10%
2	2	Samsung Electronics	16,902	17,496	3.50%	7.60%
3	3	Toshiba	11,081	10,319	-6.90%	4.50%
4	4	Texas Instruments	11,068	9,671	-12.60%	4.20%
5	5	STMicrolectronics	10,325	8,510	-17.60%	3.70%
8	6	Qualcomm	6,477	6,409	-1.10%	2.80%
9	7	Hynix	6,023	6,246	3.70%	2.70%
12	8	Advanced Micro Devices (AMD)	5,455	5,207	-4.60%	2.30%
6	9	Renesas Technology	7,017	5,153	-26.60%	2.20%
7	10	Sony	6,950	4,468	-35.70%	1.90%

Table 4: Top 10 Semiconductor Companies 2009. *Source*: iSupply Corporation

The Origin of Silicon Semiconductors

The history of semiconductors can be traced back all the way to 1893, when Michael Faraday was the first person to observe and document that "electrical conductivity increased with increasing temperature"[26]. After this initial discovery, there are several other important milestones in the history of the semiconductor device, one of which is the invention of the point-contact transistor in 1947[27]. In this year, John Bardeen and Walter Brattain of Bell Labs concluded their year-long research by creating the "first semiconductor amplifier"[28]. This initial transistor was created using germanium, which is an electrical semiconductor like silicon. However, it is not until 1954 that the first silicon transistor was created by Morris Tanenbaum while working for Bell Labs[29]. Tanenbaum had used a grown-junction technique originally developed by Morgan Sparks and Gordon Teal.

Bell Labs, however, chose not to pursue silicon semiconductors due to their perception that the process of creating these silicon semiconductors was unattractive for commercialization. This opened the door for Texas Instruments (TI) to be the first to manufacture and sell silicon semiconductors when later in 1954, Gordon Teal created TI's first silicon semiconductor transistor without knowing about Tanenbaum's success. The reason for the importance of this achievement is that to date, silicon serves as the "substrate material on which most semiconductor devices or 'chips' are fabricated"[30]. Current silicon wafer shipments, as of Q2 of 2010 were recorded at about 2.3 billions square inches[31]. Wafer sizes can range from 1 inch to 12 inches in diameter, and the total wafer shipments described above, assuming a 12 inches diameter for example purposes, would represent approximately 20.9 million wafers.

One last early milestone worth mentioning is the origin of Silicon Valley. In 1955, William Shockley and Arnold Beckman founded the Shockley Semiconductor Laboratory, which settled in a rented building in Mountain View, California[32]. This new company suffered some internal tumult when eight of their employees resigned in 1957 over issues with Beckman and his unwillingness to hire a new manager. These eight employees then went on to found Fairchild Semiconductor Corporation in Palo Alto[33]. Fairchild Semiconductor became one of the most important and innovative companies in the industry, laying the foundations for Silicon Valley and at the same time spinning-off several successful companies, such as Advanced Micro Devices (AMD) and Intel[34].

Semiconductor Manufacturing Process Overview

The semiconductor manufacturing process is a very complex process, and "it differs markedly from other processes"[35]. While most processes follow a straight line, from beginning to end, the semiconductor manufacturing process follows only seemingly follows a straight line. An example of the very high level manufacturing process can be seen in Figure 3 below.

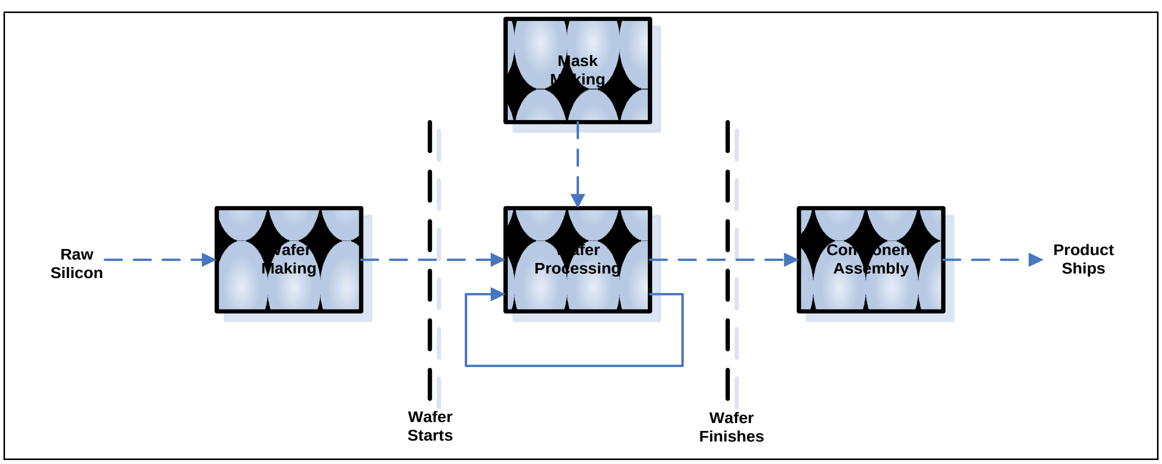

Figure 4: Overall semiconductor fabrication line. *Source:* VLSI Research Inc.

The initial box, Wafer Making, can be ignored for these purposes since semiconductor manufacturers generally purchase raw silicon wafers instead of making them themselves, and the same can be said about the Mask Making box. Masks are critical in semiconductor manufacturing, but they are procured by semiconductor companies as well. The second box, Wafer Processing can be described as the front-end portion of the process, where the wafer will undergo both linear and non-linear steps. For example, every wafer in a lot, generally representing 25 wafers, must be scribed with an ID number. This step will only be performed once and at the beginning of the process. After that, however, multiple layers of circuitry are "added to the upper surface of the polished wafer via numerous repetitive"[36] steps, such as lithography and etching. After the wafer has undergone all the processing of the front end, each wafer will be probed. Probe is the part of the process in which each dice within the wafer will be tested to see if the wafer processing step was successful. Table 5 shows some examples of probe yields, possible die per wafer (PDPW) and good die per wafer (GDPW) for 16M DRAM and 64M DRAM wafers.

	16M DRAM (0.35µ)	64M DRAM (0.35µ)
Wafer Size (Diameter)	200mm	200mm
Die Size (Area)	54mm^2	150mm^2
Total Dice Available (PDPW)	476	162
Probe Yield	80% (at 0.5 defects/cm^2)	40% (at 0.7 defects/cm^2)
Number of Good Dice	380	65

Table 5: 16M and 64M DRAM Cost Analysis. *Source*: Smithsonian The Chip Collection

From Table 5 we can see that for the same size wafer (200mm), we can have very different numbers in terms of probe yield, PDPW and GDPW. This is due to the product design, which determines things like the size of the dice and the amount of processing that needs to be done to the wafer, which in turn affects the yield. It is important to note here that in Q2 2010, the actual number of wafer starts per week in the semiconductor industry was of 1.8 million wafers[37].

After Probe, the wafer is sawed and the die will then assembled into their finished product state, examples of which can be individually into a single microprocessor, or packaged together with more microprocessors to form a kit or a module. After this, each finished good will be tested to ensure it is working correctly in the final stage of the process. Figure 5 below shows a more detailed process diagram for a typical semiconductor line.

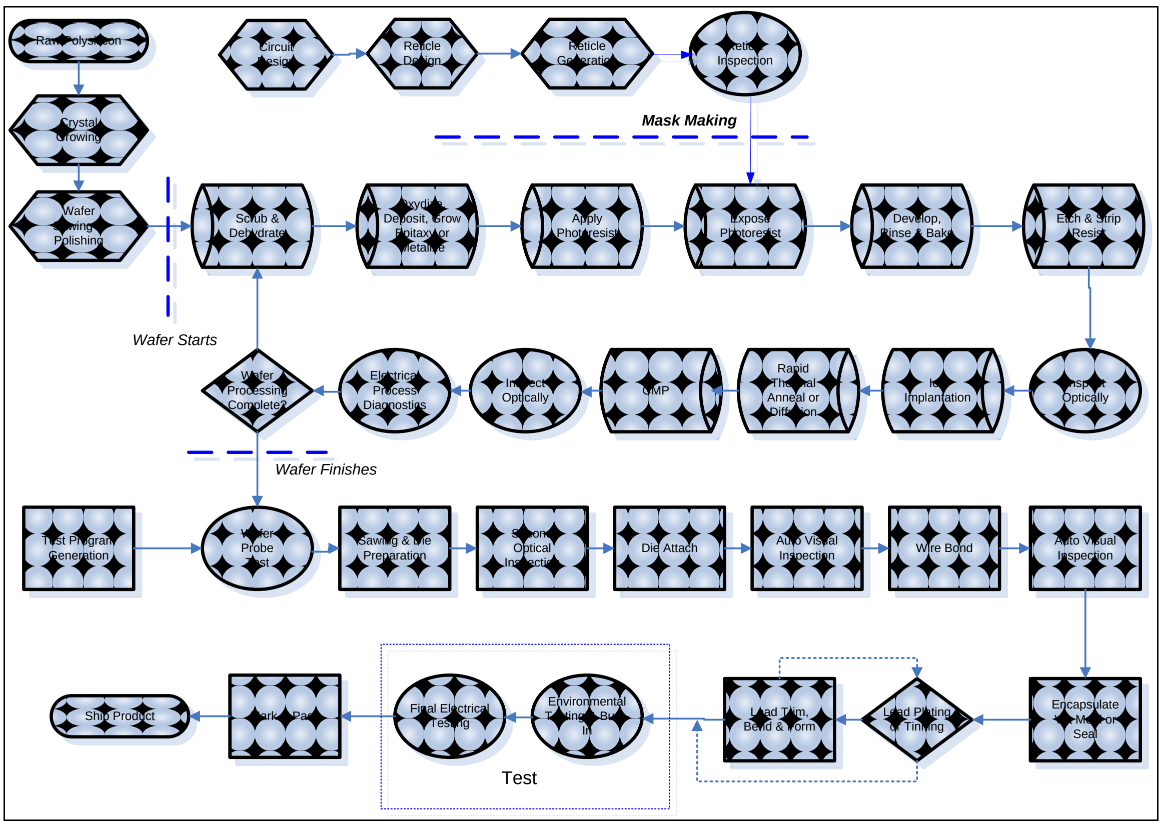

Figure 5: A typical semiconductor fabrication line. *Source:* VLSI Research Inc.

As can be seen, the semiconductor manufacturing process can be quite complex due to the need to repeat steps multiple times during the creation of a microprocessor. It is due to this complexity that the lead times for semiconductor devices can be quite extreme in comparison to other consumer products. Semiconductor lead times can be measured in weeks. Cypress Semiconductor, a company headquartered in San Jose, California, has lead times ranging from 4 weeks to 32 weeks[38]. On top of possibly long lead times, the creation of a semiconductor does not necessarily all occur in the same location from beginning to end. It might not even happen in the same continent. Figure 6 shows an example of the supply chain of an electronics company created by IDC Manufacturing Insights.

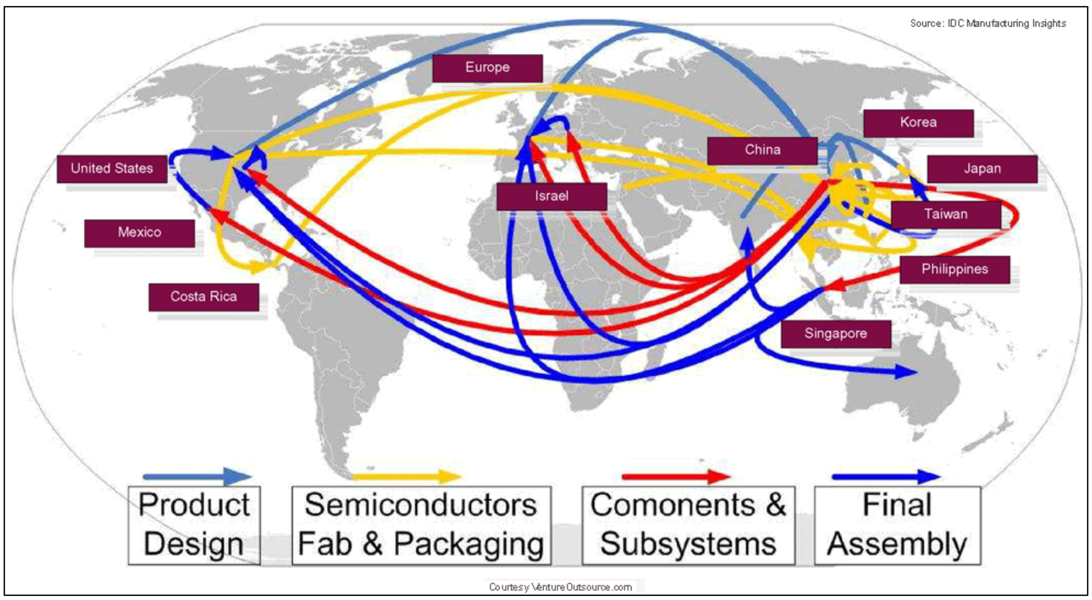

Figure 6: Electronic Industry Global Value Chain. *Source*: IDC Manufacturing Insights

Even though this figure depicts the supply chain for an electronics product, it is quite noticeable that the semiconductor portion of the supply chain is drives a lot of the complexity of this product's manufacturing.

Freescale Semiconductor

Freescale Semiconductor (FSL) is a global semiconductor manufacturing company. Freescale was originally the semiconductor division of Motorola. In 2004, Motorola announced the spin-off of its semiconductor division and named it Freescale Semiconductor[39]. After the spin-off, Freescale went public when its IPO was held on July 16, 2005[40]. The public ownership of Freescale was short-lived though, for it was bought by The Blackstone Group in December of 2006[41]. As of 2010, the company remains a privately owned.

Freescale is headquartered in Austin, Texas, and it holds locations in more than 20 countries, employing more than 20,000 people worldwide. These locations include five wafer fabs (front end manufacturing), two of which are located in Austin, while the other three are located in Arizona, Japan and France. Assembly and Test Sites (back end manufacturing) are located in China and Malaysia. Other types of locations include sales offices, design and R&D centers and support centers[42].

IV. IMPORTANCE OF BUSINESS CONTINUITY PLANNING IN SEMICONDUCTOR MANUFACTURING

As discussed earlier, business continuity planning is critical to ensure companies have the ability to withstand the impact of the realization of a risk, either by completely eliminating the risk or by minimizing the effect of the risk on business operations. As seen in the description of the semiconductor manufacturing process, it is a very complex process, with a very complex supply chain due to the fact that its manufacturing stages might occur in not only different locations, but different countries or even different continents. The following section will: review some reasons why semiconductor companies, such as Freescale, benefit from having a robust Business Continuity Plan; possible considerations to overcome these drivers and; challenges these companies can face to be able to implement and maintain these plans.

Business Continuity Drivers in Semiconductor Manufacturing

Product Differentiation in the Manufacturing Process

As opposed to other industries such as the car industry, in which a red Toyota Corolla can be differentiated towards the end of the process by using paint, product differentiation generally happens much earlier in the semiconductor manufacturing process. As discussed earlier, the basis of the type of semiconductor device being manufactured is established in the front stage, which is the most complex of the process. It is in Fab that the use of the masks and repetitive steps generally defines the type of semiconductor being created, as opposed to other stages where the semiconductor is being either tested or assembled into a final product. This, combined with the fact that one lot can consist of up to 25 wafers, which in turn can represent anywhere from 1,625 units to 9,500 units (using Table 5 for GDPW figures), makes it easier to see why having a plan in case something happens with a lot, a factory (considering the high number of wafer starts per week), or a shipment between factories or to the customer, the company could be placed in a bind to be able to make up for the losses. It is important to mention that some differentiation can happen at assembly, depending on the type of packaging of the product. In some instances, the same product can be sold in as individual units, just like they could be sold in a reel, where all units are attached to a reel, yet the product itself might change names. This does somewhat minimize the effect of product differentiation at Fab, but it is minimal.

Product Portfolio

As of September 2010, Freescale offers over 8,000 products through www.freescale.com. Table 6 shows the breakdown of products based on life cycle. Please note that devices classified as "Transferred" or "No Longer Manufactured" do not form part of Freescale's active portfolio. Devices classified as "Introduction Pending" are not yet up for sale.

Freescale Product Portfolio (Sep 2010)	Introduction Pending	Active	No Longer Recommended for New Design	End of Life	Transferred	No Longer Manufactured	Total
Analog and Power Management	-	214	105	94	-	114	527
Digital Signal Processors and Controllers	1	318	32	7	-	135	493
Microncontrollers and Processors	4	5,745	710	173	2	3,794	10,428
RF	6	376	9	62	-	35	488
Sensors	4	401	101	28	-	107	641
Total	15	7,054	957	364	2	4,185	12,577

Table 6: Freescale Semiconductor product by life-cycle breakdown. *Source*: Freescale.com

The total number of products offered is currently at 8,390. This means that Freescale has to main the ability to manufacture these devices in its supply chain. It also means that, based on lot size of 25 wafers, even if a small order comes for a product, a full lot needs to be started. This in turn means that the risk of building excess inventory for a company like this is pretty high. Even though inventory is associated with a cost, is not always a bad to carry in case of emergencies. However, it is crucial to carry the right inventory. Based on the amount of devices offered, and applying the Pareto rule that 80%, in this case of the revenue, is provided by 20% of the products offered, this would mean that close to 6,712 of these products produce less than 20% of the revenue of the company. This assumption would hold true then that carrying inventory in most cases could mean a cost that is no value to the company.

Manufacturing Costs

Wafer Costs

Raw silicon wafers prices have a wide range of prices, all depending on the diameter of the wafer and the type of wafer (pre-processing.) Table 7 shows a selection of silicon wafer average prices as identified by a Sage Concepts report in 2008.

DIA	TYPE	$	YEN	EURO
3	TEST	$ 4.24	¥ 492	€ 2.84
3	FZ	$ 5.65	¥ 655	€ 3.79
4	TEST	$ 6.04	¥ 701	€ 4.05
4	SOI	$ 26.50	¥ 3,074	€ 17.76
5	TEST	$ 9.68	¥ 1,123	€ 6.49
5	SOI	$ 46.88	¥ 5,438	€ 31.41
6	TEST	$ 14.88	¥ 1,726	€ 9.97
6	SOI	$ 68.00	¥ 7,888	€ 45.56
8	TEST	$ 36.55	¥ 4,240	€ 24.49
8	SOI	$ 209.35	¥ 24,285	€ 140.26
12	TEST	$ 153.67	¥ 17,826	€ 102.96
12	SOI	$ 748.50	¥ 86,826	€ 50,150.00

Table 7: Silicon Wafer Prices. *Source*: Sage Concepts Online

As it can be seen in Table 7, silicon wafers can be an expensive raw material. An average, well-balanced factory can start anywhere from 2,500 to 11,000 per week[43]. If we classify any of the 5 Freescale wafer fabs as well-balanced, that would mean that Freescale coul starting anywhere from 12,500 to 55,000, which depending on raw material cost per Table 7, could range anywhere from $53,000 to over $41 million in new WIP every week (not counting sold inventory during the week.) This means that even before the raw materials go into production, they carry a very high cost, which in turn means that any accident in which lots are lost would represent a big loss to a company like Freescale.

Equipment Costs

By venue of having a very complex production process, semiconductor manufacturing equipment can be quite expensive. Research was able to find an Applied Materials P5000 Plasma Etch being offered for $537,000[44], while a Teradyne J750, an equipment piece used in final test, was found to start at $99,000[45]. This means that any disruption in a location, in which equipment is compromised, could mean not only a loss in productivity if not appropriately backed up, but also a high loss in investment.

Worldwide Supply Chain

Just as in the example provided in the Semiconductor Manufacturing Process Overview section of this analysis, Freescale has a worldwide supply chain. With front-end locations in the United States, France, and Japan, and back-end locations in Malaysia and China, Freescale faces several challenges. Due to the distance between locations, the company depends heavily on transportation. This means that any disruption or delay could be detrimental. Not only is transportation critical, but the fact that the back-end of the process occurs in Asia raises concerns about weather/environmental-related issues as well. Table 8 shows damages, in thousands of dollars, that both China and Malaysia have suffered during the past five years (2005 through September 2010) by disaster type.

Damages (in $,000)	China P Rep	Malaysia	Total
Drought	$ 3,144,294	$ -	$ 3,144,294
Earthquake (seismic activity)	$ 86,163,691	$ -	$ 86,163,691
Epidemic	$ -	$ -	$ -
Extreme temperature	$ 21,100,000	$ -	$ 21,100,000
Flood	$ 21,510,235	$990,000	$ 22,500,235
Industrial Accident	$ -	$ -	$ -
Mass movement dry	$ -	$ -	$ -
Mass movement wet	$ 139,000	$ -	$ 139,000
Miscellaneous accident	$ -	$ -	$ -
Storm	$ 23,339,161	$ -	$ 23,339,161
Transport accident	$ -	$ -	$ -
Wildfire	$ -	$ -	$ -
Total	$ 155,396,381	$990,000	$ 156,386,381

Table 8: Damages ($US) caused by disasters in China and Malaysia 2005-2010.
Source: EM-DAT: The International Disaster Database

Even though Malaysia seems to not have suffered as bad as China, with only $990 million in damages, it is not reassuring to companies who operate in China to know that China has suffered, in the past 5 years, of more than $155 billion in damages, some of which must come from damages to business and companies as well.

It is also important to know that semiconductor companies, like Freescale, also hire companies to do portions of the manufacturing of the semiconductor, be it the fab portion, the probe portion, the assembly portion, the test portion, or combinations of those stages (mainly front-end or back-end groupings.) Some of the companies that provide this outsourcing of semiconductor manufacturing are Amkor Technology[46], ASE Inc.[47], and STATSChipPAC[48], all of which have worldwide operations as well. This means that companies like Freescale incorporate their locations as part of their supply chain, thus growing even larger and possibly facing more issues in terms of transportation or other.

Extreme Lead Times

Earlier we identified how the semiconductor industry had long lead times. Freescale also suffers from this same affliction, in which products cannot necessarily be finished quickly, but need long notice in terms of receipt of orders to be able to accommodate the manufacturing process. Research was able to find that there were some products being offered by Freescale distributors, such as Mouser, with lead times of up to 26 weeks for Freescale's MC13783JVK5R2 or its MC13783JVK5 power management controllers[49]. This means that unless Freescale considers these products important enough and has a plan in place to source them in case of an accident, if an issue arises with a shipment after it has been processed for 20 of the 26 weeks, then it will take another 26 weeks to be able to cope with the issue.

Customer Requirements

As found in the research by iJET, 49% of respondents agreed customers are drivers of the need for effective business continuity planning. Freescale is no exception to the rule. By having over 10,000 customers, Freescale must ensure to have a robust business continuity plan to accommodate customer audits and assure customers that measures are in place to protect Freescale in case of an eventuality which could potentially hurt Freescale's operations.

Semiconductor Market Cyclical Nature

The semiconductor industry suffers is often described as cyclical, which means that "semiconductor companies face constant booms and busts in demand for products"[50]. This means that when the times are good, they are good; when the times are bad, they are bad. Figure7 below shows the year-on-year changes in semiconductor revenue from January 1996 to January 2010.

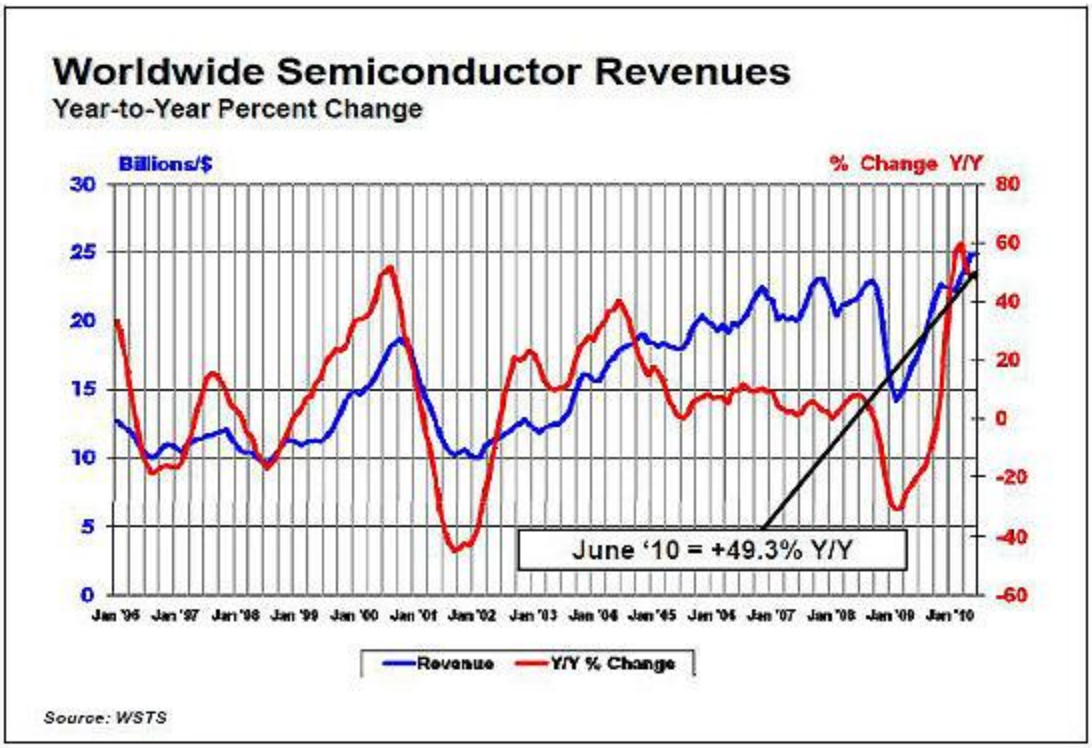

Figure 7: World Semiconductor Revenues. *Source*: WSTS

The cyclicality of the industry can be seen clearly in this chart: high revenues followed by low revenues and so on. This is something that affects semiconductor companies because it has multiple negative effects when the industry experiences a down cycle: companies undergo layoffs, good personnel chose to leave the company, and expenses are kept at a minimum, which can affect a company's ability to survive in case of a catastrophe.

Business Continuity Considerations in Semiconductor Manufacturing

The above list is not an exhaustive list of drivers for business continuity, but do pose interesting and complex questions that must be analyzed by the creators of the Business Continuity Plan for any semiconductor company. The below section provides a couple of considerations which could be considered by as part of business continuity for these types of companies.

Dual Sourcing – Internal, External, Mixed

Dual sourcing can be described as being able to do either steps or entire stages of a manufacturing process through more than one avenue. Internal dual sourcing could be:

1. The internal manufacturing location has extra equipment, which either sits idle or the all equipment does not operate at top capacity levels, thus leaving area to process extra requirements if needed.
2. The company has two different manufacturing locations which can accommodate producing the step or stage of product technology in question.
3. A combination of 1 and 2 above.

External dual sourcing would represent when the product can be processed through one or more subcontractors, depending on the company strategy. In this case, the company would not perform that particular step or stage of the process internally. The final case, which is probably more common for Integrated Device Manufacturers (IDMs) like Freescale, is a mixed sourcing approach.

Obviously, when we are talking about semiconductor companies, which seem to have very prolific product portfolios (Cypress Semiconductor offering 4,070 products[51], for example), the company would have to conduct an analysis to identify which technologies should be dual sourced, since not all technologies or products might be worth the investment which would be needed. Whenever a technology is to be manufactured in a different place, be it internally or externally, the manufacturing process must endure a period of qualification, which generally consists of three steps[52]:

1. Identify potential failure modes and failure mechanisms that the process change may bring about;
2. Subject samples to the appropriate reliability stresses to accelerate these potential failure mechanisms;
3. Test the samples to determine if they are still acceptable after completing the reliability stresses.

These qualification processes take time, and if they are unsatisfactory, then even more time will be needed. Qualification processes are usually conducted when a new product is created, or when the product will be manufactured in a different location. Lots of time and money is invested. Based on this description, it is evident that in a case of an emergency, a new site cannot be brought up to speed that easily to accommodate a new process. In July 2009, Peregrine Semiconductor Corporation and MagnaChip Semiconductor Ltd announced the completion of the 9-month long transfer of process technology from Peregrine to MagnaChip, which was considered short due to a standard foundation[53]. A long qualification time, coupled with the long semiconductor lead times, make any site qualification an investment of the company to be made when developing a continuity plan. Dual sourcing must be a way of conducting business to ensure that negative effects are reduced or eliminated in case of, say, a disruption of transportation or an earthquake.

Inventory Build Up

Carrying inventory can sometimes be viewed as a negative thing, especially in semiconductors whenever the industry is experiencing one its cyclical downturns. In times like these, inventory is viewed as cost that is being carried that needs to be reduced. For critical product, and again it should be clearly identified which product should be carried as inventory, it could be a lifesaver in cases of an unplanned eventuality. As discussed earlier, just due to the nature of the semiconductor manufacturing process, excess inventory can arise. In order to limit excess unwanted inventory, companies implement minimum order quantities, which help them reduce the risk of holding extra inventory which could be unsellable. These ordering quantities can and should vary by product, based not only on the ranking of the product (e.g. top seller versus minimal sales), but also on the manufacturing process and lead time associated with the product. Freescale's MC56F8006VLC microcontroller has a minimum quantity of 1,250 units[54], while their MC56F8002VWL has one of 26[55].

Inventory build-up, just like dual sourcing available, implies extra investment which must be placed by the company to ensure that risk is minimized in case of an unplanned eventuality. This investment should be approved by senior management, and also upheld during times of crisis and economical downturn conditions, since cutting funding could put semiconductor companies in a precarious position ant not allow them to be able to overcome a rough time. Below, we will discuss some of these challenges that semiconductor companies could face while developing and implementing their business continuity plans.

World Economy as a Challenge to Business Continuity Planning in Semiconductor Manufacturing

The economy will affect every industry in the world. However, as described above, besides the normal economic challenges normal industries face, the semiconductor industry has its own revenue cyclicality as another challenge that affects their survival. As it can be seen in Figure 8, during the last economic downturn, the overall semiconductor revenue had a sharp decline year-on-year.

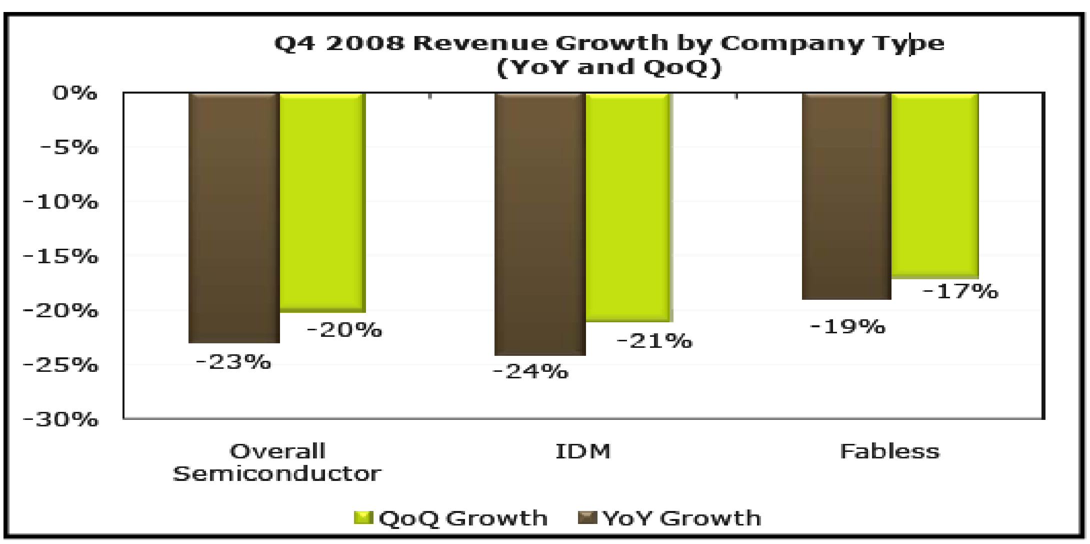

Figure 8: Q4 2008 Revenue Growth by Company Type. *Source*: Global Semiconductor Alliance

IDMs, such as Freescale, experienced a year-on-year revenue decrease of 24%, while fables companies, such as Qualcomm, suffered a decrease of 19% in revenue. These decreases in revenue had a great impact on semiconductor companies, as can be seen in a KPMG survey of the top 100 semiconductor companies, conducted in Q4 of 2008, predicting company behaviors for Q1 of 2009. Table 9 shows a selection of the findings of the survey, versus the results to the same questions from the previous year's survey.

	2007	2008	Delta
Semiconductor Revenue Growth in the Next Fiscal Year	99%	49%	50%
Semiconductor-Related Capital Spending (Equipment and Software) over the Next Fiscal Year	22%	45%	23%
Semiconductor R&D Spending Increase over the Next Fiscal Year	75%	28%	47%
Global Semiconductor Workforce Decrease in the Next Year	10%	54%	44%

Table 9: Semiconductor Industry survey results year-on-year change (2008 vs. 2009). *Source*: KPMG

From these results we can see that the forecast for 2009 for the semiconductor industry was bleak. Major points to discuss here are the fact that revenues were expected to decrease substantially, versus the high expectation of revenue increase in 2007 (for 2008); the reduction of capital and R&D spending, which could be directly related to business continuity, since it takes capital investment to be able to accommodate business continuity planning (e.g. buying capacity in subcontractors, equipment purchases, qualification process); and the reduction in workforce, which again is a natural reaction to downtown in this industry. This workforce reduction can be considered as another hit to business continuity, since the moment the economy improves, these companies will being rehiring. When this rehiring happens, it might not be the same level of qualified individuals which were laid off during these reductions, thus ending possibly spending more money in bringing new individuals up to speed by taking time, money and training to do so. It is clear to see from these results that the economy proves to be a big challenge to a company's business continuity plans.

The same survey was conducted towards the end of 2009, and it painted a better picture, as can be seen in Table 10.

	2008	2009	Delta
Semiconductor Revenue Growth in the Next Fiscal Year	49%	92%	43%
Semiconductor-Related Capital Spending (Equipment and Software) over the Next Fiscal Year	45%	9%	-38%
Semiconductor R&D Spending Increase over the Next Fiscal Year	28%	72%	44%
Global Semiconductor Workforce Decrease in the Next Year	54%	16%	-38%

Table 10: Semiconductor Industry survey results year-on-year change (2009 vs. 2010).
Source: KPMG

In Q4 of 2009, the semiconductor industry was more optimistic about 2010, which has realized itself. The Semiconductor Industry Association (SIA) announced in August of 2010 that the year-on-year change in revenue in July 2010 was of a positive 37% increase over the same month in 2009[55]. This forecast should have proven positive for business continuity purposes, but it does not diminish the fact that economics impact a company's behavior towards spending, and that that behavior can affect business continuity. It is important to notice that it just takes one catastrophe to put an unprepared company at risk, and if this catastrophe were to happen during a year such as 2009, effect could be much worse than during a more positive year, such as 2010.

V. CONCLUSION

Business Continuity Planning, or BCP, is a critical component of a company's ability to withstand the effects of an unplanned eventuality, be it a negative one, such as an earthquake, or a positive one, such as an unexpected surge in demand. Semiconductor companies, in particular, could benefit from a robust business continuity plan which should tackle major risks to its operations, be it due to the external factors, such as environmental catastrophes or due to the complexity of its own manufacturing process.

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