Methodology to Manage Process Technology Innovation

By

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METHODOLOGY TO MANAGE PROCESS TECHNOLOGY INNOVATION

By Daniel Schweizer
Submitted to the MIT Sloan School of Management and the Engineering Systems Division on May 7, 2010 in Partial Fulfillment of the Requirements for the Degrees of Master of Business Administration & Master of Science in Engineering Systems

ABSTRACT

The research conducted for this thesis was performed at "Company X", a U.S.-based engineered goods manufacturer. This project focused on the company's Advanced Manufacturing group and its process technology development methodology. The newly founded Advanced Manufacturing group started multiple innovation projects, but did not successfully implement any of them so far. Lack of organizational integration, an overall R&D strategy, as well as a defined innovation methodology negatively affected the difficult situation of that small group of engineers.

This project seeks to compare the innovation methodology and process technology development of Advanced Manufacturing with best practices from similar industries as well as literature. An analysis of how to choose the right R&D projects, as well as how to execute these projects, demonstrates the differences between Company X and other organizations that are considered innovative. Case studies of a specific R&D project, in addition to an interdisciplinary workgroup of Advanced Manufacturing, highlight the positive and negative characteristics of the current innovation process.

The results of this analysis provide Company X with additional insights how to use the existing innovation resources more successfully. Recommendations provided in this thesis can be used by Company X to support future technology development projects but also to help the newly founded task force that started to develop a company-wide innovation strategy (process and product innovation).

Keywords: Product Development, Process Development, Advanced Manufacturing, Innovation

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Chapter 1: Introduction

1.1. Problem Statement

He who loves practice without theory is like the sailor who boards ship without a rudder and compass and never knows where he may cast.

- **Leonardo da Vinci**

Company X is a multi-billion US company that produces electromechanical consumer products. In the past, it did not always systematically search for innovative manufacturing processes to introduce them into new products. New processes were introduced simultaneous to new products late in their design phase, resulting in problems during launch. In addition, designers are not completely aware of future manufacturing capabilities.

Two years ago, Company X started a small group called Advanced Manufacturing (AM) to address these issues. One of the group's targets was the development and implementation of advanced process technologies to guarantee a smoother launch of new products and lower production costs. By analyzing and understanding process technologies before they are actually introduced in mass production, AM wanted to avoid the significant problems they faced during previous production starts. For example, Company X had to spend a significant amount of money and ended up with only mediocre processes when they introduced a new product that needed hydro-formed parts. In another case, the market introduction of new product was jeopardized because of a new adhesive bonding process. In both cases an early investigation and development of processes, as well as a closer corporation with product engineering, could have prevented such issues.

However, AM did not introduce any major process technology in mass production so far. Limited support by leadership and the engineering community, in addition to the lack of a clear R&D strategy, resulted in dozens of process development projects that, so far, did not fulfill all expectations of the main stakeholders.

1.2. Purpose of Study

This research proposes a methodology and strategic framework for the Advanced Manufacturing group to gather innovative ideas that meet specific needs or provide a competitive advantage. Moreover, the recommended methodology can help to improve the speed and success of introducing new technologies into products and processes. The risk of an experimental production process and a new product introduction at the same time will be avoided. The research will not recommend a new product design process but will complement the exciting product design process with a process development process.

1.3. Approach and Methodology

The primary sources of information include interviews with multiple stakeholders and levels within the organization as well as selected suppliers and comparable companies, internal surveys, plant visits, attendance of multiple meetings, company data, academic literature, benchmarking other organizations, and various publications.

Most importantly, the author spent over six months from June to December 2009 with AM to gain a better understanding of the challenges. The overall approach was to identify the problem, research existing studies and frameworks, and to propose an idealized approach for AM and Company X. Based on detailed analyzes of one specific project (Quiet Steel) as well as one specific interdisciplinary group (Fabrication Best Practice Circle), the recommended methodology was adjusted to the specific circumstances of AM and Company X as of December 2009.

The next section presents the company context and describes the organizational integration of Advanced Manufacturing. By analyzing the strategic, cultural, and political dimensions of AM the author highlights the complexity Company X's situation.
Chapter 3 introduces different definitions of the word "innovation" and describes the different categories of innovation activities. The author compares characteristics of organizations that focus on radical as well as on incremental innovations with Company X. Moreover, the high-level concept of an innovation strategy including innovation funnel is introduced.
Chapter 4 describes theories and best practices how organizations are choosing the right innovation projects as well as how they execute these projects successfully. The author emphasizes especially the importance of an R&D strategy in addition to a decoupling process, a new cross-functional teamwork approach, a stage-gate process for innovation projects, and the usage of metrics.
Chapter 5 benchmarks some best practice activities of Volkswagen and Toyota to demonstrate that a long-term commitment and multiple dimensions of activities have to be combined to develop industry-leading process and product technologies.
Chapter 6 uses two case studies to demonstrate the challenges of AM. Concrete and detailed examples explain why some projects and activities did not fulfill all stakeholder's expectations so far. This chapter should also help the reader to understand the complexity of process development activities.
Chapter 7 provides concrete recommendations for Company X and AM including an R&D strategy, new operational model for AM, cross functional R&D teams, decoupling innovation process, innovation metrics, idea generation tools, and a stage-gate innovation funnel framework.
Chapter 8 briefly describes organizational changes that happened at the end of this research project.

Chapter 2: Context

"The only things that evolve by themselves in an organization are disorder, friction, and malperformance"

- **Peter F. Drucker**

2.1. Company X

Company X is a manufacturer of engineered consumer products that are highly prized and electromechanically complex with approximately 2,000 parts. With its headquarters in the mid-western U.S., Company X concentrates on a specific market segment and is the established leader in their US market with modest success in Europe and Japan. The basis of their products' popularity is not on their technological superiority or competitive pricing but on Company X's very strong brand image. In fact, it considers technological change as a threat for the brand image. The bases of its products are on a few major platforms with different models. Company X is a very late adopter of new technologies, especially product technologies, because of its fear that too much change could challenge the brand. This leads to the introduction of process and product innovations than by competitors, sometimes by more than a decade. However, due to market demand, Company X must change its models every year slightly and introduce major technological changes every 7-10 years with new platforms.

For three years, Company X faces an economic challenge. While very successful most of the past decade and increasing its production capacity dramatically, the company is recently experiencing a decrease in sales by over 30% and profits by 90%, leading to many changes in 2009 including new leadership, extreme workforce reduction, plant consolidation, and temporary production shutdowns.

2.2. Company X's Product Development Center

The Product Development Center (PDC) is Company X's centralized design and engineering facility. Established in 1997, the PDC houses Styling, Engineering, Finance, Manufacturing, Information Services, Product Liability, Purchasing, Marketing, Homologation, Sales, Service and key suppliers over 350,000 square-feet. Its 700 employees, down from 1000 one year ago, design and engineer future products. A standalone facility, PDC is up to 700 miles away from manufacturing plants. The focus of the PDC is product development with only limited resources for materials or process R&D. The PDC's very strong culture and the influence of the chief designer, a grandchild of Company X's founder, is evident. The building bears his name and every product follows his design guidelines and ideas. Reports from interviews with engineers suggest that any new technologies that the chief designer opposes, they cannot introduce. Cross-functional teams develop most products with platform managers and Centers of Excellence (CoE) that are responsible for specific system groups, see Figure 2.1. The projects link to a Life Cycle Plan (LCP) that includes the new products for the next 3-4 years. The Concurrent Product and Process Delivery Methodology (CPPDM) execute projects that are part of the LCP which should guarantee the systematic involvement and corporation of Design Engineering, Manufacturing, and Purchasing as well as major suppliers.

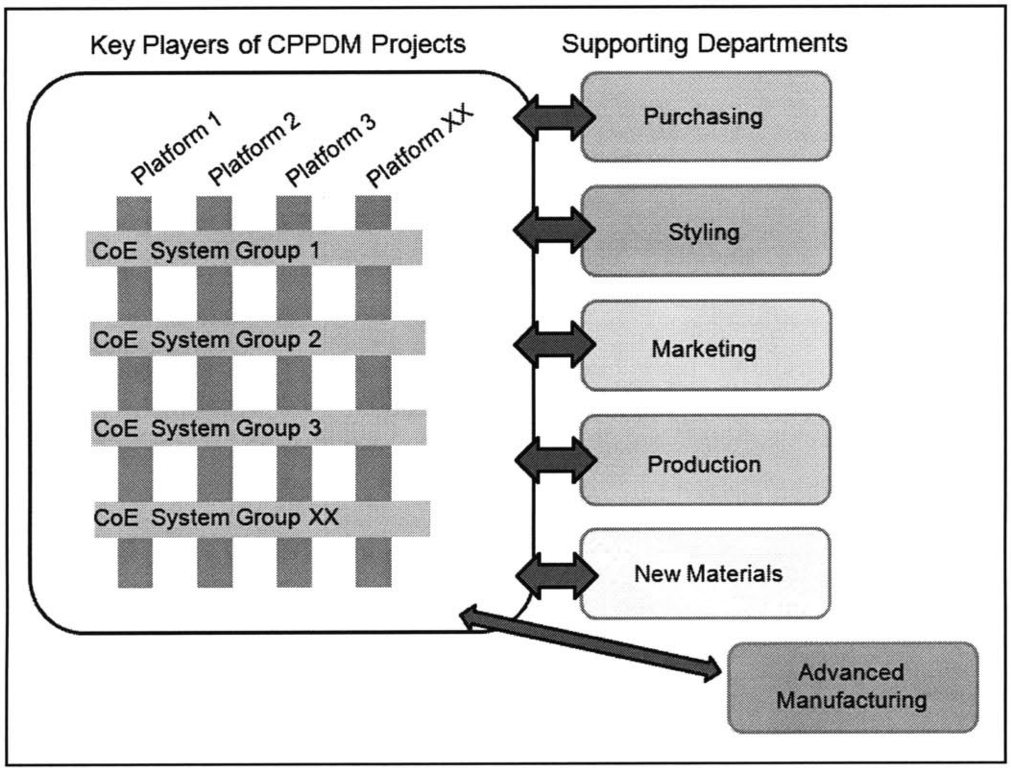


Figure 2.1: Organizational structure for Product Development

2.3. Advanced Manufacturing Group

Advanced Manufacturing is a group of 13 mainly manufacturing engineers inside the PDC that reports to the SVP of Operations. From its foundation in 2007, its mission is the development and implementation of new manufacturing technologies as well as supporting new product launches (more details in Appendix 2.1). While almost all 700 engineers of the PDC report to VPs from styling, engineering, and purchasing, Advanced Manufacturing is included into the organizational structure of the SVP of Operations, who is located at a distant site. Figure 2.2 shows the organizational structure. A few months after AM's establishment, its manager decides to leave Company X. A new General Manager oversees the group and implements the strategy and approach that is described in this thesis. It is worth mentioning that this General Manager is now in another position, this transfer occurring towards the end of the research period for this thesis. A new VP has put AM into a slightly different structure with a new focus and mission. Appendix 2.2 shows the milestones of the integration of AM.

The Principal Engineers of AM have four main tasks: they have to lead the so-called Best Practice Circles (BPC, see Chapter 6.2), lead standardization initiatives (including Bill of Process, Bill of Equipment), provide input for new product projects (as part of CPPDM), and develop new processes and production technologies. In addition, some Principal Engineers are heavily involved in an ad-hoc project to restructure an existing facility and construct a new factory in 2009. During the internship, most process technology development activities are executed in the areas of Fabrication (metal fabrication) as well as Composites and Plastics.

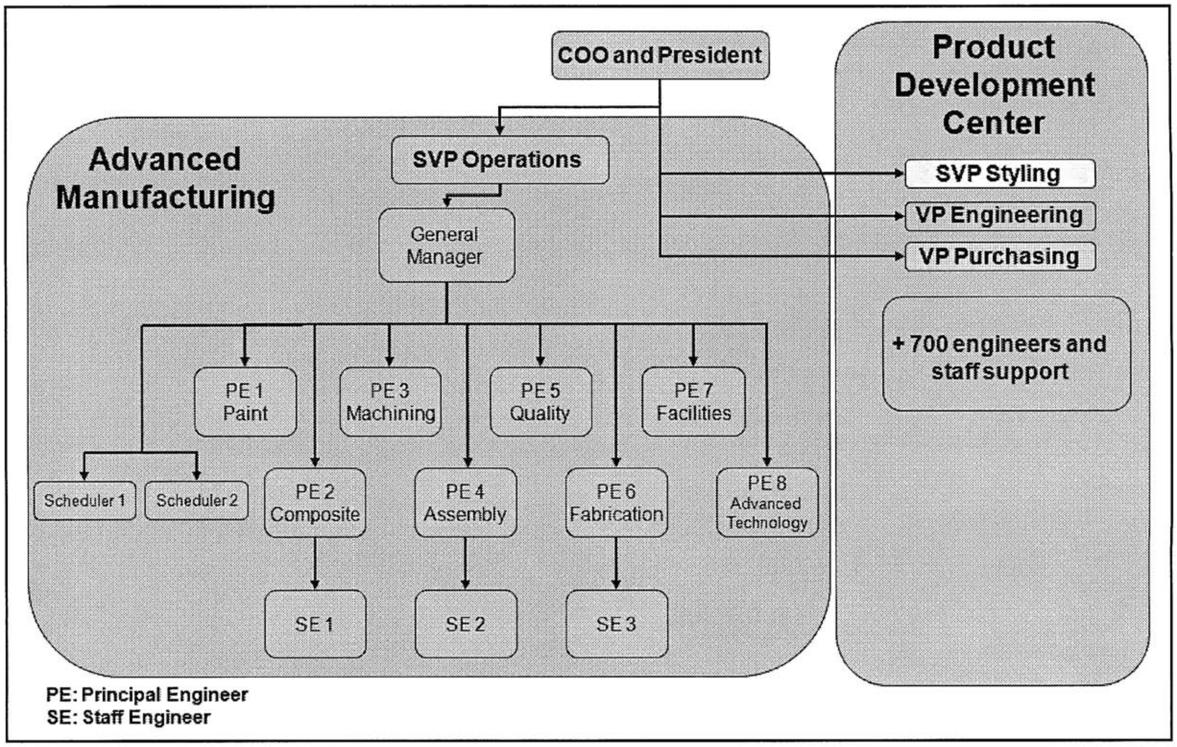


Figure 2.2: Organizational structure Advanced Manufacturing

Appendix 2.3 shows the results of an internal survey with the Principal Engineers. Although new process technology is as a critical field for Company X's future, only three Principal Engineers concentrate actively on the development of such technology. The ones who are engaged in process development are leading or involved in 5-7 projects. These projects range from developing new paint technologies, new plastic molding processes and carbon-fiber components and new welding or metal forming processes. There is no overall portfolio strategy but individuals or small manufacturing groups drive and choose projects. Nearly all projects are cost-saving projects for current products and Manufacturing initiates them. More importantly, although all the engineers like to do more benchmarking activities and collaborate more intensively with other departments at PDC, they mainly concentrate on internal knowledge. Surprisingly, only one engineer has the experience of visiting a competitor in Europe. No other engineer of this group has any trips to another factory that produces the same products. Most benchmark activities concentrate on automotive companies and suppliers that are close to Company X. Furthermore, competitive comparisons mainly focus on product characteristics but not on process technology.

Edgar Schein's Three-Lenses framework highlights the complex layers of Company X's organization. The strategic, cultural, and political lenses emphasize the unique situation of AM and provide insights that explain why this group of engineers faces challenges on different levels.

2.3.1 Strategic Design Lens

According to AM's officially communicated statements (see Appendix 2.1) and statements by its General Manager, the group focuses on the launch of new products and processes by developing process technologies upfront and by supporting the product development activities in early stages. Moreover, the group supports the sharing of best practice process knowledge.

While they can present a few success stories about their input during CPPDM and best practice sharing, so far the group cannot develop and introduce a single manufacturing technology. Most of their projects are not ready for implementation. They currently have over 35 small projects. According to Financial Controlling, over 50 projects have approvals. Official presentations list the execution of 30 projects by AM. During the research period for this thesis, less than 20 projects reach execution. The overall budget for these technology development projects is over $2MM/year. Most of the time, these projects are driven by individuals. In addition, more projects are starting/planning that lack official documentation. Many of these projects are either cost-saving projects for current products or new materials for potential future usage. The rejection of one of the most mature projects, Quiet Steel, by the responsible product manager (platform director is analyzed in Chapter 6.1

The organizational structure of PDC and AM, Figure 2.1, shows one possible reason for conflicts. AM is in an outsider and lacks full integration into PDC. Platform Directors are ultimately responsible to deliver products that meet the requirements of marketing and styling. To achieve that goal they use engineers of the different Centers of Excellence (CoE) as well as supporting areas like New Materials or Purchasing. For 10 years, this system is developing and integrating. Due to Manufacturing's problems in the past (e.g. new products requiring new manufacturing processes not available immediately), the SVP of Operations founds AM with his best manufacturing engineers to give manufacturing a voice inside PDC and to support the product development process. However, the organizational structure provides limited support through this approach. Although some group members attend meetings, the PDC community does not fully integrate Advanced Manufacturing. In particular, the CoE's and the platform directors oppose many projects from AM that potentially threaten their ultimate goal, the introduction of new products without any problems ("silent launch"). Since "silent launch" is the main metric for the PDC community, the platform directors have become very risk-averse and do not support innovation or major changes, which is a goal of AM.

Despite a strategic 5-year plan on how to integrate AM into PDC (Appendix 2.2), the integration progress fails to live up to its expectations. A survey of the Platform Directors show that they have a different understanding of AM's task and do not fully understand how AM group members can help them (e.g. one director complains that he does not know why an AM member attends his meetings for the past year). Moreover, some directors claim that Advanced Manufacturing has no input on Model Years 2010 and 2011. One reason for the failure of the 5-year plan is the absence of any metrics and controls. Although the team starts most of the milestones of that plan, it lacks any checks of how successful the integration is, what can be improved, and how they will guarantee the ultimate goals. Moreover, with goals like "competency development" being too vague, there is a need for a concrete action plan including a control mechanism.

Since most group members are long-term manufacturing specialists (Ø 20 years experience in manufacturing, Ø 15 years worked for Company X), they have only limited knowledge in running R&D projects. Additionally, only one of them has the experience of visiting a competitor factory. This "legacy" hinders them to think strategically about their R&D projects, to manage these projects properly, and to analyze and integrate their stakeholders. As a result, the majority of AM's projects address cost or quality needs of the shop floor. None of the projects are "game changers"; rather they are continuous improvement projects.

Company X does not have a clear communicable technology strategy or outlook. Besides the LCP, which only describes very briefly the products for the next 3-4 years, there is no guideline for AM or the product engineering community. While projects who share a connection to LCP follow the CPPDM, all other projects, including AM's projects, do not follow a standardized methodology. AM's General Manager wants to develop new process technologies to put on a shelf where they are waiting for a business need. In addition, AM wants to demonstrate innovative processes and product systems to the styling and engineering community in hope to start excitement.

2.3.2 Cultural Lens

Company X has a very strong corporate culture. All employees are extremely proud about the products and the majority of the employees adopt Company X's culture into their own lifestyle. Employees wear Company X gear almost every day. The brand name and symbols are everywhere. While everybody is proud about the company history, this is also a problem for introducing innovative technologies. For the past 15 years, the only concern is how to produce more of the same products. The biggest fear is to trouble the start of production of new model years. Furthermore, the design lack changes because of its prior success. This results in a very risk-averse culture; any change and innovation is a potential problem. People are not used to the current economic downturn and the risk-averse culture prevents them to develop new products and processes that target new customers. In contrast to most employees, AM members seem to be more open for risk because they understand the results of lower sales from previous years and the loss of thousands of coworkers on the production floor. The PDC community has yet to experience this until recently when the new CEO decision is to let go 30% of the engineers. In addition, there are the introductions of significant organizational changes at PDC. Outside consultants analyze the product development process and show areas of improvement to the top management. Many workers now begin to understand that Company X has to change, but there are only limited incentives or other attempts to support this process on a work level. There is the implementation of a task force by a group of old and new VPs whose goal it is to improve the product development process. However, it seems that innovation, especially manufacturing technology innovation, is not a focus of that group. They want mainly to streamline the development process to introduce slightly new products with well-known and existing technologies.

2.3.3 Political Lens

AM's vision and mission supports the overall interest of Company X, surviving this crisis and becoming stronger in the future. However, some stakeholders have a different understanding about AM's role. While some groups want the integration of AM into their processes and recognize them as a strong partner, others believe AM to be only a supporting service provider. Moreover, since the strategy and tasks of Advanced Manufacturing are never communicated very well, other groups do not understand why AM even exists and why to integrate them.

In addition, there are many groups at PDC that focus on similar tasks. When AM investigates in new materials or products, oftentimes they infringe on the scope of other PDC groups which then oppose these activities. The Quiet Steel case is such an example when leadership of the engineering community did not support the project anymore and ask for requirements and tests that impossible for AM to fulfill due its limited product knowhow. The author observes a "not-invented-here" mentality by some PDC members. Since AM often cannot finish or introduce a project without the support and resources of other PDC groups, the AM projects are not very successful. AM can only ask for help, give recommendations, and try to influence these groups, but they do not have the power to push their projects or interests (unless it is on the LCP or a very convincing cost saving project that cannot be rejected by common sense). Due to the lack of any successful technology development projects, AM has very limited political power. The absence of a VP-level leader inside PDC only worsens the situation.

In general, Am continues to face many problems..The lack of organizational integration as well as limited acceptance by the PDC increases the obstacles that many AM projects must overcome. Leadership support as well as the expertise of AM's engineers is not in alignment with the group's goals. The strong culture at PDC and past successes hinder the change processes that is necessary to guarantee the success of AM's projects. Most stakeholders do not understand AM's goals and oppose their activities. This is a very complex problem with significant organizational, cultural, and political challenges. Only a sound concept that addresses most of these aspects will allow AM to be successful. Chapter 7 describes recommendations that potentially can solve some of the main issues.

Chapter 3: Innovation

"It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is the most adaptable to change"

- **Charles Darwin**

The ability to develop and implement innovation is increasingly important for organizations since almost all markets are more global and competitive than ever before. Companies, managers, and consultants in different situations frequently use the word "innovation". Most of the many existing definitions for innovation include the terms "new" and "introduction". For example, the Merriam-Webster Online Dictionary (2010) defines innovation as "The introduction of something new" while Hesselbein (2002) describes it as "Change that creates a new dimension of performance". Schumpeter (1982) concludes "The introduction of new goods (...), new methods of production (...), the opening of new markets (...), the conquest of new sources of supply (...) and the carrying out of a new organization of any industry" and Carlson claims "Innovation is the successful creation and delivery of a new or improved product or service in the market place". Kanter (1983) explains, "Innovation is the generation, acceptance, and implementation of new ideas, processes, products, or services".

In general, innovation is the commercialization of new knowledge (not necessarily new for the world but new in a specific context). Innovation is more than finding new ideas. According to Trott (2002), Innovation = theoretical conception + technical invention + commercial exploitation. Often a catchphrase and not a core competency, attempts to enable innovation frequently fail because of misconceptions and the wrong use of the right tools.

Although being major focuses, enterprises and societies often incorrectly see innovation and technology as something mysterious that requires a revolution, an extreme creative culture, or have to focus on cutting-edge technologies. In most cases, the success of innovation does not depend on unlimited R&D budgets or the luck of finding silver-bullets that will change an industry (Miller, 1999).

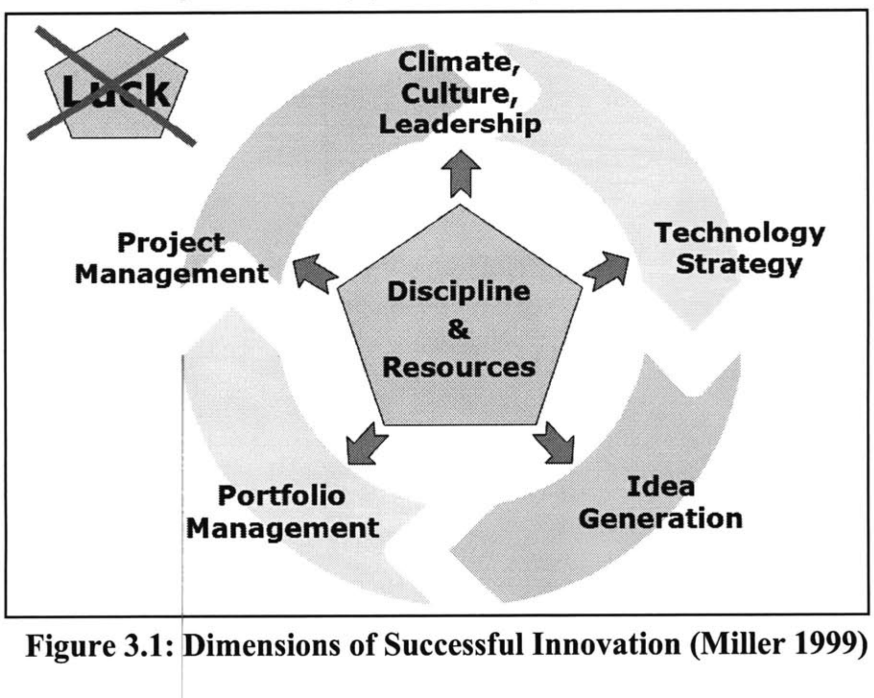


Figure 3.1: Dimensions of Successful Innovation (Miller 1999)

Instead, innovation is a management process that requires tools, incentives, rules, measurements, strategy, leadership, discipline, and resources, see Figure 3.1

Research by Davila (2006) indicates that successful innovation management follows a few simple rules like neutralizing organizational antibodies, concentrating on networks and not individuals, and balancing project portfolio. Company X's Advanced Manufacturing group and its leadership only partly follow these rules, see Appendix 3.1. Instead of introducing clear and detailed guidelines including metrics and a defined organizational structure with all related departments, leadership only provides vague innovation targets, e.g. "developing and implementing new manufacturing technologies to ensure successful product launches and reduced costs". Projects depend mainly on individuals. They decide on project focus, rely on their own personal relationships, and decide how to achieve self-defined goals.

3.1 Dimensions of Innovation

Innovation does not only include the development of breakthrough technologies by specialized R&D teams and scientists, but also includes the adoption of existing knowledge in a new context or the incremental improvement of an existing product.

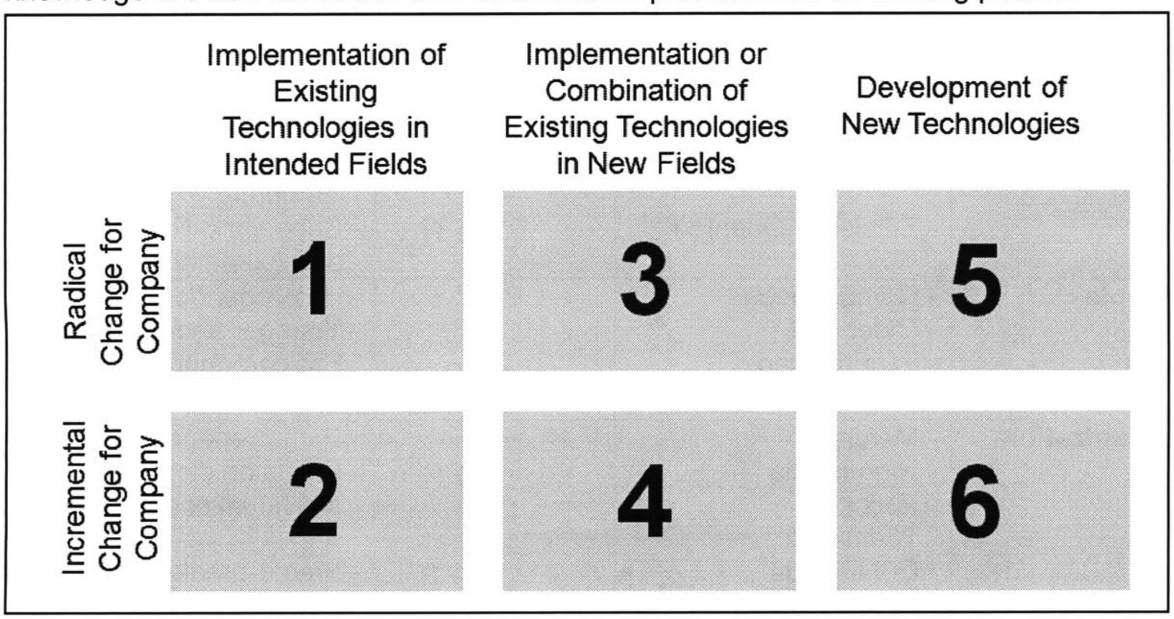


Figure 3.2: Differentiation of distinct innovation dimensions

Figure 3.2 shows six different innovation categories. Each of these categories requires specific strategies and tools to be successful. One dimension of (technology) innovation is novelty. It ranges from the implementation of existing technology that uses comparable situations (e.g. introducing a welding process that competitors use for similar products) to the implementation or combination of existing technologies in new fields (e.g. car airbags at motorcycles) to the complete new development of technologies (e.g. OLCD screens). The other dimension is the impact of these innovations inside of the company. While some innovations only incrementally change a product or business (e.g. continuous improvement projects), highly radical innovations have the ability to change significantly a product, a company, or a complete industry. It is important that a

R&D group narrows down these dimensions and implement tools and structures that support a specific category. For example, if a company wants to focus on innovations that are in category 5 or 6, it needs R&D capacities and scientific knowhow and networks. However, if a company decides to focus on field 1 or 2, it is more important to have tools that analyze competition and similar industries and an organization and products that are able to adopt these technologies very quickly.

Officially, AM concentrates on the implementation of existing technologies. Due to the risk-averse culture and limited cooperation with other departments, mainly continuous improvement projects are started. According to Figure 3.2 AM's main focus lies in field 2. However, many of AM's projects are in other fields. The example of a field 4 project is the implementation of a new material in a novel application (Quiet Steel, see Chapter 6.1). Even the application of field 6 projects, such as the development of a self-made bulge-forming process for utilization in existing presses. This project can be described as a new technology development because Company X re-develops its own process technology with limited outside experts help. Even if bulge-forming knowledge exists outside Company X, the group reinvents this knowledge for its own purposes.

	Incremental	Company X	Radical
Procedures	- Formalized - Centralized - Systematic	→ R I ← → R	- Contingent - Decentralized - Loosely Structured
Structure	- Functional - Efficiency Oriented	I ← → R	- Facilitating Knowledge Gathering - Supporting Risk Taking and Experimentation
People	- Homogeneous - Older and Experienced	I ← I ← → R	- Heterogeneous - Younger and Entrepreneurial - Questioning
Organization	- Mature - High Inertia - Focus on Teamwork - Continuous Improvement	I ← → R O → R	- Entrepreneurial - Focus on discovery - Individual cooperation - Frame-breaking Improvement
Focus	- Cost Reduction - Feature addition - Efficiency Improvement	O O O	- Experimentation - New Ideas - New Methods and Technologies
Technologies	- Mostly Existing	I ←	- Mostly New
Management	- Exploitation	O	- Exploration

Explanation:
I ← **Company X shows evidence of an incremental organization**
O **Company X does not show a clear direction**
→ R **Company X shows evidence of a radical organization**

Figure 3.3: Characteristics of incremental and radical innovation organizations (McLaughlin, 2008) in comparison to Company X's Advanced Manufacturing

Nevertheless, the organizational structure and existing tools inside Company X do not support field 4 or field 6 projects. Figure 3.3 shows the different characteristics of organizations that enable incremental or radical innovations.

Instead of being an organization that clearly focuses on one or the other, Advanced Manufacturing shows a random combination of different characteristics. Some parts, such as a very experienced and homogeneous workforce or the traditional testing methods, can be appropriate for incremental innovations, while its loose structure, experimentation with radical materials (e.g. carbon-fiber), and the absence of formalized policies support rather radical innovations.

In general, an organization must always differentiate between radical vs. incremental and adoption vs. developmental innovations. Each of these dimensions requires unique strategies and resources. Advanced Manufacturing's official decision is to concentrate solely on the adoption of incremental innovations without introducing all required tools for such projects and without stopping projects outside this scope.

3.2 Innovation Strategy and Management

Most important is a clear innovation strategy. A company's senior management is responsible for a clear defined strategy including goals, tools, and resources. According to Davila (2006), leadership must choose between a Playing-to-Win (PTW) and a Playing-Not-To-Lose (PNTL) strategy. The PTW strategy is the more aggressive approach and focuses on field 3 and field 5 innovations that will provide an important competitive advantage for a company. High-tech companies especially adopt this strategy because quick technology changes can threaten their business model. A PTW strategy can also include smaller continuous improvement innovations, but its focus is on game-changing technology. Alternatively, many mature companies, including Company X, utilize a PNTL strategy, because of internal and external constraints, the high risks, and a very mature market without any major technological changes. However, PNTL still needs the right tools and resources. Even if a company does not aggressively develop new technologies by itself, it must constantly monitor the market, react quickly on changes, and try to follow competitors. Companies utilizing a system that continuously delivers incremental innovations beat competitors by offering the most complete products. The development of a single technological innovation under a PNTL strategy will normally not enable market leadership (e.g. a superior car-door opener will not enable Lincoln to be more successful than Audi or Lexus).

Another relevant factor of innovation is the right combination of technology push and market pull. Technology push is a strategy involving the promotion of a new technology and pressure on the (internal and external) market. The development of such a technology depends on internal competencies (e.g., experienced R&D laser welding team) or external technology capabilities (e.g., supplier develops a new battery type). Oftentimes, such a technology satisfies latent market needs that clear articulation in advance. On the other hand, market pull concentrates on the identification of customer needs in the market first. Activities of competitors as well as changes in the market are the most influential forces. The development of appropriate technology enables a competitive reaction or satisfaction of these known needs.

All three strategy parts, the PTW-PNTL strategy, technology strategy, and competition strategy, need connection to the overall corporate strategy. This will provide the framework for the so-called innovation funnel, see Figure 3.4. This funnel (or pipeline) includes all innovation projects of a company. The funnel concept allows many initial ideas and projects and gradually whittles them down to a few preferred ones. More information about innovation funnels is widely available in the literature, for example the open innovation paradigm of Chesbrough (2003). The division of such an innovation funnel into different stages requires different resources and tools. To enter each stage, a project must fulfill different criteria. Further explanations can be found in Chapters 4 and 7. In general, an innovation project can be divided into a research and exploration phase where a company gathers all information for its technology and competition strategy (e.g. latest technology trends, market research results) as well as multiple ideas how to solve a problem. Afterwards, the company has to develop and/or implement the technology innovation. Finally, introduce the innovation into the internal or external market.

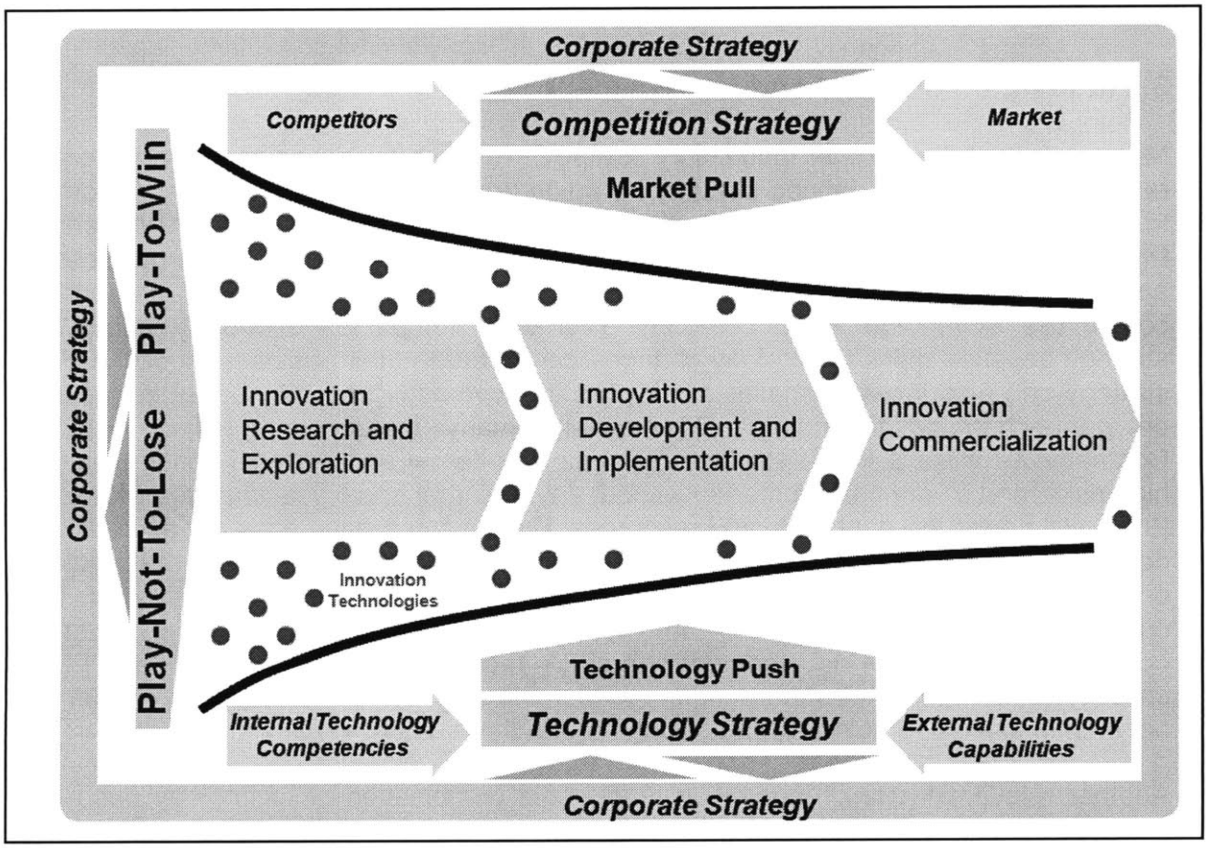


Figure 3.4: Innovation funnel and the influence of different strategic dimensions

Company X does have neither a clear Technology Strategy nor a concrete PTW-PNTL strategy at the time of the research. While it sets the industry standard in paint technologies for its products, it is 10-20 years behind its competitors in other technologies and sub-systems. Not only is the product partly outdated, but also the production technologies. This is the intention of Company X because one of its main selling points is the unchanged traditional technology. Due to the success in selling its old products, Company X focuses on the expansion of production capacity. However, its industry faces a possible game-changing scenario, akin to the car industry. New regulations, especially in Europe and Japan, as well as the environmental concerns of many customers will cause radical technological changes.

If Company X cannot lead or quickly follow these changes, it will risk its business (e.g. Company X has no technology innovations to meet environmental standards in Europe in 2015). The communicated corporate strategy has yet to emphasize innovation. Company X wants to target new customer segments, but without any technological changes and improvements, this goal will be more difficult to achieve. Although the marketing team of Company X has a clear competition strategy, Advanced Manufacturing and the PDC only receive a segment of their knowledge. Overall, different strategy portions are missing or not connected to an overall innovation framework like in Figure 3.4.

Advanced Manufacturing will have problems to fulfill its targets as long as the organization does not foster an innovation friendly culture. Appendix 3.2 compares the different innovation cultures of AM and Company X. Even with AM and their introduction of an innovative culture, the missing innovative culture of the overall organization creates many conflicts and underperformance. AM's leadership wants to explore unknown technology fields and push the organization to new materials, processes, and product features. However, other leaders of Company X oppose this idea and concentrate on short-term, risk-neutral, and well-known projects. A mismatch in resources often ends in project failures. Whereas AM allocates significant resources (people and money) to innovation projects without any short-term pay-offs, PDC has only very limited resources for these activities. Moreover, these resources already have their own agenda and have no connection with AM's resources and projects.

To summarize, missing an overall innovation and technology strategy impairs Company X and AM.. The usage of different tools is essential for different categories of innovation. Successful organizations clearly define if they focus on radical or incremental changes that incorporate a Playing-to-Win (PTW) and a Playing-Not-To-Lose (PNTL) strategy. These guidelines then help to choose the right tools and allocate the right resources. However, Company X and AM did not demonstrate such a clear focus. The assumption is that the current problems significantly influence the lack of an overall innovation strategy.

Chapter 4: Process Technology Development

"If you need a new process and don't install it, you pay for it without getting it"

- **Ken Stork (President of Association for Manufacturing Excellence)**

Innovation in process technology is the research, development, and application of new manufacturing tools, processes and techniques. Although many companies often concentrate their R&D and innovation activities on product development, it is very important for a company also to able to develop processes that can produce these products as cost-effective as possible with the best quality. In many industries, process technologies provide a significant competitive advantage. Japanese and German companies especially have a strong focus on the development of advanced process technologies to compete on the global market. Their unique products often depend heavily on proprietary developments of process equipment. Besides in high-tech industries where changes in process technology can cause extreme product revolutions, mature industries with a dominant product architecture and only limited product innovations also depend on process technology innovation. Utterback (1996) points out that after a dominant design is established in a mature industry, the rate of process innovation is higher than the rate of product innovation, see Figure 4.1. When a product can no longer be improved radically, companies start to concentrate on process innovation and allocate more resources to process R&D than product R&D. Most of them use process technology development mainly to reduce production costs. However, the ability to shorten the time-to-market, smoothen production starts, and proprietary position is another significant advantage of process development. Company X's situation can be compared with the current car industry where a dominant design is established and most product innovations happen on a systems level.

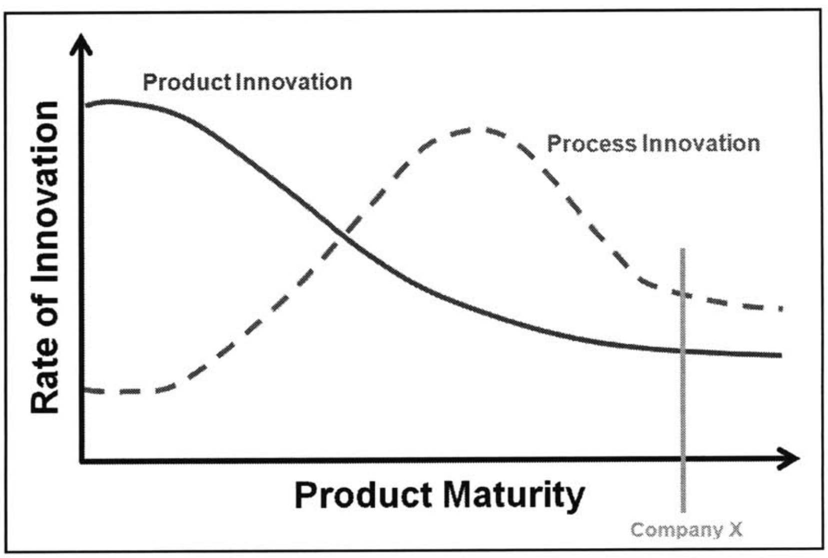


Figure 4.1: Rate of innovation during product lifecycle

However, the car industry's mature market faces possible radical changes in its product design. Due to political incentives and environmental concerns, cars will need an alternative propulsion system that can trigger new car architecture as well as new materials and ultimately new process technologies. The current maturity situation with low rates of product and process innovation can switch in the next few years when electric cars revolutionize the existing dominant product design. Figure 4.2 shows the relationship of product and process innovation of different industries. While Company X's is like the car or shipbuilding industry in a very mature market now, this can shift quickly to an industry that is process or product driven. For example, the missing subsystem for electric cars is the battery. Whoever develops a manufacturing process that can produce cheap accumulators with the desired performance can be the market leader of that new car segment. Company X faces a similar situation where new process or product innovations can change the competitive landscape.

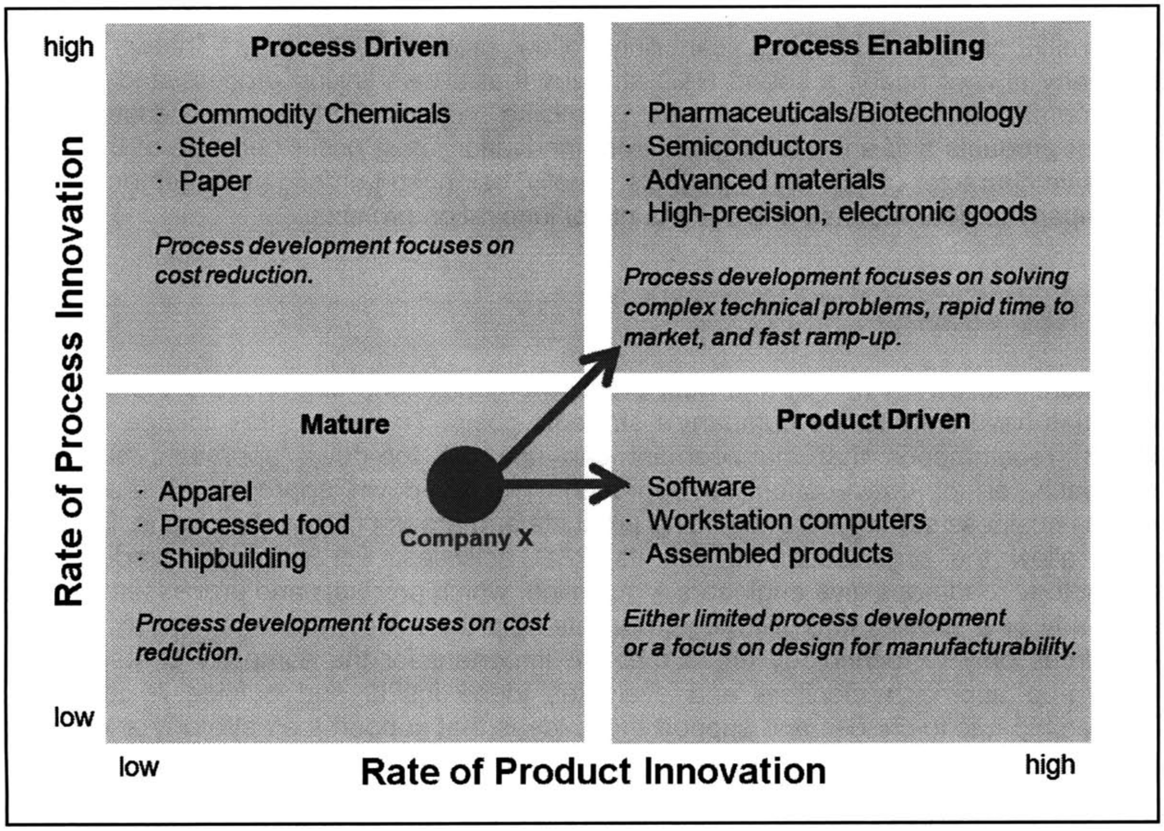


Figure 4.2: Relationship between Product and Process Innovation (Pisano, 1997)

During the research, it is clear that Advanced Manufacturing has two main areas of problems. On the one hand, the group has difficulties to choose the right projects. That is emphasized by the over 50 projects that are not connected to any strategy, do not promise any significant change, and are opposed or in many cases at least not supported by main stakeholders. On the other hand, the group has difficulties to successfully finish and implement these projects. So far, implementation of a technology innovation project has yet to occur. Moreover, no project seems to be ready for implementation in the near future. The causes of both problem areas are multiple root problems that are briefly described in this chapter as well as in Chapter 6.

4.1 Doing the right projects

It is very difficult to choose the correct process innovation projects when the overall organization does not have a technology and/or innovation strategy. As highlighted in Chapter 3, innovation success highly depends on leadership decisions, strategic guidelines, and the interaction of technology push and market pull. This is also true for process innovation. Very often, process and product technology cannot be separated. Generally, process technology can only follow product technology. That is why a company always needs a sound R&D strategy that allows linking process and product development and focusing on the most promising projects. Furthermore, decoupling of current products and short-term goals from innovation must occur because of the time-intensive character of innovation projects. Finally, balanced portfolio management allows a company to deal with risk and uncertainty of innovation projects.

4.1.1 R&D strategy

Literature like Davila (2006) and best practice organizations demonstrate that all R&D activities have links to the company's strategic goals. To archive this linkage, Cooper (1998) recommends that management can use the top-down approach, button-up approach, or top-down-bottom-up approach. The top-down approach translates the overall business strategy into the fitting products and areas of innovation focus. Different tools allow the organization to link its R&D activities. For example, product and technology roadmaps give engineers a guideline, which products and processes have to be ready at a specific time. Strategic buckets help the middle management to allocate resources only to technology areas that are important for the company strategy. The bottom-up approach monitors and evaluates ideas inside and outside a company. Leadership has to choose and support these ideas that support their strategy and goals. It is important that a company has good selection and prioritization tools; otherwise, a company can end up with numerous projects that do not support each other. The top-down-bottom-up approach, a combination of the two previous ones, overcomes some shortfalls. Leadership has to execute both approaches, combine, and reconcile the results in multiple iterations. In general, a company has to install an R&D strategy to give its employees a guideline and to allocate resources to the right projects. Process technology development must be part of such an R&D strategy because manufacturing technologies ultimately enable the production of a product. Sometimes the link between process and product can be very strong (e.g. pharmaceutical or computer-chip industry), sometimes it is weaker (e.g. clothing or toys industry).

Company X did not have a clear R&D strategy until 2009. By focusing on producing more of the same products, product innovations lack necessity and demand by customers. Innovations on a system level lack coordination and are reactive to competition. In absence of a technology or R&D strategy, Advanced Manufacturing instead attempts to push process innovation. Oftentimes, new processes also include new materials or product changes. Due to missing input from product related departments like styling, engineering, or marketing, AM decisions on specific projects come from their limited viewpoint. Its manager wants to develop process technologies to put them on a shelf so that styling and engineering can use this knowledge to develop new products. 3M uses a similar R&D concept where the internal research groups innovate technologies in the hope that somebody needs them in the future.

4.1.2 Portfolio Management

One common aspect of all innovation projects is their uncertainty and the involved risk. It is clear that not all technology developments will have a successful introduction. That is why most companies introduce different tools to maximize the portfolio value against different business objectives. All of these tools have strengths and weaknesses. For detailed evaluations, the author refers to the available literature, for example Cooper (1998), which comprehensively describes different tools.

In general, most companies use financial approaches (e.g. Net Present Value), business strategy approach (e.g. strategic buckets), or scoring models to maximize the potential value of all projects, see Appendix 4.1. Advanced Manufacturing does not use any tools to maximize its portfolio value. It is impossible to finish a complete list with current projects, the investment and necessary amount of time to introduce these in production, the expenses already incurred, and what will be the financial impact of these projects. Some cost-saving projects have rough estimations about future possible savings and estimations about investments. However, financial experts analyze only projects that support an LCP product. For these projects, calculations of yearly savings and return on investment were available, but not used by AM to balance their project portfolio (although their portfolio contains 30-50 projects).

Financial approaches have an obvious disadvantage because of their dependency on financial data (most future financial data depends on assumptions) and nonobservance of other factors like strategic goals, environmental issues, or regulatory needs. Some financial methods, like the Expected Commercial Value (ECV) incorporates risks and probabilities. This reduces the risk to overvalue projects. Oftentimes, AM lacks the ability to evaluate the risk of a project. Thus, the risk for the product is often unknown. That is why multiple stakeholders have to be included during project evaluation.

Business strategy approaches are methods in use by the more successful companies. Tools like strategic buckets, technology roadmaps, or platform projects allow the creation of a link from the portfolio to the business strategy. Technology roadmaps and strategic buckets, both top-down approaches, are especially favorable according to Cooper (1998). While Company X has a product roadmap with its Life Cycle Plan (LCP), the organization is missing a technology roadmap. Different interviewees express their need for such a technology roadmap. It is the logical derivation of the LCP. The development of such a roadmap forces Company X to think about present and future opportunities and desired technological competencies. The roadmap can function as communication tool for internal and external innovators. The strategic bucket approach is another tool that some interviewees request. Such a tool allocates resources to specific topics and sets spending targets. Multiple prioritized projects can be in these buckets.

To evaluate different characteristics of a project according to qualitative and quantitative factors may necessitate the usage of scoring models. They are especially useful for go/kill decision at project gates (see Section 4.2.3) because they can provide a holistic viewpoint and contain a lot of data for use in discussions during gate meetings. Well-defined scoring models allow input of multiple stakeholders and help to identify areas of ignorance. However, scoring models can create a false sense of security. The weighting of each characteristic influences the overall score significantly. Users have to understand the calculation of the overall score. Regardless, scoring models are a useful diagnostic tool. In Chapter 7, additional detailed information can be found about recommended portfolio management tools for Company X.

4.2 Doing projects right

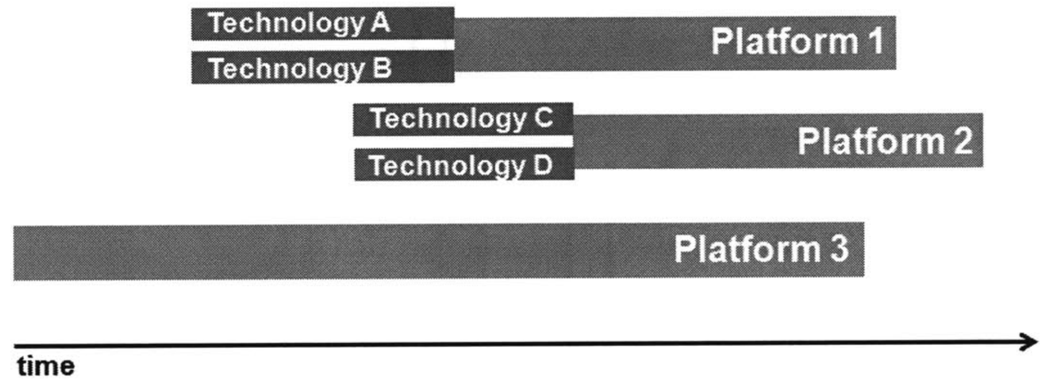
Even if a company is able to set up an innovation strategy and chooses the right projects that can offer a competitive advantage and maximum profit, the innovative technology still has to be developed, tested, implemented, and be desired by the (internal or external) customers. Besides common project-management tools, which are widely described in literature, it is especially important that a company decouples innovation projects from day-to-day work, establish true cross-functional teams, enable idea generation, and follow a specific gate process.

4.2.1 Decoupling Innovation

Many companies face the problem that the introduction of a new technology that has a connection to a new product. Any delays in the technology development will result in product introduction delays. Even worse, the failure of developing a new technology can jeopardize the future of a product and vice-versa. Boeing's Dreamliner disaster shows that new technologies (in this case composite materials) can delay a product for many years. Volkswagen's 1-Litre car (a concept car introduced in 2002 that gets 235 MPG) includes multiple innovations for energy consumption reduction, but lacks the continuation of the development or usage of these innovations after the project's cancellation in 2005. Both extremes demonstrate that connecting single innovations to a single product can be risky. That is why innovative companies try to disconnect the development of specific innovations and subsystems from a single final product. To achieve this decoupling, separate resources to develop new products on the one hand as well as research on product-independent innovations on the other hand. When a new technology is mature enough for market introduction, existing product platforms are ready to easily adopt these technologies.

Company X has a well-organized product development process for all projects that are on the LCP. The projects include modifications of current products and the development of new platforms. The time frame is up to the next 5 years, but most of the time the LCP includes projects that have to be introduced in the next 1-2 years. The engineering community leads all projects. The most important metric for LCP projects is a smooth start without any problems. That is why only well-known and proven technologies are normally accepted for the LCP. Nearly all resources of PDC are tied to LCP projects.

This is one main dilemma for AM. In order to put a new technology on the LCP, they have to prove its readiness. However, to prove its readiness AM needs the support of PDC resources which only concentrates on LCP projects. The limited resources for non-LCP projects, as well as missing guidelines how to prove readiness, prevent AM to introduce any technology. In addition, all new technologies (product and process) are always connected to an LCP product release. This time pressure results in suboptimal and expensive solutions, delays product starts, or even the rejection of a new technology. This is very evident when Company X stops the development of a new platform, such as in 2009. All new technologies that have a connection to that platform have stopped and will not be continued in the near future. Other platforms are not ready to adopt these technologies. Figure 4.3 shows the current system of Company X

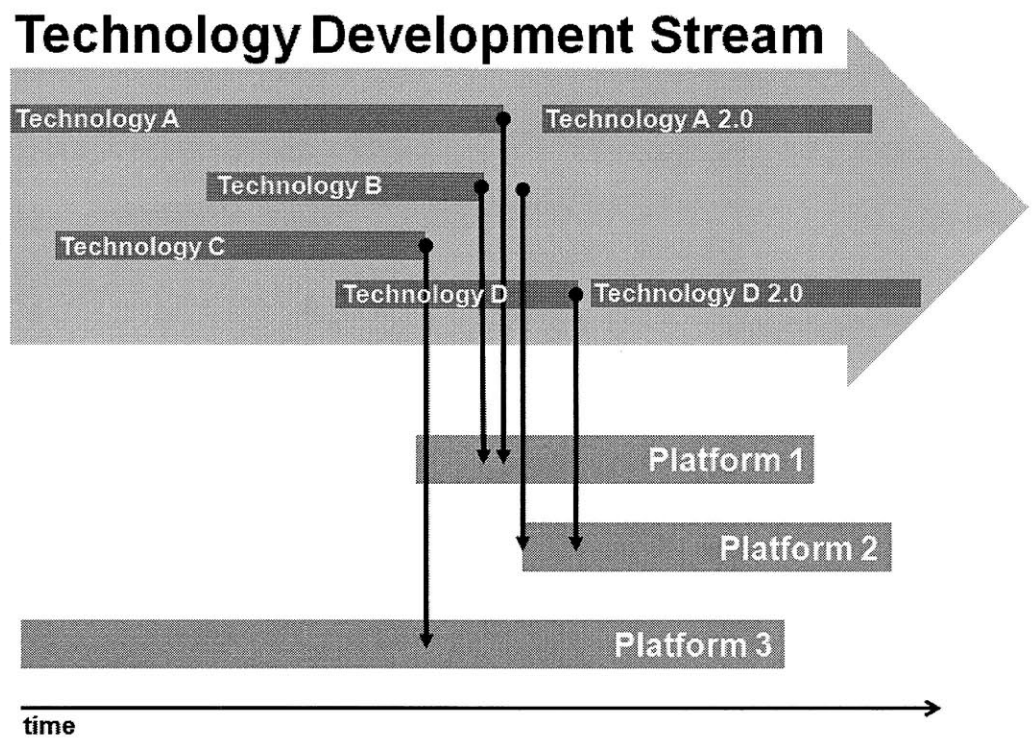


New technologies are directly linked to specific product development projects. No flexibility in timing or platform implementation

Figure 4.3: Current flow of technology development at Company X

In case of the stoppage of the development of Platform 2, Technology C and D can also stop. These technologies would be continued only if a new platform that needs Technology C and D was introduced to the LCP. However, then old knowledge is obsolete and extreme time-pressure for redevelopment can occur.

In order to develop technologies that are not tied to current or soon-to-be-introduced projects, many companies develop methodologies on decoupling innovation. They have to set up a technology development stream that is parallel to the current product development activities and feeds in new or existing products when the technology is ready and fully tested. Figure 4.4 illustrates such a decoupled technology innovation stream. Moreover, specific technology core competencies have to continue and improve in order to maintain a competitive advantage. For example, to consider Technology A as a core competency of a company, the development cannot stop due to introduction to a product. In fact, after the market introduction of a new technology encouragement of the development of the next generation of that technology (Technology 2.0) must occur to maintain the innovation lead.



In a parallel structure, new technologies are developed independent of platform launch and only introduced when ready. To ensure core capabilities, next generation technologies (2.0) are immediately continued.

Figure 4.4: Decoupled innovation development stream

4.2.2 Cross-functional Teams

Literature and common sense recommend having cross-functional teams with clear roles and goals, teamwork, focus, incentives, regular communication, accountability etc. for technology development projects. That is why most people concentrate on the inside of a team to increase performance.

However, studies of dozens of teams from product development, consulting, and pharmaceutical research groups indicate that teams concentrate only on the inside of the teams are not always successful (Ancona and Bresman 2007). Although most of these team members are more satisfied than others and consider themselves as successful, there is a clear difference in the outcome. Studies indicate that high-performing teams that find innovative solutions concentrate on "scouting ideas from outside their boundaries, receive feedback from and coordinate with outsiders, and get support from top managers". Deborah Ancona and Henrik Bresman introduce the concept of X-Teams (eXternal activity, eXtreme executing inside) whose main mission is focusing on external activities, see Appendix 4.2. An X-Team's external activities include scouting for new ideas, opportunities, and resources. These teams seem to be very successful in repeatedly delivering breakthrough innovations. Although many teams argue that they look for solutions outside their boundaries and include external stakeholders, the reality shows that external focus is not an active driver of most teams.

They focus mainly on idea generation by its team members and interact with the environment in a one-way direction. Such teams have difficulties to deliver game-changing innovations. In fact, they often end up a downward spiral and these teams are highly unsuccessful.

Observations during multiple interviews suggest Company X's Advanced Manufacturing group shows characteristics of this downward spiral. Two years after the group's start from a difficult position without external support, the group has yet to meet outsiders' expectations, has a very limited number of allies, and focuses on projects that require rather deep technical understanding of the current factories than on innovative future projects. Details see Appendix 4.3.

The few Advanced Manufacturing projects that focus on innovative technologies, like Quiet Steel, carbon fiber parts, and bulge forming, face significant problems because of missing external support and acceptance. Significant differences between the recommended framework of X-Teams and projects of Advanced Manufacturing are evident. The X-Team approach focuses on three phases of an innovation project (Exploration, Exploitation, and Exportation) that requires different strategies, members, and activities. Appendix 4.2 shows the theoretical framework including the main phase tasks, activities, and cultural aspects. While this model emphasizes the importance of external support and connections, Advanced Manufacturing often concentrates on internal sources and collaboration. While X-Teams spend a significant amount of time and resources on Phase 1, Exploration, and Phase 3, Exportation, Advanced Manufacturing groups concentrate mainly on Phase 2, the actual execution. This has its basis in the engineering background of most members; virtually all projects start with an interest in one technology. Sub-groups of BPCs then focus with internal resources and some local suppliers on solving technical problems. By trail-and-error tests, as well as limited numerical virtual simulation tools, the sub-groups try to adopt new technologies on current products. After they understand the main characteristics of these new technologies, they hope that current or future products will adopt these innovations. Table 4.1, 4.2, and 4.3 illustrates an in-depth explanation and comparison between the different elements of the X-Team framework and the current Advanced Manufacturing framework. Interestingly, the implementation of Quiet Steel project occurs two times. Its first start is in 2005 as a joint effort of Manufacturing and Engineering. When management (see Chapter 6.1) rejects the Quiet Steel Component F in 2009, the project comes back to Advanced Manufacturing. Despite the change in the project's focus and the introduction of more external help, the Quiet Steel Project 2009 still did not respect an X-Team's framework, see Table 4.4.

The Advanced Manufacturing approach works very well for continuous improvement and small cost saving projects. However, for projects that can deliver innovative or even game-changing solutions, the X-Team approach is more promising. Although its design is mainly for new product or service development projects, it is also beneficial for manufacturing technology development projects. Since most process development activities require changes in the product, the X-Team's concentration on external factors increases the possibility of success. Appendix 4.4 demonstrates the differences between a traditional team and an X-Team including the relative position of Company X.

Table 4.1: The Three Stages of X-Team projects

	Activity	Description	Advanced Manufacturing
1. Exploration	Sensemaking	Exploring and understanding of the projects' and teams' environment (organization, technology, market, customers, industry, and macroeconomics) by intense scouting activities. Preexisting mindsets and models have to be switched-off.	Limited exploration of technology trends observed. Preexisting mindsets are evident (and needed for other tasks of the group like standardization).
	Mapping	Creating a map or other medium to visualize external context, major issues, stakeholders' needs, and hoped outcomes. Understanding the complexity of the tasks and sharing it with outsiders to get additional input.	No extensive mapping observed.
	Relating	Establishing relationships with key individuals inside and outside the company to get support, be challenged, and become included in strategic activities.	Some relationships to internal sponsors and external experts, but not active task for most teams.
2. Exploitation	Visioning	Creating and committing to a realistic future state by exploring and choosing specific solutions and details and deciding on ways of execution.	Scope of Work describes current and future state in a few words.
	Inventing	Creating processes and structures for execution incl. encouraging experimentation and risk, monitoring results, and accelerating team momentum.	Using of ad-hoc and inconsistent project management tools
	Decoupling	Finding right balance between decoupling from organization to concentrate on undisturbed prototyping and execution and staying in contact to maintain organization's support.	Too much decoupling from some stakeholders (e.g. engineering and design) while too much cooperation with others (e.g. manufacturing) observed.
	Execution	Developing the product, process, technology, service etc. based on all former information and decisions and together with all necessary resources and stakeholders; using Culture of Extreme Execution.	Projects executed with the limited resources, information, and stakeholder impact that are given.
3. Exportation	Relating	Developing relationships to decision makers, key stakeholders, and executing leaders to get them exited about adopting and continuing the project.	No active relating observed. Trust on convincing technical or financial results.
	Handing-Off	Guidance, active support, and information sharing while the project is transferred Communicating all knowledge. Motivating restraint executers by transferring enthusiasm and ownership.	Continuing technical support when asked for. Most observed projects did not reach handing-off phase.
	Ending or Repeating	Reviewing project from member's viewpoints and	Project review for bigger projects. No details observed.

Table 4.2: The Main Activities of X-Team projects

	Activity	Description	Advanced Manufacturing
Scouting	Investigating the Organizational Terrain	Understanding the team's tasks and boundaries by asking for all stakeholders' expectations, outside and inside the organization.	Define tasks mainly by themselves
	Investigating Customers, Competitors, and Current Trends	Systematically identifying, mapping, and interviewing critical groups to collect as much upfront information as possible. Active investigation and communication especially with suppliers, competitors, consultants, scientists, industry experts, etc. is crucial.	Contact very limited number of outside sources; mostly known sources or close to Company X
	Vicarious Learning	Contacting and analyzing teams that have done similar tasks before to understand what worked well or where they faced problems. This is not limited to internal teams, but especially contacting teams from other industries can be very insightful.	Very limited contact to internal individuals to get brief feedback about their insights.
Ambassadorship	Linking to Strategic Initiatives and Getting Early Buy-In	Proactively contacting various high-level leadership to get their support; including their expectations especially in target definition and staffing helps getting their buy-in. Linking projects to overall strategy to get attention by leadership.	Projects get attention and resources from Operations leadership, but only limited attempts to get support from other managers.
	Lobbying for the Team and Members' Ideas	Passionately and continuously advocating teams' viewpoints and project and demonstrating the value of their goals to opposing stakeholders and leadership.	Teams avoid confrontation and finish as much as possible without support from hostile stakeholders.
	Cultivating Allies and Containing Adversaries	Understanding political landscape of the organization and find powerful supporters who protect team from political issues and manage conflicts.	Teams have only limited allies outside Operations and do not actively search for them.
Task Coordination	Identifying Dependencies	Systematic analyzing of stakeholders the team depends on (need of other's resources) and agreement how these dependencies can be coordinated in the future.	Teams often just ask for support now when support is needed. No upfront work observed.
	Getting Feedback	Continuous feedback from external sources and includes their ideas and feedback to think outside the box.	Limited external sources are used to answer specific questions or solve problems.
	Convincing, Negotiating, and Cajoling	Very actively asking and pushing for support of stakeholders who are not specifically concerned about team's agenda.	Limited pushing; teams often accept other's apathy and try to solve issues by themselves.

Table 4.3: Elements and Tools for Extreme Execution

	Activity	Description	Advanced Manufacturing
Safe culture of Extreme Execution	Psychological Safety	Supporting the frank exchange of controversial ideas, acknowledging errors, and admitting weaknesses.	Team members are open for controversial ideas, ask for help, and admit mistakes.
	Team Reflection	Spending significant time on reflecting actions, strategies, and objectives. Teams reflect about outside change and how to adjust. Defined times to reflect during different project phases. Reflection on everybody's role in successes and failures as well as reflection on big-picture questions.	Formal project reviews are part of bigger projects at Company X. No evidence for active times of reflection in past projects, but new projects include analyses of former projects.
	Knowing What Others Know	Integrating others experience by knowing everyone's expertise and connecting the right people. Open sharing of information and pro-active introduction of everyone. knowledge and network. Repeated activity.	Team members know each other well from previous assignments. Introduction of new members observed.
Tools for Extreme Execution	Integrative Meetings	Regular face-to-face meetings to share knowledge and experiences obtained through external activities. No required attendance during all meetings.	Very evident during frequent Best Practice Circle meetings.
	Participatory and Transparent Decision-Making Procedures	Truly merit-based decisions by inviting everybody to participate during decision-making processes.	Main decisions are made by groups, but solo attempts by some team members observed.
	Heuristics	Autonomy with common-sense guidelines. Compromise between tight control and total freedom to guarantee fast but focused activities. Rules-of-thumb without bureaucracy.	Team members are very heuristic and with no bureaucracy. However, sometimes too extreme since no guidelines, control, or structure exist.
	Shared Timelines	Pacing and task coordination through synchronized timelines incl. very frequent electronic reports and shared deadlines. Setting main milestones in advance and respect them.	Only limited use of milestones. Tasks are separated in small steps without overall time targets. Most stage gates are not met without consequences.
	Information Management Systems	User-friendly access to information, know-how, and experts and easy to fill with information for each member. Advanced expert database to easily find the appropriate contact persons. Incentives for participation.	Good software platform (eRoom), but information incomplete, unstructured, and not standardized. No expert finding tool.

Table 4.4: Comparison Quiet Steel Team vs. X-Team

	Group Quiet Steel 2005	Group Quiet Steel 2009	X-Team
Primary Goal	Understand Quiet Steel to meet NVH requirements	Understand Quiet Steel material limits for Component F	Understand the needs of Company X and stakeholders relative to Component F
Primary Focus	Demonstrate und understand manufacturability of Component F with Quiet Steel	Solving known problems of prototypes	Identifying, connecting, and understanding all stakeholders relative to Component F
Secondary Focus	Demonstrate NVH capabilities of Quiet Steel on component F	Looking for alternatives to meet NVH requirements	Create team cohesion and organization to find solutions
Team building	Unknown	Limited	Coming together as a team while learning about the stakeholders needs
Initial amount of interaction with stakeholders inside the company	Medium/high; included main stakeholders from engineering and manufacturing	Medium; includes main stakeholders from engineering and manufacturing	High; includes all main stakeholders from engineering, manufacturing, finance, marketing, purchasing, and styling
Initial amount of interaction outside the company	Low; concentration on one supplier with one solution	Medium; work with limited amount of suppliers and external experts; analyzing existing knowledge	High; includes many experts and suppliers as well as existing knowledge
Source of information used to map the environment	Inside team; old, secondary sources	Inside team; old primary sources	Outside team; new primary sources
Source of information used to understand the task	Inside team; old, secondary sources	Inside team; old primary sources	Outside team; new primary sources
Source of information to find solutions	Inside team with one-way outside communication	Inside team and limited outside team	Mainly outside team and limited inside team

4.2.3 Front-end loading

A description of innovation is of a flow that starts with many ideas and alternatives that ends up with a few superior solutions. While it is important to have a specific process that evaluates, refines, and winnows the best ideas like a funnel (see Chapter 4.2.3), it is even more important to fill (or overfill) this funnel with ideas in the beginning. When many ideas from different sources compete against each other, the chance to maximize the portfolio value and to find the best possible solution is significantly higher.

At AM, there is no observable competition between many ideas or any systematic method to generate ideas. Oftentimes, individuals are aware of one potential technology and pushes this technology into an R&D project. It is unknown if this specific technology is the best available and most suitable. Normally an innovation project has to go through an ideation phase (generating and communicating ideas), a funding phase (stakeholders allocate resources to the ideas), and an execution phase (development and commercialization). However, the budget of AM significantly exceeds the necessary investments for the current and planned innovation projects (mainly because employees spend their time for other tasks than technology development) in 2009. That is why there is financing for every idea and no initiation of competition between different ideas. In addition, there is no observation of any break-through ideas although the leadership states multiple times their desire for a "silver bullet".

Discussions of idea generation tools are accessible throughout literature, for example Silverstein and Samuel (2008). In general, a company has to concentrate on internal idea generation as well as environmental scanning. While there are many different idea generation processes available, none can be used as a blue print for every organization. However, the so-called Structured Idea Management (SIM) approach has been widely used in different industries for 20 years (Davila, 2006). An illustration of a theoretical concept of a SIM process is in Appendix 4.5. Such a process creates a working environment for maximum creativity and includes screening tools to ensure higher quality of ideas. It enables the recognition, bundling, and combination of idea fragments to real innovative ideas. Besides such a SIM approach, multiple other factors influence the amount of new ideas for the innovation pipeline. Skarzynski and Gibson (2008) summarize different imperatives for leadership to increase the volume of ideas. Appendix 4.6 presents an overview including a comparison how well AM incorporates these rules. Generally, AM and Company X limitedly respects the rules that derive from industry best practices. In particular, they fail to involve outsiders, do not use methods to validate technology very cost-effectively, face a lack of innovation goals, and do not have discovery teams to evaluate existing constraints and the environment. Tools to collect and analyze the ideas of outside stakeholders are especially limited at AM. There is no observation of active searching for ideas outside AM or the BPC's. There is no utilization of existing tools like intranet, as well as accessible partnerships with suppliers and universities, to invite outside ideas and innovation. Moreover, there is the pushing of single ideas and solutions with extensive feasibility studies (including prototype tooling and tests) instead of searching for many different solutions worldwide and comparing them. Although AM's leadership does not expect any short-term results and is open for radical ideas (even if it is product development), the current projects are mostly continuous improvement and cost saving activities. Significant influence is missing aiming points and goals that can guide innovation activities. AM concentrates on single unrelated problems instead of collecting many different ideas to have a holistic approach solving business relevant problems.

4.2.3 Idea-to-launch process

Robust idea-to-launch and stage-gate processes are easily available in literature, for example Cooper (1998). Innovation best practice companies like P&G and 3M can improve the effectiveness and efficiency of new product developments by robust stage-gate methods. Company X introduces CPPDM, a stage-gate method to develop new products and platforms. However, AM does not have such a stage-gate method for its development of new process technologies. In general, a stage-gate method is the modus operandi including go/kill decision points. Figure 4.5 shows a typical stage-gate process for new product development as a series of five stages.

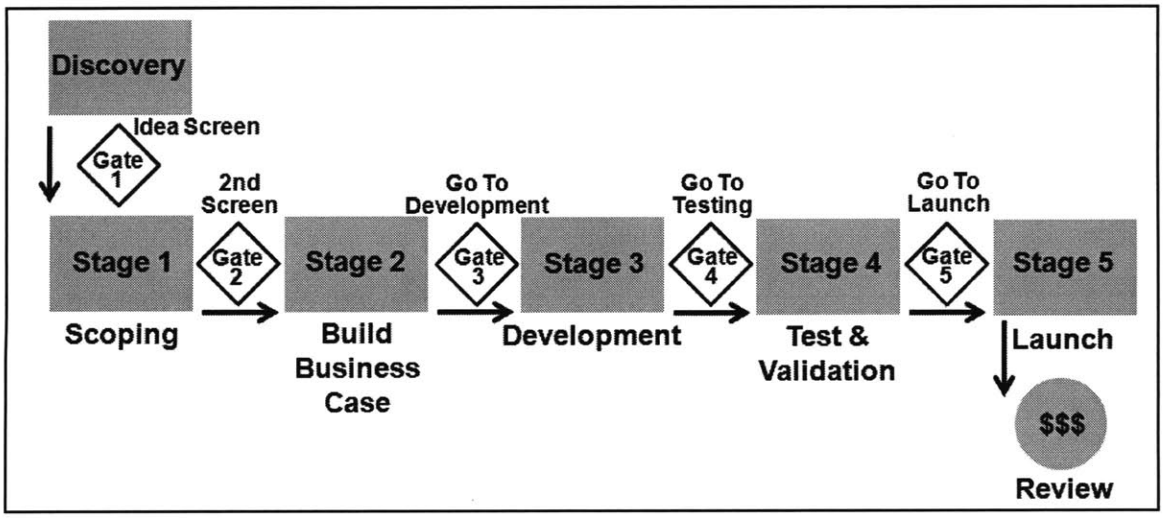


Figure 4.5: Overview Stage-Gate Process for NPD (Cooper 1998)

Each stage includes information gathering and a comprehensive analysis to make a go/kill decision at the following gate (see Appendix 4.7). At most gates, there is also a necessary resource commitment.

The role of the gatekeepers is very important. Mainly senior people, they own the resources that require the project leader and team to move forward. For major projects, the gatekeepers can be a cross-functional senior group since resources are essential from many departments. The gatekeeper group must involve executives from these resource-providing areas leading to the achievement of alignment and the placement necessary resources. In addition, a multifaceted view of the project leads to better decisions than a single-functional view (Cooper, 2008). There must be clear rules for the gatekeepers in place to have a transparent and comparable decision-making process. Appendix 4.8 shows an example of such rules list.

Although the initial design is for product development projects, utilizing this stage-gate approach is possible for process development projects. Dividing a project into sequential stages and including prerequisites to move to the next stage helps to control and track the evolution of an innovation project. This, in combination with the innovation funnel concept can narrow down the amount of ideas and projects at each gate. However, poorly defined gates can also hinder radical innovations. In early stages when the costs and impact of radical ideas are very uncertain, these projects can be discarded in favor of well-defined incremental innovations (Cooper, 1998).

AM's failure to make adequate go/kill decisions is due to a missing stage-gate concept. Many projects are ongoing for years without any clear deliverables and resource allocation. Leadership and priority changes cause additional delays, see Appendix 4.9. Additionally, Company X has no policies or standards to what development degree a technology has to be before its introduction into LCP projects. AM depends on individuals who accept or reject their projects for introduction into mass production.

4.2.4 Metrics

Most managers will agree that performance measurements are critical tools in any business context. While the introduction metrics is successful in areas like manufacturing for many decades, innovation seems to be a gray field. On one hand, some managers do not believe that there are useful metrics that actually would significantly improve the success and outcome of innovation processes. On the other hand, literature describes many examples where metrics' contribution to innovation successes. Since the basis of good decision-making is good information, metrics can be an important tool when developing innovative technologies. However, a recent study (BCG, 2009) indicates that nearly 75% of the interviewed executives believe the importance of making innovation tracking as rigorous as other business operations, but less than 45% of them agree that their organization is actually doing it. Only a small number (27%) link employee incentives to such innovation metrics. Figure 4.6 shows that the number of companies that use different innovation metrics is growing, but also that most people are unsatisfied with the metrics.

Company X and AM do not actively measure the innovativeness of their organization. AM has a few budget metrics in place but without any strict targets or connected responsibilities. The only active measurement is the amount of actual project investments against the yearly overall budget. The Financial Department tracks all

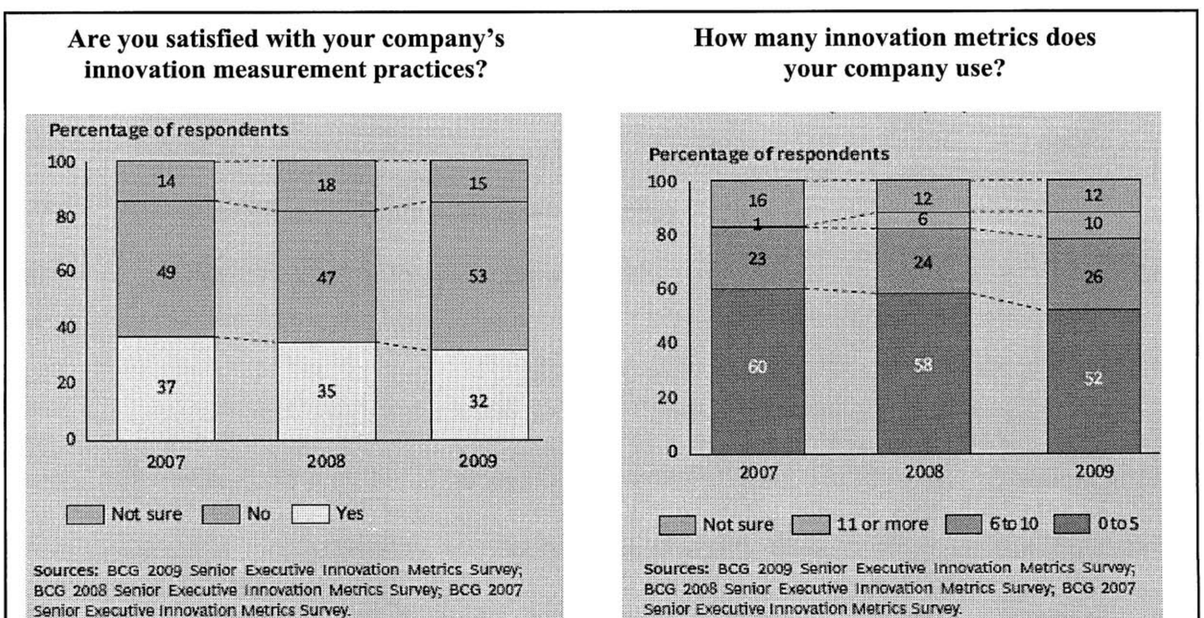


Figure 4.6: Survey Usage of Innovation Metrics (BCG, 2009)

monthly expenses and lists them against the budget numbers. Since AM's overall spending is significantly under budget (many projects are paused because of other priorities) in 2009, this metric did not influence anything. Only in the event of excessive spending over the budget will leadership take action.

Given the importance of innovation, as well as the amount of working hours and money that AM spends on technology innovation projects, it is surprising the lack of performance measurements of these projects. It is worth mentioning that measuring innovation is more difficult than many other processes, but best practice cases clearly show that it is possible (e.g. 3M or Whirlpool at Skarzynski and Gibson, 2008). Given the association of long-term nature and risk with innovation projects, metrics can help base objective decisions on objective data. In addition, metrics can help to connect goals and daily activities with the long-term innovation agenda.

My company uses metrics to asses these components of innovation or innovation returns:

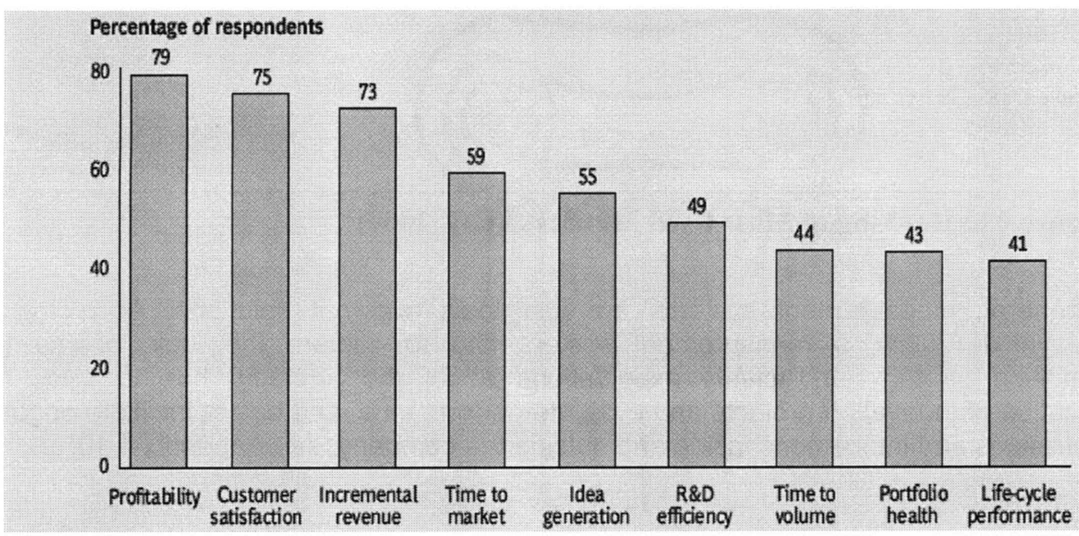


Figure 4.7: Reasons for Measuring Innovation (BCG, 2009)

There is no blueprint for an innovation measurement and metrics system. Each organization has to choose specific metrics that link directly to their individual strategy and goals. Figure 4.7 illustrates that companies generally use metrics to measure probability of innovation, customer satisfaction, and incremental revenue growth. Most of them use metrics such as "total funds invested in growth projects", "revenue from new offerings", and "projected versus actual performance", see Figure 4.8.

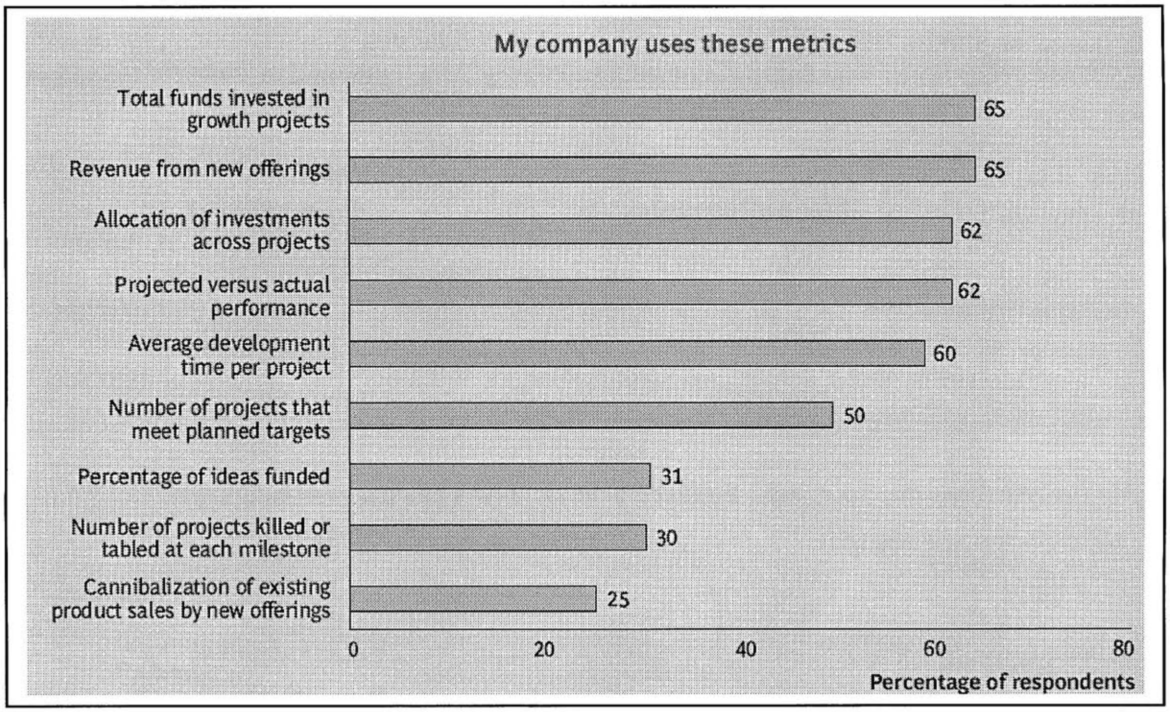


Figure 4.8: Ranking of Most Used Metrics (BCG, 2009)

In general, measurement systems are just tools and not solutions. According to Skarzynski (2008), a measurement system has to capture the logic behind the innovation strategy and clarify expectations about the strategy, has to track the execution of innovation projects and evaluate performance, and has to facilitate ongoing discussions and interactions inside and outside the company, see Appendix 4.10.

Chapter 5: Benchmarking Innovative Companies

To turn really interesting ideas and fledgling technologies into a company that can continue to innovate for years, it requires a lot of disciplines

- **Steve Jobs**

Many companies in different industry sectors are able to use innovative process technologies to achieve market leadership. IT and pharmaceutical industries especially depend heavily on process technology that provides a competitive advantage. These examples are widely described in different case studies and books. For example, Beckman and Rosenfied (2008) describe Intel's "Copy Exactly!" approach to reduce production costs significantly and push new products. Company X will have difficulties to copy such an extreme focus on process technology development because process technology is not a competitive advantage for them and the organizational architecture does not support such activities. However, many other companies in comparable industry sectors demonstrate best practices for process technology development and the integration of process innovation in product development, even if they do not have such an extreme focus on process innovation like Intel or Novartis.

The author picks a limited number of companies that illustrate the successful use of specific innovation tools and strategies. The examples demonstrate how these companies are able to foster process innovation.

5.1 Volkswagen

Volkswagen's different brands demonstrate leadership in many product and process innovations during its history. Three examples presents best practices that help the brand Volkswagen to introduce cutting-edge process technologies like laserwelding, Audi to become industry leader in aluminum car bodies, and Porsche to adopt a very sound innovation strategy with the industry's highest profit margins.

<u>Volkswagen / Audi Tool and Die</u>

Similar to Company X, Volkswagen also employs engineers to develop advanced process technologies. However, because of its size and strategic decisions, the dedication of many more resources are essential to this goal. Volkswagen considers its process technologies and methods as a competitive advantage and links it directly to its corporate strategy. Centralized departments, like Tool and Die or Process Engineering with hundreds of engineers, are not integrated into each step of the product development. Instead, they develop their own process technologies, oftentimes together with machine suppliers, that have to compete for internal contracts with 3rd party suppliers. For example, 1300 employees concentrate on body shop parts for the Volkswagen brand (facts see Appendix 5.1). At least three years before the introduction of new cars the Tool and Die experts are already involved in the body design, development, and parallel testing of relevant process technologies. Every two years, Volkswagen organizes at its headquarters in Wolfsburg the so-called IZB, the leading European trade fair for the automotive supplier industry where there are presentations of the latest trends and innovations of the industry to the engineers and managers of Volkswagen. Its beginnings lie as a trade fair in 2001 as an in-house presentation of 128 exhibitors to 13,500 Volkswagen employees to report information about latest product and process innovations. Nowadays, the trade fair is open to public and competitors with 680 exhibitors and 46,000 visitors in 2008. More importantly, it allows an easy way to connect the right people with the right suppliers. Since high-level managers, including CEO and Board of Management, spend a significant time at this fair to understand technology trends, it is easy for suppliers and lower-level Volkswagen employees to get the attention and, eventually, support for the development and introduction of innovative technologies. Moreover, internally developed process technologies have to compete against third party suppliers at this fair. More information about IZB can be found in Appendix 5.2. The creation of Tool and Die organization by the brand Audi in 1993 as a sub-company inside Audi, a so called Center Of Excellence, with 1.700 employees at four different locations (900 in Ingolstadt, 400 in Neckarsulm, 370 in Györ and 25 in Barcelona). They have to compete with external machine suppliers and generate EUR 400 million of revenues per year. Due to competition, this leads to investments, such as a EUR18 million new process development center in Neckarsulm in 2008. Recently, Audi Tool and Die celebrate with multiple industry awards wins for its superior process development and engineering results. Audi uses latest simulation and R&D tools, like all big carmakers, but also introduce some unique tools to be more innovative. For example, every year Audi awards the best thesis in innovation for press tools and for body shop tools with its Audi Tool Trophy. By doing this, Audi has access not only to latest R&D results of universities, but also can attract high-potential engineering graduates. Like many German companies, Audi also employs numerous PhD students fulltime (based on the unique PhD education in Germany) who develop and research cutting-edge production technologies.

Audi's Aluminum Center

Today, Audi is the world's technology leader in designing and producing aluminum car bodies. Company X is also thinking about introducing aluminum products and production technologies in the future and already starts to spend money for preliminary feasibility studies. That is why there is a brief discussion of history and success factors of Audi's aluminum journey here. Pfaffmann (2000) summarizes this 20-year project. It started in 1981 with an agreement between the aluminum supplier Alcoa and Audi to launch a joint project to develop a 100% aluminum car body. In attendance at this early meeting in the USA, the VP of "Technology Development", who later became the CEO of Audi. Since then, aluminum is an essential part of Audi's strategic goal to reduce car weight significantly to lower gas consumption of its fleet. Figure 5.1 gives an overview of the main milestones of this project until the production start of the Audi A8, the world's first aluminum car platform.

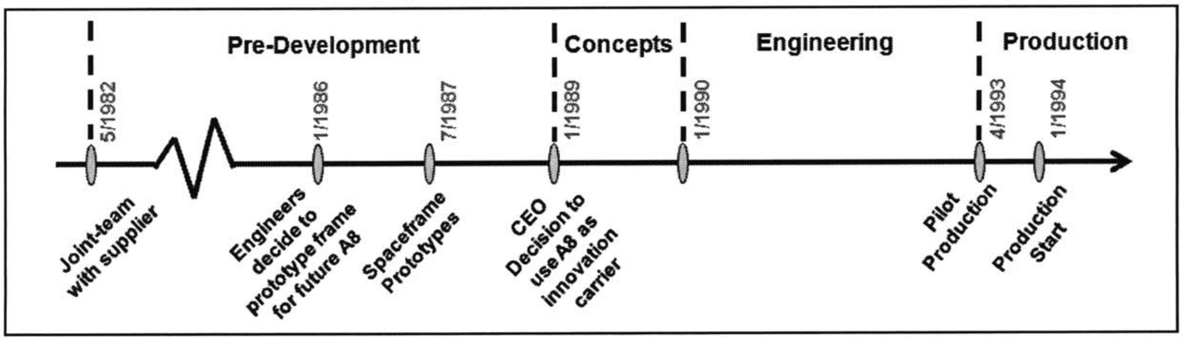


Figure 5.1: Major milestones for developing Audi's aluminum car platform

Audi realizes that this technology can be a competitive advantage, but not on its own. Due to the lack of internal knowledge about the material, Audi did not know how to design with it or how to use it in mass production. The implementation of a joint team of 20-30 engineers from each company allows both companies to solve this problem.. Appendix 5.3 shows the agreement contract, which regulates the international project. The decision by Audi to decouple the innovation project from other daily business allows the engineers to concentrate on solving technical problems and interests of management. After 1987, the CEO of Audi decides to decrease the amount of attention to the project received. This leads to engineers needing over one year to find enough allies and managerial support to bring this project back to the top managers' table. Shortly after the introduction of the model A8, Audi realizes the difficulties but more importantly, the potential of lightweight car bodies. This leads to the establishment of the Aluminum and Lightweight Design Centre in 1994 to focus process and product development capabilities on one specific topic: aluminum. With a $12 million initial investment, as well as 110 people from R&D, engineering, manufacturing, quality departments, this R&D center specializes in process and product innovations. Audi introduces the next aluminum platform with the Audi A2 in 1999. Today, the aluminum center is highly recognized in the automotive world:

- Development of car bodies for Audi A2, A8, TT, R8, and Lamborghini Gallardo
- Over 100 patents (frame, welding, coating, casting, etc.)
- Unmatched weight reduction in industry
- Unique selling point for brand Audi
- Five years knowledge lead to competition
- The production of 550.000 aluminum cars
- "European Inventor of the Year 2008"

Porsche's Technology Strategy

With 12,000 employees, Porsche's size is comparable with the one of Company X. Both companies also profit from their great brand image. However, in contrast to Company X Porsche includes technological innovation and engineering superiority in its brand image as well as in its strategy. Knowing that they do not have enough resources to develop many radical product and process innovations by themselves, Porsche exploits a very detailed technology strategy. Specifically, Porsche analyzes each subsystem of its cars and decides if they want to be a first mover (introducing technology first in market), fast follower (introducing technology second or third in market), or late follower (introducing technology only after it is mature or standard in market). Figure 5.2 shows an example of some categorized subsystems by Porsche according to the overall corporate strategy and constraints. Based on internal and external constraints, as well as the embedment in the overall corporate strategy, Porsche develops a clear technical roadmap and guidelines for each subsystem. For example, the management decides that Porsche has to become the "world champion" in brake systems. Consequently, the limited engineering resources at Porsche concentrate on developing products and processes that will support this goal. Today, many experts and customers consider the Porsche Ceramic Composite Brakes as the best in the industry. Another example is valve control technology. Porsche identifies BMW's Valvetronic system (variable valve timing system) as the leading technology. However, due to corporate strategy and constraints the decision of Porsche is not to aim for technological leadership in that subsystem but to follow BMW as quick as possible. Therefore, Porsche's engineers know that they do not have to spend resources for developing cutting-edge valve technology but closely monitor and benchmark BMW and its suppliers to be ready to react fast on changes. Furthermore, Porsche decide that some technologies such as Diesel engines do not align with corporate strategy and constraints. Therefore, there is no encouragement for engineers to spend resources on such late-follower subsystem.

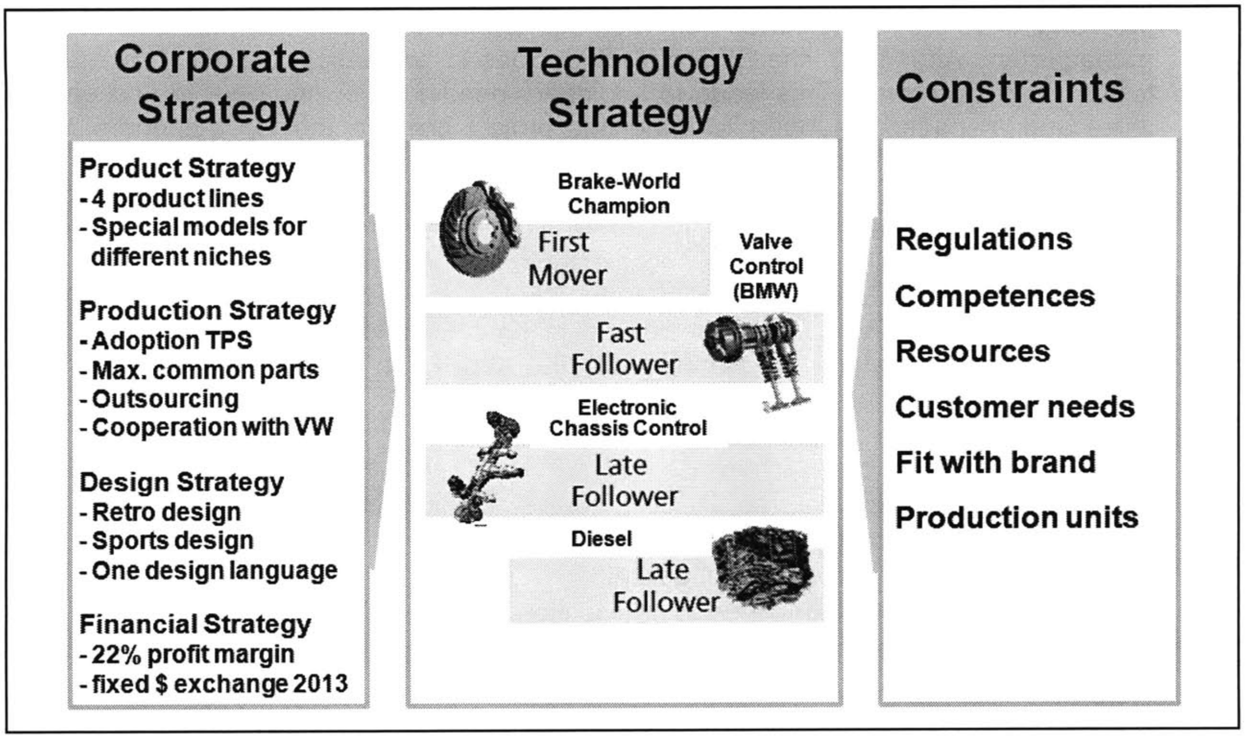


Figure 5.2: Porsche's Technology Strategy based on constraints and corporate strategy

5.2 Toyota

Though Toyota is known mostly for its process methodology innovation (Toyota Production System, Lean Manufacturing), the introduction of a a very successful product development system that includes process technology development in a unique way must be highlighted. Similar to its standardized products and processes, Toyota standardizes its production engineering activities. Morgan and Liker (2006) describe the synchronized approach of concurrent engineering. Standardized processes and policies for die design and manufacturing or assembly engineering, including common weld standards, checking points, and standardized locators, allow Toyota to introduce new process technologies in a smooth and coordinated way. Company X starts with a similar approach with standardized best practices due its BPC's. However, one significant difference to Company X is Toyota's standardization of skill sets. It is a very critical part of its Lean Product Development System. Morgan and Liker (2006) describe the specific hiring activities of Toyota to develop technical competence.

Based on very rigorous hiring process, Toyota hires only 1.1% of professional candidates applying for engineering positions. In 2006, the author's decision to apply for an engineering position at Toyota's European headquarters in Brussels, Belgium illustrates the rigorous nature of the process. The participation in multiple interviews and selection methods, mostly by professional third-party HR experts, to assess his technical and social skills illustrates its thoroughness. When Toyota hires engineers for process and product development positions, it invests three to four years in on-the-job trainings before consideration as serious team contributors. After that, the engineers have to specialize for another five to six years before further consideration as a superior engineer. During this 8-10 year development period, interviews of these engineers occur four times per year to assess and develop a standardized skills set. Production engineers also have to work in different areas during this development period. For example, a new engineer in the Stamping Engineering Group has to absolve the following education steps:

- 6 month freshman project (technical challenging continuous improvement task)
- 3-4 years work in die design
- 2-3 years work in processing and binder development
- 2-3 years in tryout and construction of tools and dies

Technical achievements during this time result in career jumps. Managers who serve as mentors have deep technical expertise and oftentimes have a better technical knowledge than the engineers themselves have.

Emphasis remains that Toyota is very conservative and risk-averse regarding new process technologies. Its principle "Technologies should support the process, not drive it" (Morgan and Liker, 2006) prevents Toyota from adopting cutting-edge technologies too early. The expectation is that changing processes results in instability, process variation, creates waste, and confuse people. That is why Toyota does not look for single technology solutions but holistically improves the existing process system. They carefully adopt only new technologies when necessary and only after extensive testing and integration planning.

The examples of Volkswagen and Porsche show that developing and introducing new process technologies require multiple activities and a long-term plan. Only the combination of substantial efforts in different areas allows these companies to be world-class innovators. The broad range of activities, from Volkswagen's massive Tool & Die tryout facilities to Audi's 12-year long development project with a supplier to Toyota's 8-year training period for production engineers, emphasizes that Advanced Manufacturing with its very limited resources and its short 2-year history can face more challenges and tasks than what leadership anticipates. Moreover, these examples also demonstrate that becoming a world-class leader in innovative process technologies requires a long-term focus and commitment.

Chapter 6: Case Studies

"If your project doesn't work, look for the part that you didn't think was important"
- **Arthur Bloch**

Advanced Manufacturing has multiple process technology development projects. The author concentrates his research on projects and organizational activities around the area of metal fabrication. Quiet Steel is chosen as the case study due to its recent transfer to the LCP. The case study Paint Best Practice Circle – Fabrication Best Practice Circle is chosen because they are both the most active platforms for technology development projects. Moreover, the Paint Best Practice Circle is considered as the most innovative and successful cross-functional collaboration between manufacturing, engineering, and styling.

6.1 Case 1: Quiet Steel

Company X has to meet worldwide noise regulations with their products. One component, component F, influences at some products the noise level significantly. After investigating and testing different solutions, Company X decides to use an aftermarket damping material (damping sheets that are adhesively bonded to finished product) in 2006. However, this solution has multiple downsides: it is expensive, labor intensive (one person has to glue the sheets into component), an extra work station and machines is needed (investment cost in 2004: $330k; possible reinvestment for future versions of component F), and the finished surface of component F is often damaged through the process (estimated scrap costs: $30k/year). The introduction of the solution with the damping sheets is mainly due to time pressure. Engineers continue testing different alternatives, but none is in serial production.
One of the alternative solutions is using "Quiet Steel", a laminated sheet product composed of two steel facing sheets separated by a viscoelastic polymer resin core (metal-to-polymer-to metal laminates) (Appendix 6.1).

The implantation of cross-functional activities starts after ongoing international discussions and testing by Company X in 2005. A team of the Advanced Product & Process Development group (predecessor of AM) with seven engineers including platform manager, factory engineers, and a materials engineer begin to concentrate on Quiet Steel to understand the feasibility, potential benefits, and impact for manufacturing.

After 5 years, however, the project is still not complete. Although the noise test results are superior to other damping solutions, the engineers cannot solve significant production and product performance issues. Appendix 6.2 shows the main events that influence the outcome of that Quiet Steel project, while more detailed milestones history in Appendix 6.3. An interdisciplinary team starts to demonstrate the feasibility to produce component F, beginning in 2005. It must meet all requirements (noise, cosmetics, rework; press-to-paint without surface treatment) and not require any process changes (fabrication, paint). Driven by Engineering and Manufacturing, the concentration of the team is on the following tasks: noise requirements, material specifications, blank lube specifications, tooling requirement, cosmetic requirements, rework requirements, paint processes, costs, and simulation of press process. The completion of the initial investigations around manufacturability, as well as the production of multiple prototypes, are in October 2006 and shows some critical issues, especially around surface quality and spot welding. FEA and real prototypes indicates problems with wrinkles and thinning. Driving these tests are Manufacturing with the support of MSC (supplier of Quiet Steel; solely chosen source by the team) and tooling suppliers. Company X decides to use aftermarket damping pads (EAR material) to meet noise regulations, but continues to investigate Quiet Steel. As of January 2007, noise testing continues to show superior noise damping results.

During 2007, manufacturing engineers mainly drive for more testing and evaluations (including production level tooling and drawing analysis). Once the project focuses changes to cost savings, no longer is it a high priority. Increasing scrap problems in production encourages manufacturing engineers to continue work. The results are convincing enough to put component F made of Quiet Steel on the LCP. The manufacturing engineers are convinced to solve current issues and presents prototypes that look acceptable (surface is polished; this additional step will not be part of future manufacturing process).

During project integration into the official CPPDM process, a very structured testing process begins. However, since the mainly Advanced Manufacturing pushes this project, the responsible product engineers do not support this project ("not invented here"). In June 2009 the platform committee removes the project from the LCP because of unsolved problems. The CoE blames the Manufacturing engineers that they cover problems by secretly polishing the prototypes (this argument is never clarified).

It is not completely clear of the investments of time and money into prototypes, testing, and 3rd party costs; the amount of internal working hours is especially unclear, see Appendix 6.4. However, the project is not successful. The main problem is that Manufacturing pushes a technology and that the project does not get support from principal stakeholders (although initiation is by product engineers whom later lose interest).

The team's concentration is on manufacturing parameters, but not on all product characteristics, (especially the neglecting of surface problems and product requirements in the beginning). Moreover, the team does not scientifically analyze the limits of Quiet Steel but tries to reproduce

	Project Scope	Project Team	Project Management	Discipline
Positive Influence	• Focused on product and process in the beginning • Included additional fields of investigation when needed	• Started with many different stakeholders • Close cooperation with suppliers • Leadership change when necessary	• Detailed Scope of Work description in 2005/2007 • Regularly reporting at BPC • Documentation at eRoom • Good integration into CPPDM • Platform manager removed project from critical path • More structured approach by new project lead • Good financial model	• Tried to overcome internal barriers • Single people championed parts of the project
Negative Influence	• Wrong goal (focused on pushing Quiet Steel into component F, not on finding best noise reduction solution) • Goals were vague in the beginning • No scientific analysis of Quiet Steel to understand limits • Product testing too late • Limited use of FEA • Worldwide 1st time use of Quiet Steel for high-grade surface	• Not all stakeholders included • No powerful project champion • Only focus on one supplier • No internal lobbying	• No Go/Kill decisions • No risk/benefit analyses • Limited Documentation • Responsibility of team members unclear • No strict deadlines • No budget limitations • No idea generation phase • No data-based risk evaluation	• Nobody's priority #1 • Accepted long delays • No cost tracking • Covered problems

Figure 6.1: Positive and Negative Effects on Project Quiet Steel

an existing product by using an unknown material with existing tools. Further deficits in project management and discipline, in combination with technical problems, only worsen the situation. Additionally, it is unknown of the usage of Quiet Steel for high-class surface applications, so no outside experience and knowhow is available. This project is not only introduces existing technology into the factory but also is a real R&D project that needs a structured and holistic problem solving approach. Figure 6.1 lists all positive and negative influences on this project. In retrospect, it is obvious the delays and eventually the rejection of the project by platform management start with the significant shortcomings in the project scope, team selection, project management, and discipline.

After its removal from the LCP, Advanced Manufacturing starts to pilot the project again in summer 2009. It marks the first time a questioned project results in the investigation of alternative noise reduction solutions, and basic tests, like a Limiting Dome Height test, lead to a better understanding of the limits of the material. Its main execution is by one engineer with support from outside experts and MSC. Future steps are dependent on the results of the dome tests.

The Quiet Steel example demonstrates that Company X needs an innovation strategy due to the consuming of many resources over many years of this project without connection to any strategic goal. It ends up as a cost savings project for Manufacturing. Although the Quiet Steel material is a technology whose utilization is possible for other components, no internal stakeholder has any interest in it during the research. Moreover, it clearly demonstrates the missing decoupling process. The expectation of product engineers are for comprehensive tests and prototypes that guarantee a smooth launch when introduction into a LCP project occurs. Since these test requirements are not standardized and there are no communicated expectations upfront, AM engineers become upset when the PDC engineers set new specifications later on (that not even current solutions fulfill). A stage-gate process can prevent that such a project can go on for so many years without solving problems evident from the beginning (wrinkles on surface). An X-Team structure can help the project to identify main stakeholders upfront and include all internal customers to understand their requirements. Because AM mainly drives the project, the engineering community rejects it regardless of the results ("not-invented-here" mentality). Moreover, it is also an example of AM pushing a technology instead of looking for the best solution (front-end loading). In 2009, it becomes evident that other aftermarket solutions can also provide significant cost savings. There is even knowledge that design changes can solve the initial problem (meeting noise regulations) without the need of Quiet Steel or any other damping material. The addition of missing metrics and lack of expense documentation only increases the ongoing shortcomings. Missing is a decision to kill or question the project when significant technical or financial problems lack conclusion. Instead, the project is delayed multiple times because of low priority only to restart to due to the activities of a few.

6.2 Case 2: Paint Best Practice Circle – Fabrication Best Practice Circle

Other important parts of Advanced Manufacturing's work are the so-called Best Practice Circles (BPC). These committees or work groups focus on sharing industry best practices in manufacturing with the target of standardization, cost saving, and innovation. Advanced Manufacturing engineers are leading and facilitating the BPCs. Company X has several of these groups according to operational units. The Paint Best Practice Circle (PBPC) is highly recognized inside Company X's manufacturing and engineering community. As the oldest BPC, it is considered as the ideal model of this type of a work group with an impressive track record. The PBPC is one reason of Company X's industry leadership position in paint. Other Best Practice Circles has yet to develop such a track record and reputation. The author compares the PBPC with the Fabrication Best Practice Circle (FBPC) due to the analysis of mainly projects from Company X's fabrication section (detailed comparison see Appendix 6.5 and 6.6).

Starting in 2004, The FBPC's concentrations are welding standards, dimensional management strategy, and cost reduction. Up to 20 experts from operations and engineering meet every two months at different locations of Company X. Only after 1.5 years, the SVP of Operations decides to attend one of these meetings to demand that the FBPC become the strongest BPC of Company X including systematically investigating new technologies (especially aluminum) and offering additional resources for R&D projects if necessary. However, the FBPC focus remains on cost savings, standardization, LCP projects support, and continuous improvement. Manufacturing drives most projects with limited support of Engineering. Some FBPC members visit local tooling suppliers and start some projects with them, e.g. the Quiet Steel Project. Besides this one meeting, neither the SVP of Operations nor any other high-level leadership have yet to attend additional meetings or give any further directions.

Interviewees claim that leadership and executive committees have more involvement in the PBPC than in other PBCs. It takes the SVP of Operations three years after the start of the FBPC to ask for clear deliverables, a technology innovation plan and budget controlling, and even then the objectives are very vague (meeting minutes: "Sub group deliverables for 2008: Each Sub-group must deliver 1 thing in first 6 months; Each Sub-group must deliver something that affects Standardization, Innovation, and/or CI by end of year"). This clearly demonstrates the need for a sound R&D strategy and more leadership guidelines. However, the FBPC manages to introduce an overall strategy for its sub-groups, see Appendix 6.7. Although they define categories of focus, they fail to define clear goals and metrics. While the FBPC has significantly involvement in supporting current product launches and different smaller projects, they do not introduce any major technology innovation in 2008. In the beginning of 2009, the group establishes a work unit plan with different actions items (e.g. roller hemming, Quiet Steel) including metrics, deadlines, and status (see appendix 6.8).

The metric examples demonstrate the need for a more proficient measurement system. Metrics like "Completion of Prototype" do not encourage the expected actions (the goal is not producing one very expensive prototype but getting as many information as possible to finish a sound feasibility study as quickly and cheaply as possible).

In 2009, in influence of the economic problems of Company X is clear in the work of the FBPC. The group does not only face significant changes in its team composition, but also has to focus on a new task. Company X's evaluation of the productivity of its facilities leads to the development of a possible relocation of a facility. The VP of Operations assigns most members of Advanced Manufacturing and members of the FBPC to support these activities.

Although the initial ideas behind PBPC and FBPC (standardization, cost saving, and innovation) are identical, there are multiple reasons why the outcomes are different. Most importantly, the mission, the leadership support, the personnel continuity (some members of the PBPC attend these meetings for over ten years) as well as the complexity of the products and processes of both groups, is very different.

The PBPC focus is on becoming the industry leader in paint from a manufacturing and customer viewpoint. The product "paint" has three main stakeholders (styling, materials, and manufacturing) and its main restriction is process capabilities. The product "paint" is changeable every model year.

The FBPC focus is on standardization and cost reduction of different metal components. The products "metal components" has six main stakeholders (styling, materials, testing, systems engineering, platform engineering, and manufacturing) and has many restrictions: process capabilities, regulations, engineering requirements, and platform requirements. The products "metal components" can be changed often only at new platforms (every 5-7 years).

While the PBPC can include commitment and resources from the leadership of all main stakeholders, the FBPC can only win limited commitment and resources from main stakeholders like engineering and styling. Since paint is a competitive advantage and is one main cost factor, executive leadership puts more attention to this field than other manufacturing areas. Most PBPC innovation projects are jointly driven by styling and manufacturing, while FBPC innovation projects are driven by manufacturing engineers who are naturally focusing on cost saving and continuous improvement activities (with the support of local suppliers and experts). Due to limited involvement by engineering, most projects focus on current products.

Appendix 6.9 shows an example of a FBPC sub-group charter. These guidelines can help members to focus their projects. This is much shorter than the PBPC sub-group charters that describe very detailed goals and limits of such a task force.

Both case studies show basic evidence of AM's underperformance on multiple problems. The Quiet Steel projects demonstrates that some decisions in regard to project scope, project team, and project management influence the delay and PDC's opposition of this new technology. The comparison of the PBPC and FBPC emphasizes that both groups execute their projects in a different way. Although leadership expects a similar outcome from both groups, the leadership support, cross functional integration, as well as strategy and policy activities are very different. These described dissimilarities can cause the different success levels.

Chapter 7: Recommendations

Innovation is important for the future success of a company. Many companies do include innovation in their strategy and business model. Oftentimes the focus is then on product innovation while process innovation will follow later. Some companies even overemphasize innovation and face reduced profitability because resources are used for technology developments that are never successfully commercialized. Other companies do not focus an innovation at all. Generally, these companies blame financial or organizational restrictions and hope that in the long-term they can be innovative again.

Company X shows both extremes. On the product side, the active abandonment of innovation is part of the branding strategy. Traditional products that are only slightly changed are used to differentiate themselves from competitors. However, a shrinking core customer base and new environmental regulations will make innovation necessary. On the process side, AM introduced a very open innovation model without any regulations, strategy, or goals. The hope was that money and very experienced manufacturing engineers will be able to drive process and product innovation.

The research showed that implanting different strategies and cultures for product and process innovation inside one company can cause conflicts and a waste of resources. Due to the observed shortcomings and limited success of AM, the author recommends different major changes at Company X and AM. These changes have to affect the strategy, culture, policies, and management tools. They are an important part of an overall methodology to manage process technology innovation. Figure 7.1 shows the main elements of such a recommended methodology.

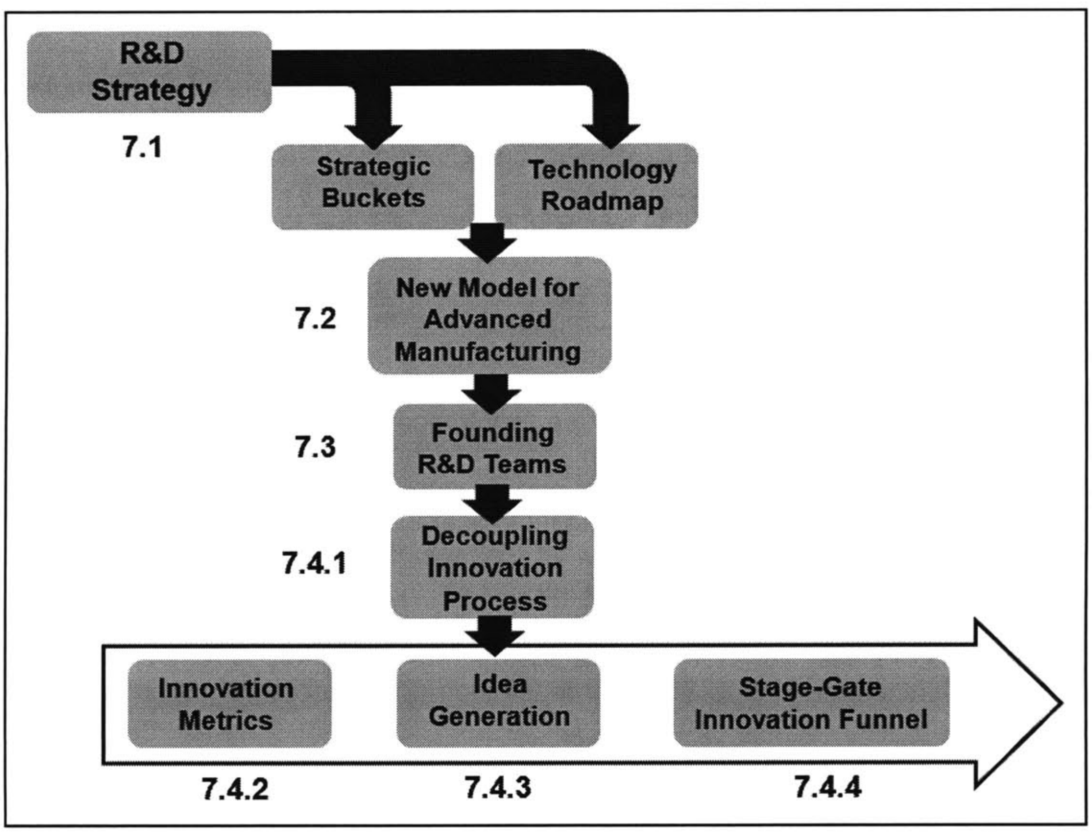


Figure 7.1: Recommended elements of a process development methodology

7.1 R&D Strategy

As mentioned, Company X currently does not have an R&D strategy. The new leadership recognized, with the help of external consultants, this problem and initiated a cross-functional taskforce that has to introduce solutions in the next few months. The author does not have enough product and marketing insights to recommend a detailed R&D strategy. This must be an exercise of top-management and key stakeholders like styling, product development, AM, and marketing.

However, it will be critical for AM and the engineers at PDC to get a framework and guidelines for their daily innovation projects that includes all the elements that are described in Chapter 3. A technology strategy will be a crucial factor for future success. Based on the limited resources of Company X and the technology lead of competitors a Play-Not-To-Lose strategy will be more feasible. That also means that cutting-edge projects like carbon-fiber components or Quiet Steel for highest-quality surfaces should no longer be pushed. Competitors and suppliers already have enough working solutions that can be adopted. AM has to install an active technology radar and a network of outside innovators to be a quick adopter of these solutions. The focus should be on innovations of the fields 1 to 4.

Additionally, one possible scenario requires a Play-To-Win strategy. Similar to the automotive industry with the electric car, the industry of Company X faces a possible technology change in the next decade. Environmental regulations and awareness will probably cause new product architecture with new product features. For that scenario Company X should chose a Play-To-Win strategy. New materials and new system groups could heavily influence manufacturing. AM has to be ahead of its competitors to use this unique chance to set industry standards again.

At the very least, Company X should introduce the strategic tools of a technology roadmap and strategic buckets as soon as possible. Many technology development projects are executed that need the specific guidelines that such tools can provide. Although Company X has a process for continuous improvements (new technologies to reduce costs of current products) and value engineering (new technologies to reduce costs of soon-to-be-introduced products), the author observed several projects that were not covered by these processes. Appendix 7.1 shows that there is an area of projects with technologies that are unknown to Company X and that are not connected to any current or near-future products. These projects have to be covered by an R&D strategy.

Two top-down approaches are recommended for Company X, a Technology Roadmap and Strategic Buckets. The development of a Technology Roadmap by the top leadership with the help of technical experts and market intelligence. It is critical that the experts at AM and PDC explain different technological scenarios to educate leadership. For example, the engineers have to show what technologies can foster weight reduction (one request that was repeated by multiple interviewees) with what influences on costs, manufacturing, and design. In addition, Marketing has to develop scenarios of future customers needs, for example, how much a customer is willing to pay for a 10% weight reduction. With such scenarios, a Board of Innovation (top leaders from manufacturing, engineering, marketing, styling, plus the CEO) has to decide on Customer Needs, Product, and Technology Roadmap. First, they should develop a Customer Needs Roadmap to define when and which needs and regulations need fulfillment. From that they have to derive a Product Roadmap (like the current LCP) to guarantee products that fulfill the customer needs. Lastly, a Technology Roadmap has to be defined to give PDC a guideline when which technologies have to be introduced in which products to fulfill customer needs. This Technology Roadmap should have a horizon of 5-10 years.

Additionally, this Board of Innovations also should define Strategic Buckets. If Company X knows its Product and Technology Roadmaps, it can use Strategic Buckets to allocate resources and set spending targets. Cooper (1998) describes some key steps for developing such Strategic Buckets, see Appendix 7.3. The author recommends AM and Company X to define such buckets for their portfolio of technology development projects that are outside LCP or current products. These buckets provide some guidelines for the engineers to focus on the right projects. Management can also use them to encourage or discourage projects in specific fields. When different projects are linked to one Strategic Bucket, the probability of success is higher than having multiple random projects (see Appendix 7.3). Company X also can use Strategic Buckets to invite internal and external innovators to solve its problems. Use them like "Christmas trees", show them to internal and external audience, and encourage employees, suppliers, or innovators to hang their "ornaments" on these trees. Since each tree has a specific strategic topic and its own budget, it is easy to link innovation projects to such a tree (see Appendix 7.4). So far, no one inside or outside Company X knows which technologies AM is developing and which problems they want to solve. With public "Christmas trees" AM can communicate: "We want to solve this problem! We have resources. Please bring your ideas and solutions to us to make our tree pretty." This is one approach to attract ideas instead of costly searching for them.

7.2 New Model for Process Development

In general, AM should no longer focus on small cost saving projects and random unrequested technologies but primarily support a faster, cheaper, and higher quality product development. Most AM technology development projects try to re-produce current components with new manufacturing technologies and materials. This is mainly because of AM's intense knowledge about current production conditions and problems and result in continuous improvement projects. However, the ultimate goal of AM should be the enabling of process development capabilities for future products. That is why AM should also actively foster projects that develop concurrently process and product technologies with PDC and Marketing. Appendix 7.5 shows the schema of such a process that includes continuous improvement and process development activities. The case study Quiet Steel demonstrated that concentrating on current products could hinder learning effects. Production engineers only tried to rebuild the current component F without scientifically understanding the limits and opportunities of that material; only limited knowledge to future components can be transferrred.

AM should redefine its primary goals. While other groups at the production level can execute cost saving projects, no one at Company X has a plan how to defend core-manufacturing competencies, reduce the R&D time and costs of new manufacturing technologies significantly, and expand the global network of machine suppliers and experts systematically. Table 7.1 summarizes different factors, according to Pisano (1997), that would contribute to these goals.

Table 7.1: New model for process development

	Current Model	Recommended Model
Primary Goals	• Reduce manufacturing costs of current products • Support smooth launch of LCP projects • Explore new processes and materials	• Defend core manufacturing competencies that provide competitive advantage • Create an efficient feasibility and prototyping system to allow short-run completion of technology development and introduction • Create a flexible network of global tooling and machine suppliers and experts • Highest satisfaction of internal R&D customers
Technical Focus	• Incremental improvement of current processes and products • Materials and processes that are not currently used • New capacity/equipment • Troubleshooting • Process and product modifications for enhanced manufacturability	• Exploration/development of new process architectures for future products • Feasibility studies and expanding of knowledge of alternative manufacturing processes in a timely, efficient, and high quality manner • Develop next generation system groups (product and process) together with PDC • Only projects that are demanded by internal customers
Product Development Role	• Peripheral	• Central • Product and process R&D together with PDC and outsiders
Customer	• Plants • No initial customers (technology will wait on shelf)	• Plants • PDC • R&D initiatives
Key Capabilities	• In-depth knowledge of current manufacturing • Process engineering • Minimize manufacturing problems	• Benchmark/network capabilities • Process science • Ability to anticipate future manufacturing requirements • Responsiveness to project level uncertainty • Driving cultural change
Learning	• Maximize learning curve within product/process generations	• Capture learning across product/process generations

Instead of developing new manufacturing technologies in advance (that are probably never be needed), AM should try to develop capabilities and networks that can react very quickly on the common late design and technology changes that are caused by PDC.

Together with the System Groups, they should redesign the product and process architectures for the next 5-10 years and try not to push a single manufacturing technology in some current components whose life cycle is already half over.

7.3 R&D Teams

At the end of 2009 AM started one pilot team (so-called System Strategy Team) where engineers from AM, Plants, and System Engineering agreed on establishing a cross-functional alignment to develop a desired future state for system groups (product and process), see Appendix 7.6. VP level managers should sponsor these groups. The author encourages this activity. Separating such cross-functional teams from daily LCP assignments, having shared resources, and focusing on one specific system group, are critical for the development of innovative processes and products.

If breakthrough innovation is a goal for AM, separate R&D teams that create their own culture and processes inside Company X could be especially useful. Appendix 7.7 shows the differences between the current LCP organization and such an ambidextrous group that focuses on radical innovations (directly reporting to the VP of Operations and the VP of Engineering). As explained in Chapter 4.2.2, such teams should use the X-team approach to develop internal supporters systematically and to incorporate as many outside experts as possible. Company X can further benefit from focusing heavily on upfront work before actually starting the development of new manufacturing technologies. Limited internal R&D resources and capabilities make in-house technology developments very difficult. Moreover, related industries like automotive and its advanced suppliers, currently offer many technologies that can be adopted by Company X. That is why such R&D teams should mainly concentrate on finding and combining the existing technologies instead of reinventing

Appendix 7.8 shows the recommendations for such an X-team. The purpose and scope of such an R&D should be more aggressive and concentrate on combining internal and external resources to an industry-leading network in development and production of a specific system group. Very important is the structured Exploration Stage where the group spends significant time and resources (e.g. 30% of overall project) before starting any development activities. Appendix 7.9 shows the different tasks of that stage in more details. The observed process development projects at AM barely spent any time or resources for the Exploration Stage but started almost immediately with the development and prototyping of one specific technology.

According to Thamhaim (2003), the performance of innovative R&D teams highly depends on social factors. The strongest influence has components that satisfy personal and professional needs. When team members find their assignments professionally challenging, leading to accomplishments, recognition and professional growth, they work more productively, lower communication barriers and solve conflicts, and strengthen the collective awareness of environmental trends.

7.4 R&D Process

Even with a sound R&D strategy, new goals and capabilities of AM, and cross-functional R&D teams, Company X still needs a reliable R&D process including a practical decoupling methodology, useful innovation metrics, systematic idea generation tools, and a stage-gate innovation funnel that evaluates different project stages and kills projects when necessary.

7.4.1 Decoupling Innovation

The R&D teams should not have to compete for resources with LCP projects but are supported by the Strategic Buckets. Not only should management provide them with time and money strictly associated to non-LCP projects, but other stakeholders also have to commit part of their capabilities (e.g. marketing resources, materials labs, simulation, and test facilities) to R&D projects. As mentioned in Chapter 4.2.1, Innovation should be decoupled from the next model year products and from engineers who concentrate on LCP projects. However, Innovation should not be decoupled from potential future platforms and models (but there should be a backup solution so that a postponed innovation will not jeopardize the introduction of a new product), customer and organizational needs. Through the Strategic Buckets, technology development projects should be connected to an overall topic, the so called innovation carrier. Figure 7.2 describes the principles of such an innovation carrier (e.g. Danone used the topic "Healthy Breakfast" as innovation carrier).

Carrier Definition

One "umbrella" that covers multiple innovations to give all stakeholders a drop-in center and to provide strategic guidelines

Carrier Deliverables

- Technologies/know-how/IP
- Products
- Ideas and opinions
- Reputation
- Relationships
- Staff development

Carrier Components

- Business targets
- Experienced people (experts)
- Technology/know-how
- Intellectual property
- Processes and structure
- Specialized facilities
- Budget (people and $$$)
- Organizational awareness
- Support by CEO

Carrier Advantages

- Raises attention of stakeholders
- Invites stakeholders to participate
- Guidelines and focuses activities
- Integrates different innovations
- Protects innovations
- Fosters alignment and momentum
- Cuts costs
- Increases returns

Figure 7.2: Innovation carriers to guideline innovation projects

Company X and AM have to find a balance between completely independent research projects and rapid technology adoptions. Figure 7.3 shows that premature R&D work results in ineffectiveness and rework when introduced to LCP. If a technology development project starts too late, it often ends up in a firefighting project that needs too many resources for suboptimal solutions. This too late R&D was observed multiple times at Company X.

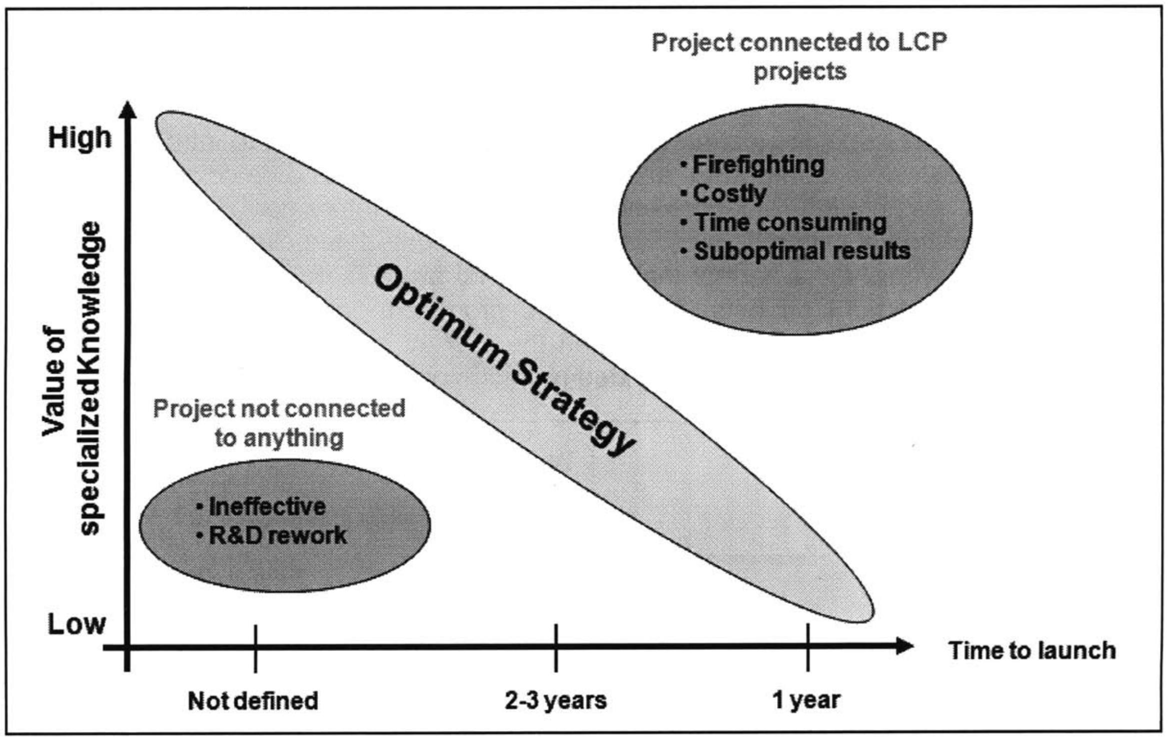


Figure 7.3: The optimal decoupling strategy is a compromise between early and late start of R&D projects

The author recommends a "Ready-To-Order" principle for decoupling technology development. Like a technology delivery service, Company X needs a system of people who orders a technology (Board of Innovation's technology roadmap is like a written order), develops the order (Strategy Teams), and picks up the technology and introduces it into a LCP product (Platform Manager). Appendix 7.10 shows the principle of such a system. To deliver a new technology, the Strategy Teams should not only develop a new System Group or a new manufacturing process, but they should offer a complete package including optimized product and process, design and manufacturing guidelines, and internal/external experts to support the introduction. With that, the "Ready-To-Order" shelf can be used to connect R&D projects (pre-CPPDM) to LCP projects (CPPDM), see Appendix 7.11. Existing processes like the LCP matrix structure and BPC's can support the Strategy Teams.

In addition, AM should systematically establish a network of outside experts and service providers to support their decoupled projects. So far AM has relationships to one university for material testing, works together with a few local tooling suppliers, and owns some surplus machines that can be used for prototyping and testing. However, if innovation is really decoupled from LCP activities, external support has to be systematically searched for and integrated into an R&D network whose focus and capabilities is linked to the R&D strategy.

Company X's new leadership decided that only 30% of technology development projects should be decoupled from LCP projects. When comparing to best practice companies, this number should be much higher. The current organizational change activities at Company X seem to end up in a partly decoupled innovation funnel with a screening gate that kills/fosters specific technologies. The author recommends to introduce a more holistic approach where Company X analyzes and decides on its core competencies and then envisions possible future competencies. To reach this future goal, Company X must fill its innovation funnel with multiple ideas that are evaluated and clustered by the Board of Innovations. With that, a normal innovation funnel process pushes and kills different technology development projects (process and product together) until the envisioned future is established. A comparison between the current innovation pipeline, Company X's planned scheme, and the recommended methodology can be found in Figure 7.4.

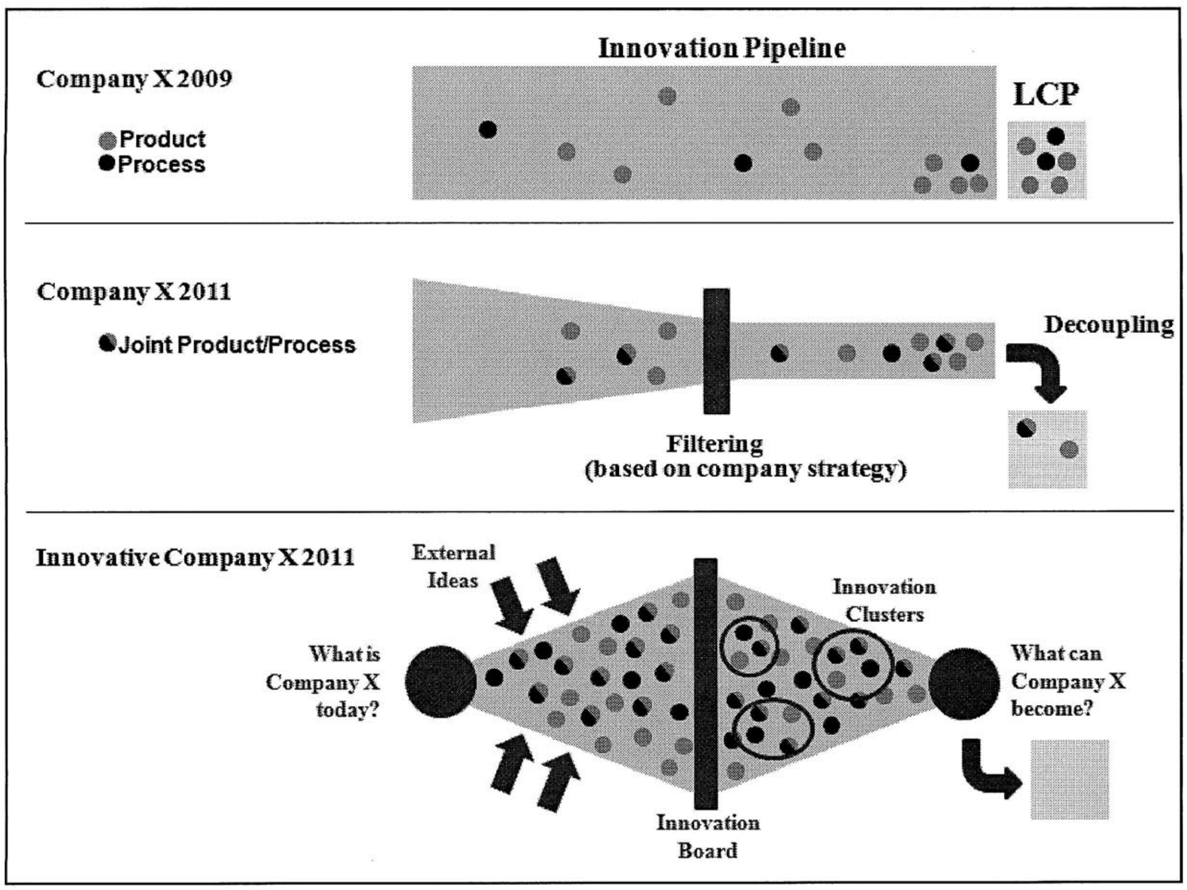


Figure 7.4: Comparison of different innovation pipeline types

7.4.2 Innovation Metrics

As mentioned before, a sound measurement system is critical for successful innovation projects. In general, metrics should measure the inputs, processes, and outcomes of an innovation process. Based on Davila (2006), the author recommends a measurement system that that describes:

- What resources are required from employees, external experts, suppliers, or best practice organizations that faces similar problems
- How the resources are combined efficiently to create innovation
- How the specific innovation translates into business value (e.g. decreased cycle time, increased quality, reduced scrap)

For each dimension AM should introduce five to seven metrics, but not exceed 15 to 20 metrics to avoid becoming overwhelmed. When objective measures like in manufacturing (e.g. accidents per employee) are not observable, subjective assessments should be used rather than none. AM should also differentiate between measures at a strategic group level and a specific project, see Figure 7.5

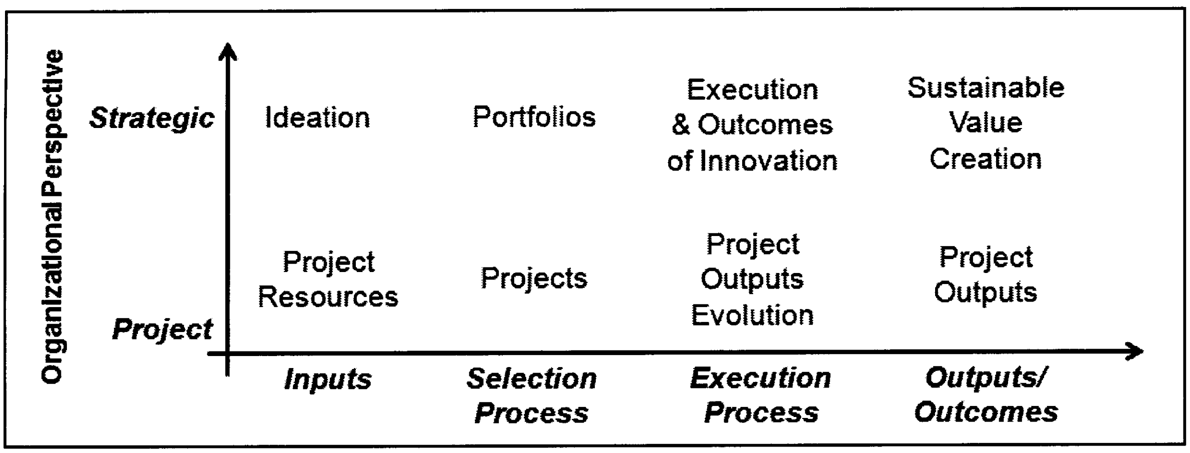


Figure 7.5: Framework for different metric levels (Davila, 2006)

Since the author observed a lack of game-changing and innovative ideas, AM should include measures for ideation. Since the quality and quantity of ideas depends on internal and external stimulation AM should measure innovation by the number and effectiveness of efforts like Strategy Teams, BPC, and 3M partnership. This can be done with appropriate surveys. For each activity AM should track the quality of people involved, meetings and communication, periodic achievements, and generated ideas. Appendix 7.12 lists more potential measures of the ideation process.

Altogether, the author recommends that the leaders of Company X, AM, and Strategy Teams develop and continually improve measurement systems that helps track and influence the different R&D projects and innovation strategy. Figure 7.6 shows the recommendations for metrics that cover the AM group level. However, these metrics have to be changed according to the managers' goals. Furthermore, metrics for a project or for Company X's R&D portfolio have to adjusted and changed.

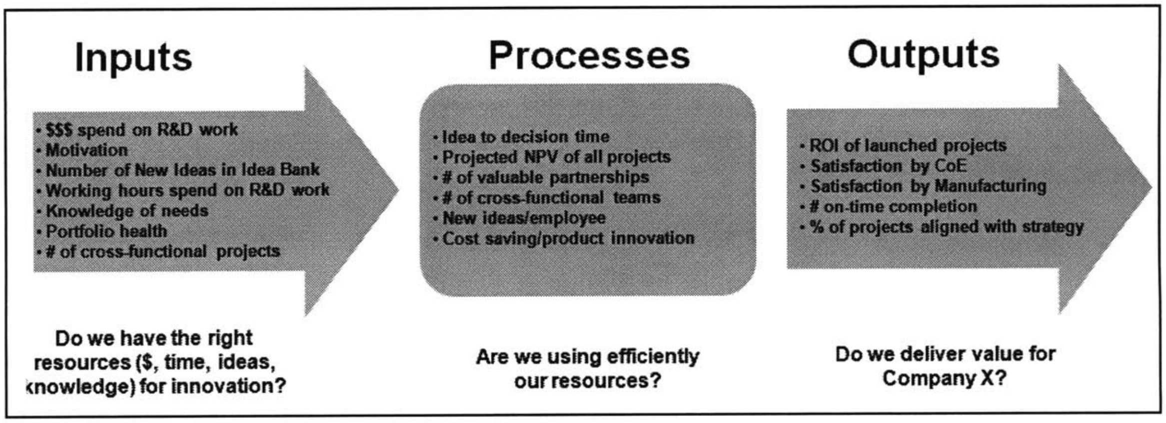


Figure 7.6: Example of recommended metrics for AM

7.4.3 Idea Generation

As illustrated in Appendix 4.6, multiple tools and factors fill the front-end with new ideas. It depends on the team characteristics and project goals which tools should be used. Literature describes extensively such tools. AM should just test some of these tools and implement what works best within the culture. Most interviewees explained that they use brainstorming and other methods to generate new ideas. While the author could not observe any of these tools due to the lack of new R&D projects, AM leadership should encourage employees to develop as many ideas as possible. Comparing the project list of 2009 to 2010 indicated that only a very limited number of new ideas were introduced. Moreover, it was observed that different groups already considered all ideas in previous years and only current project team members are involved in the ideation process. Neither outsiders like experts or suppliers nor the majority of Company X's 10.000 employees are empowered to submit their ideas. This has to be changed. Company X needs a system that encourages everybody to participate. This could start with simply inviting many more internal experts to participate in idea generation sessions or an uncomplicated employee suggestion system on AM's intranet. Supplier competitions like at Volkswagen (see Chapter 5) could also be a feasible solution. Appendix 7.13 shows the scheme of an Innovation Round Table that does not only collect and evaluate new ideas, but also quickly delivers feasibility studies and prototypes. Small investments are allocated to specific uncertainties and hypothesis of a specific technology. The Innovation Round Table (changing members from production, engineering, and marketing) then expects an answer in 30 days before more resources are allocated.

In general, AM's leadership has to encourage employees to look more systematically and frequently for new ideas. AM should be the process technology radar of Company X. Although interviewees stated that they want to do more benchmarking and visiting technology fairs, only a few employees are actually putting this into practice due to other priorities and lack of time. Metrics and incentives should support benchmarking activities and idea generation processes.

7.4.4 Stage-Gate Innovation Funnel

Most companies, which introduced a stage-gate process, reported significant improvements in project efficiency. The gates serve as quality control checkpoints, go/kill and prioritization decision points, and as reevaluation and resource commitment points. The current projects of AM, for example Quiet Steel, clearly show a lack of these gates. For projects that concentrate on developing new process technologies (in combination with product development), the author proposes the format that is described in Appendix 7.14. It combines the front-end loading with an innovation tunnel and includes five stages and four gates. Each stage has to be designed to gather vital information to remove uncertainties and to provide the gatekeepers enough information to make an informed decision.

Stage 1: Problem Definition

This stage is a critical and is similar to the first X-Team stage (see Appendix 7.8). It includes a holistic understanding of the problem and current state as well as all tasks that are described in Appendix 7.9. At the end of Problem Definition, the first gatekeeper has to be sure that the team understands the problem, what resources it needs, and the dependencies inside and outside Company X. Moreover, a team has to be established that is able to quickly move on to Stage 2. Today, AM spends limited time on that stage and only very few people are involved in that stage. It is critical that more stakeholders are involved, especially to understand the uncertainties and to evaluate the potential advantages and disadvantages of a project. At Gate 1 there has to be enough hard data to make a decision if this project is important enough to commit resources to it.

Stage 2: Scoping Product and Process

This is the front-loading stage of a project. The main goal is to generate as many ideas as possible for solving the problem. It is important that the team does not concentrate on one technical solution but tries to find the best available solution worldwide. This exercise has to be unbiased since team members often already favor one solution in the beginning and only look for other ideas to fit. It must be clear that at least 2-3 of these ideas will be transferred to Stage 3 to make a detailed feasibility study. For each idea the team (which does not have to be the same as in Stage 1) has to gather enough information for an idea evaluation process as part of Gate 2.

Stage 3: Development & Rapid Prototyping

When the team and gatekeeper decide to move-on with 3-4 ideas, Stage 3 starts with rapid prototyping and feasibility studies. AM should use much more numerical simulation tools and easy prototypes than in the past. The author realized that AM prematurely buys expensive prototyping tools for intense testing on the shop-floor or at suppliers. This is not necessary at Stage 3. The team should try to remove as many uncertainties as possible with minimal resources. However, a detailed technical and manufacturing assessment, as well as a financial and business analysis, is necessary. Appendix 7.15 shows an example of a scoring model that is based on Cooper (1998) and was adjusted with the input from different stakeholders at Company X. Such a list forces the team to reach out to many experts and to understand the impact of the different ideas. The score will also be used to compete with other projects in the same Strategic Bucket. Gate 3 is very important because of the significant investments could follow.

Stage 4: Pilot Development & Testing

At this point, the team decided to go forward with one technology. Production-like prototypes and testing occur. Manufacturing processes and requirements are mapped out. Marketing and Styling are heavily involved to understand the project's impact. This stage still does not have to happen completely in-house. AM should consider development and testing at suppliers and experts since production and testing facilities at Company X are often busy with LCP and current production activities. During this stage, cross-functional cooperation is very important and the project already has to target a specific model year and fulfill the requirements for an early introduction to an LCP product. Futhermore, the project starts to become part of the CPPDM process. The team, at this stage, will probably be completely different from the team that started the projects. Platform directors have to be convinced to adopt the technology for their platform. In addition, the team has to have a backup technology in case the first one fails because of one or more different reasons (costs, technical problems, etc.).

Stage 5: Transfer to LCP

Some projects of AM failed because this stage has not been prioritized. It is very important that team members will actively help to transfer the project into an LCP project. If you just prove feasibility and hand over the project without any further support, the probability that the plants or platform director rejects the technology is high.

The gates are important for go/kill decisions as described in Chapter 4. According to Cooper (1998) they have to following format:

Inputs: deliverables to a gate-review meeting; there should be a standard menu of deliverables for each gate.

Criteria: questions/metrics to make go/kill or prioritization decisions; qualitative and quantitative criteria including mandatory (must-meet) and desirable (should-meet) criteria.

Outputs: results of gate review; go/kill decision, prioritization score, resource commitment, approved action plan, and decision on deliverables for next gate

Chapter 8: Epilogue

During 2009, Company X's top management realized the shortfalls and inefficiencies regarding product development and innovation. As a result, a substantial cultural and organizational change of Company X was initiated and supported by high-level management as well as the executing workforce. With the help of external consultants, a new product development methodology was recommended, besides other restructuring efforts. Different task forces with mainly internal employees were assigned to develop and introduce organizational changes in the near future. One task force with members from engineering, marketing, AM, and styling started to focus on "innovation" in November 2009. This task force will rethink the importance of R&D and innovation for Company X and develop suggestions for the top management how to increase the outcome of innovation activities (product and process innovation), including decoupling innovation, innovation metrics, and developing a technology strategy.

Moreover, AM and one System group also agreed on starting joint-teams of manufacturing and engineering experts in October 2009. These so called System Strategy Teams will concentrate on significant product and process innovations of specific system groups, as explained in 7.3. These teams will start first projects in 2010.

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Appendices:

Appendix 2.1 Official Statements Advanced Manufacturing

Mission Statement Advanced Manufacturing 2009:

The Advanced Manufacturing group will help to ensure successful launches of new products and cost-effective processes by providing manufacturability input during all phases of C.P.P.D.M., developing and implementing new manufacturing technologies, and sharing and adopting best practices across the plants.

Envisioned State for Advanced Technology / Innovation:

Manufacturing LCP developed to execute the vision of Styling. New processes proven out in Lab, piloted in one site then distributed as proven out to all sites. New process introductions become a way of life. Design Verification build removed from the production assembly lines and done in a lab.

Current State Assessment for Advanced Technology / Innovation:

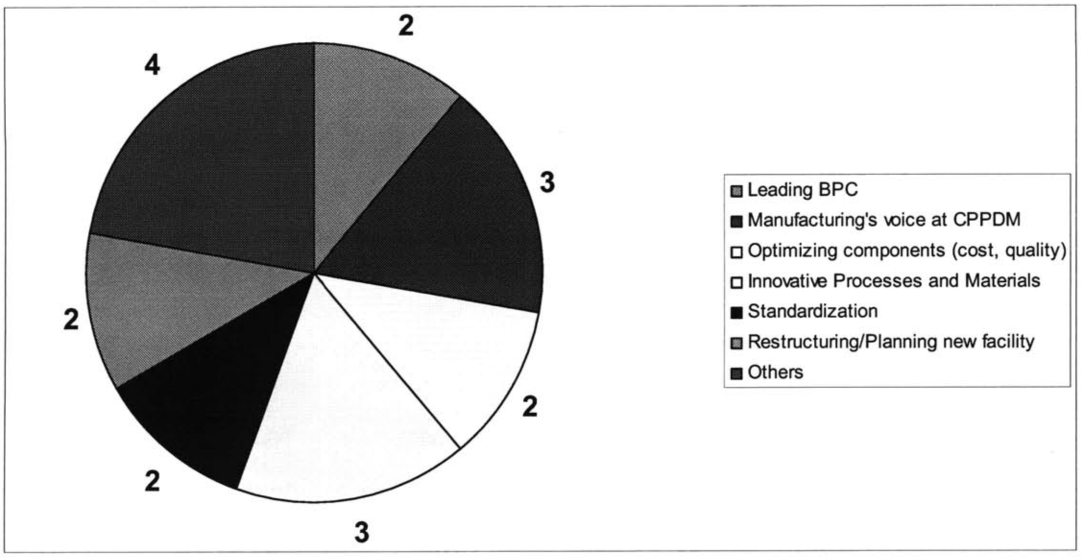
Currently using many conventional manufacturing processes even if there may be opportunities to try new ones. Incremental volume strategy bred risk avoidance. Not enough resources in place to do new process validation. Consequences severe to area leadership for failed new process introductions. No manufacturing life cycle plan. Process development tied to Model Year program.

Appendix 2.2: Milestones for Positioning AM

TIMING	07 MY (Prework)	08 MY (CB03's & Materials Move)	09 MY (CB04's Move)	10 MY (Full Impact Felt)	11 MY (Sustainable)
Phase 1 Strategy And Leadership	• Gain Support/ Approvals • Job Descriptions • Compensation Review • Staffing Plan • Define / Sell Bus. Case	• Onboard Leads • Backfills / Reorgs Begin • Engage & Align BPC's W/ P&P Strategy • Initiate Phase 2	• Staff Job Desc. • Staff Comp. Rev. • Staffing Plan • Align Support Staff	• Initial Strategy Fully Deployed • Leadership and Staff Onboard • Integrate with Product Plan	• TBD
Phase 2 Realignment And Deployment	N / A	• ID Support Staff • Limited Staff Moves • Begin Staff Competency Development	• Staff Moves Continue • Staff Backfills • Continue Competency Development • Partial Phase 2 Support	• Staff Aligned with Design COE's. • BPC's Integrated and Performing.	• Full Integration
Cost	Existing Budgets	3.0 M (1.5 M Exists)	5.0 M (1.5 M Exists)	3.0 M (1.5 M Exists)	2.0 M (sustained)

Appendix 2.3 Results Internal Surveys (7 Principal Engineers that are directly involved into process development)

What are your current main tasks?



How many technologies are you currently developing?

# of New Technology Projects 2009	Ø	Min*	Max*
Allocated to existing products	1.4	0	4
Allocated to new products	0.4	0	3
Independent of a product	0.9	0	3
Total	2.7	0	7

*per person

How many benchmark visits did you do in the last 5 years?
How many benchmark visits would you like to do each year?

Questions	Ø	Min	Max
Number of benchmark visits in the last 5 years	6.7	2	12
Preferred number of benchmark visits/year	6.6	2	20

Where do you get ideas for new technologies from?

Sources	Ø	Min	Max
Suppliers	16%	0%	50%
Universities	1%	0%	5%
Production	39%	0%	100%
Styling	5%	0%	10%
Engineering	6%	0%	30%
Others*	9%	0%	35%
Myself	23%	0%	75%

* literature, internet, BPC meetings

What are your incentives to develop new technologies?

Incentives	%
Additional bonus/salary upgrade	0%
Allure of challenging technology	57%
Critical path of career path	14%
Part of job description	71%

Are the following statements true or not true (from your viewpoint)?

Statements	True	Not True
Our activities in innovative technologies are sufficient	2	5
Company X values my efforts in developing new technologies	6	1
Developing new technologies will help my career	5	2
In 5 years, Company X will be an innovative company with many new products	3	4
I am concerned about losing my job	4	3
AM needs full-time members from styling and engineering	3	4
I would like to have regular meetings with the design community	6	1
We don't need formalized processes at AM	2	5
PBC encourages us to think outside the box	3	4
We should communicate more often with other groups at PDC	6	1
I spend too much time at PDC and not enough time at the plants	1	6
Company X will not introduce cutting-edge technologies in the next 5 years	2	5
I am afraid that AM will not exist anymore in 10 years	1	6
Platform managers don't help us introduce new technology	4	3
I know exactly what the Materials group is working on	0	7
I know exactly what the Styling group is working on	2	5
I know exactly what my AM coworkers are working on	5	2
Looking for innovative technology should be my main job	3	4
Interns from universities would be a great help for me	3	4
Company X does not need cutting-edge manufacturing technology	2	5
The PDC environment stimulates me to find new ideas	3	4
Our leadership encourage us to think outside the box	6	1
My job description covers my daily work	1	6
I weekly brainstorm with coworkers about new production concepts	3	4

Appendix 3.1 Rules of Good Innovation Management (Davila, 2006) and Existence at Advanced Manufacturing

Rules of Good Innovation Management	Company X's AM
Strong leadership that defines the innovation strategy, designs innovation portfolios, and encourages truly significant value creation	Only very limited innovation guidelines; employees have total freedom and can start any project; yearly budget exceeds project costs so that every project is internally approved
Innovation is an integral part of the company's business mentality	Innovation is seen as too risky and has low priority at Company X, while AM welcomes more risks
Innovation is matched to the company business strategy including selection of the innovation strategy (play-to-win or play-not-to-lose)	Company X has no complete innovation strategy; AM's innovation strategy is connected to some high-level business goals
Balance creativity and value capture so that the company generates successful new ideas and get the maximum return on its investment	No active portfolio balancing; value of projects is only roughly estimated; no targets on return on investment; return is not measured
Neutralize organizational antibodies that kill off good ideas because they are different from the norm	No clear strategy or leadership support on how to deal with antibodies. Neutralization dependent on personal relationships
Innovation networks inside and outside the organization because networks, not individuals, are the basic building blocks of innovation	All projects, driving forces, know-how, and resources are based individuals and very small insider groups; very limited outside networks
Correct metrics and rewards to make innovation manageable and to produce the right behavior	No metrics (including targets) or rewards in place and followed

Appendix 3.2. Innovation Climate according to Davila (2006)

This analysis of Company X's and Advanced Manufacturing's innovation climate is based on the author's observations during a six-month internship as well as on over 35 interviews with employees and managers.

X: Value Company X (overall)
A: Value Advanced Manufacturing

More likely to be innovation unfriendly --- -- - o + ++ +++ More likely to be innovation friendly

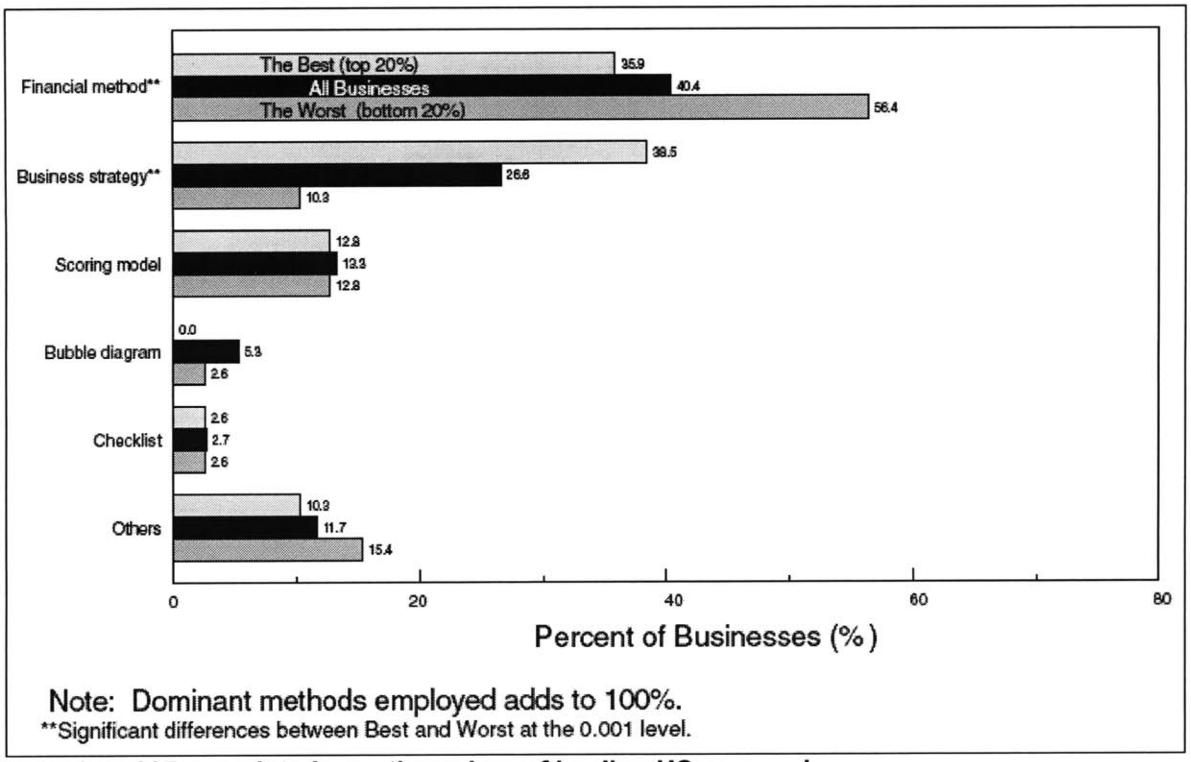
Management is looking for short-term profits		X						A	Management is prepared to wait for big payout
Management does not explicitly look for innovation		X						A	Management explicitly looks for innovation
Management has low tolerance of innovative "mavericks"	X							A	Management has high tolerance of innovative "mavericks"
Planning focuses on rationing resources		X			A				Planning focuses on identifying opportunities
Management is not tolerant of failure	X						A		Management is tolerant of failure
Leaders put little emphasis on the management of people and their interactions					X A				Leaders put strong emphasis on the management of people and their interactions
Company offers no career ladder with appropriate power and titles for innovators	X	A							Company offers a career ladder with appropriate power and titles for innovators
Sticking to the corporate norm is valued			X			A			Departure from the corporate norm is encouraged
It is no fun working here					A	X			It is very fun to work here
Management has low tolerance of uncertainty	X						A		Management has high tolerance of uncertainty
Formal vertical communications within the organization are the norm						X	A		Informal horizontal communications within the organization are the norm
Management discourages the systematic use of independent task forces for special purposes				X		A			Management encourages the systematic use of independent task forces for special purposes
Management decides without much input from other levels of organization					X	A			Management actively seeks and considers recommendations from other levels of organization
Decision process is elaborate and formal				X				A	Decision process is short and informal
Specific incentive mechanism for innovation exists	X A								No incentive mechanism for innovation exists
The organizational culture is action oriented			X			A			The organizational culture is planning-oriented
Management has an open attitude regarding external alliances and partnerships						X	A		Management is not open for external alliances and partnerships
Management expects people to be totally devoted to the development of the corporation							X A		Management encourages people to work towards their personal development
Decisions are made by the hierarchy					X		A		Decisions are made very close where the action is
Few resources are available for new ventures (budget, personnel, time, etc.)	X					A			Resources are generally available for new ventures (budget, personnel, time, etc.)

Continued…..

Individual project championing is encouraged and rewarded. Individual accountability			X	A					Team-wide project championing is encouraged and rewarded. Team accountability
Innovative successes of the company are neither publicized nor discussed	A		X						Innovative successes of the company are widely publicized nor discussed
Innovation budget is much less than competition	X	A							Innovation budget is much more than competition
Company does a poor job of balancing global and local priorities					X ?				Company is able to make balanced choices between global and local priorities
Management has not defined a clear innovation strategy and focus, relies on entrepreneurship	X A								Management has clear vision of the role and focus of innovation in archiving its objectives
Project failures are buried and nobody talks about them	A	X							Project failures are systematically reviewed and analyzed for lessons
Product and service managers are far removed from the market				A			X		Product and service managers are very much attuned to the market
Product and service managers tend to underestimate and underuse technology						X	A		Product and service managers tend to understand and use technology well
Outsiders (experts, customers) are never associated with the innovation process			A			X			Outsiders (experts, customers) participate systematically in the innovation process
High value ideas are scarce		X A							High value ideas are plentiful
Management sets unrealistic result expectations on new projects							X A		Management sets reasonable result expectations on new projects
Innovation knowledge is inferior to that of our competitors		X		A					Innovation knowledge is superior to that of our competitors
Knowledge of real customer needs is inferior to that of our competitors					A			X	Knowledge of real customer needs is superior to that of our competitors
Employees have little confidence in the company's direction			X A						Employees have high level of confidence in the company's direction
Employees are not at all self-motivated						X	A		Employees are highly self-motivated
The senior management group is working at cross purposes – a lot of conflicts exists					A		X		The senior management group is working in concert – very little conflicts exists

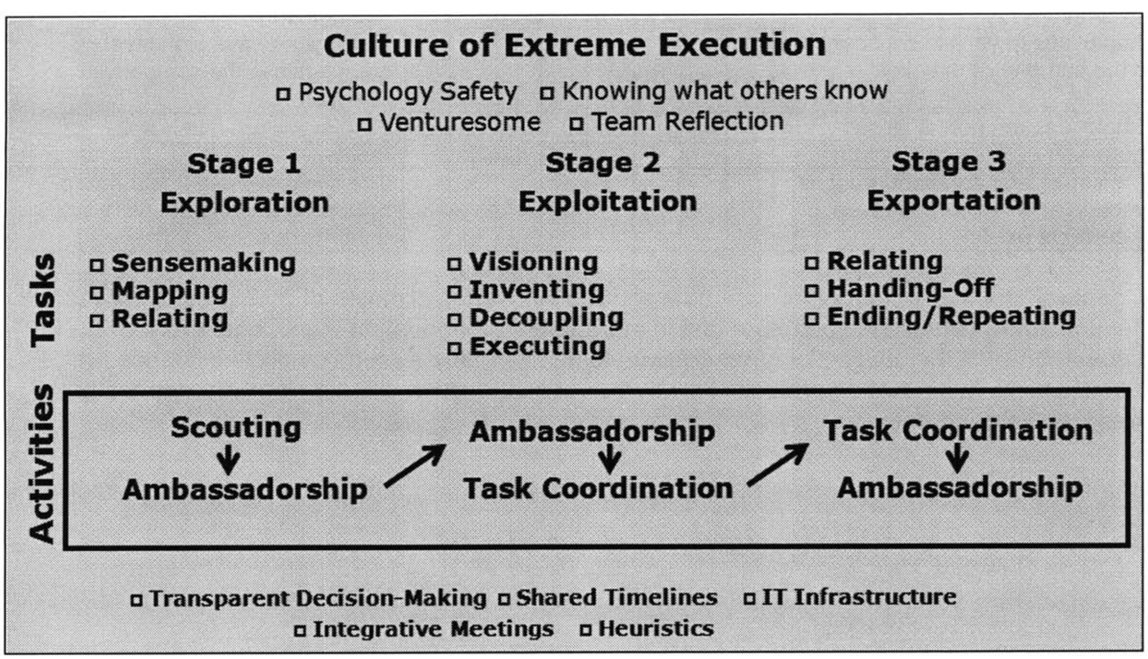
In general, there is a clear difference between the innovation climates of both groups. Advanced Manufacturing established a culture that is more open for innovation than Company X overall. Since AM needs the support of other groups inside Company X, such conflicts influence the success of AM's innovation projects. However, AM's innovation climate clearly has areas of possible improvement.

Appendix 4.1 Dominant Portfolio Methods Employed (Cooper, 2001)

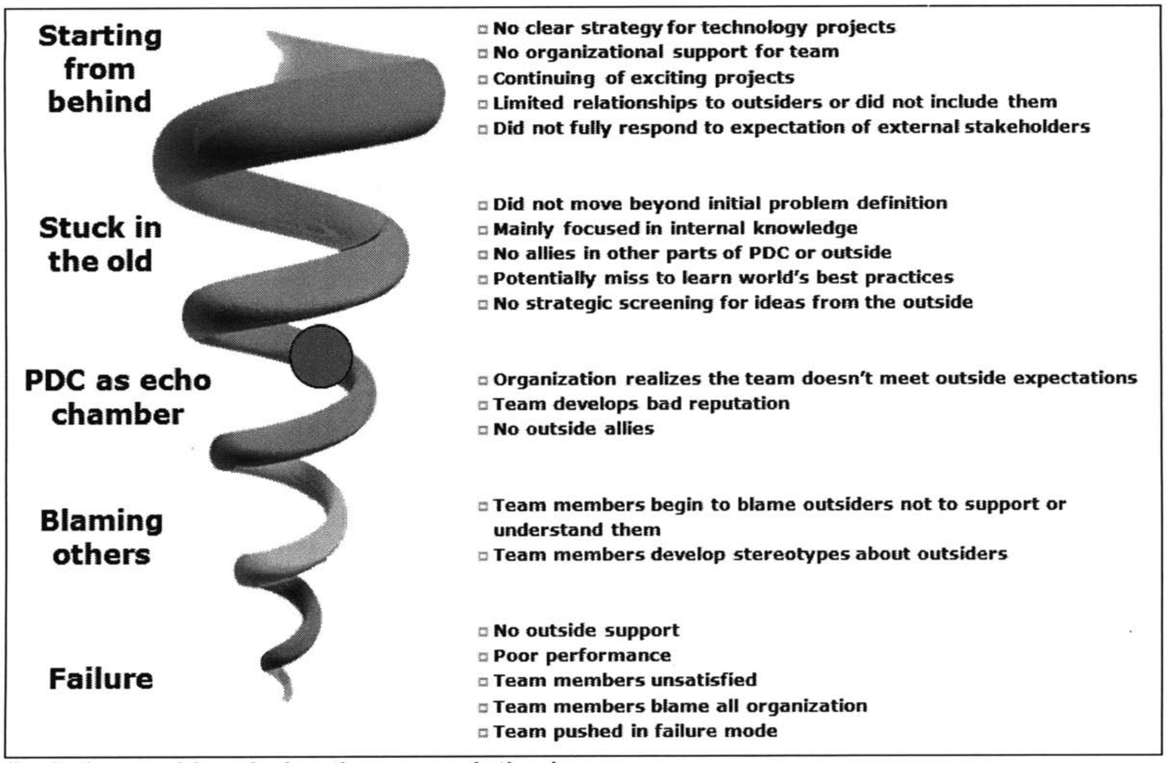


Based on 205 completed questionnaires of leading US companies

Appendix 4.2 High-level framework of innovative X-Teams

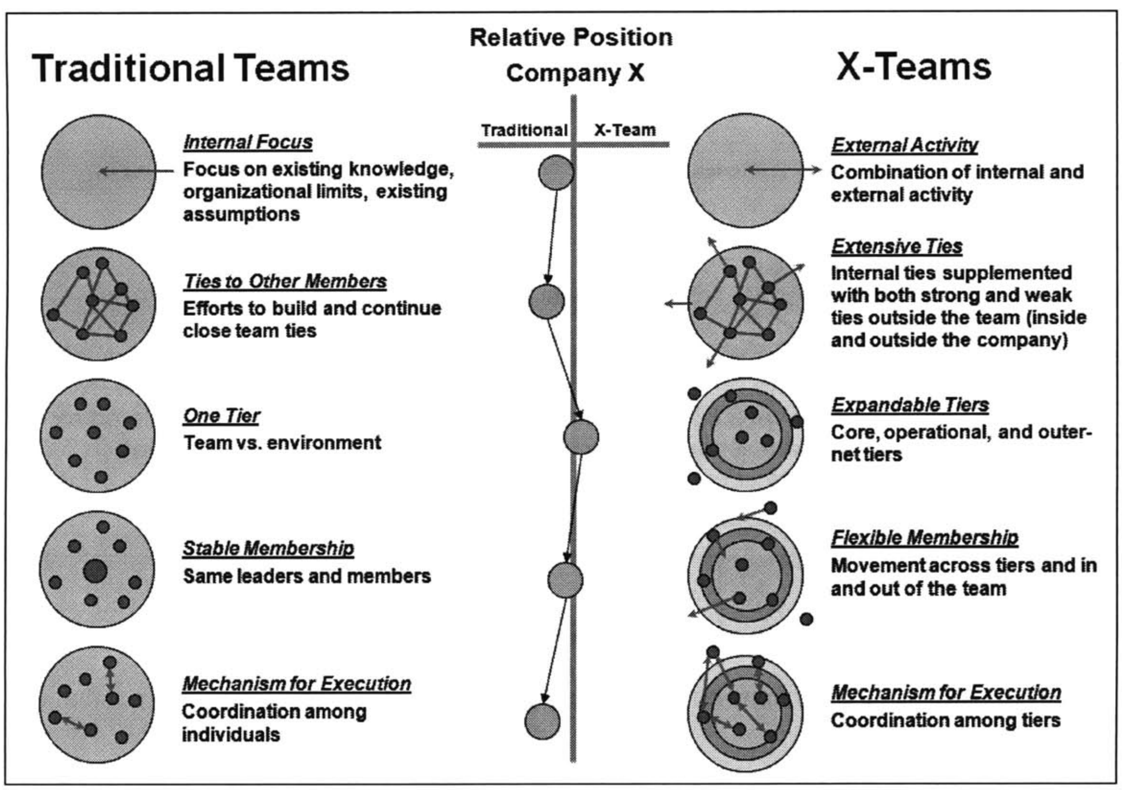


Appendix 4.3 Downward Spiral of Advanced Manufacturing

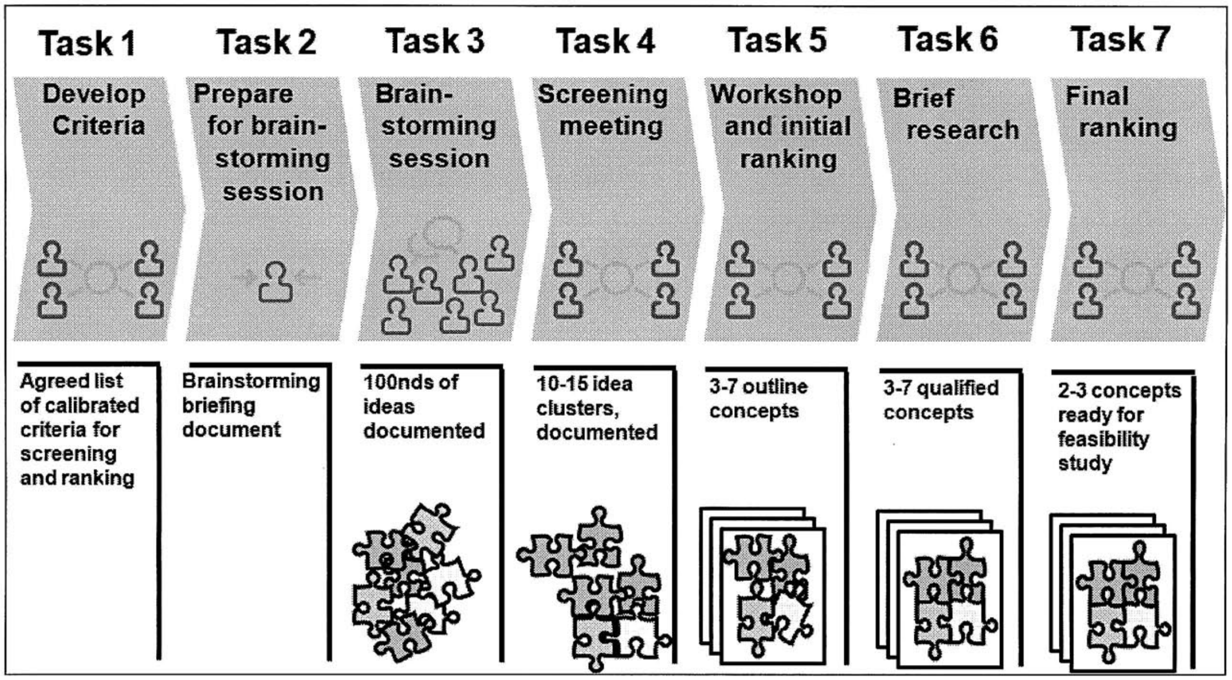


(Includes position during the research time)

Appendix 4.4 Comparison Traditional Teams vs. X-Teams



Appendix 4.5 Structured Idea Management Process (Davilia 2006)



Appendix 4.6 Design rules to enhance innovation pipeline (Skarzynski 2009) in comparison with Advanced Manufacturing's compliance

	Description	Advanced Manufacturing
Involve Many Minds	**Cultivating Innovators in Your Company:** Introduce mechanisms that provide easy opportunities for all employees to participate on innovation activities (especially low-level employees). Set a specific goal (e.g. 10%) for the ratio of employees who considers themselves as innovators. Set expectations and goals for all employees that innovation is part of their job. Give employees training, time, tools, and communication platforms for innovation. Company-wide culture of "Innovation starts with me"	**Compliance Rating: 4** AM has no tool that encourages all employees to participate in innovation. They have regular meetings with representatives of the factories to brainstorm ideas. However, these are always the same people. Only very limited # of people are considered as innovators. No active employee suggestion system, no incentives for innovation and most employees do not even know about the tasks of AM.
	Using the Power of the Net: Sharing insights and get all employees involved in "jamming" the innovation pipeline by using IT tools (e.g. internet, intranet), for example, having a 72h innovation dialogue around one specific topic.	**Compliance Rating: 1** Company X has intranet and web-based workspaces, but AM does not use it for open communication or idea generation. Only very limited number of employees (≈1%) has access to AM web tools.

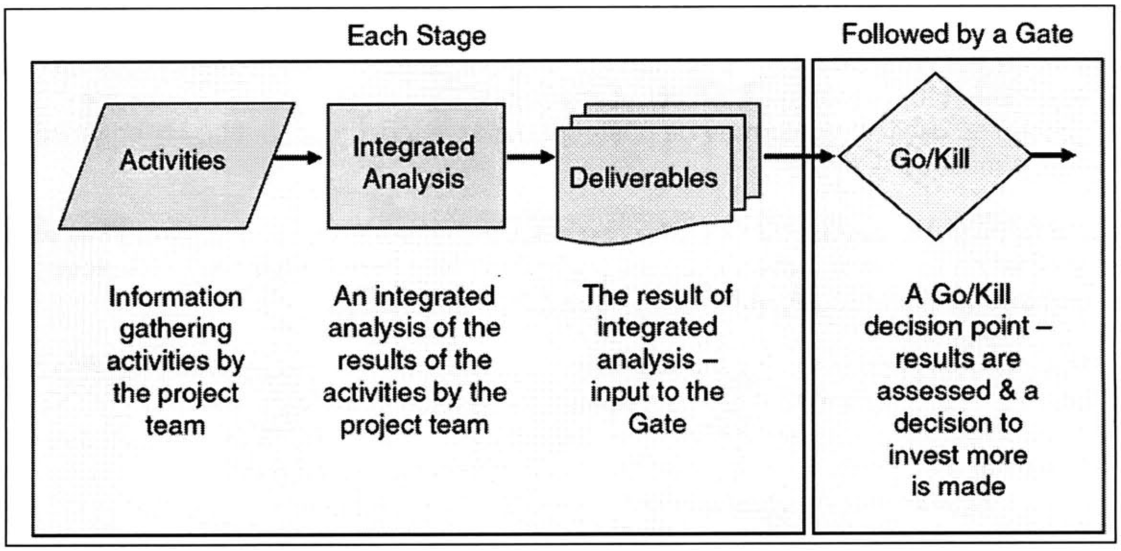
	Look beyond Your Organization: Have mechanisms to open up innovation to extended network (suppliers, partners, universities, customers). Besides an internal R&D process, companies also have an external Connect&Develop (R&D) process including employees whose main task is looking for new ideas in the external world. In addition, web-based platforms and online communities provide a huge network of innovators. Strategic partnerships of different companies and even competitors to develop new technologies by sharing risk, costs, and leveraging core competencies are also more common nowadays. In addition, external experts like consultants, scientists, or technical specialists can advance innovation projects.	**Compliance Rating: 3** AM has a limited external network. The collaboration with suppliers is often limited to the same preferred (local) companies. Only very limited innovation projects are executed by outsiders. Suppliers and experts are not often used for idea generation but to solve detailed problems during development activities. Collaborations with universities are not leveraged, but did start a strategic partnership with 3M. No systematic searching tools for new ideas; often done by individual contacts or random internet search.
	Energizing a Community of Volunteers: Connect with passionate people who volunteer their efforts to bring new ideas and solve problems. Publish ideas in an early stage and ask the worldwide community for support (oftentimes over the internet). This is not limited to software development.	**Compliance Rating: 1** Although Company X has one of the most passionate customers and brand recognition in the world, they are very limited involved in innovation and technology development. AM does not use volunteers.
Sow Enough Seeds	**Accept the innovation arithmetic:** 1000 ideas – 100 initial experiments – 10 feasibility studies – 1 introduced innovation. Create systems that can easily prototype and test different ideas. Be able to finish quickly cheap feasibility studies.	**Compliance Rating: 4** Feasibility studies at AM are very long (limited commitment) and expensive because of extensive prototype tooling and testing on the shop floor; only limited resources and knowledge about numerical simulation tools.
	Encourage hundreds of ideas: Do not start any feasibility studies when you have only one idea from one person. Set-based engineering requires dozens of equal-valued ideas that are investigated.	**Compliance Rating: 1** No set-based engineering so far; if AM has one idea, feasibility studies are started with no research for alternative solutions upfront.
	Allow defeats and throwbacks: Only very few ideas will be successful. Do not expect commercial success, but encourage employees to kill projects that look unpromising instead of forcing success.	**Compliance Rating: 8** Leadership accepted that most projects will fail and hoped that one big idea will pay off all further investments. However, projects were not killed because of a missing evaluation and stage-gate system.
Widen the Front End	**Expand the range of innovation opportunities:** Do not limit yourself to a specific innovation category but be open innovation projects in technology, product, service, process, costs, customer experience, management, business model etc. Such broad innovations provide better competitive advantage than a single small technology change; the broader and less constraint the search for innovation opportunities, the higher the probability of maximized success.	**Compliance Rating: 6** AM does not only concentrate on process technology innovation, but also tried to incorporate product, materials, or methodology innovation. However, limited support by stakeholders prevented success so far, since such projects are outside of AM's responsibility.

Increase the combinations	**Create intersection points of various types of insights:** Create a discovery team to examine orthodoxies, indentify discontinuities, and leverage core competencies and assets. A holistic view on the current situation and unconventional future scenarios enables game-changing innovation. Internal and external viewpoints.	**Compliance Rating: 3** Company X has with its Best Practice Circles a platform where multiple stakeholders could do such an exercise, but oftentimes, innovation projects focused on specific technical problems. No holistic or strategic assessment of the current situation and future scenarios (only from a manufacturing viewpoint); focused mainly on internal viewpoints.
	Reinventing: Game-changing innovations and technologies are often created when different viewpoints and knowledge are uniquely combined. Existing prejudices and assumptions especially have to be challenged.	**Compliance Rating: 5** AM challenges existing assumptions, but is limited because of restricted budgets, unwillingness of change by stakeholders, and risk-averse culture in other departments.
Ideate around Specific Themes	**Focus ideation on specific platforms and aiming points:** Ideation needs a narrowed scope on very specific corporate challenges, customer needs or industry issues. However, the topic has to be broad enough to give innovative ideas enough freedom and not to dictate one specific solution. Communicate these topics inside and outside the company and ask for help. Innovation strategy and strategic buckets are necessary for successful aiming points.	**Compliance Rating: 2** AM's leadership did not set any specific aiming points. Engineers generally do not have a cluster of ideas and projects around a specific aiming point but single projects for single problems. Missing innovation strategy resulted in an accumulation of unrelated projects.
	Push inventors out on the edge: Employees are often caught up in their own orthodoxies (company and customer viewpoint). They often have to be forced to forget their current constraints.	**Compliance Rating: 5** Employees are open-minded and willing to push themselves to the edge. However, long-term experience in manufacturing hinders them sometimes to forget all constraints.

Compliance Rating*: 1: Rule is not followed
5: Rule is partly followed
10: Rule is completely integrated

**based on author's observations*

Appendix 4.7 Stage-Gate Consists of a Set of Information-Gathering Stages Followed by Go/Kill Decision Gates (Cooper 2008)



Each stage is designed to gather information to reduce key project uncertainties and risks; the information requirements thus define the purpose of each of the stages in the process.

Each stage costs more than the preceding one: the process is an incremental commitment one—a series of increasing bets, much like a game of Texas Hold'em. However, with each stage and step increase in project cost, the unknowns and uncertainties are driven down so that risk is effectively managed.

The activities within stages are undertaken in parallel and by a team of people from different functional areas within the firm; that is, tasks within a stage are done concurrently, much like a team of football players executing a play.

Each stage is cross-functional: There is no research and development (R&D) stage or marketing stage; rather, every stage is marketing, R&D, production, or engineering. No department owns any one stage.

Appendix 4.8 Typical Gatekeeper Rules of Engagement [Example from a Major Flooring Products Manufacturer] (Cooper, 2008)

1. All projects must pass through the gates. There is no special treatment or bypassing of gates for pet projects.

2. Once a gate meeting date is agreed (calendars checked), gatekeepers must make every effort to be there. If the Team cannot provide deliverables in time for the scheduled gate, the gate may be postponed and rescheduled, but timely advance notice must be given.

3. If a gatekeeper cannot attend, s/he can send a designate that is empowered to vote and act on behalf of that gatekeeper (including committing resources). Gatekeepers can attend electronically (phone or video conference call).

4. Pre-gate decision meetings should be avoided by gatekeepers –do not prejudge the project. There will be new data presented and a Q&A at the gate meeting.

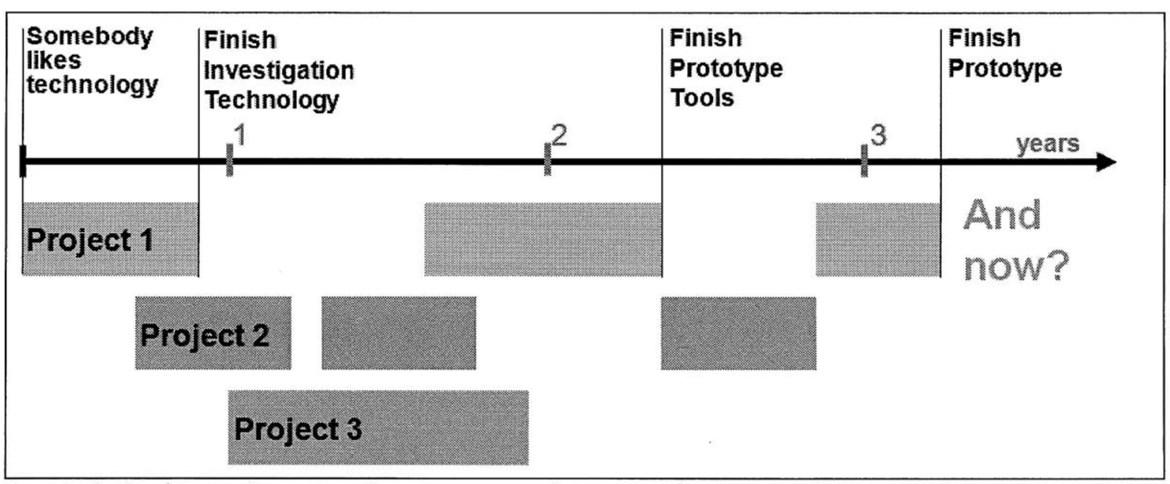
5. Gatekeepers should base their decisions on scoring criteria. Decisions must be based on facts, not emotion and gut feelings!

6. A decision must be made the day of the gate meeting (Go/Kill/Hold/Recycle). The Project Team must be informed of the decision, face to face, and reasons why.

7. When gatekeepers make resource commitments (people, time or money), every effort must be made to ensure that these commitments are kept.

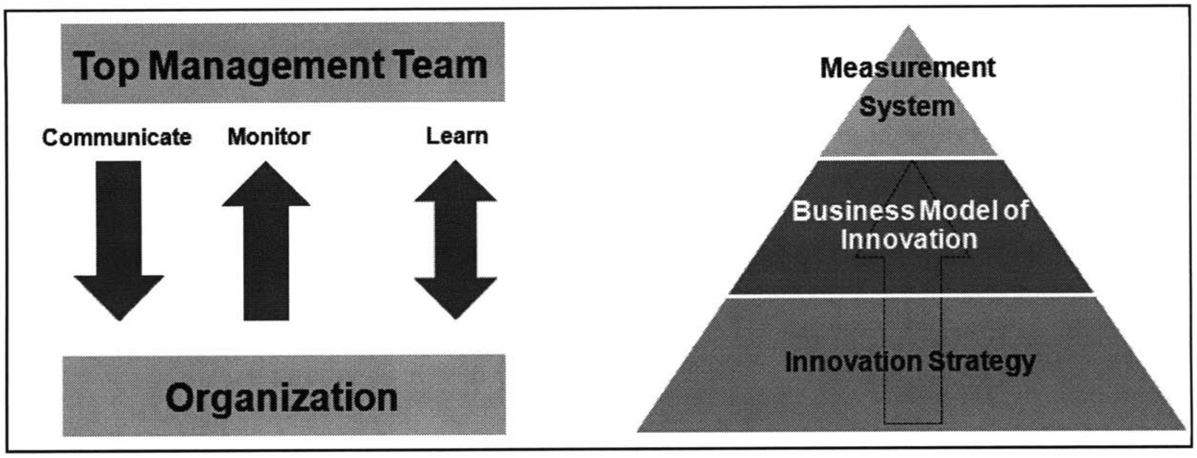
8. Gatekeepers must accept and agree to abide by these Rules of the Game.

Appendix 4.9 AM starts multiple projects without clear stage-gate process from idea-to-launch



Due to lack of commitment and resources, projects are often stopped or paused; no clear

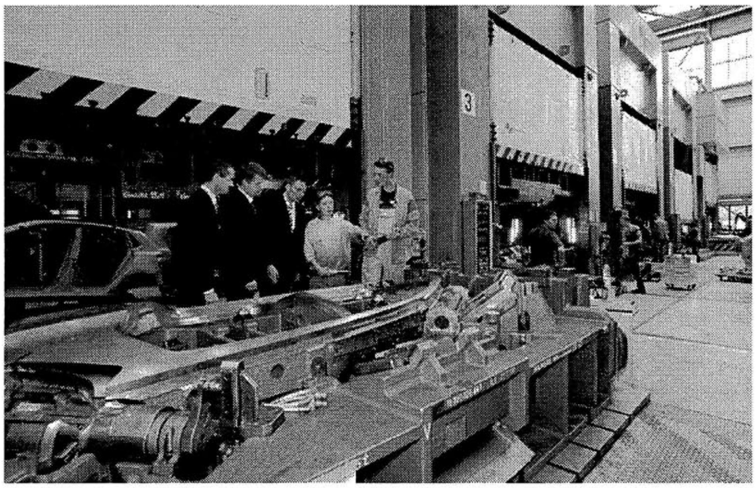
Appendix 4.10 Three Roles of a Measurement System and the Dependency of an Innovation Strategy (Skarzynski, 2008)



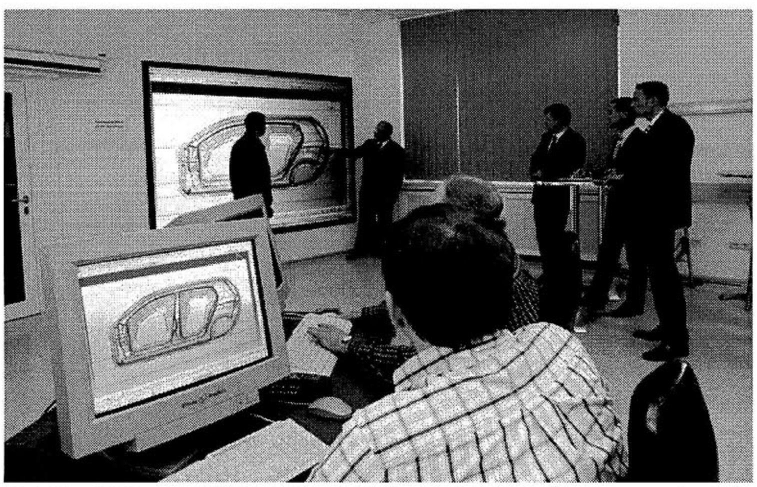
Appendix 5.1: Facts Tool and Die Volkswagen Wolfsburg

Employees:
Press shop tooling – 700 employees
Body shop tooling – 450 employees
Test equipment development – employees
100 trainees to get a three-year vocational training in tool making, chipping, welding, mechanics

Floor space: 50,000 square meters
Revenues 2008: 300 million Euros (profit center)



Test press line of Tool and Die Volkswagen



CAD of Tool and Die for joint product and process development

Source: autogram (2008)

Appendix 5.2. IZB Internationale Zuliefererbörse

"Connecting Car Competence"

www.izb-online.com

Bi-yearly International Suppliers Fair (IZB) as an important communication and business platform for the industry including a large number of key decision-makers among trade visitors. Congresses and conferences with 1800 managers and politicians.

2008 Facts:

- 6 exhibitions halls (33,000 sqm)
- 46,000 visitors
- 680 automotive suppliers from 22 nations
- 14 of the top 25 automotive suppliers

The key areas of the IZB are:

- Electrics, electronics, mechatronics
- Assembly and joining
- Metal and lightweight construction / car body manufacturing
- Plastics, passenger compartment / modules, chemical products
- Drive control / assemblies / chassis
- Development
- IT service providers
- Logistics / production
- Project financing / automotive

Appendix 5.3: Audi-Alcoa joint-development agreement

Actions	Agreements
Agreement of cooperation	1) Short and simple contract 2) Confidentiality of contents towards third parties 3) Yearly adjustment of division of work and decisions about next steps 4) Yearly project review and approval of investments
Property Rights	1) No joint patents 2) Audi will keep all patents of the Spaceframe car body 3) Alcoa will keep all patents of alloy- and process-technologies. No claim to sole rights. Process technology developed by Audi can be patented by Audi. 4) Three years after market introduction of Audi A8, Alcoa can also use Spaceframe technology for other car projects free of charge
Policies and Flow of Information	1) The project is managed by Audi 2) If required, both parties work together at one location 3) Free information-flow between project partners 4) Project's progress will be documented and is accessible to both parties when needed
Supply Agreement	1) Single sourcing for Audi A8 2) Cost plus pricing until 2002 3) Contract is valid during model life cycle 4) Guaranteed minimum purchase of 80 frames per day 5) Guarantee of a (small) profit margin per part 6) Adjustment of target costs that can be only defined after development for mass production

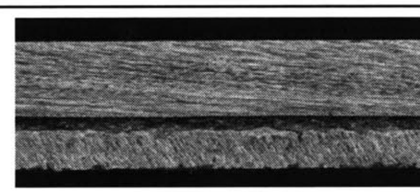
Appendix 6.1: Quiet Steel

Quiet Steel is a product and trademark of Material Sciences Corporation (MSC). It is a laminated sheet product composed of two steel facing sheets separated by a viscoelastic polymer resin core (metal-to-polymer-to metal laminates). The facing sheets can be bare or have a metal and/ or organic coating. Similar products are offered worldwide by different companies, e.g. ArcelorMittal, ThyssenKrupp.

Laminated steel improves NVH performance characteristics. While the thicknesses of the two facing sheets can be different, the damping performance is greatest when the faceplate thicknesses are the same. The viscoelastic core has an acoustically optimized thickness of 25 or 45 µm, depending on the resin used. The resin damps vibrations transmitted to the sheet by dissipating part of the mechanical energy as heat. When metal particles are added to the resin, the product can be resistance spot welded.

Cross-Section of Quiet Steel

Steel sheet 0.4 – 1.25 mm
Polymer layer 25 – 50 µm
Steel sheet 0.4 – 1.25 mm



Reasons for usage in industry:

- Reduce of noise by damping vibrations
- Improving acoustic performance
- Cost savings by eliminating the need to add damping material

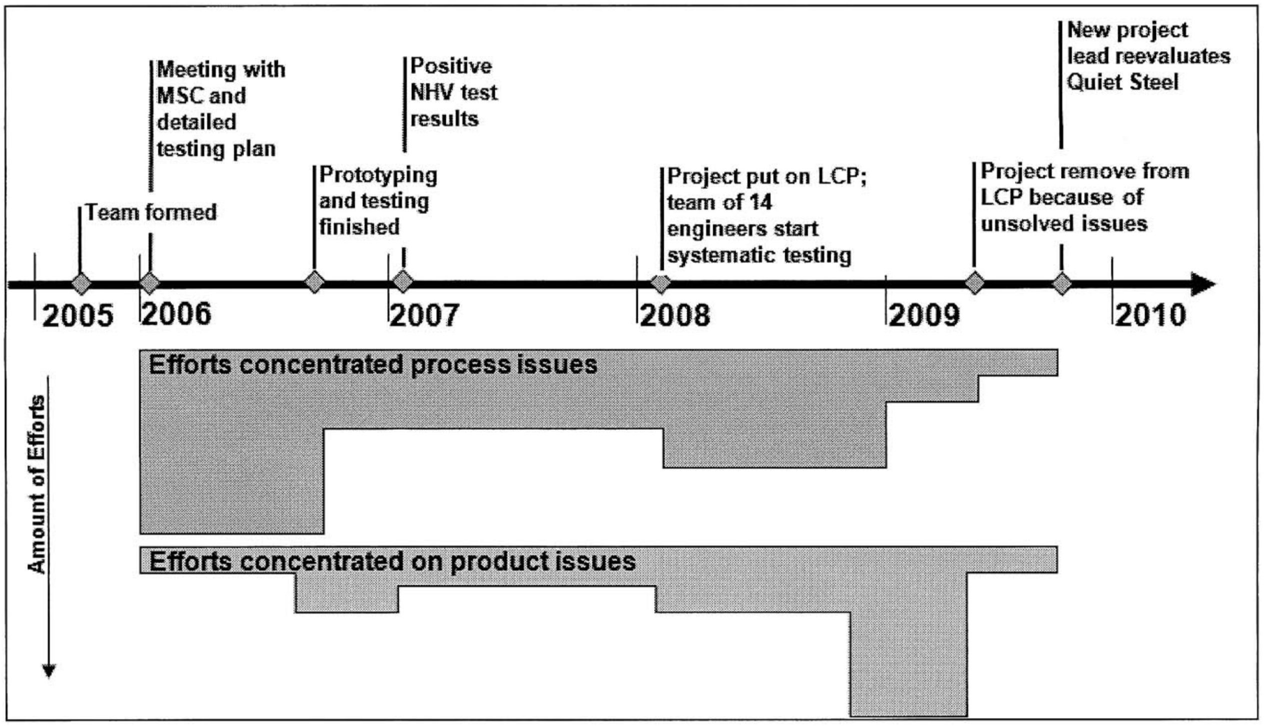
Quiet Steel is widely used at automotive applications like oil pumps, floors, dashboards, wheel arches, and heater barriers. For example, the 2004 Ford F-150 dash panel used Quiet Steel to lower overall noise level in the cabin by 5 dB. Also cars like the 2003 Chrysler Town & Country, the Voyager, and several Dodge models use Quiet Steel to replace assembled sandwiches of regular steel and a mastic material (these sandwiches were produced in a time- and labor-intensive subassembly process with a single stamping) to bock sound to the passenger cabin. All these applications are not visible for customers and do not require any specific surface quality. In electronic products laminated steel is used for Hard Disk Drive noise and vibration damping (e.g. noise reduction by 9dB compared to solid cover)

Known problems:

- Forming: drawability is equivalent to that of a conventional sheet of the same thickness. Specific wrinkling, rupture and even delaminating problems can occur under certain conditions; curl after bending; negative springback characteristics.
- Cutting: no problems on a blanking press (low punch- to- die clearance); laser cutting under inert atmosphere is possible, but reduced process time sometimes necessary;
- Resistance spot welding: possible when metal particles are added to the polymer or by bypass circuit between the two sheets
- Temperature: polymer laminate does not withstand high temperatures (> 400F)

Although laminated steel is used for more than over 25 years and well analyzed by researches and scientists, it is not known that a company used it before in high-grade surface applications.

Appendix 6.2: Main milestones of Project Quiet Steel incl. efforts spent on problem solving



Appendix 6.3: Quiet Steel Main Milestones

Date	Main Action	Results
09/2005	Kick-Off Meeting with MSC Introduction of Core Team, Goals, Assumptions, Questions, and Initial Studies	Agreement and start of information exchange and principal studies (drawings, material characteristics, chemical testing, coating testing, DMA, FEA)
01/2006	Meeting with MSC to agree on next steps	Agreement on purchasing test material Testing requirements for: • Formability (IRDI / Simulation). • E-Coat requirements / Paint • Strip – thermal • Polishing • Corrosion / Humidity • Welding (spot welding) • Fasteners – creep tests • NVH requirements
07/2006	MSC Welding study completed	MSC reports no problems
08/2006	Forming simulation completed	Simulation shows possible risks regarding thinning and wrinkling

09/2006	25 prototypes produced on Company X prototype and serial tooling incl. drawing shells, laser cutting, hem operations, spot welding, polishing, paint	Drawing shows differences compared to normal metal (surface, shape, parameters); laser cutting no major problems; hemming and welding no issues; polishing was necessary because of prototype tooling; no problems to paint
10/2006	Company X Welding study completed	30% of weld spots don't have fusion
01/2007	NVH testing with prototypes	Dramatically reduced noise and vibration; better than existing components; meets all requirements
09/2007	MSC completes FEA durability study	unknown
08/2007	Styling evaluated surface	Approved, but parts were polished
11/2007	Production level tools finished	Produce prototypes
02/2008	Start of LCP activities	Team of 14 people (manufacturing, engineering, material supplier, machine supplier) agrees on projects plan and intense testing according to Company X requirements;
10/2008	Comprehensive financial model finished	Potential cost savings of \$6-\$12 per product
10/2008	Multiple stamping trials at supplier and Company X to understand production parameters	Minor issues
01/2009	Multiple tests finished	DFMEA needed; additional tests needed; concerns about quality (surface, laser cutting, hemming, stiffness of component); 100 prototypes should be built; no problems with paint
04/2009	Laser-Cutting trials with Trumpf in Germany	Laser-cutting possible; lower speed potentially necessary (longer cycle-times)
06/2009	Removed from LCP due to various manufacturing and validation issues	Advanced Manufacturing takes project back; limited support by System Groups
09/2009	New fulltime-member of Advanced manufacturing takes over projects	Decision on holistic check and next steps Identified problems: • Wrinkled surface on large portions of surface after draw process • Laser cycle time, material melts away • Hemming causes wrinkles and pull-outs • Spot welding shows lack of fusion • Components crack at durability test • Deflection problematic
10/2009	Decision to move on project	Potential alternative with 3M damping foil indicates \$180k savings; Limiting Dome Height test (LDH) to understand surface problems and analyze different material and thickness combinations (with small pieces and outside expertise, not expensive prototyping)
11/2009	Start 3M NHV testing Start LDH testing	

In summary, Company X investigated Quiet Steel together with MSC and tool suppliers for over 4 years. There are still issues unsolved, specifically:

- Wrinkles on large portions of surface after draw process
- Laser cycle time, material melts away
- Hemming causes wrinkles and pull-outs
- Spot welding shows lack of fusion
- Components crack at durability test
- Deflection problematic

Appendix 6.4: Quiet Steel Project Expenses

Year	Costs (Money)	Costs (Hours)
2005	$ 0	280 hours
2006	$ 109,875	1500 hours
2007	$ 150,000 (budget)	1500 hours
2008	unknown	unknown
2009	unknown	unknown
2010	$40,000 (budget)	unknown

Project costs (estimations and budgets); overall, it is a fair assumption that more than $150,000 and 1500 hours were actually spent on this project.

Appendix 6.5: Comparison PBPC and FBPC (based on official statements and observations)

	Paint Best Practice Circle	**Fabrication Best Practice Circle**
Founded:	1997	2004
Mission Statement:	Lead innovations and best practices to ensure Company X paint capability that is unmatched in the industry. Deliver cosmetic coatings and graphics that provide a competitive advantage to our products. Drive to exceed our customers' expectations through continuous improvement in cost, quality, timing and the development of our people.	Manage standards, systems and best practices to support the development, execution, and CI of cost-effective, capable designs & manufacturing processes for cross-site applications. This will be accomplished through a strategic plan that focuses on commonality, technology, cost reduction, and the development of our people. □ Lead innovation at Company X relative to fabrication design and processes □ Evaluate new technology from industry and determine the needs of Company X □ Share best practices across sites □ Establish systems, standards, and best practices to support the development and execution of providing a fabricated product that provides a competitive advantage to our customer □ Drive to exceed our customers' expectations through continuous improvement in cost, quality, timing and the development of our technology and people
Members:	• Manufacturing (4) • Union (4) • Advanced Manufacturing (1) • Styling (1) • Materials (2) • Powertrain (1)	• Manufacturing (4) • Union (3) • Advanced Manufacturing (2) • Engineering (3)

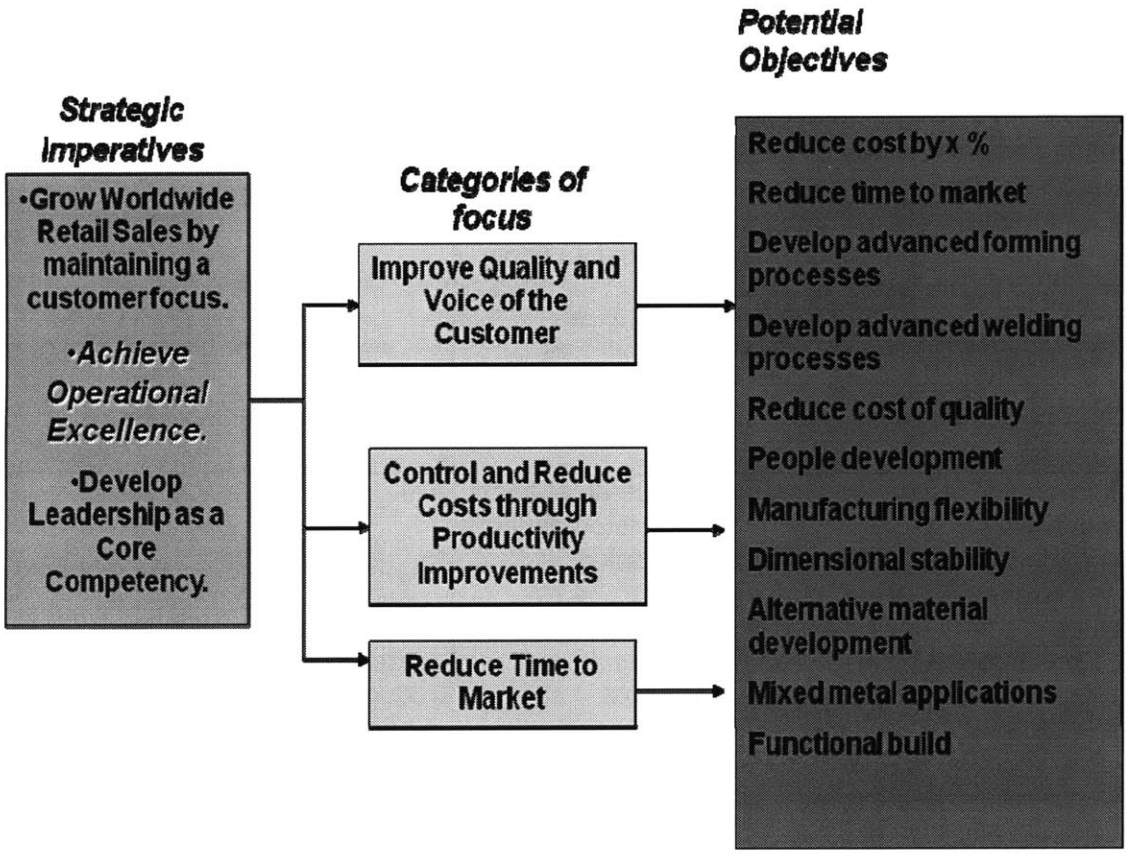
Standing Members:	• Purchasing (1) • P&A (1) • PPG (2) • Scheduling (1) • Powertrain (2) • Materials (1) • Engineering (1) • Supplier (1)	• Purchasing (2) • Materials (1) • PPG (2) • Continuous Improvement (1) • Information Systems (1)
Sub-Groups	4	5
Knowledge Management	No	No
Meeting Frequency	Quarterly for 2 days	Monthly for one day
Other Meetings	Sub-group based	Sub-group based
Benchmark Activities	Some, but not systematic	Some, but not systematic

Appendix 6.6: Comparison Sub-Groups PBPC and FBPC

	Paint Best Practice Circle	**Fabrication Best Practice Circle**
Innovation Statement	Offering customers something more and reducing costs.	Focus on investigation and integration of new technologies into Company X fabrication processes (cost reduction and technology)
Defined R&D portfolio management	1. Create list of projects that are supported by some members 2. Prioritization and categorization of projects 3. Assigning subgroups for each category 4. Defining process and responsibilities for the subgroups 5. Execution of work	1. Individuals recommend projects in meetings 2. Group agrees/disagrees 3. Assigning individuals or subgroups 4. Scope of work definition 5. Execution of work
Defined Sub-Group Members	• Team Sponsor • Team Leader • Core Team Members • Plant Implementation Experts • Extended Team Members	• Team Leader • Union Representative • Project Sponsor • Team Members

Sub-Group Tasks	• Define scope, objectives and benefits • Define responsibilities for all team members • Develop timelines • Develop budgets (capital and expense) • Meet weekly via phone • Meet quarterly face to face minimum • Provide monthly project updates • Create development A-3 • Support launches • Cross site communication • Pull in resources as needed • Assign Project leaders • Manage the projects	• Define scope, objectives and benefits • Develop timelines • Develop budgets (capital and expense) • Provide project updates • Create Scope of Work • Cross site communication • Pull in resources as needed • Assign Project leaders • Execute projects • Include stakeholders • Manage the projects
Defined member responsibilities	Yes	Limited
Working areas	• Paint process development • Equipment development • material development • Communize practices, materials, and equipment • New Model Year paint and graphics introduction • Control costs • Paint engineer recruiting • Paint engineer development • Quality and process capability improvement • Respond to market demand	• Cost reduction • Time-to-market reduction • Develop advanced forming processes • Develop advanced welding processes • Reduce cost of quality • People development • Manufacturing flexibility • Dimensional stability • Alternative material development • Mixed metal applications • Functional build
Implementation Strategy	Yes	No
Record of successful R&D projects	Yes (company-wide reputation)	Limited
Meeting Frequency	Weekly via phone or in person	Ad-hoc and monthly at BPC
Project Documentation	A-3 sheets with project description	Scope of Work sheets

Appendix 6.7: FBPC Objectives 2008 to 2012



Appendix 6.8: Examples from FBPC action list 2009

Plans and Actions	Metric	Target Timing	Current Status
Develop a methodology to review, prioritize, provide resources, and execute Fabrication related cost savings projects	Completion of project	3rd quarter	Not started
Deliver Quiet Steel on Component F for MY2011 ($250,000 savings) 1. Complete March process development trial 2. Complete May process development trial 3. Produce DV models in September	Silent launch Cost savings	See actions	On track
Bulge forming – develop a method to manufacture single piece Component T shells to simplify the manufacturing process	Completion of prototype fuel tank	Q4	On track
Reduce Component T scrap 1. Complete 2006 – 2008 total cost and cpu baseline – 1st quarter 2. Continue ABCD University study – ongoing 3. Continue white light scanning exercise 4. Begin alternative welding testing	Scrap CPU Total scrap cost	2009 and 2010 target reductions to be finalized in the 1st qtr	On track

Appendix 6.9: Example of a FBPC Sub-Group charter

Forming Sub-Group Charter

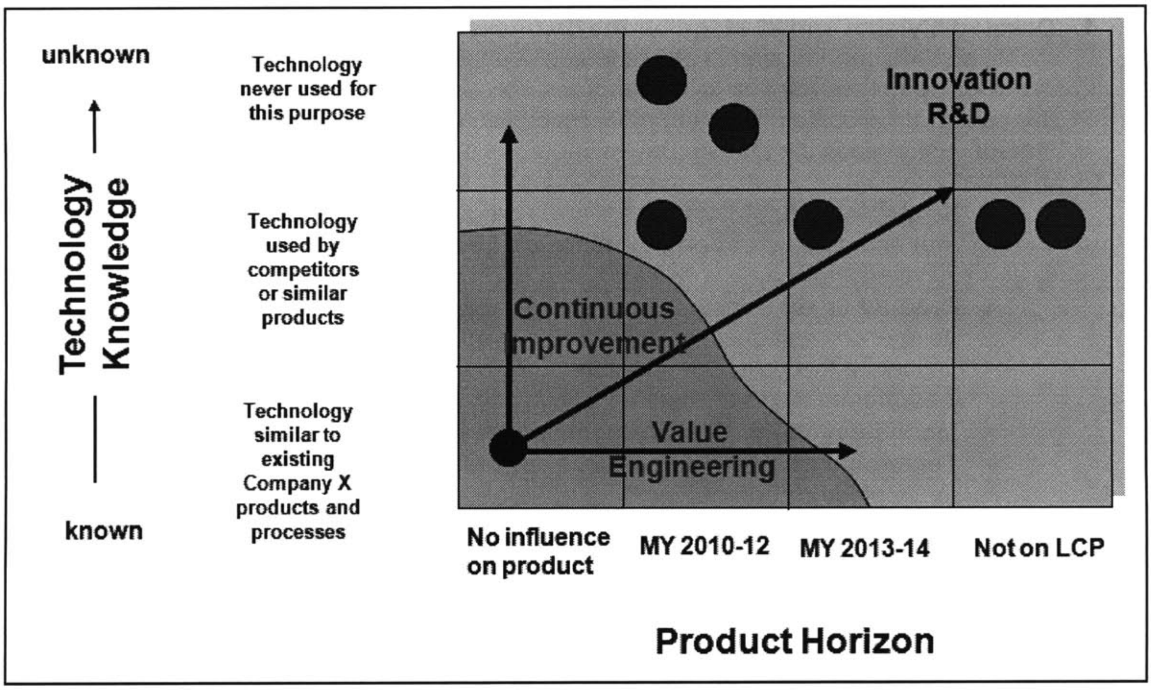
Commonize – Lead unification of Company X's forming practices

Continuous Improvement – Investigate and implement relevant solutions to chronic problems in the forming area

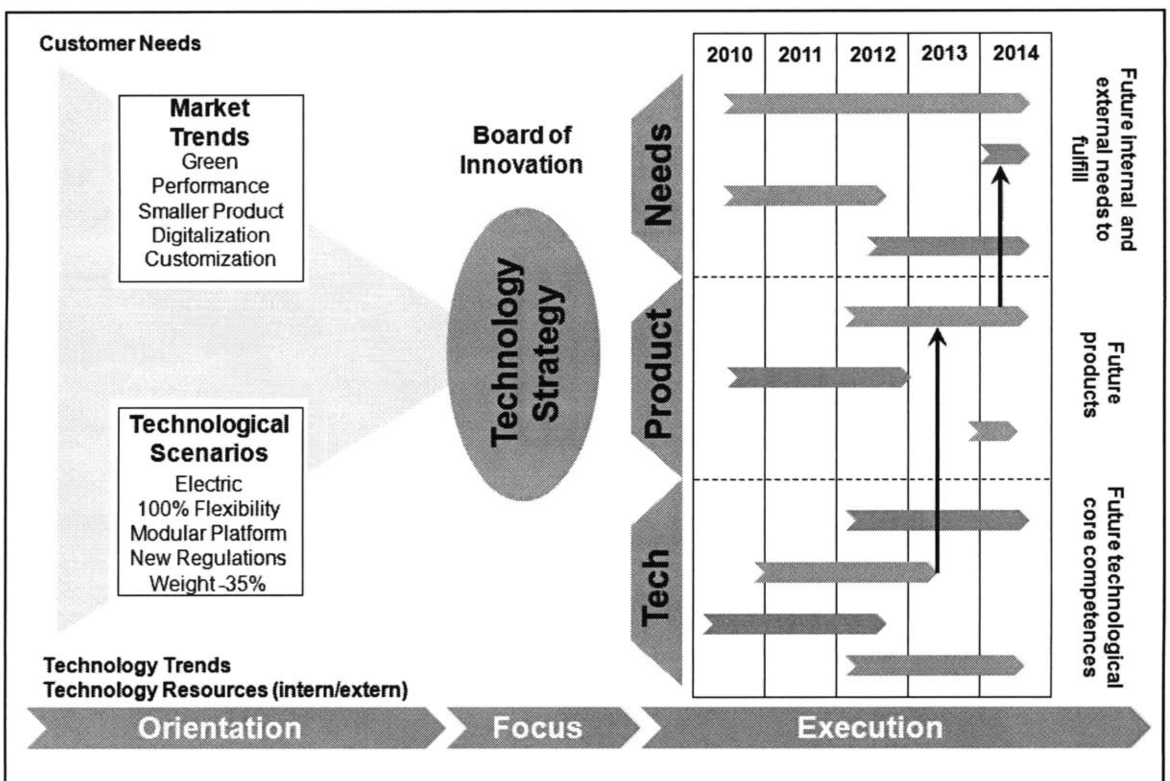
Strategic Innovation

- Support experimentation in New Technology related to forming
- Benchmark successful global applications in forming with the intent to improve Company X's forming capability

Appendix 7.1: Some R&D Projects are not guided by CI or Value Engineering Methodologies



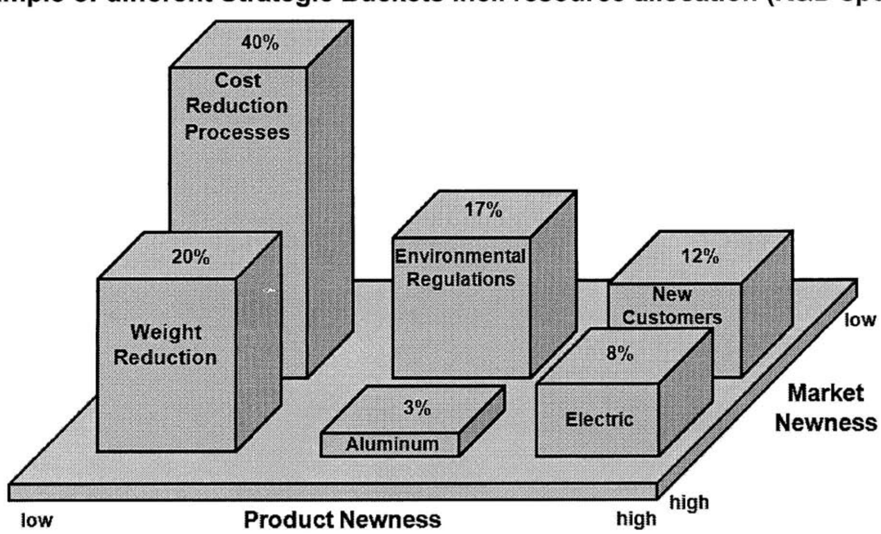
Appendix 7.2: Market Trends and Technological Scenarios are transformed to different Roadmaps



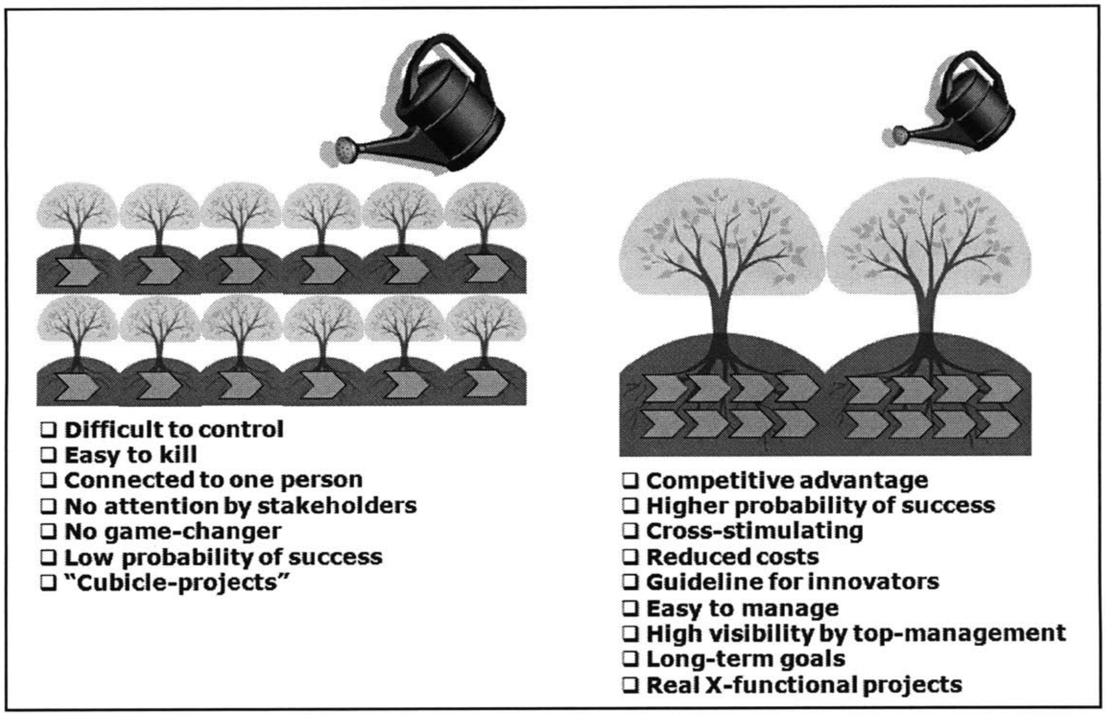
Appendix 7.2: Key Steps to Define Strategic Buckets (Cooper, 1998)

1. **Develop a vision and strategy for the business.** This includes defining the strategic goals and the general plan of attack to achieve these goals.
2. **Make forced resource allocation choices across key strategic dimensions**. Management allocates R&D and other resources (in dollar or percentages) across categories on each dimension. Seven important dimensions that companies consider include:
   - **Strategic goals:** Management splits resources across specific strategic goals. For example, what percentage should be spent on defending the base? On Diversifying?
   - **Product lines:** Recourses are split across product lines. For example, how much to spend on product line A? And B? The stage of the product life cycle should influence this split. Other factors could be the product line's market strength or importance to the business.
   - **Market segments:** Management splits resources across market segments.
   - **Technology types:** The business may rely on several types of technology or technology platforms.
   - **Project types:** What percentage of resources should go to new product development? Process development? Platform development? New materials?
   - **Familiarity matrix:** Resources are to different markets and technologies in term of their familiarity to the business (existing, extended new markets).
   - **Geography:** What proportion of recourses should be spent on projects aimed largely at North America? Europe? India?
3. **Define Strategic Buckets.** Different strategic dimensions are collapsed into a handful of buckets. Typically the number of buckets ranges from four to a dozen.
4. **Determine current spending.** Categorizes all current projects and sums up spending
5. **Determine desired spending.**
6. **Identify gaps.** Difference between current and desired spending.
7. **Rank projects by buckets**. Use ranking models and financial criteria to rank-order projects (see Chapter 7.4.4). Different criteria for different buckets are possible. For example, the buckets with new product developments should use different prioritization models than buckets with cost savings projects. Projects only compete against other projects in the same bucket.
8. **Make necessary adjustments.** When overspending occurs within one bucket, projects can be pruned. When under spending occurs within one bucket, management encourages the start of new additional projects.

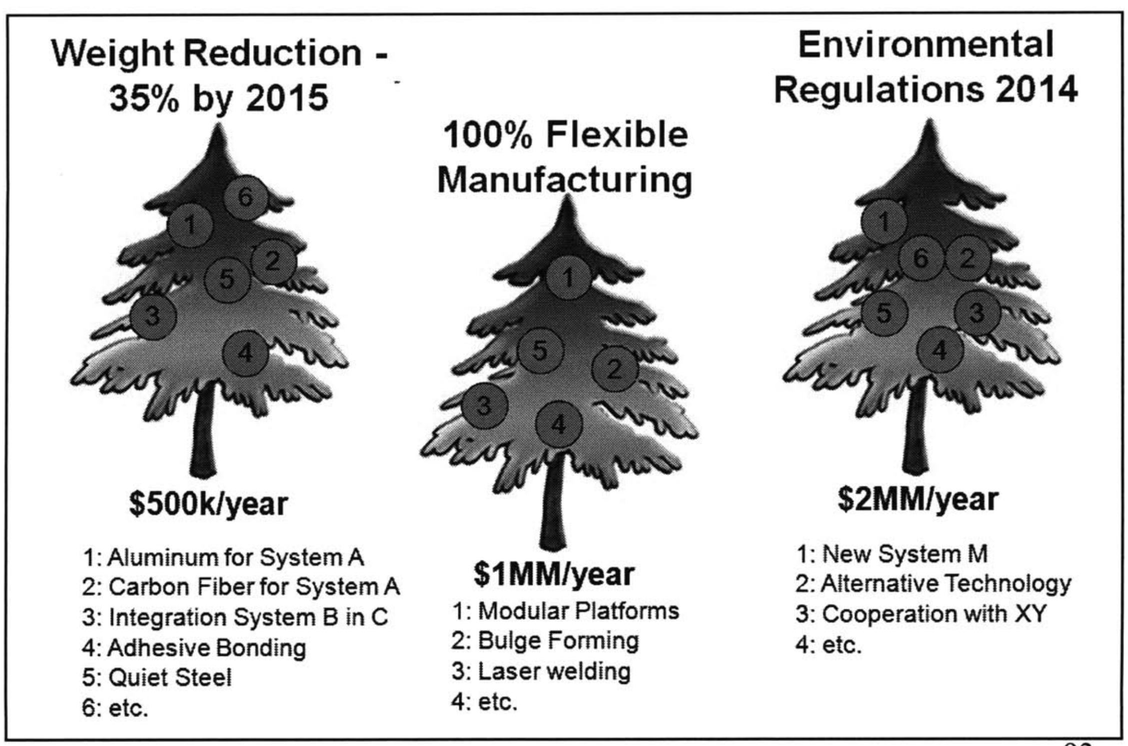
Example of different Strategic Buckets incl. resource allocation (R&D spending)



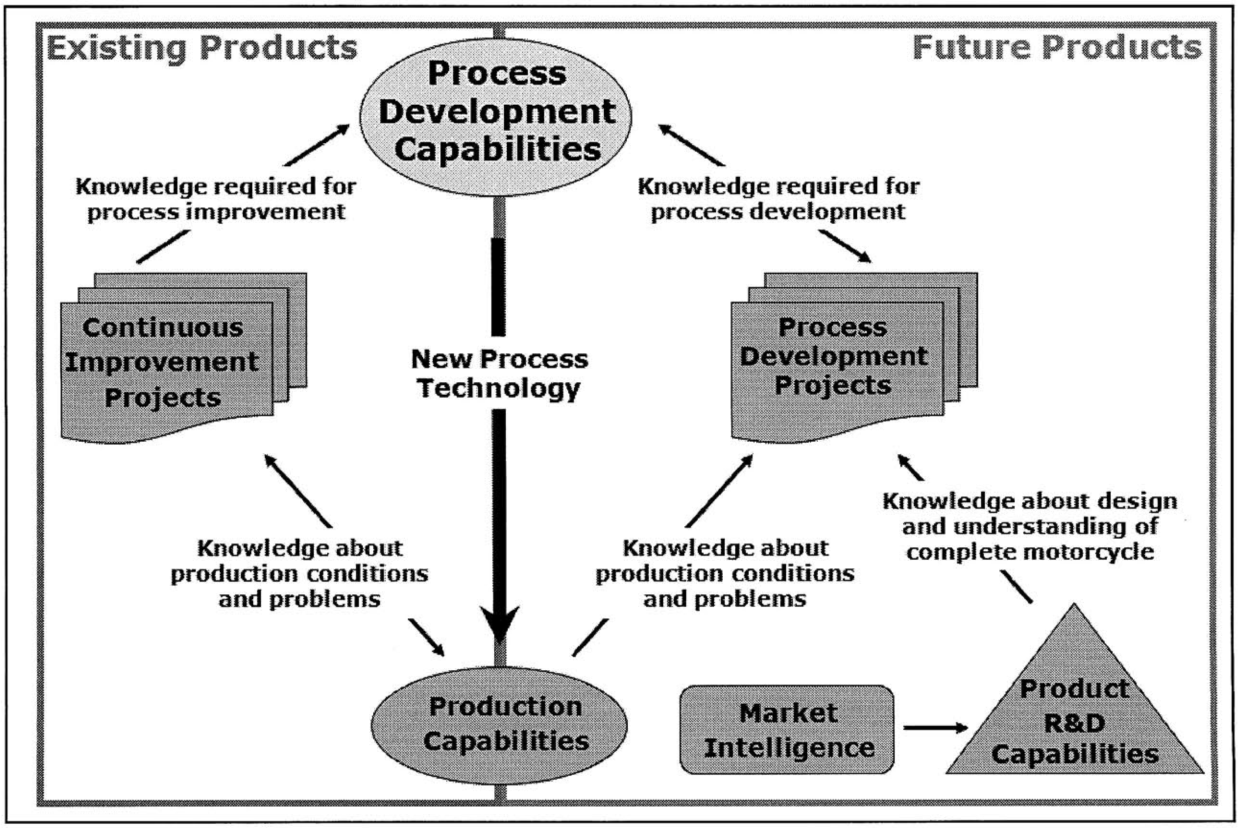
Appendix 7.3: Advantages of allocating resources only to a few Strategic Buckets (Growth Opportunities)



Appendix 7.4: Strategic Buckets as "Christmas Trees" for Open Innovation with Partners and Suppliers



Appendix 7.5: Approach to increase AM's process development capabilities by including market intelligence and product R&D capabilities



Appendix 7.6: Company X's proposal for System Strategy Teams

Purpose

The purpose of the Strategy Team is to establish cross-functional alignment in the development and implementation of a comprehensive system strategy that improves product, process, equipment, supports overall manufacturing flexibility as well as innovation but decouples it from the life cycle plan.

Scope

The scope of the Strategy Team includes the design, procurement/manufacture, and installation (assembly) of the complete portfolio of systems installed across all Company X's original equipment products. Scope will include both current production and future products.

Tasks

1. Team Formation
2. Current State Assessment & Benchmarking
3. Desired State Definition
4. Plan Creation
5. Plan Execution

Appendix 7.7: Differences between LCP and Breakthrough Innovation (Change) Organization

Ambidextrous Leadership

VP Operations– VP Engineering

Integration through common vision, values, and senior team rewards

	AM/PDC-LCP	AM/PDC-Change
Strategic Intent:	cost, profit	innovation, growth
Critical Tasks:	operations, efficiency, incremental innovation	adaptability, new products & processes, breakthrough
innovations		
Competencies:	operational	entrepreneurial
Structure:	formal, mechanistic	adaptive, loose
Controls:	margins	milestones
Rewards:	productivity	growth
Culture:	efficiency, low risk, quality, customers	risk taking, speed, flexibility, experiments
Leadership Style:	top-down	visionary, involved

Appendix 7.8: Recommendation for System Strategy Teams

Purpose

The purpose of the Strategy Team is to become the industry leader in the development and production of strategically important system groups (according to R&D strategy) by establishing cross-functional alliances inside and outside Company X. The Strategy Team has to guarantee the methodical and technological improvement of product, process, equipment, and supply-chain to support Company X's needs and current strategy. The Strategy Team will also encourage out-of-the box thinking and actively supports Company X's innovation activities.

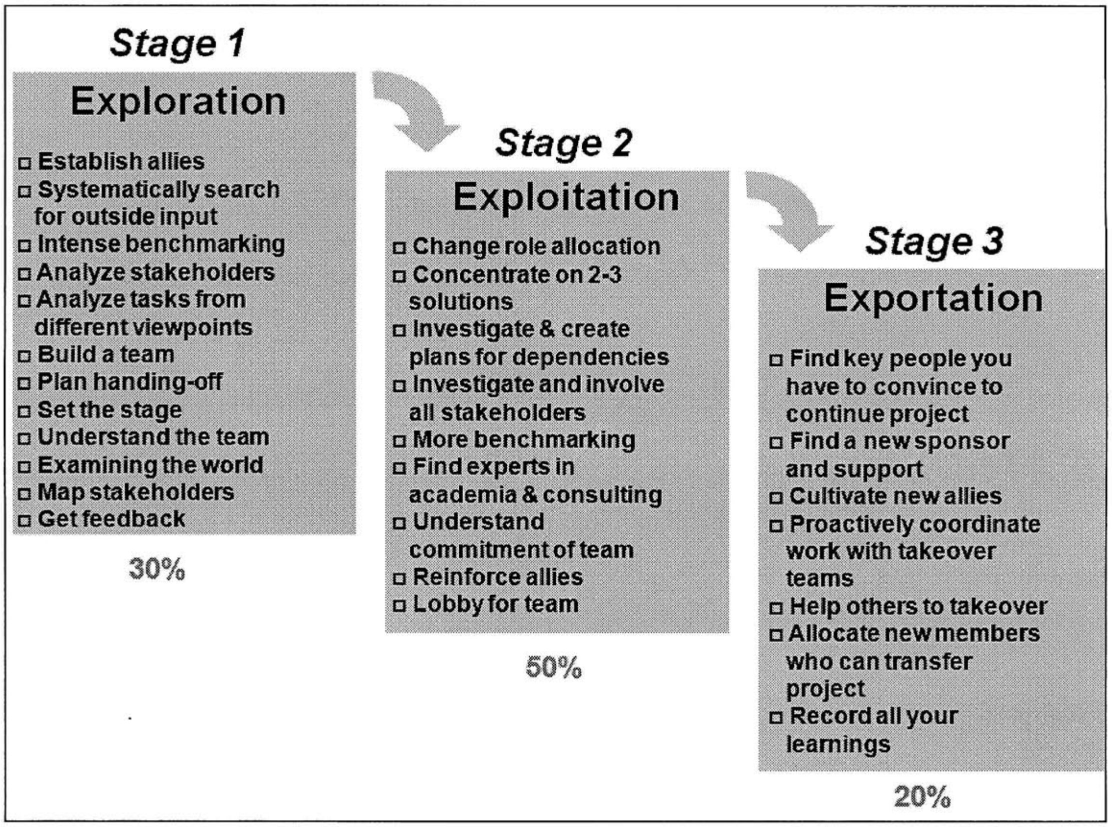
Scope

The Strategy Team will focus on the design, engineering, manufacturing, and sourcing of strategic important systems. It will spend at least 75% of its resources on future products and processes that are decoupled from any LCP project. The Strategy Team will involve and invite all stakeholders to develop advanced products, processes, or methodologies that provide a significant competitive advantage for Company X. By combining all available resources and knowledge, especially engineering and manufacturing related, the Strategy Team will introduce new technologies and methodologies that are initially not included into the LCP.

Sponsorship

This standing group is supported with resources and commitment by Manufacturing and Engineering VPs.

Tasks (based on Ancona, 2007) incl. recommended time commitment in %:



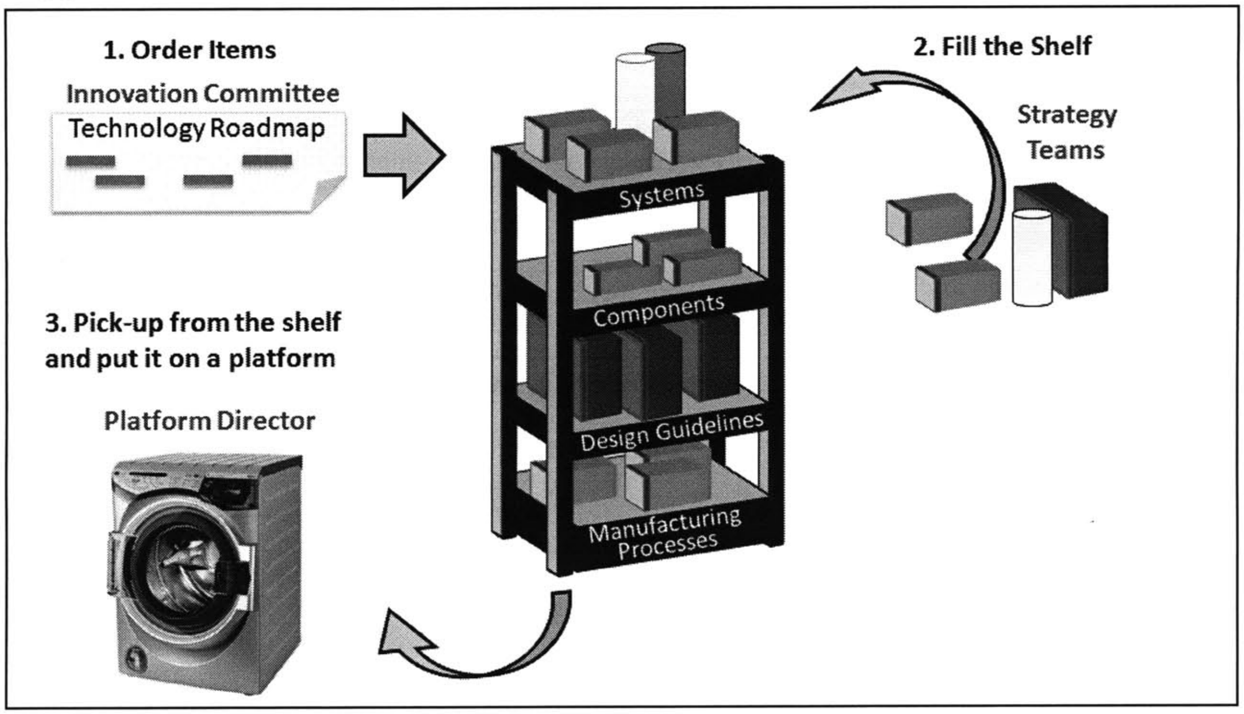
Appendix 7.9: Recommended tasks for Stage 1 (Ancona, 2007)

Stage 1 Exploration

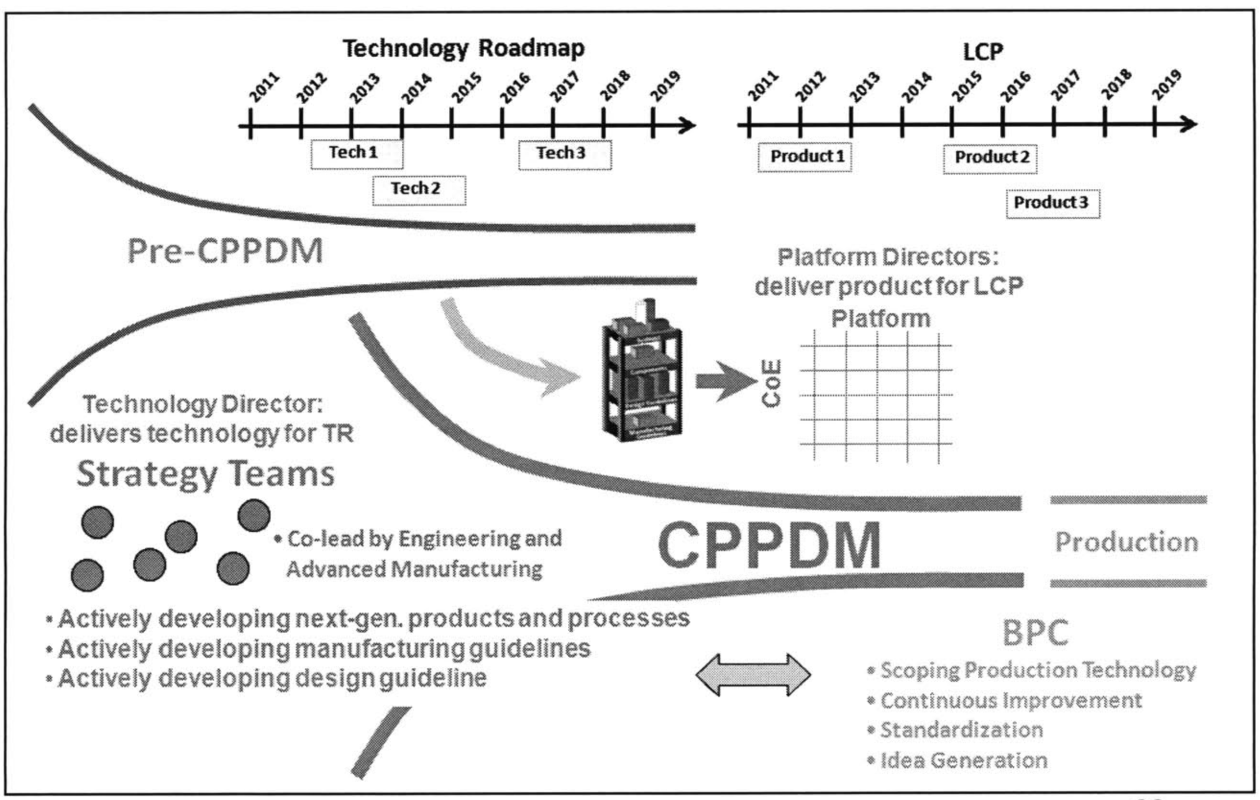
Select right team members	• Generate a list of candidates with skills, network, and motivation • Generate a list of people you want to interact with • Chose and invite right people
Understand team's knowledge	• Mapping expertise of team (network, knowledge areas, experience, etc.) • Mapping areas of interests members want to explore
Investigate organizational terrain	• Understand what others at Company X expect from you and feel about the team's task • Search for other teams at Company X that were engaged in similar tasks and learn from them
Investigate customers, current trends, and competitors	• Discover customer needs and trends • Discover customer needs and trends with help from market intelligence experts • Discover internal customer needs and trends • Scan your environment for new ideas, practices, and technologies that may be adapted to team's needs • Analyze competitors (products and processes) • Learn how to do benchmarking • Map and publish all of your findings

Investigate yourself	• Understand what biases exist within the team • Discuss what each member wants to get out of this phase and weather the team can meet these needs • Create a map of who has information, expertise, and resources that the team may need
Get buy-in from top-management	• Link project to key strategic initiatives • Explain senior leadership from all key stakeholder areas the team's plan • Ask senior managers how the team would be most helpful for the manager
Cultivate allies and protect against adversaries	• Persuade others that the team's ideas are important and need to be supported • Create a network of supporters • Identify political adversaries and try to win them over or contain their damage
Identify dependencies	• Identify those individuals and groups that have something the team might need • Identify those individuals and groups that might take over the project and understand their needs • Identify people from outside the team who might join the team to facilitate interdependent work
Get feedback from other groups	• Ask other groups that will work with the team for their suggestions about the team's plans • Brainstorm with other how to collaborate
Convince, negotiate, and cajole	• Convince, cajole, and negotiate with other interdependent groups to get commitment now • Develop a strategy how to motivate hostile groups • Reward others when they do help the team
Set norms	• How will team operate (time commitment, how to measure quality of deliverables, meeting frequency, how to make decisions, etc.) • Periodic integrative meetings (information sharing, integrating, and interpreting, planning next steps) • Participatory decision making (consideration different viewpoints, transparent decision process)
Allocate roles	• Sponsor • Team lead • Boundary spanner • Core members • Operational members • Outer-net members
General tools	• Shared timelines with strict deadlines, responsibilities, milestones, dependencies • eRoom usage with access by as many as possible; main rule: strangers have to be able to rebuilt work progress; clear structure, only complete documents, meaningful file names, etc.

Appendix 7.10: Ready-to-Order Technology Delivery System



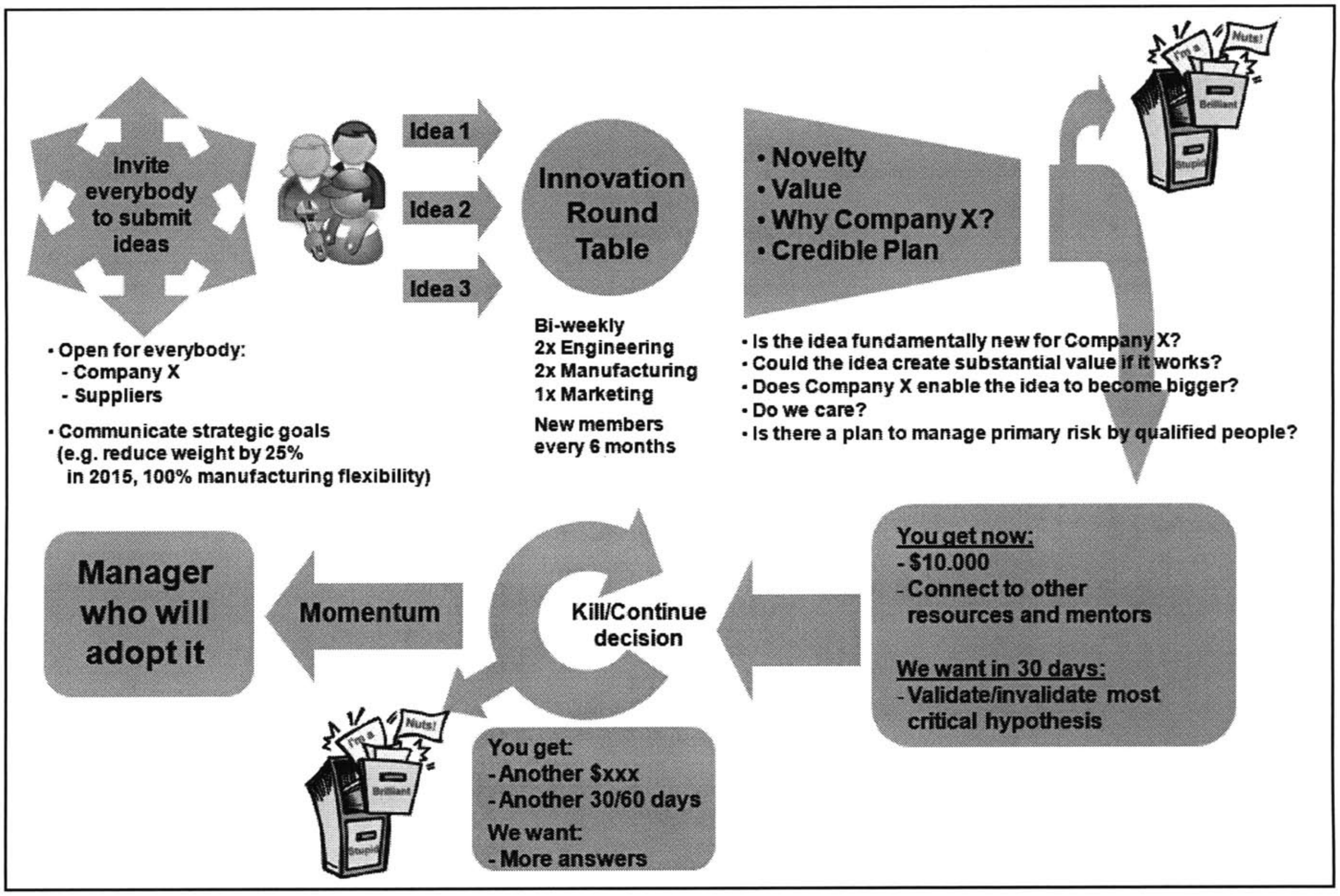
Appendix 7.11: Decoupled R&D Process



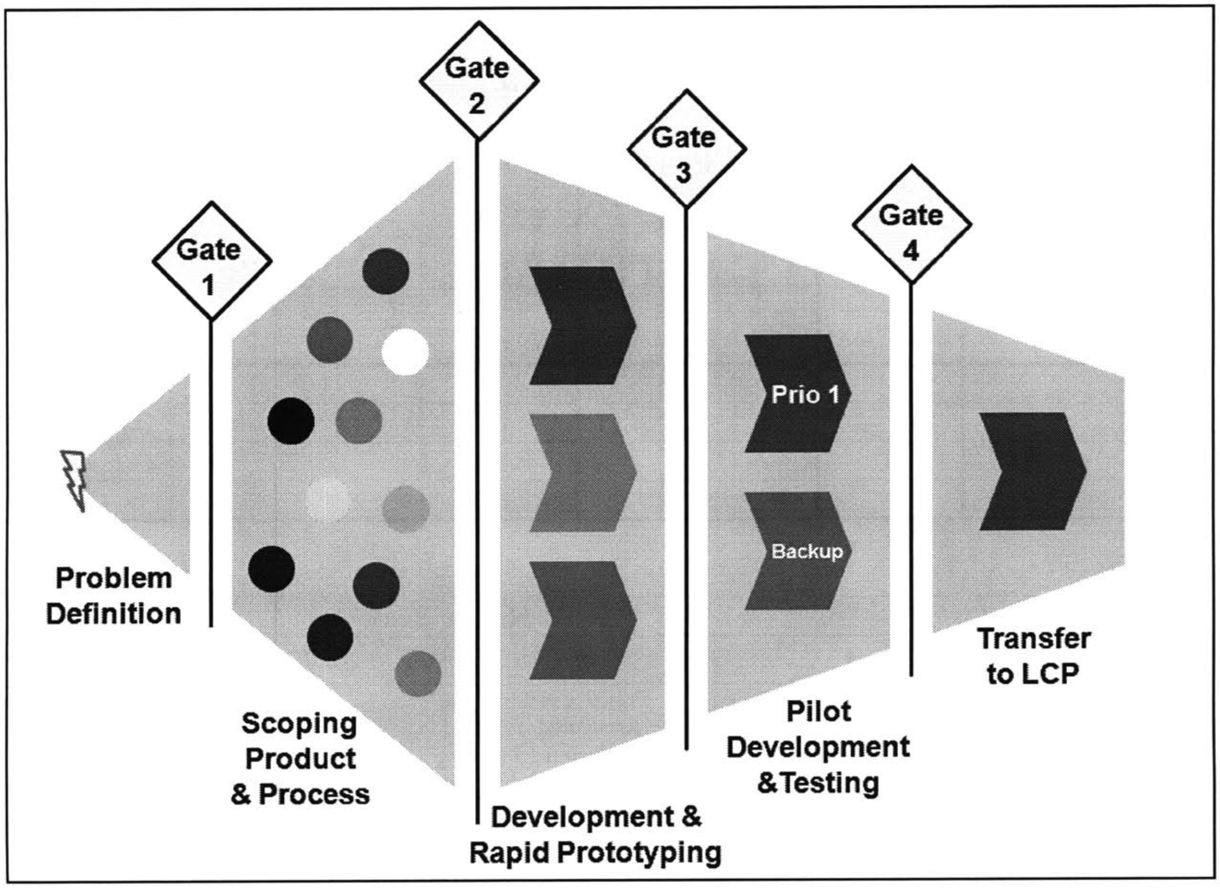
Appendix 7.12: Measures for Innovation (Davila, 2006)

	Inputs	Process	Outputs	Outcomes
Culture	Mix of backgrounds Quality of new recruits Staff motivation % of qualified people per project start	Quality of training sessions Quality of communication efforts # of ideas from planning exercise	R&D turnover # of suggestions per employee Employee commitment Results external HR audits Change in core competencies	Costs of misbehavior Change in revenue per employee
Interaction	# of research agreements with partners % of R&D budget that is non-internal Quality of IT system to support Strategy Teams Individual network skills	# of innovation workshops # of idea fairs # of conference attendance Quality of supplier participation in stage-gate process # of involved external partners	Quality of ideas funded # of alliances to further idea development Investments in new projects # of ideas from outside AM # of ideas from non-US partners	# of external generated ideas transferred to LCP Cost savings from external ideas Manufacturing improvements through external ideas
Understanding of Strategy	Funding availability Knowledge depth	# of communication workshops Competitive information Quality of development pipeline	Assessment of competitor's innovation investments Map of upcoming innovations to the market Understanding of corporate strategy Percentage of growth covered by innovation	Expected extra sales from innovations against competitors
Process and Systems	Quality of recruiting process Quality of resource allocation process Effectiveness of motivational systems Empowerment	Quality of training programs Quality of external collaborations Quality of BPC Quality of Strategy Teams	Funds committed to innovation Effectiveness of planning system Improvement in knowledge stock	Cost of developing and maintaining R&D infrastructure Cost of prototyping Cost of R&D projects

Appendix 7.13: Innovation Round Table to Capture New Ideas and to Significantly Speeding –Up the Time to Answer the Main Questions



Appendix 7.14: Recommended Stage-Gate Process for Decoupled Strategy Teams (Product & Process Development)



Gate 1: Does the team understand the problem? Are core team members and stakeholders identified? Is it worth it for Company X to start this project?

Gate 2: Did we find enough ideas to solve the problem? Are there 2-3 ideas that are worth it to build prototypes first? Are we sure some of the ideas are the best possible solution for our problem?

Gate 3: Which technology is the best one that we want to introduce into a LCP project? Which technology is our backup? Are we confident to make significant investments now?

Gate 4: Do we fulfill all requirements of the LCP project? Did the plants and platform director agree on introducing our technology? Do we have the right resources and a plan to transfer the project to the LCP? Are all critical uncertainties solved?

Appendix 7.15: Scorecard Gate 3

Overall Idea Attractiveness:							**Scores**						
Idea Name	**Bang for Buck Index**		**Expected Commercial Value**		**Investment Costs**	**Overall Score**	**Reward**	**Impact Product and Brand**	**Impact Production and Supply Chain**	**Alignment with HD Strategy**	**Confidence Technical Success**	**Confidence Commercial Success**	**Confidence Project Management Success**
	Min	Max	Min	Max									

	Rating Scale			
Factor	**1**	**4**	**7**	**10**
Overall Score	Project is not attractive for Company X	Project can be considered if uncommitted resources are available	Project is attractive; Company X should align resources to this project	Project is very attractive and/or necessary and has to be successfully executed
Reward	Breakeven/small financial impact	Moderate financial impact	Financial impact is recognized by area/department	Financial impact is recognized by company
Impact Product and Brand	Negative impact on product or brand	Improves product or brand slightly; recognized by some	Improves some features of product or brand for some customers; clearly recognized internally and/or externally	Improves product or brand significantly; clearly recognized internally and/or externally
Impact Production and Supply Chain	Negative impact on production or supply chain	Improves some production aspects; supply chain expects only minor changes	Improves production recognizable; good fit with supply chain	Improves production significantly; fits supply chain great
Alignment with Company X Strategy	R&D project is independent of business strategy and has no strategic impact	Somewhat supports strategy and has moderate impact	Supports strategy and has recognizable impact	Strongly supports strategy and has high impact

Calculation of Scores

Reward

	Rating Scale					
Factor	**1**	**4**	**7**	**10**	**Rating**	**Evaluator**
NPV	<0.5MM	$1 - $3MM	$4-$7MM	>$8MM		
Time to Commercia l Start	> 4 years	4 years	2 years	< 1 year		
Payback Period	> 4 years	4 years	2 years	< 1 year		
Return (IRR%)	<12%	15%	25%	>35%		
Certainty of Estimates	Uncertain of results	Moderately certain	Fairly certain	Positive if results		

Impact on Product and Brand

	Rating Scale					
Factor	**1**	**4**	**7**	**10**	**Rating**	**Evaluator**
Safety	Negative influence on safety possible	No impact/ unknown*	Slightly improvement on safety expected	Significant improvement/ necessary to meet safety standards		
Quality	The customer is not likely to accept end result	No impact/ unknown*	Quality improvement, but not extra valued by most customers	Most end customers will value the quality improvement		
Comfort	The customer is not likely to accept end result	No impact/ unknown*	Some customers will recognize improvement	Most customers will recognize improvement		
Perfor-mance	The customer is not likely to accept end result	No impact/ unknown*	Some customers will recognize improvement	Most customers will recognize improvement		
Economy	Higher operating costs for end customer	No impact/ unknown*	Lower operating costs for end customer	Significantly lower operating costs for end customer		
Weight	Heavier	No impact/ unknown*	Weight reduction by 10%	Weight reduction by 20%		
Styling	Negative impact on styling aspects	No impact/ unknown*	Some improvement on styling	Significant improvement on styling		
Brand	Negative impact on brand	No impact/ unknown*	Positive impact on brand expected	Measurable significant impact on brand		

Impact on Production and Supply Chain

	Rating Scale					
Factor	**1**	**4**	**7**	**10**	**Rating**	**Evaluator**
Production Synergies	Little or no experience in this area; requires new plant/facility	Some experience in this area; requires large modifications to current facility	Experience in this area; requires simple modifications	Highly experienced in this area; requires minimal/no modifications		
Production Flexibility	Reduces flexibility	No influence	Improvement in some areas	Significant improvement on overall flexibility		
Production Safety	Higher safety risks	No influence	Measurable safety improvement	Significant safety improvement		
Production Capacity	Reduces current production capacity	No influence	Increases capacity of one process step	Increases capacity of a line/area		
Platform Synergies	Limited to one product	Limited to one platform	Can be adopted at multiple platforms	Can be adopted at all platforms		
Fit to existing supply chain	Change expected	Unknown	Very minor changes expected	Fits current channels		

Alignment with Company X strategy

	Rating Scale					
Factor	**1**	**4**	**7**	**10**	**Rating**	**Evaluator**
Con-gruence	Limited fit with business strategy	Modest fit without key elements of strategy	Good fit with one or more key elements of strategy	Strong fit with several key elements of strategy		
Overall Impact	Minimal impact; no noticeable harm for HD if dropped	Modest impact; some competitive or financial impact	Significant impact; noticeable harm for HD if dropped or unsuccessful	Company X's future will be negatively influenced of dropped or unsuccessful		

Confidence Technical Success

	Rating Scale					
Factor	**1**	**4**	**7**	**10**	**Rating**	**Evaluator**
Technology Readiness Level	Basic principles observed and reported; Start of applied R&D	Basic technological components are integrated to establish that the pieces will work together.	System prototype demonstration in an operational environment finished.	Actual application of the technology in its final form and under real-life conditions.		
Technology Complexity	Unknown; difficult to define; many hurdles	Easy to define, but some hurdles	Fairly "do-able"	Straightforward		
Technical Gap	Significant difference between current practice and objective	Big difference, but some similarities with current practice	Next generation of current practice	Incremental improvement of current practice		
Technology Skill Base	Technology was never used in industry and/or totally unknown for company	Limited R&D knowledge; requires acquiring new skills	Similar technology is practiced in some parts of company	Practiced in company; leverages well existing technology		

Availability of People, Facility, and Tools (Tests, simulation, prototypes, etc.)	No appropriate people/facilities/ tools; must hire/build	Acknowledged shortage in key areas	Recourses are available, but capacity limitations	People and facilities immediately available		
Proprietary Position	Technology is protected and patents are not acquirable	Protected, but patents can be acquired	Not protected	In-house patents protect us from competitors		

Confidence Commercial Success

	Rating Scale					
Factor	**1**	**4**	**7**	**10**	**Rating**	**Evaluator**
Market Need	No apparent need; market development required	Need must be highlighted for customer; product tailoring required	One-for-one substitution of competitors' product	Product immediately responsive to customer need		
Com-petitive Advantage	None	Cost reduction and/or slightly differentiation from competitors	Enables Company X to reduce sales price and/or differentiate product from competition	Enables Company X to take over cost leadership and/or differentiate product significantly		
Regulatory	Conflict with existing or future regulations	No influence	Helpful to fulfill current or future regulations	Unsuccessful project will prevent selling affected motorcycles		
Customers	Neutral or negative customer feedback expected	Customers like it, but not willing to pay extra	Offers some "must-have" options	Some customers would buy motorcycle because of this		
Proprietary Position	Easily copied by others	Could be protected by patents, but not deterrent	Technology is worth to patent	Company X's position protected by patents, material access, secrets, etc.		

Confidence Project Management Success

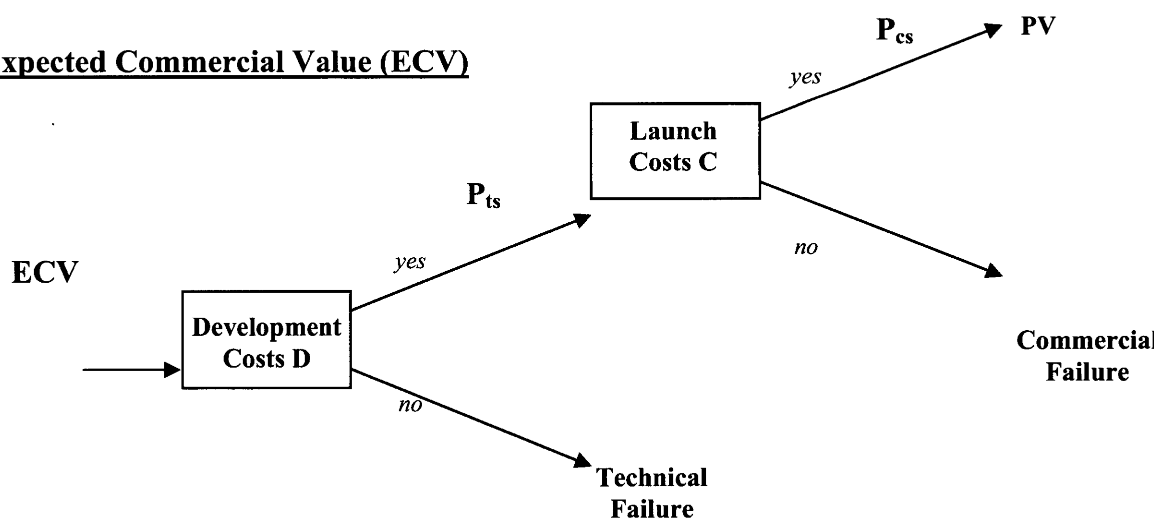
	Rating Scale					
Factor	**1**	**4**	**7**	**10**	**Rating**	**Evaluator**
Teamwork	Extensive cross-functional collaboration needed, but not all resources committed	Extensive cross-functional collaboration needed	Some cross-functional collaboration needed	Only one or two different stakeholders involved during project		
Motivation	Negative; one or more main stakeholders oppose / don't support project	Neutral; main stakeholders accept project	Committed; main stakeholders support project	Positive; all main stakeholders are excited about project; core team included project in their PEP goals		
Support by leadership	None/unknown	Director will regularly ask for results	VP will regularly ask for results	CEO or SVP will regularly ask for results		
Project leader	No experience in R&D projects	Managed R&D projects before	Management cross-functional and complex R&D projects before	Proved strong management skills in complex R&D projects		

Since the NPV is always difficult to estimate in an early stage of the project, you should use a best case and a worst-case scenario NPV. With that, the decision maker can see the range of possible outcomes

Bang for Buck Index

$$\text{Bang for buck Index} = \frac{\textit{NPV of the project}}{\textit{Total resources remaining to be spend on the project}}$$

Expected Commercial Value (ECV)



$$\text{ECV} = \left[\left(PV \cdot P_{cs} - C\right) \cdot P_{ts}\right] - D$$

PV = **Net present value of project's future earning/cost saving, discounted to today**
P_{cs} = **Probability of Commercial Success**
C = **Commercialization Costs (Launch)**
P_{ts} = **Probability of Commercial Success**
D = **Development costs remaining in project**