SYSTEMS LEVEL APPROACH TO PROCESS IMPROVEMENT INITIATIVES IN A SEMICONDUCTOR MANUFACTURING ENVIRONMENT

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Submitted to the Sloan School of Management and the
Department of Aeronautics and Astronautics Engineering
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Abstract

Many successful companies have difficulty implementing large-scale change initiatives such as Lean, Six Sigma, outsourcing or Advanced Process Control. This can often be due to the fact that they treat large-scale improvement efforts in the same way that they handle smaller improvement efforts. Instead the author suggests that companies should take a more systemic approach to implementing large-scale improvement efforts and handle them differently from other improvement efforts.

The suggested systemic approach involves four major aspects. The first aspect is to subdivide the initiative into smaller more manageable phases. The next aspect is to analyze each of the individual steps independent of each other. From there the change agent should examine the interdependencies between different steps and assess the systemic relationships of the initiative. Finally the approach suggests ways to look at the financial impact of the large-scale effort and ways to ease its implementation.

Specifically the research focused on a Fab-Wide Process Control improvement initiative at Intel's Fab 18 in Qiryat-Gat, Israel. The research is used to validate the suggested systemic approach as well as highlighting additional leadership challenges concerning the strategic design, cultural and political challenges an organization faces in implementing large-scale change.

Thus, the goal of this thesis is to create a process by which companies can easily take a systemic approach to large-scale improvement initiatives. This should help companies with the implementation of future large-scale improvement efforts.

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First and foremost I would like to thank my parents for instilling in me the value of education. By dedicating your lives to educating others, you have set a great example for me to always seek education for myself. Hopefully this will be the last of the formal education though as the bills are piling up pretty substantially.

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Next I would like to acknowledge the Intel Corporation for their dedication to the LFM program and education in general. Specifically I would like to thank all of those at Fab 18 who helped to ensure that my stay in Israel was as enjoyable as possible and my research was completed successfully.

Finally I wish to thank my other friends and family who have educated me in ways that you cannot experience in the classroom. I've been blessed with three wonderful siblings and numerous friends who are as close as family. Throughout my life you have always been there to point out my stupidity, which can sometimes be the first step in learning. Other times it is just annoying. But I guess you need to take the bad with the good. On that note, I present my thesis.

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Chapter 1: Introduction and Overview

As global competition and other complexities continue to grow it is essential that companies seek new methods to improve efficiency in order to reduce costs and increase value. This is especially true in manufacturing industries with the benefits of such improvement initiatives as Lean, Reengineering, Total Quality Management (TQM) and Six Sigma (just to name a few) readily documented. In spite of this acknowledgement of potential benefits and often times the necessity of implementing such programs, companies often struggle to effectively launch new initiatives. This chapter will discuss the author's research motivation and decision to write a thesis examining how to help companies improve their adoption of new initiatives. In addition it will go over the structure and framework for the remainder of the thesis.

1.1 Thesis Motivation

As highlighted above the current manufacturing industry is going through a level of challenges that it has never faced before. It is truly becoming a global economy with products available to be manufactured almost anywhere in the world and then available for sale almost anywhere else in the world. This has created wonderful opportunities for consumers, but has forced traditional manufacturers to re-examine ways to stay competitive. Companies located in higher wage regions have sought new initiatives to improve their operational efficiency and productivity since they cannot compete on labor costs with the lower wage regions of the world. This has led to the adoption of increased automation, Lean techniques, Six Sigma/TQM quality initiatives, outsourcing, organizational Reengineering, Advanced Process Control (APC), and many other improvement programs.

Ironically companies that have traditionally been the most successful are also those that are facing the most difficulty adapting to the new environment. This can be seen in the current issues facing General Motors and Ford. James Womack, co-author of *The Machine that Changed the World*, attributes their current financial worries not to labor or pension problems, but rather to their inability to adapt to a changing environment [1]. This problem adapting is by no means isolated to the automotive industry either. Industry leaders spanning the range from Aviation [2] to Semiconductors [3] have seen decreasing profitability and increasing challenges. Often solutions have been identified and applied by competitors and therefore the major problem is not determining how to react, but rather actually reacting and making the necessary changes.

The author sought to conduct research to help examine why companies that have a history of success in making small scale continuous improvement have such difficulty implementing large-scale improvement initiatives. Specifically the author focused on one specific effort to improve Advanced Process Control (APC) and an Intel semiconductor fabrication facility (fab). By examining this process improvement initiative the author was able to determine some of the key aspects required to make a large-scale improvement effort successful. Although the research was conducted on APC at a semiconductor company, the author feels the findings are relevant across most any industry regardless of the type of improvement initiative. This paper discuses some of those findings and presents a methodology that can be applied to help ease the adoption of a large-scale improvement initiative in any industry.

1.2 Thesis Structure

This thesis is divided into nine chapters described below. In addition each chapter may be further subdivided into sections and subsections as appropriate. Throughout the paper the author has cited numerous sources that validate and confirm the message the author is trying to deliver. With the exception of these citations and any direct quotations, all statements are solely those of the author based on his experience, perception and knowledge. The majority of the paper will focus on the author's research on launching an Advanced Process Control improvement project at an Intel Fab. In order to protect Intel proprietary data much of the exact data will be masked, but key relationships and the overall message will still be clear.

Chapter 1: Introduction and Overview: This chapter examines some of the reasons why the author sought to perform research of this nature, focusing on how to help companies adapt to a changing environment.

Chapter 2: Research Project Setting: This chapter examines the setting under which the research was conducted with a focus on the company (Intel Corporation), product line (Flash Memory), and site (Fab 18 in Qiryat-Gat, Israel). It highlights why this is the proper setting for this type of research.

Chapter 3: Improvement Methodology and Approach: This chapter gives an overview of the methodology and the approach the author took in examining how to launch a major change initiative, with a specific focus on the Advanced Process Control project.

Chapter 4: Decomposition into Manageable Phases: This chapter discusses the first major aspect of the change initiative methodology; decomposing the large Advanced Process Control project into manageable phases to help ease adoption and understanding.

Chapter 5: Individual Step Analysis: This chapter discusses the second major aspect of examining each improvement step individually using traditional return on investment (ROI) calculation techniques.

Chapter 6: Systemic Relationships: This chapter examines the third, and perhaps most crucial, aspect of the methodology. It gives an overview of the author's suggested method to model key systemic relationships between the individual steps.

Chapter 7: Overall Initiative Justification: This chapter goes over the fourth and final aspect of the methodology, how to examine the overall initiative as an improvement system based on the work in the first three aspects.

Chapter 8: Leadership Challenges: This chapter discusses some of the key leadership challenges many companies will face on trying to follow this methodology on their own improvement efforts. It focuses specifically on the strategic design, political and cultural challenges within Intel, but most of the issues will be very similar within other organizations.

Chapter 9: Conclusions and Future Opportunities: The final chapter concludes all of the information presented within the paper and also highlights some possible opportunities for further research and exploration.

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Chapter 2: Research Project Setting

In order to better understand the analysis and suggestions the author is presenting, it is essential to better understand the research setting. This chapter gives a short synopsis of the Intel Corporation, the sponsor for much of the research. In addition it delves into the Flash Memory sector of Intel to better highlight the competitive challenges that gave rise to the Advanced Process Control improvement initiative at Intel. Finally it will detail Intel's Fab 18 in Qiryat-Gat, Israel, the site for much of the research and the test bed for many of the ideas the author will present in the remainder of the paper.

2.1 Intel Corporation Background

Intel is a company that requires little or no introduction. It has been around since 1968 and employs nearly 100,000 individuals worldwide. It has helped to lead the digital revolution growing from its humble beginnings in Silicon Valley to nearly 200 offices around the world. It's $38.8 Billion in 2005 revenues placed it number 50 on the Fortune 500 list [4]. Although it has been recently replaced, the highly successful "Intel Inside" advertising campaign helped the company gain recognition with nearly every computer user and established Intel as a household name.

Because Intel is so well recognized the author does not feel that it is necessary to go into a wealth of further detail on the company. For more information the reader can obtain a copy of *Only the Paranoid Survive*, written by Intel co-founder Andrew Grove [5] or peruse previous LFM theses based on research projects at numerous different Intel sites [6,7].

There are a few aspects of Intel that are not as well known though and worth additional discussion, especially in how they relate to the author's research. The first of these aspects is Intel's presence in the flash memory industry. Intel is traditionally thought of as a microprocessor company, but they also have a strong presence in flash memory and Section 2.2 will discuss in further detail the flash memory industry and Intel's position within it. The other major area of interest is Intel's manufacturing operations within Israel. Although the majority of Intel's semiconductors are manufactured in America a growing number are being produced elsewhere in the world and Israel has a long standing history of being one of these other major locations. Section 2.3 will delve further into Intel's history in Israel and especially the current changes at Fab 18 as they transition from microprocessors to flash memory and why this made

Fab 18 the leading site for Advanced Process Control improvements and thus the site of the majority of the author's research.

2.2 Flash Memory Industry

There are two major forms of flash memory, NOR (Not Or) and NAND (Not And). NOR was invented by Intel in 1988 and is mainly used for applications where data integrity is extremely important such as operating system code storage on cell phones and handheld computers. NAND on the other hand was invented by Samsung and Toshiba shortly thereafter, 1989, and is used in devices that require quick read and write access such as memory cards for digital cameras and MP3 players. The two types are not interchangeable and as a result of this, most companies have concentrated their efforts on one technology or the other. Figure 1 below gives market share information for Q2 2005 [8]. As can be seen the two markets are roughly equal size, but NAND is growing at a fast rate, while NOR is actually receding.

NAND

Company	**Sales ($MM)**	**Market Share (%)**	**Year over Year Growth (%)**
Samsung	$1,250	55%	35%
Toshiba	$529	23%	18%
Hynix	$228	10%	470%
Renesas	$130	6%	2%
ST Microelectronics	$52	2%	940%
Infineon	$44	2%	340%
Micron Technologies	$39	2%	N/A
Other	$0	0%	N/A
Overall	**$2,272**	**100%**	**46%**

NOR

Company	**Sales ($MM)**	**Market Share (%)**	**Year over Year Growth (%)**
Intel	$528	28%	-10%
Spansion (AMD/Fujitsu)	$470	25%	-31%
ST Microelectronics	$243	13%	-23%
Samsung	$126	7%	-9%
Toshiba	$85	5%	-34%
Other	$408	22%	N/A
Overall	**$1,860**	**100%**	**-25%**

Figure 1: Flash memory market information for NAND and NOR in Q2 2005

Because of the current flash memory market conditions, Intel is in a position that it is not familiar with, having to compete aggressively in a highly competitive market where it does not have a majority market share. Intel has traditionally held a role of market leadership in microprocessors which has allowed it to define technology development via the famous "Moore's Law" shown in Figure 2 [9]. This has caused the company to mainly focus on improving technology via research and development of new products. In the more competitive flash memory market, costs can be just as important, if not more important than having the best technology. Figure 3 shows the disparity in market share presence between Intel's two major product lines, microprocessors and flash memory [10].

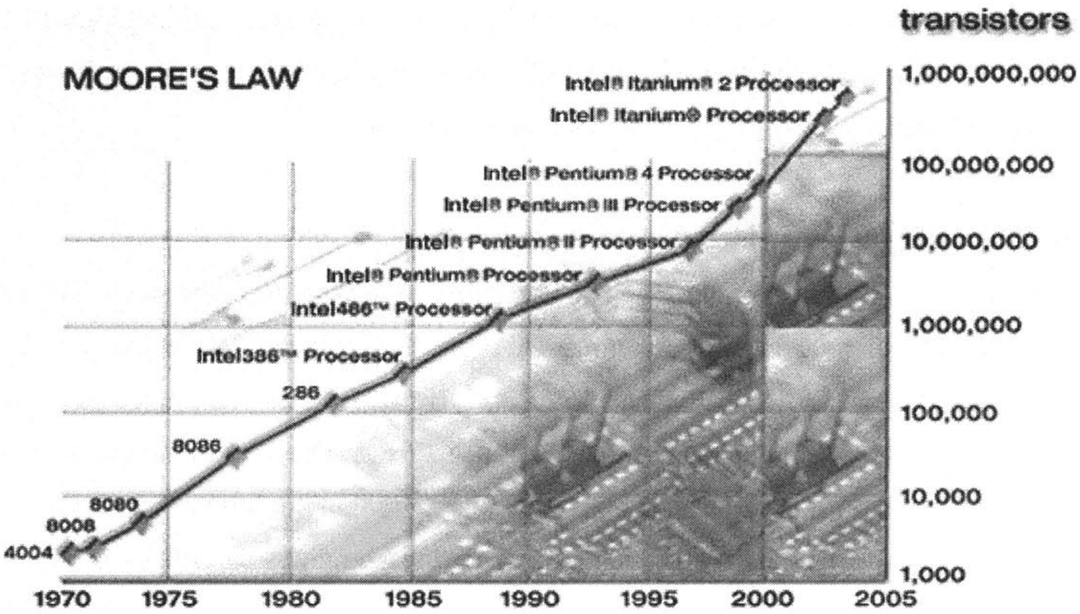

Figure 2: Moore's Law for microprocessor technology improvements

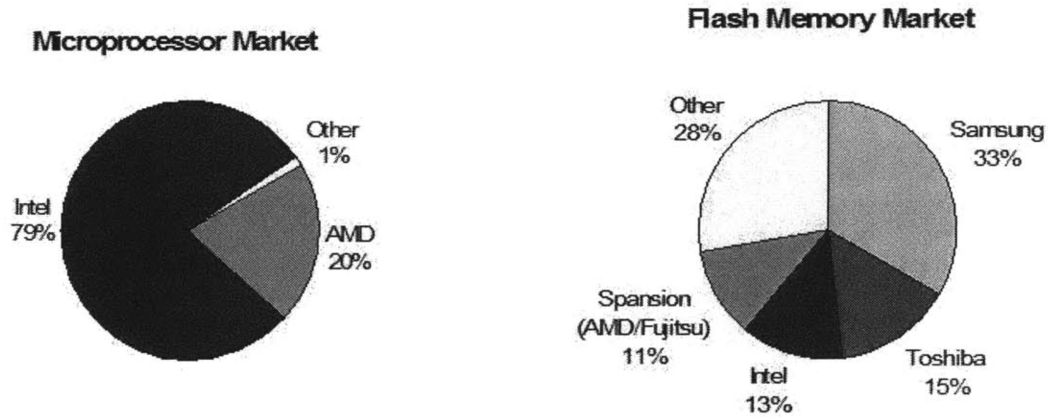

Figure 3: Comparison of market share information

These current market conditions and disparity between the NAND and NOR markets has caused Intel to take two major actions. The first was to create a joint venture, IM Flash

Technologies, with Micron Technologies in order to enter the NAND market [11]. The second aspect was to find a way to reduce the cost of producing NOR memory in order to secure margins in spite of the receding and more competitive market place. Different Intel sites are trying different operations strategies to reduce costs, although best practices are shared across multiple fabs. Some sites are examining Lean techniques while others are pursuing higher levels of automation or improved process control via APC. What they all share in common though, are the challenges of implementing large-scale improvement projects.

2.3 Fab 18 in Qiryat-Gat, Israel

Unbeknownst to many people Intel has had major operations in Israel since 1974 when they established their first technology center outside of the United States. Since then Intel Israel has grown to employ over 6,600 individuals located at five major sites. In 1985 Israel became the site of another first, when Intel opened their first manufacturing facility outside of the United States. This facility, built in Jerusalem, is one of the longest running in Intel's history and is still operating today. They expanded their Israeli manufacturing operations in 1999 by opening Fab 18 in Qiryat Gat and continue to invest in Israel with the construction of a state of the art 300mm facility, Fab 28, located next to Fab 18 and scheduled to be operational in the second half of 2008 [12].

Figure 4: The front entrance to Fab 18 in Qiryat Gat, Israel

Fab 18 has traditionally been one of the leading fabs at Intel in terms of yields and other key manufacturing metrics. This is largely due to the Fab's innovative spirit and dedicated work effort (more on this topic will be discussed in Chapter 8). In addition the Fab is currently undergoing a transition from producing microprocessor technology to flash memory technology. Because of the many challenges associated with this new market, as mentioned in the previous section, the Fab's management sought to expand on Advanced Process Control (APC) techniques to help improve product performance, equipment performance and operational stability. APC accomplishes this by using historical processing data to determine the proper process settings for each piece of equipment under different operating parameters. These operating parameters consist of such aspects as information from previous operations, duration since last maintenance process, specific fab environment conditions, product specific issues or any other source of information that is available and plays a role in influencing product performance, equipment performance or operational stability. The APC system then uses this information in order to automatically set the proper process settings on a specific piece of equipment. Traditionally APC has been focused on specific tools or operations with little data shared between different tools or different operations. Fab 18 is seeking to expand APC from this local tool level approach to a more global Fab-Wide Process Control (FWPC) approach to ensure that they can successfully meet the new challenges presented by the changeover to flash memory. This will involve the development and tracking of information for each processing step, the sharing of information between pieces of equipment, module level process optimization and eventually fab-wide process optimization for process parameter setting and also material routing.

Fab 18 was one of the forerunners in APC within Intel and no other Intel site had yet undertaken a major initiative towards FWPC. As a result of this Fab 18's management sought the assistance of the author to help them understand how to implement FWPC. The author was able to use much of what he learned within the Leaders for Manufacturing program to help Fab 18 generate a road-map they could follow as they sought to implement FWPC. More importantly though, it provided the perfect setting for the author to conduct his research, on the successful implementation of large-scale improvement initiatives. The author was able to test and confirm his hypothesis, methodology, and models that will be presented in the rest of the paper.

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Chapter 3: Improvement Methodology and Approach

To stay successful all great companies need to continually focus on improvement in both process and products. There are two major forms of improvement, small scale continuous improvement and larger scale improvement via major initiatives. This chapter will discuss why some companies can excel at one aspect or the other, but can find it difficult to do both well. It will also present the authors suggestions on how a company can strive to improve the possibility of a successful large-scale initiative implementation. Finally it will contrast the author's suggestions with some previous methods of large-scale initiative implementations.

3.1 Contradiction in Improvement Efforts

It seems that the only constant in the business world these days is that you need to focus on continually improving products and processes to stay successful. Case studies are full of examples of companies such as DEC, Pan Am, AT&T and many others that defined success in their heyday, but now either no longer exist or are shadows of what they once were. These companies come from many different industries and product offerings, but one of the aspects they share in common is that they were unable to adapt and make change when necessary. In their book on Operations Strategy, Beckman and Rosenfield talk about how:

> "In rapidly and unpredictably changing industries, it is difficult to envisage which industries, competencies, or strategic positions will be viable and for how long and the key strategic challenge becomes how to cope with ongoing and rapid change." [13]

Often part of the reason for the company's downfall was based on their previous levels of success. Hayes and Upton talk about how many companies put too much faith in their size and market position assuming that they can quickly and cheaply replicate anything a competitor may do [14]. Ohmae discusses how this view can have disastrous results:

> "Over optimism and other judgmental errors that frequently may escape serious penalty in times of prosperity may turn out to be catastrophically costly in a period of economic stagnation." [15]

Therefore it is essential that companies have a dedicated approach and prepare their organization for the necessary changes that are certain to occur if they wish to remain successful. In one of the first books ever written on strategy, *Art of War*, Sun Tzu discusses the benefits of preparedness on the military battlefield, but this also holds true on the corporate battleground:

> "Thus it is said that one who knows the enemy and knows himself will not be endangered in a hundred engagements. One who does not know the enemy, but knows himself will sometimes be victorious, sometimes meet with defeat. One who knows neither the enemy nor himself will in variably be defeated in every engagement." [16]

Very few corporate managers would argue with these statements, but yet they are still unable to make the necessary changes when the correct time presents itself.

The author's internship, thesis research and previous work experience lead him to the conclusion that one of the major causes of this, is that managers often underestimate the level of change that is required. Managers will look at what they had done successfully in the past and figure that the same approach will work again. For small scale change this may very well be true and even warranted since a company cannot try to completely overhaul itself whenever there is a minor issue. The problem is that a company may grow complacent because of their historical success with minor change initiatives and therefore be unable to recognize when or how to implement a large-scale change initiative when it is required. Ironically the companies that are the most successful with continuous improvement also tend to be the companies that have the hardest time making a large-scale change. This is one of the reasons why companies turn to consulting firms to help lead large-scale change. The consulting firms do not concentrate on what the company has done well in the past, but rather what the company needs to change in order to be successful in the future. In his book *Value Migration*, Adrian Slywotzky discusses the value an outsider can have to help lead change:

> "It illustrates why so many outsiders have been brought in to save large, previously successful organizations. A newcomer is unencumbered by the organizational rules that created past success. A newcomer has zero mental space devoted to maintenance of an historical business design." [17]

This reliance on consultants to lead large-scale change can be inefficient and wasteful for an organization. Having a few select individuals in charge of leading change, whether from within the organization or from outside consulting firms, will never produce the full potential benefits from that change. Large-scale change initiatives require the involvement of the entire organization from top level management all the way down to the line level workforce. Shah's research demonstrated that even in environments where major change initiatives, such as RFID deployment, are being mandated by the government or upper level management it can still be difficult to implement and obtain the full benefit from any necessary changes [18].

In the next section the author will present a simple approach that companies can follow on their own in order to ease the implementation of any large-scale change. It will use the author's research on an FWPC large-scale change initiative at Intel's Fab 18 as a backdrop, but the ideas and methodology will hold true for most any improvement project, from Lean manufacturing to product development.

3.2 Systemic Approach

As products and processes become more interrelated the next source of competitive advantage will be the ability to create an organization that can think systemically. Research conducted by Sterman has shown that companies that engage in systems level thinking outperform those that focus on product level strategies [19]. Building an organization that can think systemically is easier said than done though. Historically western education systems have focused on individual areas of concentration without a dedication to examining the interrelationships between different decisions. This has created a business environment where large-scale projects are broken down into smaller pieces for ease of management, an often required task, and an attempt is made to optimize each piece independently. A major issue with this approach is that the best option for any given piece is mostly likely not the best option for the entire system. Even worse this creates the possibility that important pieces of the entire system may be ignored completely. In his book *Lean Production Simplified*, Dennis Pascal talks about how:

> "Lean production is first and foremost a system, that is, an integrated series of parts with a clearly defined goal. One of the problems with lean implementation has been the tendency to cherry-pick activities, rather than grasping the system as a whole." [20]

To help and try to rectify this issue the author presents a simple approach and methodology that companies can follow in handling large-scale improvement projects via a systemic viewpoint.

Initially it is important to keep the methodology as simple as possible, in order to avoid any unnecessary confusion that will create an aversion to the systemic approach on future initiatives. As companies become better versed in systemic thinking the methodology, approach and models can become more developed. The simple approach the author suggested to the management of Fab 18 for their FWPC initiative consisted of four major aspects. The first aspect is to break the larger project into manageable phases, each composed of multiple steps.

The second aspect is to examine each step individually. The third aspect is to examine the interrelationships between each of these steps and how they fit into the greater system of improvement. The fourth and final aspect is to recombine the individual steps and present the overall initiative justification.

The decomposition of a large-scale initiative into manageable phases is necessary in order to prevent an organization from becoming overwhelmed. Projects lasting multiple years and requiring involvement from numerous individuals can seem quite daunting and therefore human nature is to try and avoid them and concentrate on simpler tasks. Although the actual number of phases and the length of ease phase will be dependant on the particular company and initiative, Chapter 4 will discuss the decomposition process at Fab 18.

The individual step analysis is very similar to the process currently practiced by many major companies such as Intel and General Electric. It involves taking each individual step within a phase and analyzing it based on expected costs, benefits, and probability of success in order to calculate a comprehensive return on investment (ROI) for that step. Chapter 5 discusses this analysis approach for the FWPC effort at Intel, but most readers will notice very similar techniques practiced at companies they have worked with.

Perhaps the most important aspect is the examination of the systemic relationships between the different individual steps. Although each step may not be warranted independently it may make sense when examining the role it plays in ensuring the success of other steps. Chapter 6 will highlight one simple method to examine the systemic relationships between different steps.

The final phase is recombining the individual steps into a cohesive package based on the systemic relationships between each step. When examining a large-scale improvement initiative it is important to make decisions on the system as a whole, rather than on the individual steps. Chapter 7 discusses how the same initiative can appear very different when looked at as a system of improvement rather than a group of individual improvement steps.

3.3 Contrasts with Previous Approaches

Part of the power of the suggested systemic approach is that it is simple and similar in many ways to the approach currently taken at many successful companies. In addition there are certain ways where it builds upon current approaches or is completely different. This section will highlight some of these major differences and illustrate why the author feels this new systemic approach is an improvement upon traditional improvement methodologies.

The first area where the systemic approach is different is in how it suggests that large-scale change initiatives are different from small scale continuous change initiatives and therefore require a different outlook and completely different approach. This is confirmed by the research others have conducted around this area. Moyne discusses how the future developments in semiconductor APC will require a whole new control hierarchy. He discusses how fab-wide control will require a step change and cannot be obtained by further improvement of the current methodology [21]. Companies need to be able to determine when a continuous improvement methodology is sufficient and when a systemic approach is required due to the need for large-scale change.

Another major difference in approaches to large-scale improvement initiatives is the method they use to handle interrelationships between different steps. Traditional methods, such as Gant Chart scheduling treat different steps as either fully linearly dependant or fully independent. Gant Charts do not accurately account for different levels of interrelationships. Certain steps will be fully dependent on previous steps in which case a Gant Chart approach, whereby a step cannot be started until the prior step has been completed, is the proper method to follow. The systemic approach suggested by the author allows for different levels of interrelationship though. As Chapter 6 will highlight, the systemic approach allows for multiple levels of interrelationship between different steps. The author feels that this approach is more accurate because often a step is not fully dependent on prior steps, but rather there are different levels of dependence. For example certain steps can be completed without first finishing the prior steps, but the completion of the prior steps will make the downstream step easier to complete. This difference in handling interrelationships is one of the most important aspects of the author's suggested systemic approach.

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Chapter 4: Decomposition into Manageable Phases

The first part of any large-scale change initiative is to identify ways to simplify it into manageable phases, while making sure to maintain the full initiative perspective. This is essential for multiple reasons. First and foremost a large multi-year initiative can seem daunting and thus delay efforts and support. Secondly by splitting a larger initiative into smaller phases it can be easier to recognize the successful completion of intermediate steps in order to gain support for the future efforts. Additionally by splitting a large-scale initiative into multiple smaller phases the change agent will find it easier to manage and properly allocate resources. This chapter will discuss each of these aspects in more detail concerning how they relate to the FWPC effort at Fab 18, as well as drawing corollaries on how they correspond to other large-scale change initiatives. Finally the chapter will conclude in highlighting how although it is necessary to sub-divide a large project into smaller phases, it is essential to not lose the understanding of how it is still an overarching system of change and not a group of smaller efforts.

4.1: Simplification

It is human nature to want to concentrate on simple efforts in order to recognize quick accomplishments. This is especially true when people are extremely busy and have a long list of tasks to complete. It seems to be much more satisfying to cross off multiple smaller tasks than a single large task, even though the larger task may be of larger importance. Companies are no different. There appears to never be a shortage of potential projects in the pipeline. Unfortunately there normally is a shortage of resources to work on all of the potential initiatives, and therefore it is important for a change agent to make their initiative appear as favorable as possible. For change agents trying to implement large-scale changes this is not always an easy task. By their very nature large-scale change initiatives are a system of changes that require substantial effort and time in order to fully accomplish. This can lead to a high level of uncertainty in the end results, especially since they may be years away. This combination of uncertainty, substantial effort and lengthy timeframe can cause management to allocate constrained resources to simpler, shorter and more certain smaller efforts. These small changes often do not hold the full possible benefits of a large-scale change, but are easier to comprehend and thus easier to support. The challenge for a change agent is to make the large-scale change initiative as easy to comprehend as these smaller efforts. This is possible by splitting the effort into multiple smaller phases that are easier to understand. Large-scale change initiatives are often already composed of multiple steps and projects, but by grouping these steps into phases the systemic approach can be maintained while still simplifying the overall initiative. Figure 5 shows the phase breakdown for the FWPC effort at Fab 18.

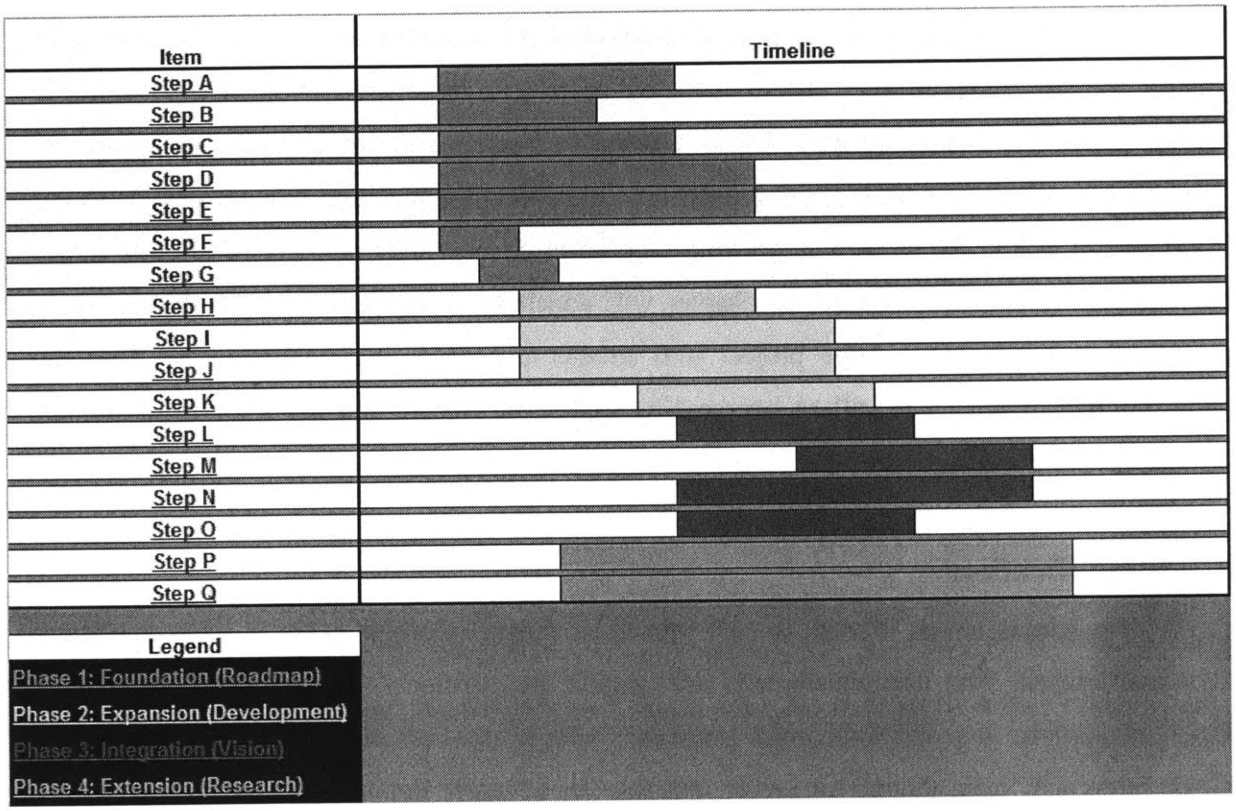

Figure 5: APC initiative decomposed into different phases

The actual step descriptions and timeline have been removed to protect Intel proprietary information, but the message is still quite clear. The figure shows that the overall initiative has been split into four different phases, each composed of between two and seven steps. The number of phases and steps is not of major importance and will depend on the particular initiative in question. For the FWPC effort this phase allocation made sense for two major reasons. First the phases correspond to roughly the different periods of the initiative. Secondly the length of the phases roughly corresponds to the strategic planning length within the fab.

The first phase is the foundation phase where the initial efforts are started to build support for future efforts. The second phase is the expansion efforts to grow the FWPC initiative beyond the initial foundation steps. After that it is important to integrate the FWPC efforts towards creating a cohesive whole. Finally is the extension phase that extends the FWPC efforts across other areas of the plant not traditionally associated with APC. Anyone involved with the FWPC initiative can relate to these phases and understand where their efforts should be concentrated and the current status of the initiative.

The length of these phases is also very important. In the case of the FWPC initiative, each of the phases tends to be roughly the same length as the budgeting horizon at Fab 18. The fab does an exceptional job of daily operations and focuses much of its effort in this regard. Thus a major initiative that is requesting resources for upwards of five years in the future may be seen as a lower priority, even though some of those resources will be needed immediately. By dividing the larger initiative into smaller phases the change agent will be able to request resources inline with the budgeting schedule of the fab. Initial requests made for the foundation phase will be of the most interest to the fab and therefore more likely to be accepted. Although with dependent phases the fab will be partially committing to the entire initiative by accepting the first phase, the author's experience has shown that it is easiest to just get your foot in the door with acceptance of the first phase. By having the other phases listed in the pipeline, the fab management will not lose track of them, but will also not be overwhelmed by them. Future phases will need to obtain funding as they come closer to their starting point, but as the next section will highlight this becomes easier to accomplish after successfully completing the current phase.

4.2: Building Support

The second major benefit in subdividing a large-scale initiative into smaller more manageable phases is that it helps garner support for both the later portion of the initiative and also the entire initiative overall. The previous section mentioned how the simplification aspect of the subdivision makes it easier for the management to understand the initiative and therefore support it. This provides the ability to gain support and resources for each different phase separately. In addition there is another opportunity to highlight the success of previous phases to build support for the future phases.

Often huge initiatives can seem daunting to a management team and the future seems to be so uncertain that there is no way to accurately predict the expected benefits. The change agent can highlight the large potential benefits, but the uncertainty can cause management to allocate limited resources to other areas initiatives with shorter durations where there is less uncertainty, but also lower potential, in the results. It is an easily understood relationship that as the amount of time before a benefit is recognized increases, the uncertainty associated with the value of that benefit will also increase. Therefore it is up to the change agent to make the benefits of their long term large-scale change initiative appear to be as certain as possible. Seldom can the duration of such an initiative be shortened and thus the change agent needs to look at other ways to decrease uncertainty. One of the easiest methods is by subdividing the initiative into smaller phases. The length of each of these phases will be much shorter than the overall total length of the initiative and therefore the earlier phases will have a higher certainty associated with their expected benefits. Coincidentally these are also the benefits that are of the most interest to the management team initially. The benefits from future phases will still have a high rate of uncertainty, but this can be mitigated by the fact that when the resources for them are needed there will be less time to phase completion and therefore less uncertainty. The change agent can also reference the success from the previous phase to build support for the future phases. In *True Change*, Klein discusses the benefits of starting with small wins to gain traction for a larger initiative. As these initial efforts are recognized the organization will pull future change efforts and thus provide them with more support and a higher probability of successful implementation [22]. This is one of the key aspects of building support for a large-scale change initiative.

4.3: Project Management

The final positive aspect of the subdivision into smaller more manageable phases is the reduction in the amount of effort required to manage the project. Much in the same way that subdividing the initiative into smaller phases simplified it for management to understand it also simplifies it for the change agent to keep track of. Rather than having to worry about a huge initiative with numerous corresponding steps the change agent can concentrate their project management efforts of the current and next phase. This means that as the project develops the change agent will only need to worry about adapting a subset of the total initiative at any given time. This may involve altering current steps, adding additional steps or even eliminating steps that may become irrelevant as additional information becomes available.

In the example of Fab 18 this means that the change agent can spend the majority of their time ensuring that the foundation phase is running smoothly and that everything is aligned to make the expansion phase successful. This involves only having to concentrate on 11 steps versus the full complement of 17 steps. As the foundation phase draws to conclusion the change agent can shift their efforts to concentrating on ensuring the success of the expansion phase while aligning everything for the integration phase and so forth. This makes the project management aspect much more feasible for the change agent to handle according to the company's best practices or the change agent's personal preferences in management techniques.

To simplify the management of the initiative even further the subdivision allows for multiple individuals to manage each phase separately while the change agent oversees the entire initiative. If the initiative is kept as one overarching effort it is inefficient to have too many project managers, the old too many cooks in the kitchen adage. The subdivision allows for the efficient use of the same number of project managers, but each focused on a specific phase and thus not getting in each others way.

4.4: Maintain Systemic Approach

While there are many benefits to subdividing a large-scale initiative into smaller more manageable phases, the author must caution towards some of the risks of taking this approach. First and foremost the change agent must ensure that everyone does not lose sight of the fact that this is the first step in a systemic approach to tackling large-scale change initiatives and not the creation of multiple smaller scale changes. The change agent must always keep in mind that these different phases are still part of a larger systemic whole and cannot be treated with no degree of dependency. In addition the change agent needs to ensure that others share this vision of a large systemic project composed of smaller phases and not multiple different, independent initiatives. If the different phases are seen as fully independent it may present a situation where management may try to pick and choose which phases they want to concentrate on. This approach will not allow for the total potential benefit and will also neglect some of the interactions that lead to the systemic approach being the optimal methodology. Chapter 6 will discuss in further detail how to generate some of the interrelationships between phases and different steps, but the author wanted to caution against taking too independent of a view on the first step of the suggested systemic approach.

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Chapter 5: Individual Step Analysis

The second part of the systemic approach, to large-scale improvement initiatives, involves further examination of the individual steps. After the initiative has been subdivided into smaller, more manageable phases it is necessary to examine each of the steps that contribute to a phase individually. This individual analysis is required because it allows for the simplification of the analysis process and also because it can be useful for better comprehension of each step that makes up a larger initiative. If the change agent tries to forego individual analysis and instead skips right to the analysis of the entire system, he may overcomplicate the process confusing both himself and those that need to approve the initiative. The next chapter will discuss how to account for the interrelationships between different steps and how they fit into the entire system of improvement. For now though the concentration should be on treating each step individually, as if they were a set of smaller scale change projects. As a result of this the individual step analysis will be very similar to the process for justifying smaller scale change projects. First the change agent must ensure that the proper data is available in order to perform any sort of step examination and then the change agent should perform return on investment (ROI) calculations for each step, based on the available information. The major difference between individual step analysis and smaller scale change projects is that the analysis performed is not used to justify the validity of each step, but rather as an essential aspect of the systemic approach. At this point the change agent must fight the pressure from management to justify each step based on the individual ROI calculations. The full value of each step will not be evident until after a better understanding of the interrelationships between steps is obtained. Therefore the next chapter will discuss the process for individual step justification. For now it is simply important to ensure that the calculations are completed as accurately as possible. The following two sections will discuss how to accomplish this task, with a specific focus on the FWPC improvement effort at Intel's Fab 18.

5.1: Information Gathering

Information is the lifeblood of any improvement effort. Proper data is essential to understanding where improvements are necessary, how to make the improvements and finally how to gain buy-in for any improvement suggestions. In a data driven organization like Intel, the gathering and analysis of data is required for any project or initiative to be deemed important enough to invest in. The greatest of ideas remain only ideas, unless the change agent can gather the data to back up their hypotheses. Perhaps W. Edwards Deming said it best in his famous quote, “In God we trust, all others must use data.”

The change agent needs to ensure that the data they are gathering provides valuable information, otherwise it will be a waste of time and effort to gather a bunch of data that does not impact the improvement effort. Therefore it is essential that before any data is gathered the change agent thinks about what type of information is going to be required, for any specific initiative, and determines the best way to obtain the required data. After the data gathering has commenced the change agent may realize that he needs additional information or perhaps that he has gathered unnecessary information that is not actually needed. This is perfectly acceptable, as information gathering is a dynamic process that lasts over the entire duration of an improvement effort. There needs to be a starting point though and the change agent should make his best guess as to what sort of information is going to be required. This determination of important information will most likely be unique for each effort, but will be similar to past efforts and therefore a change agent can leverage their own experience as well as advice from trusted peers.

A common pitfall in data gathering is that data is not readily available. This can cause the change agent to either ignore that type of data outright or else to spend too much time trying to gather the perfect data. When talking about previous modeling experiences, Sterman recognizes that the perfect data may not always be available and therefore it is best to draw on the best available data sources and used expert judgment and qualitative data when quantitative data is not available [23]. Likewise the change agent should take their best guess or even better take a survey of experts in order to try to gather informed estimates or qualitative feedback when there are data gaps.

For the FWPC improvement effort at Fab 18 the author gathered data in four major categories for each step in the initiative. These categories are the potential benefits, required resources, step schedule and probability of success. These data categories are chosen because they will provide all of the necessary information to take the systemic approach to examining this large-scale change initiative. To determine that these are the correct data categories the author examined previous APC efforts within Intel, APC efforts within other companies in the semiconductor industry and research studies conducted by the Sematech consortium. In addition he solicited feedback from experts within Fab 18 as to what sort of data has traditionally been needed to obtain management approval for similar improvement initiatives at Intel.

5.1.1: Potential Benefits

The first key data category is the determination of potential benefits from each step of the improvement effort. Although each step may have different types of benefits it is essential to use a set of standard groupings that all steps will be examined against. Even though a step may not provide any benefit within a specific grouping it is still essential to examine the step against that grouping as the grouping is essential to the overall system of improvement. The determination of the specific groupings for the FWPC initiative is based on industry standards. In a presentation given at the annual Sematech AEC/APC conference, Stanley [24] highlights the seven major cost areas where APC can be beneficial:

1. Rework Reduction
2. Scrap Reduction
3. Labor Productivity
4. Yield Improvement
5. Material Savings
6. Capital Savings
7. Cycle Time Reduction

These are the same groupings that are used for the FWPC initiative at Fab 18 as they cover the full spectrum of possible benefit areas. Each step was examined against these seven groupings to first determine the expected benefit in the raw units of each grouping. For example cycle time reductions were determined based on the total number of hours or even days that the step will reduce in total production cycle time. This raw data was then monetized by determining the dollar value benefit. For example if each hour of cycle time reduction is worth $2,500 (for example only, not actual value), a project that saves 2.5 hours would have a monetary benefit of $6,250. These correlations between raw data and monetary value should be determined with the help of the finance department and are essential in order to balance the benefits from different groupings and also to summarize the total potential benefits from each step in a single value. Finally the net present value of each benefit should be calculated based on the step schedule determined in sub-section 5.1.3.

5.1.2: Required Resources

The second category of essential information involves the resources that are required to properly complete the step in question. These resources are composed of two major aspects; step costs and step owners. Further details on these two aspects can be found in the following paragraphs.

Similar to the potential benefits from each step, the change agent must also determine a standard method to determine costs associated with each step. These costs fall into traditional groupings such as capital investment, labor, software, etc. Each company and each initiative will have a slightly different set of cost groupings, but once again it is essential that the same cost groupings be used for each step within an initiative. The standard groupings allow for easy comparison of different steps and simplified cost calculations. Not every group will have an associated cost for each project and this is not an issue as long as all cost groups have been examined for each step. For the FWPC effort at Fab 18 the cost categories are labor (development and sustaining), software, capital, wafers/material and other. These five costs categories were examined for each step in order to determine the total cost associated with that step. Again the first step is to examine the costs in raw units. For example labor was determined based on man hours required and wafer costs are initially in units of wafers. After the data is calculated in raw units the change agent should work with the financial department to determine the financial impact of the different costs. The change agent should then sum the total financial costs associated with each step and determine the net present value of the costs based on the schedule in sub-section 5.1.3.

The second resource area involves identifying candidates to own each of the individual steps. The change agent will most likely be the owner of the overall large-scale change initiative, but it is also essential to determine owners for each of the individual steps. These will be individuals that will work with the change agent to implement the different steps. Most large-scale change initiatives are too intensive for the change agent to handle all by themselves so the individual step owners provide assistance in managing the individual steps as well as providing a source of internal knowledge within a functional area. These individual owners should be local experts who are committed to the overall initiative and can assist the change agent in gathering the essential step information (potential benefits, associated costs, schedule, and probability of success). For the APC effort at Fab 18 the author identified two owners for each step although certain owners owned multiple steps. This redundancy of two owners helps ensure that there is always someone owning each step even if one of the owners transfers to a new position or leaves the company. This is especially important because owners should be identified for future steps as well as current steps and the beginning of any initiative, even though the majority of their effort will only be needed when the step is in full swing. This identification of all owners at the launch of any large-scale initiative is necessary in order to help facilitate the ROI calculations and step justification. The owners can change over the course of an initiative, but new owners should be identified as soon as a former owner moves on. These owners are an essential resource in the successful implementation of a large-scale initiative and the change agent needs to make sure that they spend time identifying the correct candidates. Otherwise it will be much more difficult to gather the essential information and gain buy-in for the initiative.

5.1.3: Step Schedule

The next area of information pertains to the schedule of each step. This involves determining the duration of each step as well as the best time for the step to commence. The change agent should work with the individual projects owners in order to determine this data.

By working with the individual step owner the change agent can determine the expected duration for each step. This is important in order to understand how long the resources will be required for, as well as when benefits can be expected to start showing up. Also understanding the duration of each step is helpful in order to determine the starting point for future steps that build on the current step.

As mentioned above the starting point of each step is partially related to the duration of prior steps that feed into it, but is also based on the availability of resources. All companies have a finite supply of resources and therefore there is always a balance between starting a project immediately and having resources available for other projects. Chapter 4 discussed how to balance resource requirements by splitting a large-scale initiative into smaller more manageable phases. In addition the change agent needs to be prepared to weigh the tradeoffs involved with each individual step. In order to obtain the benefits as soon as possible it makes sense to start all steps immediately, assuming they are not dependant on the completion of other steps. This may place too much of a strain on an organization's resources and therefore the change agent should work with the step owners to determine the best starting schedule for each step in order to determine the best balance between obtaining benefits as soon as possible and not overly taxing the organization. Figure 5 on page 23 showed the schedule for the APC initiative. Notice how even though different steps are in the same phase and therefore can be started immediately there are very different starting and completion dates for each of the steps. This is due to the limited resources at Fab 18 and thus not everything can be accomplished at once.

5.1.4: Probability of Success

The final source of essential information about each step has to do with the probability that each step will prove successful independent of all other steps. There are no guarantees that everything will work out as desired no matter how much effort is put into each step. Therefore the change agent should carefully estimate the probability of success for each step without worrying about the other steps. It has been the author's experience that this can often be a difficult process as some companies are not used to placing a numeric value on the probability a project will be successful. In spite of this it is very important that the change agent determine a numeric value for each step, as will become apparent in the next chapter where the author will address how to adjust the success probabilities based on systemic relationships.

As already mentioned many organizations are not used to assigning a numeric value to the probability that a step will be successful. The traditional techniques consist of using a qualitative success probability such as low, medium or high. This is good as a starting point, but as the next section and next chapter will illustrate it is important to determine an actual numeric value. In order to accomplish this, the change agent can take a few different approaches. First and foremost the change agent should work with the step owners to try to determine a numeric value directly. This can be accomplished by examining similar projects from the past and determining how successful they were. If this data is not available the step owners and other stakeholders can make their best estimates of the probability of success. By having multiple data points the change agent can better determine the expected probability of success. Finally if this information also is not available or individuals are not willing to make a numeric estimate the change agent can use a ranking method between different steps. By comparing one step to another the step owners and other stakeholders should be able to determine which step is more likely to be successful. By ranking all of the steps the change agent only needs to determine the numeric probability of success for one step in order to create a baseline for all of the other steps.

After these baseline numeric values have been determined the change agent can work with the step owners in order to refine these success probabilities. The author used all of these methods for the FWPC initiative at Fab 18.

5.2: Individual ROI Calculations

After all of the essential information has been gathered it is necessary to analyze each of the individual steps based on the return on investment (ROI). Although not without certain flaws ROI calculations are an important method to compare different projects and are required by most companies before making any investment in a large-scale change initiative. In his book, *The Mind of the Strategist*, Kenichi Ohmae discusses the difficulties companies face in deciding between multiple potential projects:

> "The art is to strike an optimum balance between wasteful dissipation of resources and needlessly going for broke – a balance that differs in every business situation, depending on the resources available on the diversity and quality of the available alternatives." [25]

ROI calculations are a standard practice in most organizations and therefore should be nothing new to the reader. The author suggests one minor adjustment in the ROI calculations pertaining to the steps within a large-scale change initiative. This change has to do with the way the probability of success is handled within the equation. Traditionally many companies will use an ROI calculation that absorbs the probability of success within the expected benefits as found in Equation 1 below, where it is assumed that there are no benefits obtained if the project is a failure.

$$ROI = E(B) - C \qquad \text{(Equation 1)}$$

where:

ROI: the net present value of the return on investment for the step

E(B): the net present value of the probability adjusted expected benefits for the step if it is accomplished successfully

C: the net present value of the costs associated with the step

The author on the other hand advocates keeping the probability of success separate from the potential benefits leading to Equation 2 below, where again the only benefits are obtained from successful completion.

$$ROI = P(S) \times B - C \qquad \text{(Equation 2)}$$

where:

ROI: the net present value of the return on investment for the step

P(S): the numeric value of the probability of success for that step

B: the net present value of the potential benefits for the step if it is completed successfully

C: the net present value of the costs associated with the step

This may appear to be a minor detail, but the reason for keeping the probability of success separate in the equation will become apparent in the next chapter.

After the net present value of the ROI for each step and the schedule of each step has been determined it is time to move on to going beyond the individual step analysis and once again look at the large-scale change initiative from a systemic viewpoint. Before that occurs though the author must caution against looking at the ROI of each step in isolation. Many steps may not appear to be valuable by themselves, but could be essential components of the system. Examples of this are such steps as training and re-organizations. If these steps are looked at separately from the rest of the system, they may be deemed less important because they may not have large quantifiable benefits. Therefore they may not be given the necessary investments to be successful thus hurting the entire system of improvement. The next chapter will discuss how to handle this issue. The reason the ROI calculations are performed for each of the steps individually is for simplicity and as a component in the systemic relationships.

Chapter 6: Systemic Relationships

The previous two chapters have dealt with how to sub-divide a large-scale change initiative into smaller phases and how to analyze each individual step within the initiative. This chapter focuses on taking a systemic view of the initiative as a whole. First it discusses the author's suggested method to handle the interdependencies between steps via the probability of success factor introduced in Chapter 5. Secondly it will examine the recombination of the individual steps into a cohesive whole in order to ensure that the change agent is able to seek the most optimal total system of improvement and not just a solution that only optimizes specific steps while possibly causing issues in other areas. The authors of *Lean Enterprise Value* caution against the consequences of not taking such a systemic view:

> "This risks a form of suboptimization in which the project cost savings may be achieved, but at the expense of unanticipated system consequences elsewhere." [26]

6.1: Step Interdependency Analysis

The previous chapter introduced the concept and process of obtaining a probability of success for each of the individual steps independent of each other. This section will look at how to quantify the interrelationships between different steps via adjustments to the probability of success. In addition it will examine some other methods for handling step interdependencies and compare and contrast the positives and negatives of the author's suggested method.

After the change agent has obtained the individual step probabilities of success he should concentrate on working to determine how these probabilities may change based on the completion of other related steps within the initiative. The change agent should already have determined a probability of success for a specific step independent of any other steps and now it is important that the change agent determine how that probability of success will increase or decrease based on the completion of other steps. For example, a certain step may have a 65% chance of being completed successfully if it were undertaken independently of other efforts. When other related steps are also undertaken, such as training, installing a certain software package or experience from a prior step this probability of success may increase to 85%. It is up to the change agent to determine what portion of this increase should be allocated to each of the related steps. The process for determining these success probability adders can be quite complicated for companies that are not used to handling interdependencies in this manner, but as this technique becomes more accepted within an organization it will become simpler to obtain the necessary information. In the mean time the change agent can practice a similar approach to what was used to find the success probabilities for each step. Namely the change agent can use a method of comparisons to prior projects, a ranking system between different alternatives, simulation packages, or the best estimates of the step owners and other experts. These probability adders need to be determined for all step pairs, but the change agent needs to ensure that the total adjusted probability remains between 0% and 100%. Figure 9 in the Appendix shows the probability adder matrix for the FWPC initiative at Fab 18. As can be seen a large initiative like this with 17 different steps can have 289 different probability adders. This may seem like a large amount of additional calculations, but many of the possible interdependencies can be eliminated quickly by a basic understanding of the different steps and the total number of adders that actually need to be calculated is only about 20% of those possible. In addition this information is very important, as will be shown in the next section, and therefore the extra effort to accurately determine the probability adjustments is well worth it.

This approach to examine adjustments in success probabilities can be quite different to how organizations normally handle interdependencies between different steps, although there are other similar techniques such as the Design Structure Matrix (DSM). The author's suggested approach is different from the DSM in how it handles interdependencies. The DSM usually only highlights interdependent steps via an "X" or check mark and seldom discusses the magnitude of interdependence. The author's approach on the other hand necessitates the quantitative determination of interdependence in order to fully understand the effect that the completion of a certain step will have on all other steps. In addition the reason behind the two matrices is also different. The DSM is mainly used in project planning to determine how to manage different tasks with a specific focus on clustering, sequencing or partitioning different steps depending on whether they can be completed in parallel, series or via a coupled loop. The author's suggested probability adder matrix on the other hand is focused on helping to understand the financial impact each step has on the overarching initiative.

Other traditional methods can often assume an all or nothing relationship. For example if Step A is not completed then Step B cannot be started. Although in certain extreme cases this may be true, the author feels that in many more situations Step B can be completed without first progressing through Step A, but it may be much less likely to be completed successfully. That is why the author feels that the probability adder is a better approach because it more accurately assesses the levels of interdependence between different steps and allows for both full interdependence and little or no interdependence with the same technique. One area where the author's proposed probability adder technique is lacking is in the handling of scheduling interrelationships. As it stands right now each step is assumed to take the same length regardless of what other steps have been completed or are currently being worked on. This will often not be the case as prior steps may not only increase the probability of success, but can also decrease the amount of time to completing a step. On the other end of the spectrum there may be other resource constraints that may make it so that two different steps may not be feasibly worked on in parallel. The change agent needs to be mindful of these shortcomings and other possible shortcomings and areas of improvement that will be highlighted in Chapter 9.

6.2: Systemic Evaluation

After all of the probability adjustments have been calculated it is important to recombine the separate steps to obtain the entire systemic view of the large-scale improvement initiatives. This view is reiterated by Murman et al. in the book *Lean Enterprise Value*:

> "Again, it is significant when a leader asserts that this full range of activities must be seen as an interconnected enterprise – one in which the focus is on optimizing the entire system as a whole, not just on the separate parts." [27]

This recombination of the individual steps into a full system of improvement is accomplished mainly via an update to the ROI associated with each individual step in order to better facilitate the calculation of the ROI for the entire initiative.

Chapter 5 highlighted the process for calculating the ROI for each individual step, based on the assumption that the step is completed in isolation from all of the other steps. The previous section of this chapter discusses a method for adjusting the probability of success for each step based on the interdependencies with the other steps within the initiative. The next aspect is to adjust the ROI associated with each step based on that step's role within the entire system of improvement. Simply using Equation 2, from the previous chapter, with the adjusted probabilities of success is not accurate as it does not fully share the benefits with the contributing steps. This will still undervalue steps that are essential to the system of improvement, but do not have a lot of inherent benefit. Therefore the author suggests a new hybrid approach whereby the increase in benefits, due to interdependencies, is shared between the step that has an increase in its probability of success and the step that resulted in this increase. Therefore the new ROI calculation for each step in the systemic view will be as shown in Equation 3 below.

$$SROI_d = (IP(S)_d + \sum_{m=1}^{k} (r_{dm} \times AP(S)_{dm})) \times B_d - C_d + \sum_{n=1}^{k} (r_{nd} \times AP(S)_{nd} \times B_n)$$

(Equation 3)

where:

d: subscript denoting the specific desired step

SROI$_d$: the net present value of the ROI for the desired step as part of the entire system

IP(S)$_d$: the numeric value of the independent probability of success for the desired step

k: The total number of steps within the initiative

r$_{dm}$: the portion of the change in the adjusted probability of the desired step assessed to the desired step due to the successful completion of step m

AP(S)$_{dm}$: the numeric value of the change in the probability of success for the desired step due to the completion of step m. In conditional probability terms $AP(S)_{dm} = P(S_d|m=1) - P(S_d)$.

B$_d$: the net present value of the potential benefits for the desired step if it is completed successfully

C$_d$: the net present value of the costs associated with the desired step

r$_{nd}$: the portion of the change in the adjusted probability for step n associated with the desired step that is assessed to the desired step

AP(S)$_{nd}$: the numeric value of the change in the probability of success for step n that is associated with the desired step. In conditional probability terms $AP(S)_{nd} = P(S_n|d=1) - P(S_n)$.

B$_n$: the net present value of the potential benefits for step n if it is completed successfully

This equation is basically composed of four major components. The first component is the portion of the benefits associated with the step independent from everything else ($IP(S)_d$ x B_d). The second portion of the equation is the summation of the additional benefits resulting from the contribution of the other steps in the initiative to the desired step ($\sum_{m=1}^{k}(r_{dm} \times AP(S)_{dm} \times B_d)$). The third component is the summation of the portions of the increase in benefits for all other steps due to the completion of the desired step ($\sum_{n=1}^{k}(r_{nd} \times AP(S)_{nd} \times B_n)$). The final aspect is the cost associated with the desired step (C_d). The variables in the equation that has not been previously discussed deal with the portion of change in adjusted probability to assign to each step. This can be any value the change agent chooses as long as the percentages for the pair add up to 100%.

To help tie everything together lets examine a simple case found in Figure 6 and Figure 7 on the next page. Figure 6 shows a very simple system of improvement for an initiative with three steps (A, B & C). This case shows that when the ROI's are calculated as independent projects, as discussed in Chapter 5, both Step A and Step B will have a negative ROI of one unit while Step C has a positive ROI of two units. Assume that this is due to the costs, benefits and probabilities shown in Figure 7. This results in a total ROI of two units for the three steps (it is assumed that since the steps are viewed as independent then Step A and Step B will not be undertaken since they have a negative ROI). The systemic approach on the other hand accounts for the interdependency between different steps and adjusts the probabilities of success accordingly. As a result the ROI for Step A and Step B reaches the breakeven point and the ROI for Step C increase to three units. Therefore all of the steps will be completed and the initiative will have a total ROI of three units. The author feels this better captures the real potential of a large-scale change initiative and therefore is the best method to examine systemic relationships.

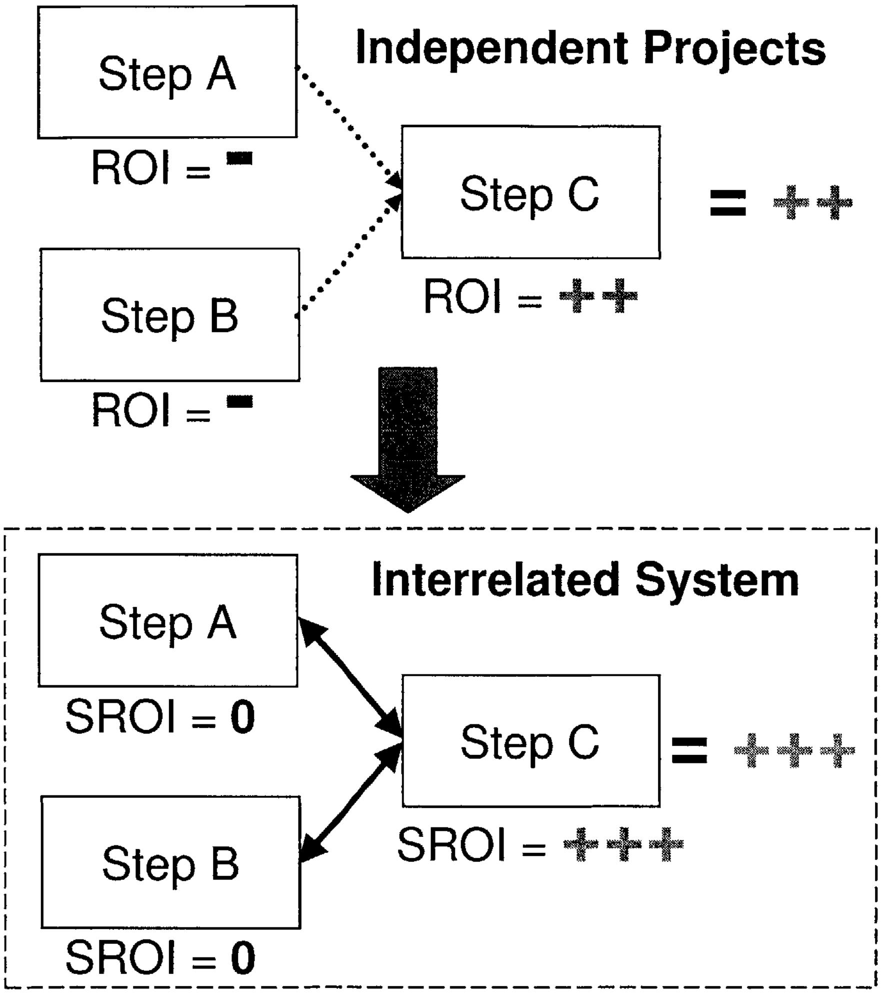

Figure 6: Differences between the two ROI approaches

	Step A	Step B	Step C
Cost [C_d]	9	9	5
Benefit given Successful Completion [B_d]	10	10	10
Independent Success Probability [$IP(S)_d$]	80%	80%	70%
Probability Adjustment from Step A [$AP(S)_d\|A=1$]	N/A	0%	15%
Probability Adjustment from Step B [$AP(S)_d\|B=1$]	0%	N/A	15%
Probability Adjustment from Step C [$AP(S)_d\|C=1$]	0%	0%	N/A
Allocation of Step A Probability Increase Due to Step B [r_{AB}]	0	0	0
Allocation of Step A Probability Increase Due to Step C [r_{AC}]	0	0	0
Allocation of Step B Probability Increase Due to Step A [r_{BA}]	0	0	0
Allocation of Step B Probability Increase Due to Step C [r_{BC}]	0	0	0
Allocation of Step C Probability Increase Due to Step A [r_{CA}]	2/3	0	1/3
Allocation of Step C Probability Increase Due to Step B [r_{BC}]	0	2/3	1/3
Independent Steps ROI Approach [ROI_d]	-1	-1	2
Systemic ROI Approach [$SROI_d$]	0	0	3

Figure 7: Summary table for differences between the different ROI approaches

Now that all of the systemic ROI's have been calculated the change agent can finally evaluate each of the steps to determine whether or not it makes sense to proceed with it. If there are steps that have extremely negative ROI's, even after accounting for the systemic interrelationships with other steps, it probably does not make sense to complete them and they should be eliminated from the initiative. Keep in mind though that the elimination of any steps will change the systemic ROI for any other steps that were interrelated to them. In addition, if any changes are made to the initiative, the change agent should proceed back through the first three aspects of the systemic approach (decomposition into manageable phases, individual step analysis and systemic relationships). Therefore steps that have a borderline ROI should most likely still be completed due to the fact that their elimination could hurt the entire system. After the change agent is confident that they have an initiative that is composed of only useful steps the final aspect is to obtain buy-in for the entire initiative as a whole. This will be discussed in further detail in the next chapter.

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Chapter 7: Overall Initiative Justification

The final aspect of the systemic approach to large-scale change initiatives is to provide an overall justification in order to obtain approval and support for the entire initiative within the organization. This aspect will build upon the previous three aspects by examining the phases, individual steps and interrelationships in order to provide the full picture of the initiative. Specifically it is important to address the financial outlook for the initiative as a whole and also to motivate the step owners and other stakeholders needed to fully accomplish the large-scale change.

7.1: Financial Outlook

Perhaps the most important aspect for many companies is the expected financial impact that the large-scale change initiative can provide. For a very large-scale initiative these financial benefits can be quite substantial. In work performed at the semiconductor division of Samsung Electronics, Leachman, Kang and Lin discuss a large-scale improvement project to lower inventory and reduce cycle times. Taken separately each of the individual projects had minimal impact, but when taken together it is estimated that the entire improvement effort resulted in an increase of $1 billion in revenue [28]. The APC project at Fab 18 does not provide quite as large of a return, but still has an expected ROI in the millions of dollars. This may seem like a large number, but a company as large as Intel always has multiple projects in the works and needs to make sure they allocate their limited investment money as efficiently as possible to ensure that they maximize their return. In order to help sell the APC initiative at Fab 18, so that it can obtain a heightened priority, the author devised a methodology that he feels is simple and can be applicable in other large-scale change initiatives as well.

The basic approach is to first understand what requirements the company has for accepting an initiative and then for the change agent to properly align the information to determine whether or not his initiative satisfies the company's requirements. In the case of Fab 18, they expected a certain level of ROI within a certain time period. Even if a project had huge potential upside near the end of its duration it may not have been approved due to the uncertainty and risk involved with future predictions. The actual levels for these limits are considered proprietary information within Intel, but Figure 8 highlights a way to examine the APC initiative against these limits.

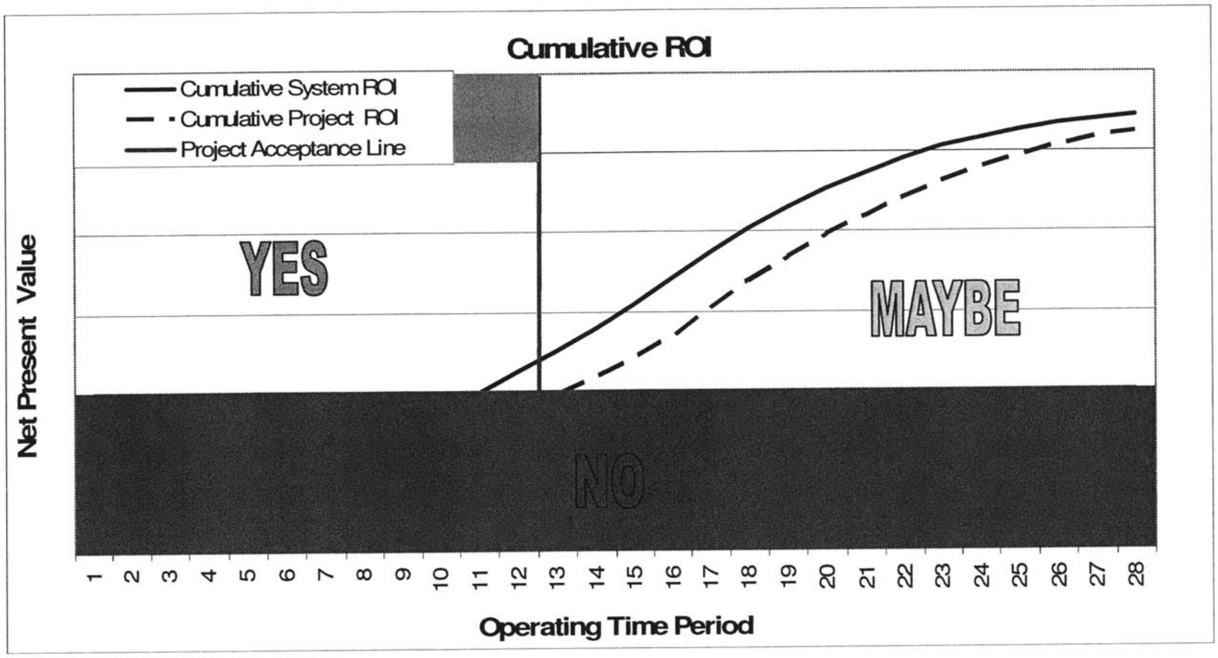

Figure 8: ROI decision plot for the APC initiative

The calculations that went into producing Figure 8 are based on information from the first three aspects of the systemic approach. By understanding the schedule, potential benefits, expected costs, and interdependencies for each step the ROI levels for the total initiative can be plotted based on a progressive time scale. This plot shows three color coded regions labeled YES, NO, and MAYBE. These correspond to the decision regions that Fab 18 uses when evaluating a potential initiative or project to invest in. By plotting the data the change agent can quickly visualize the potential situation and can also more easily obtain approval from management for the suggested initiative. For example if the cumulative ROI never goes above the NO region it can be assumed that the initiative will never be accepted under any circumstances. This makes sense since the initiative is not able to provide the required level of return on investment and thus the company would be better off investing in other projects or initiatives. On the other end of the spectrum if the cumulative ROI of an initiative is able to pass through the YES region the initiative will most likely garner support and approval from management. This is because it provides the desired level of return within the desired time horizon. The final region is for initiatives that may or may not be accepted depending on other investment possibilities. This region is for initiatives that eventually reach the desired level of

ROI, but not within the desired time frame. Therefore if there are other initiatives or projects that are able to return the desired ROI level in a shorter time period they will probably receive the investment before the change agent's initiative.

Figure 8 also highlights the value of the systemic approach to the analysis of large-scale improvement efforts. The solid line shows the cumulative ROI, for the FWPC effort at Fab 18, using the systemic approach. It can be seen that the ROI initially starts out in the NO region, below the necessary ROI level. By the 11th time period it has progressed above the cut-off line into the YES region and would therefore almost certainly be approved. By comparison the dashed line shows the cumulative ROI from using a summation of the ROI's from each individual step. Although the final ROI value is very close to the value for the systemic approach, the real difference stems from the amount of time it takes to cross the cut-off level. The summation of individual steps method takes until the 13th time period before it crosses the cut-off threshold. This is after the time frame cut-off of the 12th time period and therefore the FWPC effort would now remain in the MAYBE region and never cross through the YES region. Thus if the FWPC effort is treated as a summation of individual steps rather than an entire system of improvement it is much less likely to be approved. Even though the overall effort is the same in both cases, by not taking the systemic approach the change agent undervalues the interdependencies between steps and therefore does not capture the full value of the effort.

7.2: Implementation

By following the systemic method the change agent should find that their initiative is much easier to implement as well. Although it may have seemed like additional work at the time, the progression through the four different aspects has allowed the change agent to more easily gain acceptance for the initiative. This is accomplished via the subdivision into more manageable tasks, the individual step analysis, the examination of systemic relationships and finally a better understanding of the financial outlook.

The subdivision into more manageable tasks will help with the implementation effort by making it easier for the change agent to manage the overall initiative. By focusing his effort on only the phase of the initiative that is of the most current importance the change agent can ensure that the proper resources are in place. In addition the subdivision into smaller more manageable phases allows the change agent to more easily share management responsibilities with other individuals. These other individuals will then help gain acceptance for the initiative and be able to make sure that each phase is progressing according to plan.

The next area where the systemic approach aids initiative adoption is via a more thorough understanding of the individual steps that the initiative is composed of. By understanding the details of each individual step the change agent has a better understanding of the required schedule, associated costs and benefits and especially the owners for each individual step. By accurately knowing the schedule the change agent will know exactly when and where to focus resources for the most value and ease of total initiative implementation. Secondly a thorough understanding of the costs and benefits of each step will highlight that the change agent really understands the initiative and therefore will make it easier for the fab management to support the initiative because it will involve fewer unknowns and less risk. Finally by identifying owners for each step at an early stage the change agent creates a team of supporters who have a vested interest in seeing that the overall initiative is implemented successfully.

Similarly an understanding of the systemic relationships will aid in the implementation of the initiative by highlighting the interdependencies between steps and the value this creates for the overall initiative. This understanding of the interdependencies between steps will showcase the overall value from the initiative and will give a more accurate view of the ROI associated with the initiative. This higher and more accurate ROI will make it easier for the fab management to approve the initiative. Also the understanding of the interdependencies will allow the change agent to better manage the effort and thus ease its overall implementation. Understanding the interdependencies will let the change agent know exactly when and where to concentrate resources to capture the most overall value from the different steps

Finally the systemic approach builds on all of the previous aspects to give a more accurate depiction of the financial impact from the initiative. This more accurate financial outlook will help ease acceptance and thus implementation by giving the management team more confidence in the expected ROI. In addition the systemic approach defines a specific process for calculating an ROI, which should result in less time calculating the ROI and more time available to focus on proper implementation of the initiative.

Chapter 8: Leadership Challenges

No matter how exceptional the systemic models are or how reliable the data is that they are based on, there will always be additional challenges that need to be overcome in order to properly implement large-scale change. These difficulties often come in the form of organizational challenges. Therefore in order to be able to overcome or even prevent these challenges from occurring, it is essential to better understand the organization involved. This chapter will focus on the strategic design, cultural and political challenges within Intel, but will also draw correlations to challenges faced within other organizations. Finally the author will offer suggestions on how companies can work through these different organizational challenges in order to ensure successful implementation of their initiative.

8.1 Strategic Design Challenges

The first area of challenges is within the strategic design of the organization. This involves such aspects as the organizational structure, interaction between different groups within the organization and the location of key facilities. This section will deal with these aspects specifically at Fab 18, but will also speak to how they relate to Intel in general and also to other companies.

8.1.1 Organizational Structure

The first area to examine when looking at an organization's strategic design is the structure of the organization. At Fab 18 the site is divided into numerous different groups. The main departments in question are Engineering, Yield, Manufacturing, Automation, Electronic Test (E-Test), Sort, and the Sub-Fab. Like most major improvement initiatives, the FWPC effort at Fab 18 spans multiple groups and therefore it is important to understand each group and the role that they play within the initiative.

The Engineering Department consists of engineers who are in charge of developing and improving the manufacturing processes. The engineering group is where the APC and FWPC efforts originally started and is where many of the concepts were incubated. The FWPC effort has strong support within the engineering group, all the way up to the engineering department head.

The second major group involved with the FWPC effort is the Yield Department. The Yield Department is in charge of ensuring that the die yield, or the percentage of good dies on a wafer, is as high as possible. Since one of the main focuses of an FWPC effort is to improve the die yields it makes sense that the Yield Department needs to be directly involved in the effort.

The next group that has a heavy level of involvement in the FWPC effort is the Manufacturing Department. The Manufacturing Department is in charge of the actual processing of the wafers to produce useable dies that will then be cut into chips at an assembly and test facility. The Manufacturing Department consists of line level technicians and those in supervisor roles. Since FWPC is an effort to improve the manufacturing process it is necessary to have participation from all of those involved in the manufacturing effort.

The Automation Department is involved with creating solutions to help automate the different improvement concepts that come from the Yield or Engineering Departments. This mainly involves software solutions, but also involves the hardware and robotics within the Fab that helps to move and process wafers. Although the Automation Department does not normally come up with many of the solutions involved with APC they are in charge of implementing many of them and automating them so that they do not require as much manual effort.

The next two departments are involved with testing and sorting of the wafers after production. These are the E-Test and Sort Departments. Any successful FWPC effort is dependent on feedback from these departments based on the measurement data they take on manufactured wafers. This data currently flows to the Engineering and Yield Departments. Part of the APC effort requires that the Automation Department work to automate the flow of this information right to the control systems so it can be used to automatically control the necessary manufacturing equipment.

The final department involved in the FWPC initiative is the Sub-Fab or General Site Services (GSS) Department. This department is involved with maintaining all of the pumps, pipes, and other infrastructure involved with making a fab operate properly. Data from the Sub-Fab can be essential to a successful FWPC initiative as it will help provide early prediction of any potential problems and also will highlight possible areas for control opportunities.

These department groupings are similar to what is found in most any other Intel site and although the names may be different the roles and tasks are very similar to departments found in other companies. Most companies will find that their own large-scale initiatives will span multiple departments and therefore it is essential that each company examine their own organizational structure before beginning a major initiative to ensure that the organization is properly aligned to properly accomplish the large-scale change initiative.

8.1.2 Interaction between Different Groups

Since the APC effort involves many different departments within the fab, and across other Intel locations, it is important that they have open channels of communication and interaction. To help facilitate this communication Intel has created two teams. The first team is for internal efforts within the fab and is called the X-Team. The second team is for communication and interactions between different sites around the globe and is called the APC Coordination Team (CT). For the most part this teaming arrangement worked quite well, but is not without certain difficulties. This sub-section will focus on what worked well within these teams and possible areas for improvement. Readers should be able to recognize similar situations within their own organizations and be able to draw from the Intel example to help them with their own issues.

The X-Team is a group of individuals at each site that is in charge of the APC and FWPC efforts within that facility. Although each site organizes and runs it's X-team slightly differently the key aspects should be similar to what the author discusses concerning the Fab 18 X-Team. The Fab 18 X-Team consists of permanent members from the Engineering Department, the Yield Department and the Automation Department. It is co-chaired by one member each from the Engineering and the Automation Departments. In addition to the permanent members there is also participation from other individuals who may be working on a specific APC project at any given time.

The X-Team functions well as a venue for reviewing potential APC project ideas, sharing of the learning and best practices from prior projects and examining developments in APC across the industry. One of the areas where it appears to have a shortcoming though, is in the lack of involvement by representatives from the Manufacturing Department. APC is essentially an effort to introduce operational improvements, but yet the department perhaps most effected by these changes is not readily involved with the discussions around them. Manufacturing was never excluded from these meetings, but tended to not be present all the same. The reason for this is easily understood as traditionally project ideas have come from either the Yield or

Engineering Departments and were implemented with help from the Automation Department. Manufacturing felt that they were too busy with their daily tasks of producing wafers and did not have the time to concentrate on process improvements. The issue is as the APC efforts grow, the Manufacturing Department is composed of the individuals that best understand the shortcomings of the current production process and can therefore provide some of the best suggestions for improvements. This lack of manufacturing participation is an issue faced within many organizations, trying to implement large-scale operational improvements, and in order to rectify it, a company needs to be willing to realign some of their metrics. In the example of Fab 18, the Manufacturing Department is largely incentivized to concentrate on daily output and therefore even though they also concentrate on long term strategic programs, they may tend to take a fairly short term outlook. If on the other hand some of these daily metrics were relaxed and longer term improvements were prioritized the Manufacturing Department may be more inclined to participate on the X-Team and with APC related efforts.

The second team involved with APC efforts at Intel is the APC Coordination Team (CT). The APC CT is composed of members from the X-Teams across all of the similar Intel facilities. It functions and is organized much like an X-Team for the entire company with the tasks of reviewing the APC performance across each site, the sharing of knowledge between sites and the tracking of developments within the industry or research communities. It exists as a virtual team with the majority of communication and interaction taking place via e-mail or weekly teleconferences. Much like the individual X-Teams it has been very beneficial in the growth of APC efforts, but it may need certain adjustments as the APC efforts expand across Intel.

The first possible area for improvement is with the lack of participation by anyone from manufacturing. Since the APC CT membership is composed of members of the individual X-Teams it makes sense that the members are again from the Yield, Engineering and Automation Departments. As each X-Team works to integrate the Manufacturing Department it is likely that the APC CT will also eventually have participants from the Manufacturing Department. These individuals from the Manufacturing Department have the most direct interaction with the manufacturing operations and therefore can provide a fresh perspective on possible projects that may not be thought of by the Engineering or Yield Departments. In the mean time it may make sense to bring in a few key manufacturing individuals into the APC CT. Since APC is still in the growth stages at Intel it may not make sense to have manufacturing participation at every site at this point in time. Although it may make sense to bring in manufacturing from key sites such as Fab 18, which is one of the most advanced Intel sites in APC implementation, or else manufacturing personnel from a development fab where much of the manufacturing process is originally defined.

The second opportunity for improvement within the APC CT is the level of involvement by current members. Currently membership in the APC CT is above and beyond a worker's daily tasks. For example at Fab 18, every week the APC CT members go through a long day at work and then have an APC CT meeting at 9:00 pm local time (due to time zone differences) that can run for an hour and a half and then has to be ready for another full day of work the next day. This can be draining on an individual and distractions at this time of the day can make full participation in the teleconferences a challenge. Although the time zone issue is unavoidable, due to Intel's global reach, the one aspect that can be relaxed is the member's work scope outside of APC efforts. Perhaps instead of having multiple members from each X-Team on the APC CT it may make sense to only have one participant from each site fully dedicated to APC that would lead the local X-Team and sit on the APC CT. This individual would need to be willing to take a systemic approach to not only implementing APC, but also in how they interact with their global counterparts. Taking a systemic perspective can be valuable in helping to create a global organization to implement any sort of changes as well as in defining the process for implementing the change. Klein and Barrett talk about the value of a total system perspective in handling the sharing of knowledge in globally dispersed teams [29]. In addition this member would not be distracted by other work expectations and therefore could expedite the development and implementation of APC efforts by being fully focused on them. If someone's full incentive is to ensure that APC is successful they are going to make every effort to make it work versus if it is just one fraction of their job, in which case they may try to excel in the other aspects at the possible expense of APC.

8.1.3 Location of Key Facilities

As mentioned in the previous sub-section Intel is a globally diverse company with sites located around the world. Although this can create complications with the sharing of information across sites, the sites function almost as independent entities in day to day operations. A Fab Manager is given a fair amount of liberty in making decisions on how they feel their site can best be operated. Although initial product and process design may have been defined elsewhere, the process improvement efforts are often handled locally with manufacturing, engineering, automation and other key players all located within the same facility. Theoretically this works well in that it allows for direct interaction and the opportunity for different departments to work together. In practice though there can be a barrier due to the clean room.

The clean room is just what the name suggests, an extremely clean room (on the order of 1 particle per cubic foot). Within this clean room is where the processing of the silicon wafers is conducted. In order to improve the quality of wafers it is necessary to keep the room as clean as possible. Unfortunately the main sources of contamination are the particles that are carried into the clean room by the employees who need to work within the clean room. To try and prevent contamination anyone entering the clean room needs to go through an extensive gowning process. This gowning can take upwards of ten minutes and makes it more difficult for engineers and manufacturing individuals to interact and communicate. In other manufacturing companies, such as General Electric, Bombardier and Toyota, the desks of the engineers are actually located on the shop floor in order to facilitate interaction, but this is not feasible with a clean room environment. To counteract this increase in the inconvenience of direct interaction, Intel does a great job of having daily meetings at the beginning of every shift to facilitate information sharing and interaction between manufacturing and engineering. In addition it encourages engineers to regularly go into the clean room to interact with the manufacturing technicians, especially when there are issues. This is similar to how other companies handle the lack of co-location between manufacturing and engineering by requiring site visit meetings and problem solving teams to go to the source of the issue.

8.2 Cultural Challenges

It can be argued whether companies define their cultures or whether cultures define their companies, but one thing that is certain is a company is extremely integrated with its culture. Many corporate cultures can be as famous as the company they are a part of. IBM has traditionally been known for its blue suits and General Electric is often seen as a top manager training center. The culture at Intel is nearly as famous and is a major factor in how Intel operates on a daily basis. This section will discuss the Intel culture in more detail with a specific focus on the cultural aspects at Fab 18. In addition it will discuss how these cultural details both help and hinder the large-scale improvement efforts. Finally it will discuss how other companies must examine their internal cultures to determine how best to adapt them for large-scale change initiatives.

Intel's culture is identified by a few major aspects. First and foremost Intel has been a company that is very technology driven. This focus on technology and creating cutting edge products has led to an environment that to some extent is "cursed by success". The other major cultural aspect is a part of Intel that is often spoken about, but not fully understood. This is the concept of the "Copy Exactly" methodology. In addition to these cultural patterns, Fab 18 also has some unique Israeli characteristics.

As mentioned above, Intel is a company that has been focused on technology and seeks to create leading edge products to continue its market leadership. Intel's initial success was a result of creating the microprocessor and its storied growth has been at least partially due to continued microprocessor improvements and constantly redefining the cutting edge of technology. This has led to an environment where, in the author's opinion, product development has been the most important discipline within the company. This engineering and technology focus has resulted in Intel having a very technical approach to management as well. In her book, *True Change*, Jan Klein talks about how Hi Tech (a company surprisingly similar to Intel) has an organization that thrives on technical individuals that make data-driven decisions where recognition is based mainly on quantifiable results. She also comments on how this can lead to a not invented here mentality concerning ideas coming from other areas of the company because there is little credit for re-used ideas [30]. In the past this approach has worked well, based on the huge amount of success Intel has experienced over the last few decades. Recently though it has been the cause of some of Intel's current issues. The focus on product development has led to less importance being placed on operations and as a result has led to Intel lagging some of its major competition in the realm of operational efficiency. When the market constantly craves new products this lack of efficiency is not much of a concern, because you can mask it in the price you pass on to customers. In the current environment of increased competition, especially in Flash Memory, this operational shortcoming has led to Intel being downgraded by the equity markets [31]. In order to ensure future success Intel will need to refocus some of its priority from product development to operational improvements. Product development is still essential, but in this new competitive landscape operations may be just as important.

To further complicate this situation, certain individuals at Intel do not even perceive the need for a change. Many employees at Intel are so used to being successful that they cannot imagine Intel not being the best at something. This is what the author refers to as the "curse of success". Not only can past success make employees unable to see the need for major change it may actually create a culture where efforts to implement needed improvements are not fully supported, because it would be an admission that everything is not perfect and overhauls are needed. This can be a very difficult cultural tendency to overcome and it makes it much more difficult, but also more important, for a change agent to sell their efforts and garner the necessary support to ensure successful initiative implementation.

The next universal cultural aspect at Intel is the concept of "Copy Exactly". "Copy Exactly" is a policy implemented at Intel to ensure quick ramp up of production rates to high yield levels. It basically consists of the production fabs copying the manufacturing process exactly as it was designed at a development fab, including maintenance procedures, the type of equipment used and even the diameter and length of chemical pipes. A common misconception is that this means the production fabs need to remain identical to the development fab and cannot make any improvements independently. This is not completely true. The copy exactly portion mostly applies during the initial technology transfer. After a production fab has full control of the technology it is allowed to make changes it feels are beneficial. These changes are then shared with other fabs running the same technology as appropriate. Although they are perfectly able to make major operational improvements, "Copy Exactly" creates a culture in the production fabs where major changes can be hindered. This is due in part because a change agent not only needs to influence the local management team, but also all the other fabs involved in manufacturing the same product. It also creates an environment where process engineers are used to making smaller scale changes and do not have as much experience with large-scale changes such as new designs. As the previous chapters of this paper have highlighted small scale and large-scale improvements require different approaches to be successful. "Copy Exactly" still provides a lot of benefits and should not be eliminated, but rather Intel needs to further encourage the production fabs to make investments in more large-scale change initiatives such as the lean effort and APC mentioned in previous portions of this document.

The final cultural aspect at Fab 18 has to do with its location in Israel. For those who are not familiar with the history of modern Israel, it is really quite amazing the way the Israeli people have been able to take a desert land with few natural resources and transform it into its current status in only a few generations. Israel is the birthplace of many innovations ranging from medicine to technology. This has created a sense of pride and a can do attitude within many Israeli people. This attitude carries over to the employees at Fab 18. They feel that there is nothing they cannot accomplish. They even have a phrase for it, which in Hebrew is "גם וגם", which roughly translates to "also and also". This basically means that the Fab 18 management team tries to accomplish everything that they feel could be important. Although a very noble desire, it can lead to issues with prioritization and employees being overwhelmed with too many different efforts at once and therefore unable to accomplish anything to the best possible level. Fab 18 needs to do a better job of recognizing it has constrained resources and really focus on the projects that will offer the most benefit. That is why models like the author suggested in previous chapters are so important. They provide a method to compare different large-scale efforts from a systemic outlook.

Although the focus of this past section has been primarily on the culture at Intel, especially within Fab 18, the reader should be able to identify corollaries to organizations he is more familiar with. In addition the reader should take the same approach of examining the culture within an organization where they are trying to implement a large-scale change, so they can predict and try to prevent any possible cultural misalignments.

8.3 Political Challenges

The last area of leadership challenges has to do with the internal politics within an organization. Politics is often seen as a dirty word within an organization, but all companies have some sort of politics that defines the power structure within that company. Corporate politics tend to be influenced by the corporate culture and strategic design, but there are certain political challenges that need to be addressed independently of the other two areas. This section will specifically concentrate on the political climate at Intel's Fab 18. Some of the challenges at this site are the power structure between different departments, the channels to gain project support and the allocation of resources. Finally this section will conclude by relating how large-scale change initiatives are influenced by internal politics in any company, not just Intel.

The first aspect to understand in any political structure is the interaction and power play between different departments. At Intel, all of the different departments are technically at an equal level, but by observing the way the organization operates the author was able to identify certain differences in political power between different departments. As mentioned above, corporate culture plays a large role in internal politics and in this case especially leads to the position of power the Engineering Department has over most any of the other departments. Since Intel has been primarily a technology focused company, it makes sense that engineering would be seen as the most important of the different departments. This level of importance has allowed engineering to assume a position of power over the other organizations. This power is evident in that many of the improvement suggestions that get implemented originate from the Engineering Department. Even though APC is a method to improve operational efficiency and quality, it is very interesting that few APC project ideas have originated within the Manufacturing Department, but rather they typically come from engineering and are adapted based on input from the Manufacturing Department. The fact that the Engineering Department tends to exert the most political power is not necessarily a good or a bad thing. Rather a change agent needs to identify that this power structure exists so that they can gain the support of engineering to make a suggested change and thereby increase its odds of success.

This identification of which departments hold the most political power is only the first step in implementing a large-scale change. The next step is to identify the channels and paths that need to be followed in order to gain support for the improvement. These channels consist of both official review boards and also unofficial support groups. The official review boards are often very easy for a change agent to identify as most anyone within the organization will be aware of them. For APC projects at Fab 18 these channels consist of the X-Team, the APC CT, the Systems MRC and the Operating Excellence meeting of the top management team. These review boards approve any project suggestions and either provide their support or suggest ways in order to improve the project. In order to actually make it to these meetings though it was often essential for the change agent to first garner support within the unofficial channels. These unofficial channels consisted of those involved with previous APC projects, individuals within the Finance Department and finally powerful team leaders within the Engineering Department. Those who have been involved in previous APC efforts are helpful mentors to the change agent and also trusted advisors to the management team. It is important that the change agent create a quality standing with these individuals as they can either be a source of strong support or powerful detractors that can prevent a project from being accepted. Another necessity for project acceptance is an accurate description of the financial impact. This requires assistance from the Finance Department to be able to perform the financial analysis properly. Likewise it is important to befriend some of the key team leaders. They will be the ones to determine whether or not it is valuable for the engineers within their team to work on certain projects. No matter how great a project is, if it does not have the proper manpower to work on it, it will flounder and never reach its full potential.

This brings up the last important aspect of a political analysis, the ability to obtain the proper supply of limited resources. Companies often have multiple projects in the pipeline and therefore a change agent needs to be able to ensure that their initiative obtains the proper allocation. As mentioned in the cultural analysis, Fab 18 may try to accomplish everything at once, but there is still only a limited amount of resources. The author's experience at General Electric highlights that the allocation of resources will sometimes occur more based on the value of relationships than the value of the project itself. This is less evident at Intel, but even in Intel a change agent needs to ensure that they have created the right relationships by understanding the power structure of organizations and the channels for obtaining support. At Fab 18 this can sometimes mean not only aligning with the right individuals, but also aligning with the most important concerns at the fab. For example any APC efforts are much more likely to be accepted and properly resourced if they can be shown to relate to major strategic objective such as a reduction in cycle times or overall wafer costs. By understanding the internal politics the change agent can understand what is most important to fab management and thus ensure that their initiative is supported.

The reader should be able to recognize that many of these political aspects are not unique to Intel, but are present in one form or another in most any company. Therefore no matter what company the reader works for, he can use the ideas presented here to help ensure that their change initiative is fully supported. Taking a systemic approach to defining an initiative and then analyzing the leadership challenges should help ensure that a change agent can implement their initiative successfully.

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Chapter 9: Conclusions and Future Opportunities

The previous chapters have highlighted the authors suggested systemic approach to implementing large-scale change initiatives. In addition the last chapter showed some of the leadership challenges that an organization will face in trying to implement any large-scale improvement effort. This chapter will give an overview of the conclusions discussed in the previous chapters as well as discussing some areas where the systemic approach can be improved upon.

9.1 Conclusions

The main conclusion obtained from the author's research and this corresponding thesis is that large-scale improvement efforts are inherently different from smaller scale improvement efforts and thus they should be handled via a different, more systemic approach. This systemic approach will lead to a simplification of the initiative into more manageable phases, a better understanding of the individual steps composing an initiative, the interdependencies between these individual steps and finally how the systemic approach effects the financial outlook and implementation.

Chapter 3 showcased how large-scale change initiatives are different from smaller scale continuous change efforts. These differences cause many companies to struggle with their implementation because they treat all change efforts the same. The author suggests a unique, systemic approach to handling large-scale change initiatives. This suggested method differs from previous methods mainly in how it handles different levels of interdependency between different steps.

Chapter 4 explored a method to break the large-scale change initiative into smaller phases. These smaller, shorter phases will help the implementation of the large-scale change initiative by simplifying it to help build support and ease project management. The author did caution about making sure that you keep a systemic viewpoint though and do not try to completely subdivide the effort into independent efforts. Rather you are dividing the effort into smaller, dependent phases of an overall initiative.

Chapter 5 further simplified the initiative by independently analyzing the steps that make up the overall initiative. This involved gathering additional data concerning the potential benefits, required resources, schedule and probability of success associated with each step. It highlighted some of the difficulties with obtaining some of this information, but also stressed its importance and suggested ways to ease the gathering of the data. The chapter then discussed how to use this information in order to calculate an ROI for each step, independent of all other steps. The author cautions against evaluating the steps at this point and states that the ROI's are simply a component of the overall systemic analysis.

Chapter 6 goes on to discuss the systemic relationships between the different steps and discusses a method to analyze the entire system of improvement. This is accomplished by adjusting the individual step probabilities of success based on the interdependencies between different steps. These adjustments also lead to the creation of a systemic ROI for each step that determines the value the step contributes towards the overall initiative. This is also the point where the author feels there is enough information to evaluate each of the individual steps to ensure that it makes sense to complete them.

Chapter 7 ties together all of the previous aspects of the systemic approach and creates an overarching method to analyze the financial impact of the initiative. The author contrasts the estimated financial impact of the initiative if it is treated as a system or improvement versus a group of individual projects. This showcases the added value and accuracy of the systemic approach. In addition to the financial impact the author also discusses how the systemic approach eases the implementation of the initiative.

Finally Chapter 8 diverges from the modeling aspect of the systemic approach and rather concentrates on some of the leadership challenges that a change agent will face in implementing a large-scale change initiative. Specifically these issues consist of strategic design, cultural and political challenges. The author discuses how these challenges exist in every company in one form or another. The change agent needs to be able to recognize these challenges and work towards mitigating them or else the initiative may falter no matter how well the systemic approach is followed.

9.2 Future Research Opportunities

No analysis method is perfect and there is always room for improvement and expansion. When discussing the modeling of complex systems, Sterman acknowledges that modeling is an iterative process and no one ever gets it exactly right on the first try [32]. Specifically the systemic approach the author suggests can be improved upon by examining its usefulness in other industries, expanding it to better handle variation and also looking at other step interdependencies beyond an influence on the probability of success.

The first area for improvement has to do with testing the suggested method in other industries and within other companies. Although the approach appears to have worked well for the FWPC initiative at Fab 18, it is still somewhat unclear if it will be as successful with other initiatives. Further research needs to be conducted across a variety of different initiatives to ensure that the suggested systemic approach is universally valid and to examine ways to possibly improve upon the approach.

The second area of improvement deals with the introduction of variation into the analysis. All of the data collected has a certain amount of uncertainty associated with it and the currently suggested approach does not account for this. The reason is because most companies are not used to extensive statistical analysis and prefer to look at information in more definite terms. As already mentioned in Chapter 5 and Chapter 6 it was often difficult just obtaining the probabilities of success let alone trying to determine any variation in these estimates. As companies become more accustomed with the basic systemic approach it will be easier to expand on the systemic approach and handle variation in the different components of data.

The final major area where the systemic approach can be built upon is in a better handling of the interdependent relationships between the schedule and duration of the different steps. Currently the approach only accounts for interdependencies concerning a change in the probability of success for any given step based on the completion of other steps. Where it is lacking is in the fact that often the completion of a step in an initiative can also influence the schedule of additional steps. For example if a training step is completed not only will other steps be more likely to be completed successfully, they may also be completed in a shorter duration than had the training step not been completed.

Overall the systemic approach is a major step in the right direction for companies trying to implement large-scale change initiatives. As mentioned above there is room for improvement though and future research efforts should focus on these areas.

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COMPONENT STEPS

PROBABILITY ADJUSTMENTS

	Step A	Step B	Step C	Step D	Step E	Step F	Step G	Step H	Step I	Step J	Step K	Step L	Step M	Step N	Step O	Step P	Step Q
Initial	70%	75%	80%	75%	50%	95%	60%	60%	45%	75%	25%	40%	25%	40%	25%	10%	10%
Step A	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%	0%	0%	5%	5%
Step B	5%	0%	0%	0%	0%	0%	20%	0%	0%	0%	25%	0%	0%	0%	0%	0%	0%
Step C	0%	0%	0%	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%	0%	0%
Step D	0%	0%	5%	0%	5%	0%	0%	10%	10%	5%	0%	10%	0%	5%	10%	0%	0%
Step E	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Step F	5%	0%	5%	5%	5%	0%	10%	5%	5%	5%	5%	5%	5%	10%	5%	5%	5%
Step G	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%	5%	0%	0%	0%	0%
Step H	0%	0%	0%	0%	0%	0%	0%	0%	15%	0%	5%	0%	5%	0%	10%	10%	10%
Step I	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%	0%	0%	10%	10%
Step J	0%	0%	0%	0%	10%	0%	0%	10%	5%	0%	0%	10%	0%	10%	10%	0%	0%
Step K	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	15%	0%	0%	5%	5%
Step L	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Step M	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%	5%
Step N	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	15%	10%
Step O	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%
Step P	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Step Q	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Final	80%	75%	90%	85%	70%	95%	90%	85%	80%	85%	80%	65%	65%	65%	65%	65%	65%

Figure 9: Matrix table showing the success probability adders for each step interdependency