New Product Development Project Construction, Implementation and Continual Improvement: A Case Illustration from Semiconductor Manufacturing

By:

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Abstract

Successful projects are the backbone of companies that lead their respective fields. Failed project for one reason or another are more often than not the reason some companies fall further and further behind their counterparts. Projects are becoming more technologically advanced. Projects are more expensive and are receiving less funding than they used to due to a highly competitive economic climate. The projects in the second decade of 2000 have to meet the triple bottom line of cheaper, faster, and better than ever before. Due to these reasons project have continued to fail at an alarming rate (nearly 70% in 2009 according to the Standish Group) despite the increased awareness and the push to involve some Project Management tools.

The seemingly elusive goal of systematically addressing and excelling at the triple bottom is attainable when a project manager correctly utilizes every tool available including extending their knowledge beyond typical project management tools into the realm of knowledge management and quality management. It is with this newly dubbed Project Quality Plan (PQP) that project managers will utilize the best practices from project management (PM) by ensuring clear leadership and by using scheduling tools, from knowledge management (KM) by implementing a knowledge base and knowledge practices popularized by Toyota, and finally from quality management (QM) by identifying the customer and meeting their needs to requirements documentation. It is with the PQP that project managers can ensure successful projects are no longer rare occurrences but common place within their company.

The PQP was first constructed in response to a Hard-drive manufacturing company's (named Company A) struggle to install, qualify and release to manufacturing on time. At the time of writing this report, Company A is currently implementing their own PQP. A possible later investigation could analyze the effectiveness of this PQP implementation and will provide recommendations for next steps.

Project success is possible, but one successful project is not enough. To ensure consistent and continual project success there needs to be a change in the culture of Company A to one that fully embraces and embodies the principles of PQP.

Introduction

It is not uncommon for organizations to find that their projects are not only late, but over budget. The installation process for new wafer process equipment is complex, time consuming and fraught with pitfalls. The implications of New Product Development (NPD) projects failing to meet the requirements are drastic, and yet there lacks a definitive solution. After participating in a NPD project that was characterized by its lateness, the writer decided that there had to be a solution or at the very least an explanation for its failure. After research the writer found there to be a lot of differing explanations and even more proposed solutions.

Difficulties of projects lie within the fact that outside of the immediate project there are schedule delays, system setup changes and on top of that qualification and release to manufacturing are divided between different organizations and individuals. Lacking a central project management approach that is focused on quality and exceeding customer expectations, the equipment is often released later than needed, incompletely characterized and lack the necessary process controls. This impacts manufacturing capacity and product throughput and in some cases can result in lower processing yields due to equipment problems not identified and addressed during test and setup. Ultimately these problems increase product cost and detract from a company's ability to compete in the marketplace.

The purpose of the study is to examine what causes New Product Development projects to be late by investigating through literature and interviewing participants of a recent project of a semiconductor company. It is impractical to create a PQP to encompass every type of project, therefore this report will only focus on NPD projects. This report will provide the following:

- Discuss and Assess past project
- Develop Project Quality Plan (PQP)
    - Project Management Plan
        - Benchmarking, Team working practices
    - Knowledge Management and Knowledge Sharing Plan
        - Live data update
    - Quality Management Plan
        - Effectively Utilizing FMECA
        - Customer Identification and Involvement
- Develop recommendations for future New Product Development projects

Contained within this report is a survey of literature, where the different elements of a PQP are investigated for best practices and recommendations. Following that is a brief overview of the project. For the purpose of this project and due to nondisclosure of proprietary information the company will be referred to as Company A. Company A is one of the leaders in storage in the semiconductor industry, and because of that, there will be a brief introduction to what storage devices are, their uses, and a brief overview of the fabrication of those devices. After the release to manufacturing, the writer interviewed the many different players in order to figure out the roles they played. The results from this interview will be compared to the suggested best practices in order to assess the relative success of the project and to suggest possible areas for improvement. After discussion of the project and response from the survey of participants involved, the project and company type characterized in order to provide reasons for metrics selected and a recommendation and examples of best practices will follow. Templates will be created for the future NPD projects in order to prevent future mistakes. Upon the conclusion of best practices an economic viability assessment will be provided to conclude this report.

Background

Problem Background

Projects are complex and difficult, and project managers have the difficult job of managing a wide variety of human, financial, and technical factors all while working without sufficient authority, money or manpower (Slevin 1987). The reality of industry demands forces project managers to compress their timelines, and processes to be released before being fully finished, resulting in a product that needs the Engineering team support beyond project release. This produces a process or product that is less likely for the now disturbed production system to resort back to high productivity and low yield loss as quickly as possible (Kim 2009), and instead cause increased costs to the company, potentially remove them from a market window or even in some extreme cases force a company into bankruptcy. This is because manufacturability (the quality of development ensuring the product can be produced efficiently and reliably (Kim 2008)) is threatened due to the incomplete project being handed off. It is found that a third of projects are terminated before their nominal completion time while more that 50% of projects cost approximately double their estimate. Project managers' approaches and behaviors differed, tending to deny, avoid, ignore and delay dealing with risk. Mitigation actions can reduce the impacts of the possible risks that could affect the project. If proper risk measures and strengths are implemented for projects, the efficiency of the method will be greatly improved (ZafraCabeza 2007).

The remedy to this common problem throughout industries is a reassessment of how Project Management, commonly thought to only encapsulate the time from receiving the project to hand off, is addressed. Project management, to be truly effective, needs to be holistic. It needs to address the needs beyond the direct functional team working on it (for example: Research and Development), and instead address and involve the impacting Manufacturing, Research and Development, Marketing, and Engineering teams. On top of that, projects must be managed to the extent that the long term issues are addressed and accounted for throughout the organization. All of those different entities who normally function with resistance towards each other now become customers for each other, creating an environment that fosters companywide development and growth. And when the customers become project partners rather than distant entities, the depth of knowledge increases and the projects schedule decreases and often reduces project cost (Bommer 2002). Furthermore the partnerships created lead to an increase in jobs and mutually benefit client and company. The depth of knowledge is fostered by an increase in effective communication, which also leads to beneficial data management because of the strong knowledge base.

The world is "flattening" due to the immediacy of information flow. It is now possible to interact with people across multiple time zones in real time. Companies are no longer competing locally, or even domestically, but instead globally. To succeed, companies need to produce innovative quality products (done through new product development (NPD)) quicker than the competition (Cooper 1995). There is a demand for a new age of project managers who become responsible for the development and implementation of a Product Quality Plan (PQP), which ties together a project plan, and a data management plan. A PQP creates and unifies cross-functional teams, which benefits the company at every level. It ensures that quality is not just a problem for manufacturing by initially opening communication to the customers and then implementing good practices and by planning and accounting for the possible issues that could arise. It also implements a centralized data management structure and easily accessible knowledge base for future generations to learn and pull from. By implementing a standard of expecting a PQP from project managers and input into the PQP from all members,

companies will be able to focus on product development and not waste time on troubleshooting the reoccurring problem of failed projects.

Industry Background

Company A manufactures and sells hard disk drives. A hard disk drive (HDD) is the main permanent storage for computers, therefore it is used for long term storage. A typical HDD has a multitude of moving parts including but not limited to: the actuator arm, a read/write head, media disk, 2 electronic motors which are scaled either up or down depending on the size of the end product. Hard disk drives are used in desktop or laptop personal computers, as well as cars and airplanes, and are even used with super computers. HDD are used by companies ranging from publically traded companies like Google to the United States government.

Within the HDD manufacturing division of Company A, there are two main groups: Head and Media Disk. This case study comes from a tool installation within the Head group. Heads are manufactured in large batched called wafers, which are cut up into individual heads once the wafer reaches the final product stage. A wafer will typically take about 40 days to get from start to finish. Wafer manufacturing is done within a semiconductor-like line. The line is housed in a cleanroom and contains hundreds of multimillion dollar tools. A wafer must go through nearly 700 processes to get to the finished product stage. Photolithograhy, Vacuum deposition and etching, plating, planarization, many test and inspection tools are required. Depicted below is a figure of the wafer routing process.

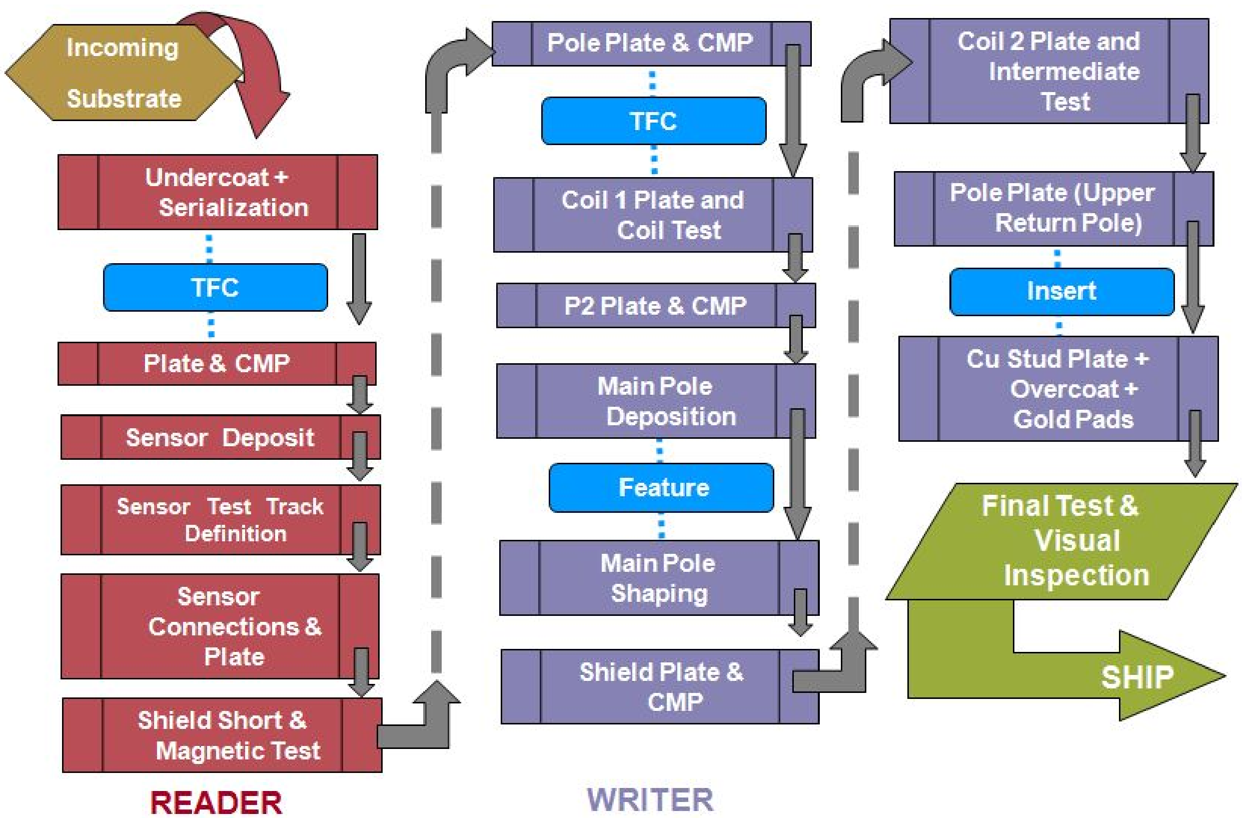


Figure 1: Wafer Routing Process

Project Background

In the summer of 2010 Company A needed a new Chemical Mechanical Planarization (CMP) tool to replace its current outdated model. Company A decided to purchase their CMP tool from a new vendor, and because of that the Development Engineers and the Process Engineers were tasked to release a first of its kind to manufacturing with a very flexible timeline. Even with this flexible timeline the release to manufacturing date was dramatically later what was originally planned. On top of that the Engineers neglected to involved the Manufacturing team early on (see Appendix C-Manufacturing Manager), which has resulted with a tense relationship between Manufacturing and Engineering as well as resulted in a large delay in project completion.

The project suffered from multiple partial project managers, because the tool started as was purchased and chosen by the Development Engineering team and then handed off to the Process Engineers to deliver to Manufacturing. Both Development and Process Managers commented that they lacked the proper upper management backing, which led to this project having a lower priority of time as well as money invested. Within Company A there was no clear or defined space for documents to be managed. There was also no clear idea of who this project actually served, or who their customer was. This led to poor resource management especially of the Development and Process Engineer time. It led to the process failing manufacturing's internal quality standards. Finally, none of this process was documented and stored in a public space to ensure the same mistakes aren't made.

The problems present within this project are present throughout the majority of projects in industry today. It was decided that research should be done in order to derive and compile the best practices within Project Management, Knowledge Management, and Quality Management and therefore create a comprehensive Project Quality Plan.

Literature Review

After researching project management, quality management, and knowledge management, the writer gained significant insight into the nuances and demands of projects. The following details the specific nuances of: project management (PM), specifically dealing with defining appropriate success metrics and focal points with case examples of implementation, quality management (QM), specifically dealing with risk management, the use of FMECA, and the necessity of customer involvement, and knowledge management (KM), specifically dealing with knowledge sharing and distribution and the current need for real time updating. Project management that follows the principles of a PQP is, in essence, comprised of a high functioning project team, and a efficient and effective project manager who fulfills the needs of the project at hand, while producing a project that is self-sufficient in meeting the needs of the future.

Project Management

The successful deployment of new products is essential for firms to gain and maintain competitive advantages today (Kim 2008). But with more than $250 billion is spent in the United States each year on industrial projects and with only 26 percent of these projects completed on time and within budget (Bounds, 1998) it is easy to see that projects often do not reach the desired goal. The question is often posed: *What causes projects to fail so often?* The answer is a lot whole lot of things. It is important to figure out the important factors that a manager should focus his or her energy on. A survey of literature and investigation of past project managers directed the writer to see that the project success depends on the project team, the project manager, and how those two work together. The management of the

project at a structural level depends mainly on the project manager. The project manager is in charge of selecting projects, selecting team members, prioritizing tasks, and most importantly facilitating and encouraging communication between the team. There are a multitude of software packages that can aid in the planning, documentation, and prioritization of projects but projects still fail. Project success cannot comprise of plugging different costs into a formula, project success depends on the management of the team.

The question arises: *What must a good leader be focused on?* A survey of literature provided the writer with multiple metrics for a PM to focus on. In order to meet the measures of project success (Project cost, schedule, impact to plant) a PM must identify the key determinates of team success and exploit them (Young 2008).

Metrics Lead to Identifying Important Factors

There are three widely accepted objective measures of project success: project cost, project schedule, and plant operability (Young 2008). Young defines success in terms of project cost if the project is completed within the proposed budget, the project schedule is completed within its initial scheduled time frame and project is characterized by high utilization with minimal maintenance shutdowns (plant operability). Often the metrics are portrayed in aggregate fashion but in order to be able to optimize one or two metrics they have been disaggregated. If the desire to optimize the project cost was suggested the best predictors (and therefore the focal points) are project team efficacy, cross-functional project teams, autonomous project team structure, and virtual office usage. If the desire is to optimize the project schedule the best predictors are the continuity of project leadership, cross-functional project teams, and project manager incentives. As stated, project leadership is important. Jha states: "the project coordinator has to be adept in team building skills, contract implementation skills, and project organization skills." Finally if the desire is to optimize plant operability the best predictors are clear project goals, and an office design that facilitates effective communication (Young 2008). In general Young proposed that the result of their cross-sectional research implies cross-functional teams have a positive correlation to project successes. Below is the full list of factors and matrices displayed graphically in Figure 1.

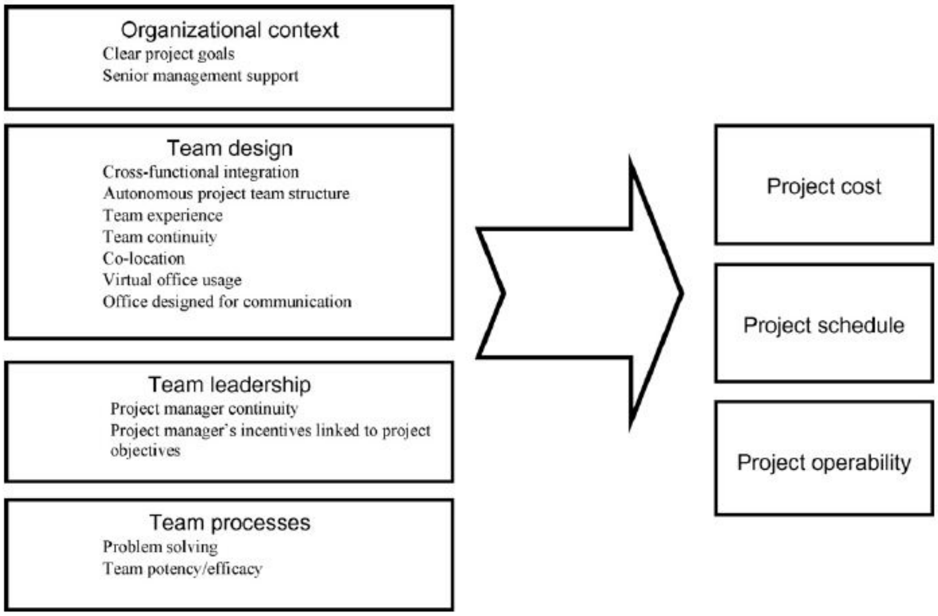


Figure 2: Projects Success Metrics and Factors (Young 2008)

The factors which displayed no interaction were the project team's co-location, and the project team's continuity, implying that within reason team members can come and go as needed for the project development and implementation (Young 2008). Young admits that for the purpose of simplicity they had to ignore the soft indicators of project success such as satisfaction of the client, and employee development and satisfaction cultural norms (Young 2008). The Skunkworks approach (Bommer 2002) affirms the importance of the "soft" factors by adding that in fact customer involvement and employee development are not only helpful but critical to project success.

The power of a good cross-functional team is continually reiterated throughout literature (Cooper 1995). In the study done by Cooper where 103 major new products were investigated. It is found that the three factors (on top of cross-functional teams) which played important roles in getting a project delivered on time are undertaking solid up-front homework, a strong market orientation, and getting sharp early product definition (Cooper 1995). On the topic of market orientation involving the customer throughout the development phase with rapid prototyping was found to be instrumental to fast product delivery (Cooper 1995). A topic that is only briefly mentioned is that of proper project launch. It is believed that project launch is a reaction to the factors mentioned above.

The metrics once aggregated to encompass all three measures of project success that a PM is concerned with fit two main groups: project manager related and influenced, and project team related and influenced. Within the project team related metrics are: team efficacy, and cross-functional team integration. Within the project leader related metrics are: PM continuity and incentives, clear goals, office design for communication, and autonomous team structure. Investigated below are the factors that make up a strong project team, and the concerns a project manager must be aware of.

Metrics Investigated: Self Managing Work Teams

As discussed above, it is imperative that a project team has efficacy (or potency) and is cross-functional. As companies are looking for more and more places to minimize their spending they are turning to Self-managing work teams. The claim to fame of self-managing work teams (SMWT) is that not only do they

enhance work-life quality, but they improve customer service, and productivity (Millikin 2010). As implied in their names, SMWT start at an individual level.

The characteristics of SMWT players are someone who performs their own duties well, and rarely solicits others to help finish their tasks. They are commonly called “self-starters” and do not rely on their boss to provide direction or tasks to do. The obvious potential issue it that when placed in a team, SMWT struggle to reach of point of cohesion and constant are working in opposite directions.

A team leader desiring to fulfill the metrics found to be crucial to project success would not only choose players that are self-managing, but would choose players coming from all of the different parts of a project. The main job of the project manager in this instance is to give these players a reason to work together, which is commonly done through creating team cohesion. Team cohesion encourages self-managers to work harder for collective pursuits according to trust scholars. Because trust reflects (and underpins) cohesiveness, individuals who trust their teammates may more fully apply their resources and energies toward the group’s task as they believe that teammates will not takes advantage of them or let them down (Millikin 2010). Millikin later states that the effective ways to induce team building is through the: “diversity training, collaborative problem-solving exercises, and conflict management training that integrates social activities.”

Once the trust is built the next task for a PM to finally have a team that effectively works together is coordination and communication. Coordination in the age of the internet is facilitated through many different software packages, ranging from openware to MicroSoft’s project management package. Because MTS (Multi-team systems) leaders are more likely share authority with teams and circulate stronger empowerment climates within MTS self-managing teams tend to adopt collective beliefs that their MTS can muster whatever it takes to succeed (Millikin 2010). With great empowerment and with shared authority, SMWT players are more likely to come up with their own goals and tasks, leaving the PM to serve as a sounding board and protection from upper management.

It is possible that a PM is not always able to find or fund a team fully comprised of self-managers. In that case Millikin suggests that the best way to enhance individual self-management with an already established team, leaders might engage in more one-on-one coaching or mentoring with team participants and ensure that excessive peer control does not constrain members.

As the paradigm of team make-up has shifted for the better due to budgetary and efficiency concerns, managers are encouraged to use this opportunity to foster the growth of players that are not quite self-managing. A potent cross-functional team is essential to project success, and a project manager is in charge of selecting, grooming, empowering that team.

Manufacturability: The Concerns of a PM

A project manager obviously has many concerns, but the most important one is that of manufacturability. For a successful NPD, a firm must be able to develop an innovative product that appeals to the customer and manufacture it in large quantity in order to reap profit from the mass market: its ability to manage the ramp-up production effectively is essential to the eventual success of new product development (Kim 2008). This ability to ramp-up production effectively is called manufacturability. An efficient production ramp-up consists of quickly restoring the production system to high productivity and low yield loss once the product has been introduced. *When is manufacturability threatened?* Manufacturability is threatened when there are unresolved problems related with the product and/or market attributes during the NPD process, since they make the transition from

development environment to ramp-up production stage difficult or delayed, causing quality problems along the way (Kim 2008).

Due to the fact that NPD is a fast-paced, creative process where participants are often switching between high-level conceptual issues and a low-level focus on details, it is an unfortunate reality that in design teams, necessary activities routinely "fall through the cracks", documentation lags development, and decisions are made then remade due to an inability to get all the players together, the introduction of new players and an inability to recall all the details (Cooper 2003). Issues are raised and forgotten because attention was diverted elsewhere. Decisions are made based on sketchy information that is not revisited. Opportunities are lost because no one is assigned to follow up on them. Quality control starts with the beginning of the project with the customers and the design team. The section below on quality management goes further in depth the purpose of customer involvement.

The benefits of the efficient ramp-up are desired by every project manager, but Kim suggests that these benefits will not be reaped unless the manager implements a cross-functional team. A cross-functional team does not mean that a random selection of people from a smattering of functional groups is desired. As mentioned above the team is best when comprised of SMWT players. Kim further adds that it is essential that the teams are balanced (and therefore the choices regarding the project are balanced) and that according to the research, a physical co-location is still relevant. As social media is still being introduced, especially to an older generation that has yet to interact with this new technology. The writer believes that because the workforce is mainly comprised of workers who grew up without social media is currently the reason why a physical location is still desired. This is because the most information can be transferred face-to-face. The writer believes that it will not be long until this norm changes to a point where the social media scene is the more desired form of interaction.

Manufacturability is a huge concern of a project manager. It is essential that a PM knows to involve every functional group and their concerns within the team in order to efficiently ramp-up production. A project manager is rendered completely ineffectual if they are managing the wrong type of project though. Discussed briefly below are the recommendations of a few scholars for figuring out the PM metrics depending on project scope.

Project Type Leads to Identifying Important Factors

Projects are inherently different from each other. Project can range from a preventative maintenance project, to research and development, or possibly in the area that this paper is focused on, New Product Development. Of course there are many other types of projects. It is suggested that it is not the type of project that makes a difference but in fact the scope (Dvir 2008). Dvir continues to specify through his research say that: "Risk management and budget control are less critical for low scope projects but extremely important for high scope projects. Flexibility in management is important for relatively small projects but is not important at all for large projects. Scope is one of the major variables in project classification (Dvir 2008)." This flexibility of management that is talk about pertains mostly to the fact that a manager often needs to manage multiple projects at the same time, some large and many small and if a manager is unable to reconcile that resources will not be moved around as they are needed. Further reading agreed with the metrics set earlier by confirming that milestones are important for project success. This is because when realistic and appropriate milestones are set, the team can work with less interruption from the manager and the manager can focus on building and growing the team rather than making sure task are completed.

Theory Vs Practice

It is important to note that management theory and actual practice often do not perfectly align. In that regard, it is important to note how managers must mix their strategies and tactics all the while carefully juggling office politics.

As defined by Slevin, strategy consists of top level management like the planning and conveying the mission and tactics consist of managing the technical tasks, managing personal, and ensuring communication channel remain open and are flowing. Obviously a PM cannot rely completely on a good strategy or on good tactics. Displayed below on Figure 2, Slevin details the consequences of a PM not being highly effective tacticians and strategists.

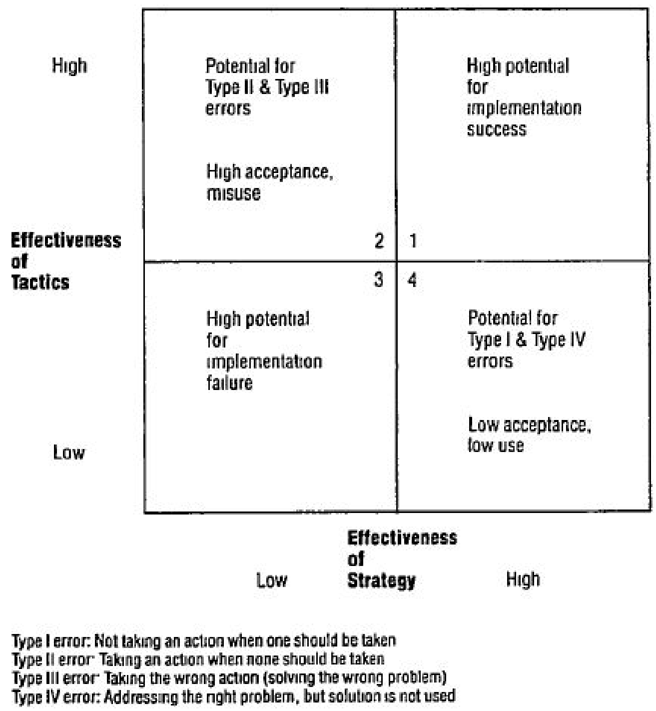


Figure 3: Strategy/Tactics Effectiveness Matrix (Slevin 1998)

It can be seen that it is important to have high effectiveness of strategy and of tactics. It is not as easy as just understanding what strategy and tactics mean though. Managers must understand when it is more important to focus on strategy (in the beginning of the project) and when it is important to focus more heavily on tactics (towards the end of the project).

The question arises: *If we already know that communication is essential for tactical implementation, what are the best practices for strategy?* PMs first start by knowing that they must present the goals of not only the project but the company as a whole in order to motivate the team to reaching the optimal mix of cost, schedule and plant operability. Project Managers today though are limited by what is considered to be the correct practices (Gutierrez 2008). When interviewed PMs would respond with apparent contradictions:

> "[PM were] talking about the importance of planning and forecasting, while concurrently expressing the impossibility of predicting everything. They advocated the use of objective financial figures in evaluating ideas, the some minutes later, they argued for the necessity of subjective judgment. One respondent stated that the existence of written routines was

> imperative, then immediately explained how ideas are developed informally over coffee breaks." (Gutierrez 2008).

If a project is force to follow project norms they are doomed to struggle with the project until they eventually hand it off. Another group of PMs interviewed detail something similar saying:

> "Team members often feel that they barely have enough time to do what they have to do, and never have enough time to do all that they want or should do. The sheer volume of work leaves little discretionary time to engage in the scanning type behaviors that enable discovery and feed into the innovation process (Cooper 2003)."

As can seen from the excerpt above there are best practices, but those best practices seem to be broken more often than they are followed. Respondents talked about the importance of planning and forecasting, while concurrently expressing the impossibility of predicting anything. Literature on selecting and prioritizing ideas has models and assumptions are based on the static paradigm, rational means, formal processes, and hierarchical decision making (Gutierrez 2008). In an age where it is part of viability consists of tangible quantification, the static paradigm, rational means, and formal process are the obvious choice for proving viability. Gutierrez notes that while the reality seems contradictory to the theory that: "due to the complexity of the innovation process, there is no single approach for making decisions or understanding innovation that is suitable for all situations (Gutierrez 2008)."

It should be noted though that despite the fact that other approaches would be more appropriate for most circumstances, organizations display different levels of acceptance of them. This puts decision makers in the conflictive situation of applying approaches that are sometimes appropriate but not accepted, and other times accepted but inappropriate.

As noted above the reality is that projects are not made to follow the paradigm that is currently accepted for proving viability. A manager must be flexible and often if not always work within the constraints of office politics while at the same time motivating their team beyond them. The project manager's only hope lies within their team. They need their team to make sure they can produce a quality product within time and cost which does not negatively impact the production plant. Often the best way the make sure a NPD project impacts a production plant in a positive manner is to ensure the quality of the deliverables.

Quality Management

The quality of what is delivered depends heavily on planning for and addressing possible problems before they happen. A quality project is one that will sustain itself no matter the possible scenarios. An industry standard for indentifying and assessing risk is through the use of Failure Mode Effects and Criticality Analysis (FMECA) and through involving the customer early and often.

Identifying and Assessing Risk

Every project has risk and risk assessment is important to the NPD process because it helps to "flush out the risk management actions – doing something like this ensures that actions are taken (Szwejczewski 2008)." Risk always consists from not meeting one of the three measures of project success. There is a risk that the project will go over budget, there is a risk that a product will take longer than it was scheduled, and there is the risk that the implementation of the project will result in the production loss and/or defective products. Obviously there is an infinite amount of risks. So the next question that is asked is: *Because time is finite, where do you look first?*

Typically any risk that might cause the total failure of the project would be tackled first and then it is common to then figure out which of the measures are the most important to the company and then figure out the risks associated with a failure in one of those measures. Obviously there is uncertainty in every process and NPD is no immune to this. Often process uncertainties such as flow rate and temperature variations, feed quality fluctuations and equipment deteriorations, may lead to significant disturbances to the processes, thereby degrading the operation performance (Zhao 2008).

The PMs and their team must be continuously appraising and managing all types of risk during the NPD process itself, because what distinguishes NPD project from others is that they are characterized by a high level of risk (Szwejczewski 2008). Szwejczewski found that companies on a whole utilize simpler and less sophisticated techniques. These techniques rely heavily on the intuition of the leader and the team members, it is important that the team is focused on every different aspect of the project which further cements the need of cross-functional teams. There are many techniques for hazard identification which totally depend on human observation (Mili 2008). Risk analysis is presented as a tool to support decision-making. The robustness of the risk assement depends firstly on human expertise.

It is important that reliability assessment (often paired with risk assessment) is highlights the potential problem areas so that they can be dealt at the design stage of the system life cycle (Zafiropoulous 2004). Once possible risks are identified the next question is: *how are risks assessed once they are addressed?*

Found that on a whole, companies were not using advanced normative techniques discussed and were instead utilizing simpler and less sophisticated approaches. One common approach is through FMECA. FMECA are asked by customers but hardly employed operationally (Mili 2008). Throughout the assessment process those involved must maintain the mindset that they are aiming to design an optimal maintenance strategy must minimize maintenance costs and maximize equipment reliability (Mili).

Continual FMECA

An important document that a project manager should be working into team discussions of risk assessment and control is the FMECA document. Often suppliers perform FMECA to satisfy customer demand, but that is when the document dies, because it is not seen as mandatory to complete daily work (Mili 2008). Often the process is just performed to satisfy customers' mistrust, which leads to documents only oriented towards the customer and is unusable for daily risk management and technical decision in a "real life" manufacturing (Mili 2008). On top of the FMECA is produced separately from integration or the design tools, which is normally to protect proprietary information. Finally FMECA documentation is known for its unwieldiness, which is a further disincentive for continual use. This adds to the amount of risk that is not addressed from the first day the NPD starts.

When used correctly it is found that although a FMECA was performed to satisfy a contractual requirement, it was the insights derived from it, coupled with the interactions with the rest of the design team, which provided the increased functionality and reliability of the end product (Frank 2005). Frank continues saying that an essential part of the team gain insights from the FMECA lay heavily on the shoulders of the reliability engineer on the team. He says that the reliability engineer brought to bear on the project insights gained from thinking about how the system, including interactions with people, and its components, might fail (Frank 2005). Obviously an important part of team is someone who understands the whole system. The writer would like to point out that precursory knowledge of the

system is not sufficient, the insights of those deeply involved in different processes are essential to finding the possible risks and figuring out the correct way to address them.

The power of a FMECA lies in the recognition that sometimes a frequent but small (and sometimes easily solved) risks provides more benefit when addressed than that of an infrequent risk, which would be more costly to fix. Mili proposes that the automation of the FMECA process greatly reduces the cumbersomeness of the method, and productivity gains are easily made. On top of that if data retrieval and update (discussed more in-depth later) is as automatic as possible then there is a much less risk of data obsolescence (Mili 2008).

The project manager must keep in mind that their team is essential to correctly assessing risk. They need to make sure they are designing for graceful degradation to combat incipient or partial failures, or system aging. The concept is sometimes called fault tolerance or forgiveness, and includes notions that essentially provide a margin of safety to the expected/intended operation (Frank 2005). The team is the PM's best tool to addressing the risks, often what is forgotten is that the customer is also an essential part of the team. The customer is what the product is designed for, and while the customer could lie within the company (for example the manufacturing team is often the customer of the Engineering team) or outside (i.e. the end user) the customer is the one who ultimately decides of the product fails or not.

Customer Involvement

Quality management starts and ends with the customer. As shown in Figure 3 below, when the customer is involved the whole process when the customer is placed in a position of control and made part of the team, costs were contained through better decision making, which drastically reduced the amount rework to do and controlled project scope.

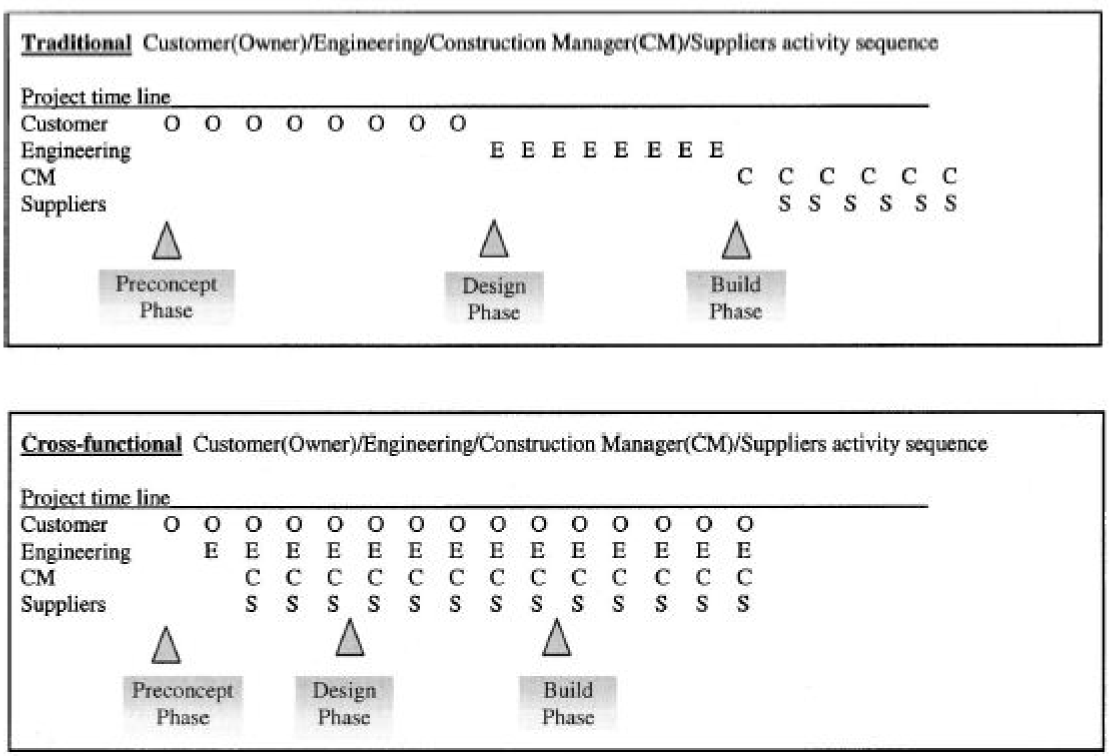


Figure 4: Project Time Shortened By Customer Involvement (Bommer 2002)

Skunkworks teams (a concept developed by Lockheed Martin) are characterized by their ability to make ad hoc decisions and by often bypassing time-consuming bureaucracy. This dedicated project team even when presented with 3 NPD (new product development) projects and an R&D (Research and Development) project delivered a quality product because of extensive up-front planning, leveraging project overlaps, empowering the team, and critically analyzing customer needs (Bommer 2002).

In terms of directly applying a quality improvement program, the project manager must follow similar methods and practices to that of the current project manager. If a quality improvement project manager is to ensure the quality program succeeds, they are to make sure that: they address the fundamental trade-off between current and future performance levels, they make sure that the source of commitment to ongoing improvement effort shifts from managerial actions to employee initiative, and that when change occurs they adapt their improvement tools and manage expectations for continued gains (Keating 1999).

Feedback is Essential

The last step in risk analysis and quality management is implementation. The problem is that even though continuous improvement is widely accepted quality programs often struggle to gain initial acceptance and sustain that improvement. Scholars suggest that main reason is: that the failure to account for feedback from these tightly coupled activities leads to unanticipated and often harmful side effects that can cause the premature collapse and abandonment of otherwise successful improvement programs (Keating 1999). Keating further suggest that the "employees doing a job are the best-informed experts and should be responsible for identifying improvement opportunities and implementing changes." It is the feedback and the insight gained from working with the operators upfront that can aid in the assessment of risk and the implementation of risk mitigation programs.

Knowledge Management

Data managed well is data that induces the sharing of knowledge and incorporates constant feedback. Knowledge sharing relies on making the (even if they are not an official team) work together and remove the idea of proprietary information as Toyota has done within their organization and with their suppliers.

Knowledge Base and Knowledge Sharing: Following Toyota's Example

It is important to first start with a base definition of knowledge. As defined by Toyota: compared to information (a good example being sales figures), know-how is more likely to result in advantages that are sustainable. Know-how is sticky, tacit, and difficult to codify and this is difficult to transfer. Thus, it requires "thick" or dense ties with other members of the network (Dyer 2000). This sharing of know-how is what leads to organizational learning, which in turns leads to true change and organizational improvement. Dyer asserts that organizational learning is perhaps the key factor in achieving sustainable competitive advantage and organizations learn by collaborating with other organizations as well as observing and importing the practices of other organizations. A firm's customers and suppliers were is primary sources of innovative ideas.

The common roadblocks to implementing knowledge sharing programs are that the parties involved are concerned with: (1) preventing "free riders", and (2) preventing undesirable knowledge spillovers and the requirements of effective sharing of know-how requires: (1) absorptive capacity on the part of the

receiving firm, (2) the appropriate process to make the transfer happen, and (3) incentives for knowledge sharing (transferring firm) and knowledge acquisition (receiving firm) (Dyer 2000).

Toyota addresses these within and outside their organization in a few different ways. Toyota first solves the issue of "free riders" and the worry of knowledge spillover by "eliminating the notion that there is "proprietary knowledge" within certain knowledge domains (Dyer 2000)." Because of Toyota's market strength, they can essentially make their own rules; Toyota is able to dictate cooperation between their suppliers.

In response to the sharing of knowledge requirement, Toyota addresses the situation as a long term investment. They are known for the quality of their product and because of that they are sought after. For their suppliers, Toyota does not charge fees for its assistance but does demand that participating suppliers be willing to let Toyota bring other companies to see their operations when the project is completed. On top of that, Toyota does not ask for immediate price decreases or a portion of the savings from the improvements (Dyer 2000). Toyota is generous in offering assistance, but they also expect results. It is the desire of Toyota to improve the quality of their product, which is why they are willing to invest into their suppliers to ensure that their suppliers can meet their quality requirements. Toyota is known to have at least two different suppliers for the product they want, and detailed below in Figure 4 the natural progression of knowledge sharing that Toyota desires. They do not need to be only place where knowledge can be gained. They know that if their suppliers talk with each other than they will learn from each other, and in turn produce a higher quality product.

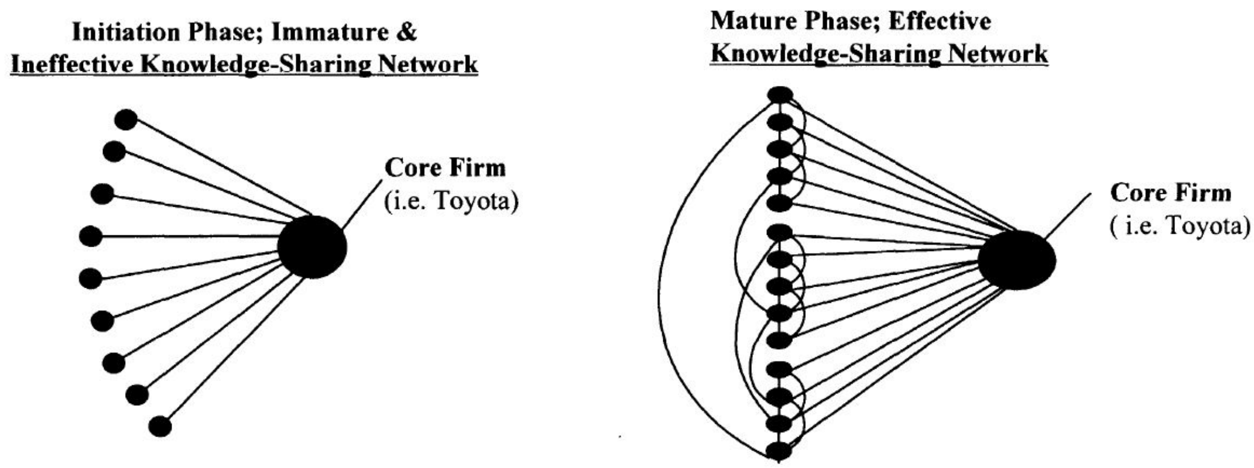


Figure 4: Mature Knowledge Sharing (Dyer 2000)

In summary Toyota is effective at creating and effective knowledge sharing network because it: (1) creates organizational units with the explicit responsibility to accumulate, store, and diffuse relevant knowledge within the network, (2) creates "rules" or norms for participation in the network which essentially eliminates the free rider problem, (3) creates a ranges of processes and nested networks within the full network to facilitate the effective transfer of both explicit and tacit knowledge, and (4) creates incentives for knowledge acquisition and application (Dyer 2000). Toyota is known internationally because it is able to gain and disseminate know-how efficiently and effectively throughout the suppliers in their industry. They have make quality control everyone's problem and they ensure that quality in gained through appropriate sharing of knowledge.

Live Data Update

As suggested above in the discussion about FMECA, a continually updating situation is the best for the organization, as Mili states that: "A regular FMECA database update, by maintenance events allows for enhanced knowledge about in line risks in the workshop." Displayed graphically in Figure 5 is the process for data updating and feedback. It should be noted that it is a never-ending loop. The continuous feedbacks from various sections together with an agreement on detailed methods of construction with all parties involved and preparation of a project quality plan would automatically put all parties on a more responsive position that enhances coordination (Jha 2006).

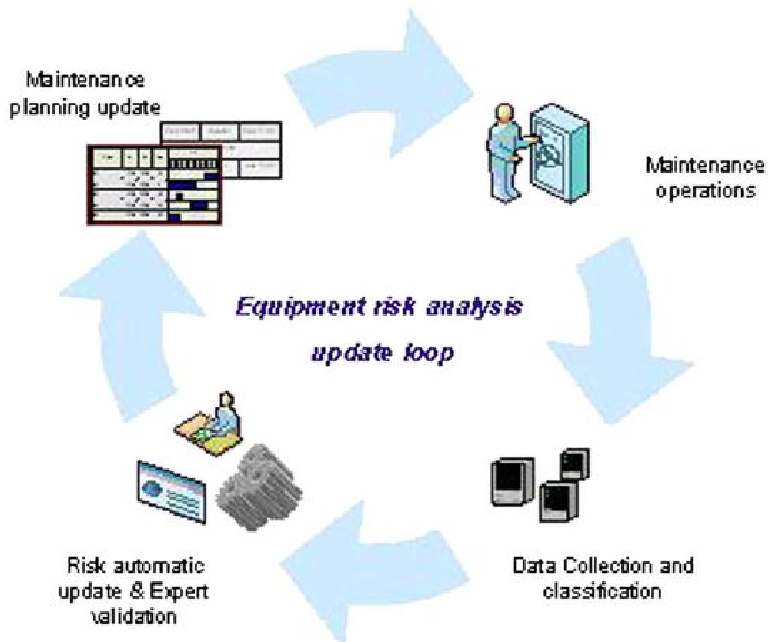


Figure 5: Update Loop for Risk Analysis (Mili 2008)

Tools have the potential to reduce uncertainty and NPD risk. Typically the problems with information systems are that they: exhibit cross-platform incompatibility, non-standard output formats, steep learning curves, and high initial investment and maintenance costs. All of these are hurdles to implementing a more open and accessible data management system (Cooper 2003).

Cooper warns PMs desiring to quickly see the results of database implementation saying: "Leaders need to appreciate that the knowledge acquisition and development process must gradually and iteratively lead to risk reduction, despite the inherent unpredictability, if the NPD process is to succeed. It is not simply networking people, as in collaborative tools. Moreover, NPD participants are overwhelmed so that proactive search and retrieval is unlikely (Cooper 2003)."

While Data management, especially through the use of a database has the potential to positively impact every aspect of project implementation, including quality management, it is essential that project managers enter into knowledge sharing endeavors knowing that even if knowledge gained is immediate, it the knowledge utilized that ultimately makes knowledge useful.

PQP in Practice: Skunkworks

The most visible representation of a PQP utilized comes from Lockheed Martin with their Skunkworks team. Skunkworks teams (a concept developed by Lockheed Martin) are characterized by their ability to

make ad hoc decisions and by often bypassing time-consuming bureaucracy (Bommer 2002). A prime example, which was examined through literature tells of a time when the Skunkworks team even when presented with 3 NPD (new product development) projects and an R&D (Research and Development) project delivered a quality product because of extensive up-front planning, leveraging project overlaps, empowering the team, and critically analyzing customer needs (Bommer 2002). When Boomer broke down the essential parts that made the Skunkworks team successful he said: "The skunkworks project management team was able to deliver the projects on time and within budget by: (1) adhering to a clear focus on their mission; (2) including extensive up-front planning efforts; (3) critically analyzing customer needs; (4) leveraging project overlaps; (5) involving supplier early; (6) empowering the team; and (7) breaking rules (Bommer 2002)."

It is easy to compare the metrics of a successfully managed project detailed earlier and see that those are the very same reasons why the Skunkworks team was successful. To some degree, a successful PM has to have the ability to orchestrate, foster, nurture, and develop the relationships of several diverse groups, while at the same time being able to plan for the project gates and address future risks.

Assessing Economic Viability

Proving economic viability of a project is essential to project implementation. The question of how to detail project saving for a product that didn't exist beforehand arises. Bauer suggests that the correct way to present economic viability is through the use of improvement of profit factors, and the reduction of cost factors. The profit factors suggested are (Bauer 2007):

- Throughput increase
- Process stability improvement
- Energy consumption reduction
- Increased yield of more valuable products
    - Reduction of Variability (Zhao 2008)
- Downtime reduction, and less waste (better use of raw materials)

The cost factors include the cost of (Bauer 2007):

- Software upgrade (data management)
- Manpower cost, control hardware
- Production loss due to installation downtime
- Implementation Cost

Often the link between quality improvement (often hard to define) and throughput (often used as a performance metric) is displayed on the graph below. It is this link that begins to display the effect that a PQP has on economic viability. When a project is managed correctly and the metrics are defined and known, there is often a reduction in the production downtime. Figure 6 below is the common argument for a holistic PQP. The argument is that it must address the quality of the needs of the future because that in turn will produce greater throughput due to less maintenance.

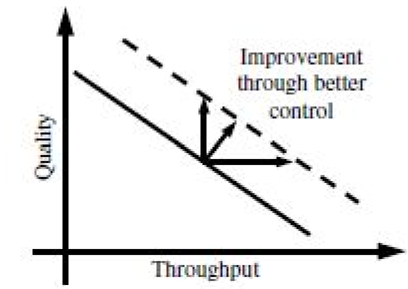


Figure 5: The Relationship between Quality and Throughput (Bauer 2007)

As discussed above project managers are in the constant battle of proving economic viability according to metrics that are not directly applicable to the project at hand, but the best that can be done is present a plan that will reduce the cost, while at the same time increase the quality of the current product.

After compiling the best practices from each of the different schools of through, the researcher constructed a few simple steps and tools which Company A could use to develop their own PQP. Those steps and discussion of tools are detailed within the next section.

Design of Solution

The engineering method that was followed in order to come to an acceptable solution is called DMAIC. DMAIC is an acronym that stands for Define, Measure, Analyze, Improve, and Control. The following sections reflect the use of that method.

Define

In order to design the most versatile PQP the user must understand the goal of a PQP, to eliminate waste and severely reduce failure.

The question arises: "What is considered a failure?" After investigating the Standish Group's many definitions it was decided that at the most base level a failure is when the project does not meet the intended goals and requirements of the project. More specifically, it was decided that if the project was either: abandoned, delivered and never used, late, over budget, or completed with less than the required functions than the project as a whole can be considered a failure. It is important to understand the definition of a failure because it allows future project managers plan ways of addressing the five failures described above.

Furthermore, after first understanding what a failure will look like the next step is to understand what the impacts of project failure are. The three main impacts to the company are: the loss of strategic opportunity, the increased financial costs, and the extended use of limited resources. In this case, Company A experienced all three of these main impacts. Company A ended up hiring on temporary work in order to crash the rest of the project timeline and ensure they finished the project within a year. Interviewing the employees involved in tool installations led the understanding that the acceptable tool release to manufacturing was just over 3 months. By hiring on temporary work force Company A relinquished the strategic benefit of installing that tool, as well as missing the opportunity to use the temporary workforce to become involved in cost savings or other value added processes.

It was also found that there are some more intangible impacts to the company when a project fails. The most prevalent and potentially the longest lasting impact is the lost faith in either that individual's worth to the company or the worth of the group they are involved in. In an excerpt of the project post-mortem interview the interviewer asked about just simply prioritizing and working on the project the Process Engineer responded that he prioritizes:

> *"Like every other project there is. This was a first of a kind tool, which offered more flexibility within the process and it would produce higher quality product as well as being a more reliable tool that would require less maintenance, but it required more time to complete this project than I have. I don't really have a method. I will do what my manager tells me is most important that day and if I have extra time I will work on side projects. Every day when I come in I rank my work with two criteria: maintaining the manufacturing line is always number 1, process improvement is then number 2"*
> *– Process Engineer*

From this response it can be seen that Company A is going to have a hard time changing the current culture of just firefighting problems. The Process Engineer knew the possible benefits of completing this project correctly. He knew that with the successful implementation of this new tool that his firefighting job could decrease and he would be free to make a positive and lasting impact on the company. This negative impact has a more detrimental effect on the company because it cuts to the heart of the company, its employees.

By correctly implementing a full PQP, Company A has the opportunity to address both the immediate and long term impacts of project failure and to change the culture of the company. The next step in the quest to devise an appropriate PQP design for Company A was to analyze the results of the post-mortem interview.

Measure and Analyze

The interviews conducted allowed the researcher to investigate and measure the extent to which Company A was exposed to the PQP principles as well as the extent to which the employees believed they had been successful on the project for which this study is based upon.

Detailed below in Figure 6, are the responses of 16 employees who were involved to one extent or another with the project when there were asked if they believed that the project was: "Fully Successful", "Marginally Successful", "Failed", or "No Idea"

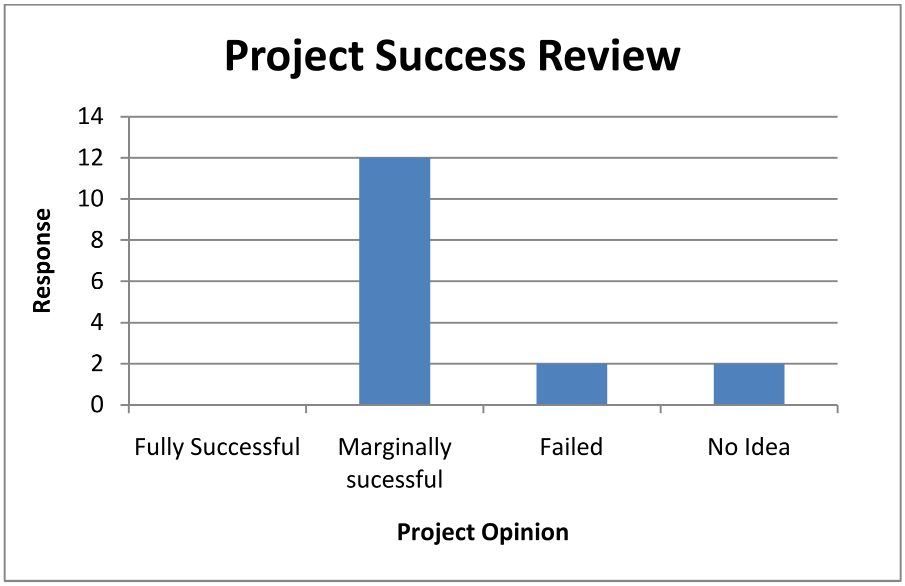


Figure 6: Employee Analysis of Project Success

From Figure 6 alone, one can derive many conclusions. First of all it is important to note that not one person of this wide ranging sample believed this project was fully successful. When one compares the survey choices to that of the definition of project failure applies to all but the "Fully Successful" choice. Furthermore it is important to note that the responses are not consistent. Upon analysis of the follow up questions it can be seen that this discrepancy is due to the lack of communication between the different groups as well as the lack of communication within the individual groups. This can also been seen with the group that responded that they had no idea of the relative success of the project. The interview with the Facilities/Supplier Manager was particularly revealing because is distinctly details the divisions that exist between different groups at Company A. The Facilities/Supplier Manager was only concerned that the tool went in, but had no idea how the release to manufacturing ended up going. Furthermore this manager was able to detail the project management tools she used but her information was not fully shared across the company. The Process Engineer remembered that they as a team were just told when the tool was ready to be tested.

The interview that detailed the largest disconnect between organizational groups was the interview with the manufacturing manager. The word distrust was used to describe the relationship now between manufacturing and engineering. On top of that he expressed frustration that his group wasn't even involved upfront with the purchasing decision. The relationship between Engineering and Manufacturing needs to be strong by necessity. Both groups need cooperation with each other in order to make positive changes as well as make lasting changes. Both play a crucial role in improving every company process, because the engineer's expertise and knowledge is useless and ineffectual if s/he is applying their insight and time to a problem that is irrelevant to the work at hand.

The full list of questions and the responses are located in Appendix C.

Improve

The accumulation of the observations while working on qualifying the tool, the post-mortem interview and the research into PM, QM and KM has lead to a PQP that will adequately address the current and future project needs of Company A, the list of the best practice for PM, QM and KM are located in

Appendix F. The main facets of a PQP can be described as a plan that addresses needs in three time periods. First it serves as framework for the project prepping, and then it gives direction to complete the project in time and within budget, and finally it leaves a legacy for future projects to call upon in order to reduce redundant errors. A visual of how project management, knowledge management and quality management work together to become a PQP is displayed in Figure 7.

Figure 7: Elements of PQP

For Company A it is recommended that they implement a three pronged PQP, in which customer needs are addressed, knowledge bases are implemented and continually updated, and the project is managed by a visible and organized leader. The first step is to correctly identify the customer. The chart below is a useful tool for figuring out no matter the project that is being worked on. This is especially important for the Engineering teams to realize that more often than not their immediate customer is manufacturing. This should shape the engineer's new tool purchasing decisions as well as guide the other projects that they undertake. This intimate knowledge shapes the use tools like FMEA to reflect and address the needs of the customer. Understanding the customer is the first step to a strong PQP. Understanding the customer allows the project manager to accurately construct first a vision statement and then goals, a requirements document, and a project timeline or Gantt chart.

Table 1: Identify the Customer

	Equipment Engineers	**Process Engineers**	**Manufacturing**	**Equipment Vendor**	**Facilities**	**Control Engineers**	**Operations**
Equipment Engineers	---	Supplier	Supplier	Customer	Customer	N/A	Supplier
Process Engineers	Customer	---	Supplier	Customer	Customer	Customer	Supplier
Manufacturing	Customer	Customer	---	*N/A*	N/A	Customer	Customer
Equipment Vendor	Supplier	Supplier	*N/A*	---	Supplier	N/A	N/A
Facilities	Supplier	Supplier	N/A	Customer	---	N/A	N/A
Control Engineers	N/A	Supplier	Supplier	N/A	N/A	---	Supplier
Operations	Customer	Customer	Supplier	N/A	N/A	Customer	---

Once the needs of the customer is understood fully the next step is for the project manager is to design a Gantt chart. A Gantt chart is an effective way to depict how tasks are related to each other. This is useful because it allows the manager to allocate resources efficiently and get a complete picture of which tasks are essential and which ones can be pushed back if they need to. Because it is useful to have the continually updated Gantt chart updated and tasks for each employee visible it is recommended that project managers use project management software that is viewable and editable online.

After extensive research and testing it was decided that Plandora (http://www.plandora.org/) is the program which would address the needs of Company A. Because cost of implementation has been often used as reason for not using project management software, research was direct toward free software. Plandora stands out against free software as well as the software that cost money because it is intuitive, it has a lot of features, it is web based as well as open source. On top of all of that, the information about the projects (task, risks, issues, lesson learned, etc) are automatically indexed and can be searched through a 'google-like' GUI, consolidating a knowledge base of all projects in a collaborative way and with common sharing. This knowledge base serves as a quick and easy way for the project manager to wrap up a project.

The project wrap up is as equally important to maintaining successful projects as understanding the customer and planning scheduling. A final wrap up for a project gives the employees involved closure and allows them to be proud of the hard work they put into it. It also gives the team a chance to document the lessons learned and reduce the likelihood of repeating that error. It is also recommended that this knowledge base is located where everybody within the company can access it. Commonly in an academic setting Dropbox (http://www.dropbox.com/) is used as the central meeting place, but due to security concerns it is recommended to use either Lotus Notes Database or an in-house web application where security can be maintained.

The PQP addresses the needs of any project by being involved at every part of the project life cycle. This full involvement will lead to consistent project success due to the fact that it induces an open and learning culture within the company. The PQP has been very easy to sell to Company A initially. It has been presented, accurately, as a change that will cost Company A nothing. It is important to note, as was explained to Company A that every change needs to be sustained to ensure positive results.

Control

The control aspect of the DMAIC process is arguably the most important of the whole design process. This element really is the defining characteristic that determines whether the recommendations will be a flash in the pan or if they will be a long lasting and impactful change.

The method that had been popularized by Toyota for making lasting change starts with the employees. Toyota knows and has proven that to make a lasting change, the change must come from those forced to make the change.

In this case, the largest and most impactful is to ensure the necessary business units are involved from the beginning instead of when it seems they are needed. This is especially important in light of the customer chart (Table 1) because once the customer is involved from design the design flaws can be caught upfront instead of having to wait for corrections to happen to the final product. While seemingly the easiest change for a company is within the control element it cannot be stressed enough that until the change is lasting employees will continue to slip into their old ways and projects will continually to

only be “Marginally Successful.” Project will continue to be more than budgeted for, later, and not completely fulfilling customer requirements unless sustainable changes are made.

Methodology

The real power of the PQP lies within the fact that it is focused on long term change. The change of company culture to preparedness and transparency are the reason for the PQP tools. These tools and software programs make the change easier but to actually assess how successful the PQP implementation at Company A was one will need to investigate the projects that the Process Engineers take on for the next five years. The testing and assessment of the PQP proposal will have to be done through periodical interview of the team members involved. Continual documentation will be done to assess how Company A is allowing the new methods of the PQP to germinate and grow into methods that are truly specialized to their needs.

At the start of April 2011, Company A began the process of the installing, qualifying and release to manufacturing process of two new CMP tools. As of May 27, 2011 the tool is a week away from being handed off to the Process Engineers. This is the first stage of analyzing their PQP.

Results

As mentioned in the Methodology section, it is virtually impossible to analyze how effective PQP has been over a short time span. What can be assessed though is how the users feel about implementing and how excited they are to interact with these new ideas. A recent check up with the Process Engineer involved shows that the PQP culture is starting to be taken seriously.

> *“We are much more prepared this time, and using Gantt charts has made this project easier to convince people that certain work takes precedence.”* – Process Engineer

One can see that the first benefit of a PQP has been derived by the Process Engineer, he understands (and can explain to others) the way a project must fit together to be completed successfully. The Process Engineering Manager, the previous Project Manager, was also able to speak to another tool.

> *“The FMEA is great for addressing problems we have habitually had.”*- Process Engineering Manager

Both of these responses are very encouraging. They both speak to the team members of the project utilizing tools that they have been given and finding uses for them. These positive interactions will lead to further interaction with the tools until expert status is reached and they can in turn teach their fellow team members and widen the strength and influence of the PQP.

The results as a whole have been better than expected. In a large company often there is often a larger resistance to change. It is believed that the previous project’s limited success played a larger part into the team’s willingness to try something new. Furthermore due to the offer of something for free (the tools that were given initially) the team was also willing to give PQP in the very least a small chance. If given the chance to revise the initial implementation of a PQP, a more effective way to convey and encourage implementation would have been through a daylong seminar and workshop, instead of an hour PowerPoint presentation. Due to the current time constraints this would have been nearly

impossible. Furthermore, a full hour together to present the tools and goals and in turn for the participants to ask questions obviously made an impact. As can be seen from the comments from the engineer and the manager the tools are proving to be useful, and therefore have a great likelihood to continue to be used.

At the end of the day, a PQP demands a change in culture in the CMP department. This will always be the greatest limitation of a PQP and any sustainable change for that matter. The hardest thing about qualifying the results of PQP implementation will be ensuring that the teams continue to use the tools and ideas they learned about and then have the patience to observe for the next few years.

Based on results and knowledge and experience at Company A, it is believed that they will struggle to implement and in turn fail to utilize a PQP without a strong and charismatic leader. Without that leader and a strong backing from upper management, project success will continue to be intermittent. Furthermore, the tools will only become truly useful when the entire team buys into the idea that culture needs to change. The PQP has the ability to radically change any company, especially Company A, but the seeds to transparency and willingness to try must be present with the team members.

Conclusion

Every object listed in the introduction has been completed. The past CMP project at Company A was assessed through the lens of project success using the simple criteria of: was the project completed on time, within budget and did the project satisfy the customer's requirements. The past project failed all of these requirements. This failure led to the construction of a Project Quality Plan, and the initial steps of full implementation being put into motion at Company A. Companies in every industry are in desperate need on a strong PQP. Every sector of every industry is continuing to have large, more expensive projects that are expected to be completed sooner and sooner. It is essential that companies understand that project management no longer only pertains to managing the project during implementation but that project management must be combined with knowledge management, as well as quality management. It is with this combination that companies will become more transparent and knowledge will be easily gained throughout the company. This connectedness will allow projects to finish quicker and a fraction of the cost. Further studies would include conducting as a long term study of Company A as well as other semiconductor companies. This will provide even more insight to the possible effects of a PQP.

To ensure consistent and continual project success there needs to be a change in the culture of Company A to one that fully embraces and embodies the principles of PQP. By applying PM, KM, QM tools and methods project success can become a reality. For Company A, areas of focus for new tool deployments should be: Assigning a PM and setting the expectation of utilizing the tools discussed previously as well as the expectation of involving the entire team through and open and easily viewable project schedule and deadlines. Finally this charismatic Project Manager needs to focus on created a culture that can fully utilize the many tools that have been gained. Project success is possible, but one successful project is not enough.

Appendix A: Cost Analysis

Description	Current Time (days)	Labor Cost (Current)	Proposed Time	Labor Cost (Proposed)
Tool Installation	10	$11,538	10	$11,538
Development Team	30	$46,154	21	$32,308
Process Qual	40	$53,846	28	$37,692
Product Ramp (10%-90%)	30	$16,154	21	$11,308
Total	110	$127,692	80	$92,846

30 Day Improvement
27% Improvement

Appendix B: Table of Project Management Software

Comparison of project management software

Software	Collaborative software	Issue tracking system	Scheduling	Project Portfolio Management	Resource Management	Document Management	Web-based	License
Collabtive	Yes	No	No	No	No	No	Yes	Open source
Dolibarr ERP/CRM	Yes	No	No	Yes	Yes	Yes	Yes	Open source
dotProject	Yes	Yes	No	No	No	Yes	Yes	Open source
Endeavour Software Project Management	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Open source
eGroupWare	Yes	Yes	No	Yes	Yes	Yes	Yes	Open source
GanttProject	No	No	Yes	No	Yes	No	No	Open source
KForge	Yes	Yes	No	No	No	Yes	Yes	Open source
KPlato	No	No	Yes	No	Yes	No	No	Open source
Launchpad	Yes	Yes	No	Yes	No	No	Yes	Open source
MantisBT	No	Yes	No	No	No	No	No	Open source
NavalPlan	Yes	No	Yes	No	Yes	No	Yes	Open source
OpenProj	No	No	Yes	No	Yes	No	No	Open source
PHProjekt	Yes	Yes	Yes	No	No	No	Yes	Open source
Plandora	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Open source
Project.net	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Open source
Project-Open	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Open source
Rachota	No	Yes	No	No	No	No	No	Open source
Redmine	Yes	Yes	Yes	Yes	No	Yes	Yes	Open source
TaskJuggler	Yes	No	Yes	No	Yes	No	No	Open source
Trac	Yes	Yes	No	No	No	No	Yes	Open source
web2project	Yes	Yes	No	Yes	No	Yes	Yes	Open source
Xplanner	Yes	No	Yes	No	Yes	No	Yes	Open source
Open Workbench	No	No	Yes	No	Yes	No	No	Open source (disputed)
TeamLab	Yes	No	No	Yes	No	Yes	Yes	Open source and SaaS
5pm	Yes	No	Yes	No	No	Yes	Yes	SaaS
Apollo	Yes	No	No	No	Yes	No	Yes	SaaS
AtTask	Yes	Yes	Yes	Yes	Yes	Yes	Yes	SaaS
Basecamp	Yes	No	No	No	Yes	Yes	Yes	SaaS
Bontq	Yes	Yes	Yes	Yes	No	Yes	Yes	SaaS
DeskAway	Yes	Yes	Yes	No	Yes	Yes	Yes	SaaS
enQuire - Grants Project & Contract Management	Yes	Yes	Yes	Yes	Yes	Yes	Yes	SaaS
Feng Office Community Edition	Yes	No	Yes	Yes	No	Yes	Yes	SaaS
GroveSite	Yes	Yes	Yes	Yes	No	Yes	Yes	SaaS
iManageProject	Yes	No	No	No	Yes	Yes	Yes	SaaS
Mavenlink	Yes	No	Yes	Yes	Yes	Yes	Yes	SaaS
Planbox	Yes	Yes	Yes	Yes	Yes	Yes	Yes	SaaS
TeamDynamix HE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	SaaS
Webforum Project	Yes	No	Yes	Yes	Yes	Yes	Yes	SaaS
WebSPOC	Yes	Yes	No	Yes	Yes	No	Yes	SaaS
Zoho Projects	Yes	Yes	No	No	Yes	Yes	Yes	SaaS

Figure 8: Full Analysis of Project Management Software

Project Managing Tools Investigate

Endeavour Software Project Management

Open source, Web based
Reports with charts
Visible project plan including tasks
free

Plandora

Open source, Web based
Task breakdown
Forum available
Gantt chart
Link to mind maps
The information about the projects (task, risks, issues, lesson learned, etc) are automatically indexed and can be searched through a **'google-like'** GUI, consolidating a **knowledge base** of all projects in a collaborative way and with common sharing.
Multiple projects
Free
Export to MS project and google calendar

Project.net

Free
Open source
Built in document management
Visible project status
Project plan/ gantt chart
Project.net is available via the GNU General Public License or a commercial license if preferred by the user. However, Project.net cannot be used without an Oracle database, which is a commercial product.

Project-Open

Free
PM and KM
Gantt charts
Project completion tracking
calendar

Openproj

http://openproj.org/openproj
Sun Microsystems's open source PM software

AtTask

Pm
Resource management
Online
Interactive gantt charts
Custom dashboards
Cost money
Approachable, simple user interface

Planbox

Simple and intuitive user interface
Web-based

Free for 2 users- up to $200/month (50 users) but is $40/month for 10 users
Based on SCRUM and Agile

Project Planning Tools

Mind Manager Mind Jet
- http://www.mindjet.com/
- -Cost $349 per machine
- Has Gantt chart capability
- Intuitive interface
- Integrates with MS Office and Adobe products
- Map out resource assignments and dependencies

Time line (through MS PowerPoint or MS Visio)
- Comes with MS Office Suite
- Visually presents schedule
- -doesn't necessary show relationships between other tasks
- -doesn't show resources required

Project Documentation and Collaboration

Dropbox
- https://www.dropbox.com/
- Basic: Free- 2GB
- Pro50: $10.00/month, 50GB
- Pro100: $20.00/month, 100GB
- Updates automatically, apps for phones etc
- All transmission of file data occurs over an encrypted channel (SSL)
- All files stored on Dropbox are encrypted (AES-256)

MS Sharepoint
- http://sharepoint.microsoft.com/en-us/Pages/default.aspx
- Costs money

Lotus Notes Database
- Currently possible to have

Appendix C: Interview Data

This interview was conducted to serve as a post-mortem project analysis. It was conduct in order to figure out the perception of the project throughout the entire lifecycle. Due to availability constraints the entire team was not interviewed. The questions have been personalized to each team member's involvement in the project, and their answers have been paraphrased and highlighted in red. Due to privacy concerns the team member's names have been replaced with their job title at the time of the project completion.

Feb 6th, 2011
Interview Questions and Answers

"This is for my senior project. I'm doing an analysis of projects for installing new complex tools and I would appreciate if you could answer a few questions I have about the Company A's most recent CMP tool project. I have tried to tailor some questions to what I believe are specific parts of the project. I will be brief and to the point. Thank you for volunteering your time."

Process Engineer 1

1. Who assigned the project to you?
   Process Engineering Manager
   a. How was the project presented to you?
      Just told it had to be ready,
2. How did you prioritize this project?
   "Like every other project there is. This was a first of a kind tool, which offered more flexibility, but it required more time to complete this project that I have. I don't really have a method. Every day when I come in I rank my work with two criteria: maintaining the manufacturing line is always number 1, process improvement is then number 2"
3. What were your initial responsibilities?
   Metrology Tool Installation, APC integration
   a. What did your responsibilities end up being?
      Metrology Tool installation and integration, APC integration, bridge for Development and the Process Engineers
4. What was the strategic benefit of installing these tools?
   Technology, better uniformity control, "produce better", new chemistry (new slurrys)
5. What are the specific skills that you brought (or could have brought) to the project team?
   Knowledge of metrology, talking with APC
6. What part of the tool qualification were your involved in?
   No process,
   a. What metrics did you use to qualify the tool?
      Speed, reproducibility,
7. Are there acceptance documents that you have to adhere to?
   Industry standard
   a. Who was the original author? Where they appropriate? What was missing?
      Metrology Manufacturer, slight modifications, all
8. What were the tools used to manage this project?
   a. Gantt Chart, Work Breakdown structure, risk analysis, War room, Identification of the Key Stakeholders, Quality Criteria, Project manager, Project phase definitions, project scorecard, critical path analysis

   Had Log sheet, standardized to previous CMP tool manufacturer

9. Did anyone understand the economic impact associated with project delays?
   No dollar amount associated with project delay. I was just told that it would be bad.
10. How do you think this project went?
   Path finding mission, now have template (now strategy, config files, process)
   a. What in your opinion would have made it more successful?
      Better project management, id risk,

Overall

Original misgivings?

No idea what we were doing,

Risks now?

Hope to copy everything across.

Teams?

2:00 meeting daily, every couple weeks- tool status review,

Process Engineering Manager

1. Was there a single project manager responsible for all aspects of the project?

   Previous was Development Engineering Mananger, because when I came the tool was already installed,

   It started with him, but he was not responsible for installation. I took over once the tool was accepted. At that point I was responsible to put it into production
   a. Who was that person? Development Engineering Mananger (start with), It became the Process Engineering Manager's tool over after tool accepted
   b. Was this project best characterized by a bunch of little projects and therefore many project managers?
2. What was the strategic benefit of these tools?
   Build more and more advanced devices, previous CMP tool technology was old, and often break down. The new tool enable us to increase uniformity, target control, end point control was never used for the Old CMP tool. Higher throughput
   a. Was the project aligned with the company's strategic goals?
   In terms of general strategic goals, yes. The life time is about a year. Better product is more important. You either advance or you are left behind. This industry is more brutal than semiconductor.
      i. Was everyone on board with the purchase decision? How were differences resolved?
      Yes, they were all on board, but.. not all Engineers have equal exposure to the new tool.
   b. How did you create buy-in within your team? No conflict
   People understand that the tool has a limited capacity. The goal for the whole team is to improve the whole CMP area
3. How did you prioritize this project?
   Manufacturing most important,
   One of the important projects to work on
   First priority is always to support mfg,
   Meet technology requirement, the new product release has high priority
   In terms of priority, it changed within the team
4. How much did the development team collaborate with manufacturing/ engineering team in regards to specifying the tool requirements?

5. Are there acceptance documents that you have to adhere to?
    a. Who was the original author? Where they appropriate? What was missing?
6. What were the tools used to manage this project?
    a. Gantt Chart (Process Engineer 1 made one), Work Breakdown structure (yes, for example we need the equipment people to put it in the equipment server. We had a pretty good idea these things had to be done, because of Control Engineer on the APC team. We did not do a good job predicting how long. A lot of times a different priority will change and take you away), risk analysis (single path tool, came up with a non ideal back up plan if New CMP tool is down. Did not do one for if not done on time), War room, Identification of the Key Stakeholders, Quality Criteria, Project manager, Project phase definitions, project scorecard (no, you know what, this environment is so busy, before we are even done we are on new projects, it is very hard to stop and think of a summary, it is very difficult), critical path analysis (for us the major critical path, it must be in the system, the wafer processing must be in the system, to do wafer testing it does not need to be in the system)

    Spreadsheet, I do not have MS project. Yes I think Process Engineer 1 made a nice Gantt chart. But it was modified many times because our initial understanding of the work was not sufficient.
7. Was an economic analysis done in order to understand the cost per day/week/month late of completion of the project? No, in this case, we did not do that. Because I know that in a big project in a big organization, but here as a process engineering I do not have access to. I tried to do a similar thing for another item, and no one could tell. It is very hard when you are cut to the bone.
    a. Did anyone understand the economic impact associated with project delays?
        i. Could that have used to motivate your team?
8. How do you think this project went? Passing score, I would say. We learned a lot. There were a lot of factors. Members of the project team should also do the same. A lot of the time do not have commitment for members from other teams. A lot of time do not have control of our resources
    a. What in your opinion would have made it more successful?
    Commitment from all the team members. They have to listen to you. Cross functional team.

Development Engineer

1. How did you prioritize this project?
2. What were your initial responsibilities?
    a. What did your responsibilities end up being?
        i. What specific requirements did you need to meet?
            1. How did those requirements change over the course of the project?
3. Who was in charge of the installation and qualification of the Tool Vendor tools?
4. What part of the tool qualification were your involved in?
    a. What metrics did you use to qualify the tool?
5. What metrics were used to select the Tool Vendor?
6. How much did the development team collaborate with manufacturing/ engineering team in regards to specifying the tool requirements?
7. Are there acceptance documents that you have to adhere to?
    a. Who was the original author? Where they appropriate? What was missing?
8. What were the tools used to manage this project?

    a. Gantt Chart, Work Breakdown structure, risk analysis, War room, Identification of the Key Stakeholders, Quality Criteria, Project manager, Project phase definitions, project scorecard, critical path analysis
9. Did you understand the economic impact associated with project delays?
10. How do you think this project went?
    a. What in your opinion would have made it more successful?

Control Engineer II(A)/ Control Engineer I (S)

1. What was the strategic benefit of installing these tools? Better control (great uniformity), required for damescene process,

S: I think they have better control compared to Old CMP tool tools

A: they were required for the damescene process, they couldn't do that on the old tools. There was also a uniformity improvement, built in endpoint detection

2. How did you prioritize this project? Told behind and this was key tool, ranked high, prioritize by what is important, dvp came first to APC,

A: I guess for us, because we were being told that we were behind on Dam, we ranked it high on a technology. We try to rank based on cycle time reduction, tech, or yield, and if it is one or more of those t

Interviewer: Was it Process Engineering Manager or Control Engineering Manager who came to you?

A: actually I think it was the development engineer in the beginning. We worked with them early on. Once the tool was installed, the contact point switch.

3. What were your initial responsibilities?

   Get APC on tool

   A: it was just an APC responsibility. I will work early on getting people to understand gem capability, set up a schedule, make sure people have the funding, maybe work with the facilities

   S: strategy

    a. What did your responsibilities end up being? Education and pull information from everyone.

       A: they tend to just know that it is required. A lot of time they don't understand what a strategy is.

       Interviewer: so would you say that because a lot of engineers do not fully understand APC and its capabilities part of your responsibilities end up being education of the engineers

       S: yes because eventually they have to own the process

       A: and it depends on the team that you are working with, and in this case the engineers were pretty new and there was a fairly big mix of people. So Control Engineer probably had a different role, because he has to teach as well as pull together different ideas. So I think that is an example where a project manager would have been useful.

        i. What specific requirements did you need to meet?
            1. How did those requirements change over the course of the project?

4. What are the specific skills that you brought (or could have brought) to the project team?

   S: Knowledge of APC (DOE, gem, WORKS, ARTIST, statistical analysis, software testing, level of project management)

   A: Did you do any data analysis for them?

   S: yes I did

   A: Software testing skills, ummm some level of project management for our part of it. Nothing really for the tool side except for the installation of the host computer

5. Who was in charge of this project? Vague, (initially Development Engineering Manager, and worked with the purchase of the tool project. He tried to bring in people from different organizations when assessing the tool. no hand off seen, it was just groups doing what they knew needed to be done),
   A: There was not a single gantt chart that I ever saw that had all of the APC stuff, the production, release to manufacturing, etc.
   for apc: Control Engineer II until final set up for strategy then it was Control Engineer.
6. What were the tools used to manage this project?
   a. Gantt Chart (we have own that we generated and worked with our supplier, because software is done with external supplier) Project Plan (A: I originally sent a project plan to Development Engineering Manager. I don't think that we ~~every~~ ever got a release date from the process engineers A: wasn't some of that being driven by hardware too?), Work Breakdown structure, risk analysis (not for APC either, realized after GEM testing), War Room (A: this office. We are small enough), Identification of the Key Stakeholders, Quality Criteria, Project manager, Project phase definitions (yea, And initially we will do a basic critical path analysis, but ~~this~~ these? projects are pretty predictable. I don't know if I want to call this a risk analysis. We realize that we weren't getting the polish time, and we went back to the vendor. It was factored in and we went with it), project scorecard, critical path analysis
7. Did you understand the economic impact associated with project delays? No,

A&S: no.

A: we just heard that for damescene that it was pretty important. It was brought to our attention that there would be a negative economic impact if we didn't change our processing records. There was a lot of urgent discussions to figure out it how to address it.

8. How do you think this project went? Fairly well, could have been release sooner (for APC: went smoothly, waiting more on recipe work, good at forcing issues to the surface, positive critic)
   S: I think that it went well. In the end the process team came out with at least a knowledge of WORKS and strategy development
   a. What in your opinion would have made it more successful? More active management, a lot of confusion, communication, no central place for info.. this is interviewer prompting?

   A: there could have been a real reduction to the cycle time if there was a project manager. The vendor has their gantt charts, I never saw a master gantt chart

Interviewer: How do you think the APC project went?
A: we were probably waiting more on recipe works, what apc does in projects is,
Interviewer: because APC was involved in almost all aspects, it served to locate all of the holes.
A: it added a level of exposure that you would not have seen otherwise. Yea I think it's typical, we tend to be discovers of things.
A: we cannot get involved much earlier.
These were used tools, it probably limited what the supplier wanted to do. It was kinda overshadowing things a bit.
Interviewer: is there ~~anyhitng~~anything that would have made this project .....better?
A: there was not central place to get information on the project.

on knowledge base:
A: if there was a place where
showcase Active discussion on points
the more information you can float to the surface to more useful.
***no knowledge base, new ideas about collaboration…

Interviewer:If you can't have a centralized project mananger would it be better to just have centralized project work space.

A: yes, but it couldn't be Google docs. It is necessary through because even in strategy dvp, Control Engineer had to seek out people and pull them in.

Manufacturing Manager

1. Did anyone explain the strategic benefit of these tools for manufacturing?

   Not to me at the time. Again my role has changed. Now my job would have been much more in tune than before.

   New CMP tool was pretty much already within mfg. the second tool was already here

2. Did anyone present a project plan to you?

   no

   a. What was going to be delivered and when?

3. Was there one person you could go to determine project status? Yes, that would be Process Engineering Manager

   a. Did you get regular updates on project status? No regular updates

4. Were manufacturing's needs considered as part of the project deliverables? Layers, I am fighting for it now. Ie: the New CMP tool cannot process in slot 1. It violates all our current procedures. It is a bit of a process and it is too . exposing us to either additional scrap or additional cycle time.

   Iinterviewer: what else was missed?

   K: the other thing would be, what layers. The second tool inherited pretty much the same thing. We are not single path, but our existing paths are not great. There was not a consultation with these new tools. Originally a lot of things were not implemented with CMP METROLOGY TOOL

5. Did anyone explain manufacturing's responsibilities for this project? No
6. How was the project managed? poorly
7. Is there an acceptance document that manufacturing provides to engineering explaining what is needed to release a tool? (operator training, process documentation, PCN, checklists, etc.) They have the MRR and to this day, I have not been involved in that. In my view, mfg has not been involved early enough.
8. What is the economic impact associated with project delays? It can be huge. Yield improvement, cycle time, since our cycle time is so long. I think its useful to consider when they are purchasing the tool and when they are going though the installation and qual plans.

   It primarily came on for new layers. We don't see quality improvement directly.

   I currently have all the vacuum side. Any of the bottlenecks, and qual issues, working with engineering. I'm kinda the go between for mfg and engineering

9. How do you think this project went? Not well, it's into production without slot 1 issue, again I'm coming into it late, but I am seeing the after effects. No decisions had been made, no presentations, it was not until the operator said something. A lot of times the operator will just accept what engineering has to say. The fact that it got that far without being addressed

   a. What in your opinion would have made it more successful? Gap in MRR (manf readiness review), again it does not come on early enough

      I don't think from the mfg side, I don't think there is anyone engaged hands on enough, things like, when they are going through the MRR, they are demonstrating the quals, and their yields. It needs to be more than a rubber stamp.

      I think that the MRR process needs to reviewed. The time frame is probably not stringent enough. People need to be more vocal in the beginning. If doc is present early on than it can be reviewed early on.

      If it goes too long, it comes to a point where you can't stop the train.

   Interviewer: With the new tools they are now installing what is changing?

K: I probably need to be more active in that process. I am not as involved as I want to be.

10. What tools do you use to manage projects?
    a. Gantt Chart, Work Breakdown structure, risk analysis (yes. Evaluates the results on path), War Room, Identification of the Key Stakeholders, Quality Criteria, Project manager, Project phase definitions, project scorecard, critical path analysis

    Primarily here it is just done in excel. Tend to do a work breakdown of what is required for each project.

    Interviewer: do your tools ever get integrated with engineering?

    K: some of it?

    Interviewer: any for New CMP tool?

    K: not yet. All I have seen for New CMP tool are just delivery date

    Interviewer: how early would you need it to be useful?

    K: ideally they have already justified the tools, so when tools are being purchased,

    Interviewer: so you would prefer to be involved as soon as possible

    K: the sooner the better, I don't need tools aren't useful to me. There might be times, where I am like new tools are nice, but I don't need that right now.

    We are the customer. But yes if it was on the engineering side I would want to make sure that I was in turn with my customer.

11. Who should have the responsibility of being the point person?

    I think it should be the process engineer. I probably should be Process Engineering Manager. The tools would be multiuse. Other times its black and white, CMP is not. He should be the one coordinating with MFg, the customer.

    K: the process engineers are putting out fires all the time

    Everyone's got a full plate. Its easy for something not to be have Clear communication and Documented plans. Too many things fall though in the end.

    Interviewer: but you are looking to standardize everything…

    K: the expectation is that a completed professional project…

    You don't have that unless you got buy in from your customers

    You don't have that unless your procedures are clean

    You just got to do your diligence and do what is expected

Facilities Manager and Supplier Manager

- What were your responsibilities for this project? I am the hitachi rep that oversees the construction management project
- Did anyone explain the strategic benefit of installing these tools? Product , alleviate a few of the CMP and a few of the DNS
- Was there a single project manager that you worked with that understood all aspects of the project? (APC, release to MFG, process dvp, tool qual, DVP) There is a project manager but only from the construction side.
- What special requirements did you have to meet related to the facilities or approvals from external agencies (fire department, OSHA)?
- Who coordinates internal and external approvals? (customs, permits, internal equipment safety approval) driven thru RESO
- How was the project prioritized? Delivery date
- What were the tools used to manage this project?

- Gantt Chart, Work Breakdown structure, risk analysis, War room, Identification of the Key Stakeholders, Quality Criteria, Project manager, Project phase definitions, project scorecard, critical path analysis

  Gantt charts were used

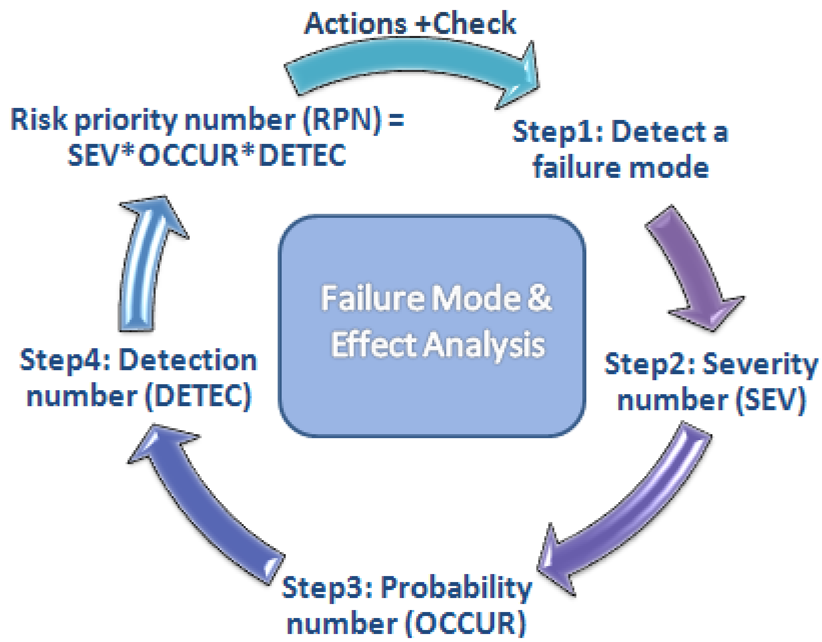
- How do you think this project went? It went okay. Because it was the first tool we expect a few kinks that we fix later on.
  - What in your opinion would have made it more successful? Punch list,

Appendix D: FMEA

An example of an FMEA is displayed below. This tool is used to identify risks and address problems before they arise.

Potential Failure Modes	Classification	Potential Effects Of Failure	Severity	Criticality	Potential Failure Mechanisms	Occurrence	Current Process Control	Detection	RPN (x100)	Recommended Actions
High I_R	10	Excessive power dissipation that result in high junction temperature and device damage	7	8	Poor wafer cutting edge	4	Monitoring chipping width using X-R chart	5	112	Deepen the uncutting index
					Thermal stress induced	3	Monitoring baking condition (1 time/lot) and oven temperature (once per day) using check list		84	Reduce the transfer pressure and extend transfer time
					Excessive molding temperature	2	Monitoring molding temperature (once per week) using checklist		56	Reduce the molding temperature
					Siliastic undercure	2	Monitoring oven temperature (once per week) using thermocouple		56	Extend the curing time
					Poor passivation	2	Monitoring electrically using curve tracer		56	None
					Presence of moisture residual	1	None		28	None
					Rough die edge	1	Monitoring using condition setting (once per hour)		28	Replace the worn-out jig periodically
		Excessive current flow to adjacent circuit that could damage adjacent components	7	4	Poor wafer cutting edge	4	Monitoring chipping width using X-R chart	5	56	Deepen the uncutting index
					Thermal stress induced	3	Monitoring baking condition (1 time/lot) and oven temperature (once per day) using check list		42	Reduce the transfer pressure and extend transfer time
					Excessive molding temperature	2	Monitoring molding temperature (once per week) using checklist		28	Reduce the molding temperature
					Siliastic undercure	2	Monitoring oven temperature (once per week) using thermocouple		28	Extend the curing time
					Poor passivation	2	Monitoring electrically using curve tracer		28	None
					Presence of moisture residual	1	None		14	None
					Rough die edge	1	Monitoring using condition setting (once per hour)		14	Replace the worn-out jig periodically
		Excessive reverse current that could lead to passivation degradation	5	6	Poor wafer cutting edge	4	Monitoring chipping width using X-R chart	5	60	Deepen the uncutting index
					Thermal stress induced	3	Monitoring baking condition (1 time/lot) and oven temperature (once per day) using check list		45	Reduce the transfer pressure and extend transfer time
					Excessive molding temperature	2	Monitoring molding temperature (once per week) using checklist		30	Reduce the molding temperature
					Siliastic undercure	2	Monitoring oven temperature (once per week) using thermocouple		30	Extend the curing time
					Poor passivation	2	Monitoring electrically using curve tracer		30	None
					Presence of moisture residual	1	None		15	None
					Rough die edge	1	Monitoring using condition setting (once per hour)		15	Replace the worn-out jig periodically

Cher Ming Tan, *Customer-focused build-in reliability: a case study*



Dieter Vandeun, Wikipedia

Appendix E: Acronyms Used

PQP: Project Quality Plan

PM: Project Management/ Project Manager

QM; Quality Management

KM: Knowledge Management

NPD: New Project Development

FMECA: Failure Mode Effects and Criticality Analysis

R&D: Research and Development

APC: Advanced Process Control

SMWT: Self Managing Work Teams

MTS: Multi-team Systems

TPM: Toyota Production Method

HDD: Hard Disk Drive

Appendix F: Best Practices

PM best practices

Single PM for coordination to avoid groups working without a view of the big picture

- Coordinator with big picture view
    - Multidisciplinary experience
    - Team leader
    - Clearly defined deliverables
- Coordinator Identifies keys to success
    - Clear Goals
    - Designated Communication Channel
    - Team Empowerment
    - Active involvement in all phases
    - Understand Customer
    - Knows sponsor and how to get things done

KM best practices

Common and needed by all resources
Processing data, converting it into knowledge

- information that is used by more than one group
    - Recipe Names, log in names and passwords for computers

Giving access to the people who need it
    Lose less in translation
Schedule in a central place – having people able to update their part
-slurry information
    eqp and

- Use of Collaborative Media
    - Internal forums
        - Increases corporate knowledge and memory
        - Converts data and experience into usable knowledge
        - Captures intellectual property
- Common meeting place for sharing information
    - Process Operation Information (Operation)
    - Equipment Configuration (Slurry)
    - Security/Access Information (Users)
    - Schedules and Reports
    - Troubleshooting guides

QM best practices

- Quality management starts and ends with the customer
- Reduction of variability
    - Within product/process/project
- Identify risks upfront
    - Robustness depends of expertise
- Continual risk analysis and assessment

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