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Lean Front End Framework Development

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Abstract

The aim of this research is to develop a Lean Front End model which can be used for analyzing the very early stage of New Product Development process. The need of this study is originated from industrial world because a fuzzy beginning stage is confronted when a NPD is carried out. In another hand, customer value is the start point and very important part of Front End stage. But this value is very difficult to catch and communicate inside the project team between marketers and designers. Therefore, the purpose of the Lean Front End framework we developed is to provide a systematical way to help the companies to understand and well organize the Front End phase by capturing customer value and correctly communicate it.

For achieving the goal of this study mentioned above, three aspects of work have been done in this work:

First, a firmed literature review is undertaken. We systematically reviewed what the pioneers have studied in the past related to field of New Product Development, Fuzzy Front End, Knowledge Management, Customer Value and TRIZ methodology.

Second, the Lean Front End framework is built which contains two phases (Concept Development& Feasibility Analysis and Technical Marketing), three parties (WHAT information involved, WHO is executor of the activity and HOW it can be done).

Last but not the least; we validated the model in a real business case by applying the matrices and templates to practice. Additionally, in this part, VSM(Value Stream Mapping) is used to analyze the process flow of the Initial Marketing part of the company.

Key Words

New Product Development, Lean Front End, Knowledge Management

Sintesi del lavoro

Lo scopo di questo studio è di sviluppare un modello di lean front-end che può essere utilizzato per analizzare la fase molto precoce del processo di New Product Development. La necessità di questo studio nasce dal mondo industriale perché lo stadio iniziale fuzzy è confrontato quando un NPD viene eseguito. In secondo luogo, il valore per il cliente è il punto di inizio e parte molto importante della fase di Front End. Ma questo valore è molto difficile da catturare e comunicare all'interno del team di progetto tra marketing e designer. Pertanto, lo scopo del quadro Lean front-end che abbiamo sviluppato è quello di fornire un modo sistematico per aiutare le aziende a comprendere e ben organizzare la fase di Front End catturando il valore per il cliente e comunicandolo in modo corretto.

Per raggiungere l'obiettivo di questo studio sopra citato, sono stati analizzati tre aspetti del lavoro:

In primo luogo, è stata intrapresa una dettagliata revisione della letteratura. Abbiamo rivisto sistematicamente ciò che gli studiosi hanno appreso in passato in relazione al campo dello sviluppo di nuovi prodotti, Front End Fuzzy, Knowledge Management, Customer Value e la metodologia TRIZ.

In secondo luogo, la struttura del Lean Front End è stata costruita; contiene due fasi (Progettazione e Sviluppo e analisi di fattibilità e Marketing Tecnico), tre parti (QUALI informazioni devono essere considerate , CHI è l' esecutore dell'attività e COME può essere eseguito).

Ultimo ma non meno importante, abbiamo convalidato il modello ad un caso vero e proprio applicando le matrici e i modelli per la pratica. Inoltre, in questa parte, VSM (Mappatura del Flusso di Valore) viene utilizzato per analizzare il processo della parte iniziale Marketing della società

Key Words

Sviluppo di nuovi prodotti, Front End Lean, Knowledge Management

Struttura della Tesi

La tesi è strutturata in sei capitoli:

Capitolo 1: Introduzione. L'introduzione di questa ricerca comprende il contesto in cui abbiamo effettuato il nostro studio e gli oggetti della nostra ricerca.

Capitolo 2: sviluppo di nuovi prodotti e di front-end. Questo capitolo è su ciò che è stato detto in letteratura sul Lean Product Development e Front End Lean. Abbiamo sistematicamente introdotto il concetto di sviluppo di nuovi prodotti, Lean Thinking, Lean Product Development New, Knowledge Management applicato al Lean NPD e anteriore Lean e Front End Lean e il modo in cui sono stati studiati finora.

Capitolo 3: Creazione di valore per i clienti Front End Lean. Questo capitolo revisione della letteratura si concentra sul valore del cliente e come è stato importato nel processo di Lean sviluppo di nuovi prodotti. Qui metodologia TRIZ è volto a migliorare il Fronte End Fuzzy per l'innovazione continua.

Capitolo 4: Lean modello di front-end. Questo è il capitolo essenziale di questa ricerca in cui abbiamo proposto il modello lean front-end. La struttura, il processo, le metodologie e gli strumenti utilizzati sono stati spiegati in modo dettagliato.

Capitolo 5: ricerca empirica. Questo capitolo riguarda la convalida del modello. Il compito della ricerca empirica è quello di testimoniare l'efficacia del modello di lean front-end. In questo capitolo abbiamo analizzato il VSM corrente della fase di commercializzazione iniziale della società e il modello applicato a questo caso.

Capitolo 6: Conclusione. Qui si riassume ciò che è stato fatto in questa ricerca e qual è il risultato. Sono stati segnalati anche i suoi limiti e le future direttive di ricerca riguardo l’argomento.

Chapter 1 Introduction

This first chapter introduces the context and the aims of this study. The New Product Development becomes a very crucial issue for those innovative companies and the importance of capturing customers' needs has been recognized both in academic and industrial fields, meanwhile the study of the area of Fuzzy Front End is still not under progressing. That is why the authors chose this field to make some efforts.

1.1 Overview

In recent years, firms have focused on how to enter markets and meet customer requirements by improving product attributes and processes to boost their market share and profits. Therefore, market-driven product design and development has become a popular topic in the literature. Companies started to continuously innovate and introduce new products to the market. New Product Development is becoming crucial, and its performances determine the success of the whole enterprise. New Product development is recognized as cross-functional teamwork that has become important in the fast-paced, globally competitive environment. Also lean techniques have been implemented to this process in order to optimize the performance of this process with lowest costs.

The entire product development process typically is broken down into a number of stages that are addressed separately in product design optimization. A successful product design requires an efficient and effective integration of engineering and marketing. Any firm that hopes to compete on the basis of innovation clearly must be proficient in all phases of the new product development (NPD) process. However, the real keys to success can be found in the activities that occur before management makes the go/no-go decision for any NPD project. In other words, the most significant benefits can be achieved through improvements in the performance of the Front End (the very early phase of product development) activities-product strategy formulation and communication, opportunity identification and assessment, idea generation, product definition, project planning and executive reviews.

The term "Fuzzy Front End" is first popularized by Smith and Reinertsen (1991), it is considered to be the earliest stage of the NPD process and roughly is meant to denote all time and activity spent on an idea prior to the first official group meeting to discuss it, or what they call "the start date of team alignment". Effectively perform front-end activities can contribute directly to the success of a new product. It is also a phase which can find several low cost opportunities to achieve large improvement.

When talking about Fuzzy Front End, another very important concept related to this topic is Customer Value Creation. Because to capture customer need, understand the market demand is the first thing and the most important thing inside Front End activities. Therefore, to understand better the concept of customer need, how to capture it and correctly communicate it became a key issue in Fuzzy Front End studies.

However, Front End phase of a New Product Development process is still an area where a significant degree of uncertainty continues to reside within organizations and is mirrored by equal uncertainty in academia. Over decades, some new techniques and tools have been proposed to improve the practice of Fuzzy Front End by scholars, consultants and practitioners. But Lean Font End as a new concept has just been brought up for a couple years. That intrigued the authors of this research to follow the previous pioneers to continue study in this area.

1.2 Objective and structure of the research

From the previous section, we understood the criticality of Fuzzy Front End phase in New Product Development process and why this thesis focused on it. Based on literature review, in this research we proposed a Lean Front End framework to analyze the initial part of the New Product Development process. Inside this model, several methodologies and tools are employed to analyze the problem and optimize the results of Front End activities. In this process, we also considered the importance about information flow since it is one of the biggest reason of resource waste and time consuming activity which has been revealed in the previous research. New product development generates vast amounts of knowledge—not only about the product and technology but also knowledge about the processes used by the NPD team (Cohen and Levinthal, 1989).The third aspect is about improving the process flow of Front End phase by Value Stream Mapping. In order to improve a process, analyze and understand criticalities, the process should be understood and mapped. VSM which is the main mapping tool proposed in lean literature since it is simple, gives idea of flow and timing, highlighting waiting time and hen wastes.

The second object of this research is to validate the Lean Front End model we built by applying it into a real business case. In order to achieve this goal, we carried out the empirical research to testify the usability of the model. The study is undertaken in a world-wide microelectronics company which takes care of technology innovation and cooperative studying with academic institution. And it turns out to be a very success model.

The thesis is structured in six chapters:

Chapter 1: *Introduction*. The introduction of this research includes the context under which we carried out our study and the objects of our research.

Chapter 2: *New Product Development and Front End.* This chapter is about what has been said in literature about Lean Product Development and Lean Front End. We systematically introduced the concept of New Product Development, Lean Thinking, Lean New Product Development, Knowledge Management applied to Lean NPD and Lean front and Lean Front End and how they have been studied so far.

Chapter 3: *Customer Value Creation for Lean Front End*. This literature review chapter is focused on Customer Value and how it has been imported to the process of Lean New Product Development. Here TRIZ methodology is introduced to improve the Fuzzy Front End for continuous innovation.

Chapter 4: *Lean Front End Model*. This is the essential chapter of this research where we proposed the Lean Front End Model. The structure, process and the methodologies and tools used have been explained in a detailed way.

Chapter 5: *Empirical Research*. This chapter is about model validation. The task of the empirical research is to testify the effectiveness of the Lean Front End model. In this chapter we analyzed the current VSM of initial marketing phase of the company and applied the model to this case.

Chapter 6: *Conclusion*. Here we summed up what has been done in this research and what is the result. Also the limits of this research and future studying directions have been pointed out.

Chapter 2 New Product Development and Front End

First, this chapter provides an overview of New Product Development and Lean Thinking. Based on this, the concept of Lean New Product Development is introduced. The aim of this Chapter is to explore the world-wide of Lean New Product Development and to analyze tools and methodologies used to perform it. The last section part relate to the Knowledge Management that provides tools facilitating lean new product development.

2.1 Lean Product Development

2.1.1 New Product Development

2.1.1.1 New Product Development

When talking about new product development, it is easy to come up with concepts of product development, new product development process, and new product introduction. First, some definitions of “new product development” are given to help to understand what new product development is and differences among different concepts, such as product development, new product introduction, new product development process and so on.

In business and engineering, new product development (NPD) is the term used to describe the complete process of bringing a new product or service to market. There are two parallel paths involved in the NPD process: one involves the idea generation, product design and detail engineering; the other involves market research and marketing analysis. Companies typically see new product development as the first stage in generating and commercializing new products within the overall strategic process of product life cycle management used to maintain or grow their market share. (wikipedia.org)

New Product Development (NPD): The overall process of strategy, organization, *concept generation, product and marketing plan creation and evaluation, and commercialization of a new product. Also frequently it is referred to just as "product development".*

(PDMA)[1]

New Product Development Process (NPD Process): A disciplined and defined set of tasks and steps that describe the normal means by which a company repetitively converts embryonic ideas into salable products or services.

(PDMA)

New Product Introduction (NPI): The launch or commercialization of a new product into the marketplace. Takes place at the end of a successful product development project.

(PDMA)

Product development is "the set of activities beginning with the perception of a market opportunity and ending in the production, sale, and delivery of a product."

(Ulrich and Eppinger,1995)

"Agile Product Development Process" is one that can rapidly introduce a steady succession of incremental product improvements – which can be called "NEW" products – that are really planned based on common parts and modular product architecture. This capability results in ultra-fast time-to-market, much faster than possible with independent products that do not benefit from product-family synergies in design and manufacture."

(Anderson, 1997)

Process: "A series of actions or steps towards achieving a particular end".

(Oxford dictionary)

A business process can be described as "a number of interrelated activities

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[1] PDMA: The Product Development and Management Association (*PDMA) is the premier global advocate for product development and management professionals.* The mission is to improve the effectiveness of individuals and organizations in product development and management. *This is accomp*lished by providing resources for professional development, information, collaboration and promotion of new product development and management.

needed to accomplish a specific task".

(Garside, 1998).

From literature, some authors emphasize the fact that NPD is a collaborative process since there has been a gradual shift from intra-organizational to inter-organizational collaboration regarding product design and development (Paraw and Sharify, 2001). NPD involves thousands of decisions, sometimes over a period of years, with numerous interdependencies, and under a highly uncertain environment. A large number of participants are involved, such as architects, project managers, discipline engineers, service engineers, and market consultants. Each category of professionals has a different background, culture, and learning style (Formosoetal, 1998). Ulrich and Eppinger (1995) show that NPD is used to indicate the complete business process of introducing new products to market. It spans the entire product life-cycle from initial identification of market/technology opportunity, conception, design and development through to production, market launch, support, enhancement and retirement. Huthwaite (2007) states that the product development process is an integrated system of sub-processes (such as market intelligence gathering, portfolio planning and phase gate review) which is for managing the overall product delivery system. It is a true "mega process". A Product Development (PD) process is defined as a set of activities involved in taking a design problem during product development from setting initial specifications to producing a finished artefact that meets specifications (Johnson, Brockman, Vigeland, 1996).

We can see from the different definitions mentioned above and the literature that the concepts of product development, new product development, new product introduction, new product development process are all establishing two important points: first, a process includes set of activities, second, it is a broad field of effort in different areas such as design, creation and production of new products. So in the following context, when coming with these three concepts, we will use "New Product Development (NPD)" to present all the four concepts.

To understand NPD well, it is also necessary for us to be clear what the newness is. There is a common list of the different types of possible developed products with their attributes and contributions in the book "The pursuit of new product development" (Anacchino, 2006) which indicates us different kinds of newness.

- *"New to the world" products: These products are somewhat revolutionary in the marketplace; they generally create entire new markets that never before existed. An example would be the cellular phone which has revolutionized person-to-person communications in modern-day society. One such product looming on the 10-year horizon today is mass-market fuel cells. These product development programs generate entire new markets; they enable true growth in the economy by generating revenue to the enterprise. They also have a multiplication effect in the economy by generating requirements for parts and subassemblies that need to be developed and supplied by the vendors. In many cases, they generate new channels of sales and new routes to market.*
- *New product lines: these new categories of products allow entry into newer markets not previously participated in by the manufacturer. By adding new categories of products, manufacturers must be careful to protect the positioning of their existing products, which generate the existing business. Failure to do so will place them in danger of converting loyal customers away from one already successful product to a new one, with not net gain in market share. The new product lines generate incremental revenue to the manufacturer by leveraging the market's familiarity with the manufacturer into new categories of products. In many cases, the market familiarity with the manufacturer paves the way for new categories of products. Sometimes these products go into new markets, but can also be an alternative to existing ones.*
- *Additions to existing product lines: these efforts support existing product lines by creating line completers to extend the influence of the original products' brand to larger audiences or extending range, power and scope. An example of this type of product would be tomato sauce versions- hearty, traditional,*

roasted garlic. By taking the basic product and modifying it, a wider market share is realized. The addition to existing lines has a similar effect on the company's revenue as the new product lines. They generate incremental revenue by leveraging the existing product familiarity rather than the company familiarity. These programs generate incremental improvement in the economy, but generally fall short of the contribution made by the totally new products.

- *Improvements and revisions of existing products: as time advances, customers have higher expectations of products and the competition adds features to their offering. It becomes necessary to improve a company's offering to increase market share or to retain it. By redesigning the product or repackaging it, a company can offer a greater value or satisfaction to the costumer. An example of this type of product development is the automotive companies adding features to their basis models each year as standard. Generally, the improvements to existing products do not generate additional revenue. They are simply a means to retain the market share or to slightly improve it. They are defensive in nature and in many cases are stopgap measures until a new product program can be introduced.*
- *Repositioning: it is another way of increasing or maintaining market share. Repositioning is an exercise in changing the perception in the mind of the consumer. It generally can happen with products that are lower in value or the consumer spends little time evaluating the actual data. It is truly a marketing activity rather than a development activity, and it is another stopgap measure for generating revenue from an existing product.*

For the New Product Development, 8 processes are given by Ulrich, Karl T. and Eppinger, Steven D (2004), as is shown in **Figure 1**:

1. *Idea Generation, often called the "fuzzy front end" of the NPD process*

   - Ideas for new products can be obtained from basic research using a SWOT analysis (Strengths, Weaknesses, Opportunities & Threats), Market and consumer trends, company's R&D department, competitors, focus groups, employees, salespeople, corporate spies, trade shows, or ethnographic discovery methods (searching for user patterns and habits) may also be used to get an insight into new product lines or product features.

- Lots of ideas are being generated about the new product. Out of these ideas many ideas are being implemented. The ideas use to generate in many forms and their generating places are also various. Many reasons are responsible for generation of an idea.
- Idea Generation or Brainstorming of new product, service, or store concepts- idea generation techniques can begin when you have done your opportunity analysis to support your ideas in the Idea Screening Phase (shown in the next development step).

2. *Idea Screening*

- The object is to eliminate unsound concepts prior to devoting resources to them.
- The screeners should ask several questions:
  - Will the customer in the target market benefit from the product?
  - What is the size and growth forecasts of the market segment/target market?
  - What is the current or expected competitive pressure for the product idea?
  - What are the industry sales and market trends the product idea is based on?
  - Is it technically feasible to manufacture the product?
  - Will the product be profitable when manufactured and delivered to the customer at the target price?

3. *Concept Development and Testing*

- Develop the marketing and engineering details:
  - Investigate intellectual property issues and search patent data bases.

- Define the target market and the decision maker in the purchasing process.
- Make sure product features that the product must incorporate.
- Identify benefits the product will provide.
- Forcasting consumers' react to the product.
- Exploiting methods to make the product to be produced most cost effectively.
- Prove feasibility through virtual computer aided rendering, and rapid prototyping
- Specifying costs to produce the product.

➢ Testing the Concept by asking a sample of prospective customers what they think of the idea. Usually via Choice Modelling.

4. *Business Analysis*

➢ Estimate likely selling price based upon competition and customer feedback.
➢ Estimate sales volume based upon size of market.
➢ Estimate profitability and break-even point.

5. *Beta Testing and Market Testing*

➢ Produce a physical prototype or mock-up.
➢ Test the product (and its packaging) in typical usage situations.
➢ Conduct focus group customer interviews or introduce at trade show.
➢ Make adjustments where necessary.
➢ Produce an initial run of the product and sell it in a test market area to determine customer acceptance.

6. *Technical Implementation*

➢ New program initiation
➢ Finalize Quality management system
➢ Resource estimation
➢ Requirement publication

- Publish technical communications such as data sheets
- Engineering operations planning
- Department scheduling
- Supplier collaboration
- Logistics plan
- Resource plan publication
- Program review and monitoring
- Contingencies - what-if planning

7. *Commercialization (often considered post-NPD)*

- Launch the product
- Produce and place advertisements and other promotions
- Fill the distribution pipeline with product
- Critical path analysis is most useful at this stage

8. *New Product Pricing*

- Impact of new product on the entire product portfolio
- Value Analysis (internal & external)
- Competition and alternative competitive technologies
- Differing value segments (price, value, and need)
- Product Costs (fixed & variable)
- Forecast of unit volumes, revenue, and profit

These steps may be iterated as needed. Some steps may be eliminated. To reduce the time that the NPD process takes, many companies are completing several steps at the same time (referred to as concurrent engineering or time to market). Most industry leaders see new product development as a proactive process where resources are allocated to identify market changes and seize upon new product opportunities before they occur (in contrast to a reactive strategy in which nothing is done until problems occur or the competitor introduces an innovation). Many industry leaders see new product development as an on-going process (referred to as continuous development) in which the entire organization is always looking for opportunities.

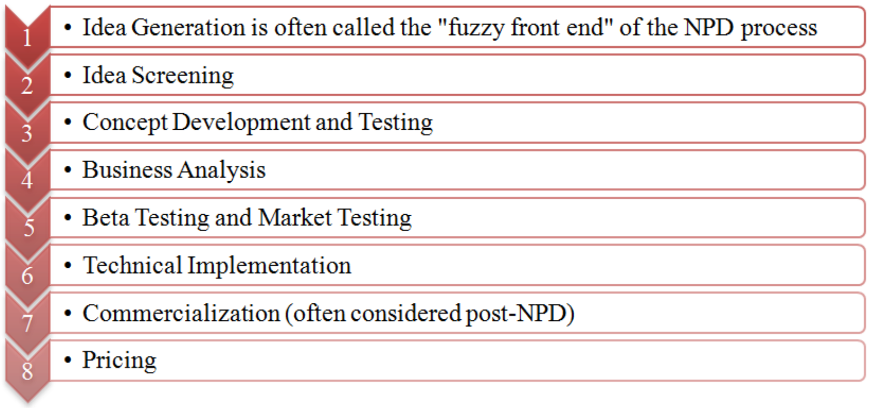

Figure 1. Processes of New Product Development (Ulrich, Karl T. and Eppinger, Steven D, 2004)

2.1.1.2 Models for New Product Development

From literature review of last paragraph, we have known the definition of NPD and detailed processes. In order to manage NPD well, some models will be introduced in this section.

Even though various models for managing the new product development process have been suggested, the basic progression of activities over the course of the process is similar (Ulrich and Eppinger, 2000). The most common NPD processes mentioned in literature are: Departmental-stage models, Activity-stage models and Decision-stage models (Saren 1984).

The Departmental-stage models are the oldest and are characterized by the “functional”, “sequential” and “over the wall” approach for NPI. The focus is on the functions (departments) that are responsible to carry out each stage. Product development is a reactive process by its nature (Kennedy, 2003), the design teams naturally react to what is learnt in the previous step. In other words, it is not unusual that the results from one step drive the actions of the next step, which may suggest that this process is appropriate.

The Activity-stage models of NPD offer a better view of the process since they focus on the activities that are carried out. Activity-stage models and their extension, Decision-stage models, are the models that have been most rigorously investigated and used. One of the first examples of activity-stage model was described by Booz, Allen and Hamilton (1968, quoted in Ehmke and Boehlje, 2005).

The Decision-stage models have various names in practice: Phased Project Planning, Gating System, Stage-Gate Systems or Phase-Gate Systems. Their characteristic is that the process consists of Stages (where the activity takes place) which are always followed by Gates (which are review points with specific input, exit criteria and a go/kill/hold/reiterate decision as output).

Garside describes a Stage-Gate model with formal reviews and overlapping activities, which is applicable to an engineering business. The model is based upon four interconnected stages: product and process design and development; concept validation; process implementation and verification; and manufacturing support (Garside, 1998). Garside defines the starting point of the NPI process just after a Bid, which is after the Opportunity Evaluation Phase (i.e. bid and proposal phase).

The first new product development model was the Phased Project Planning [PPP] model of NASA which is based on a similar US-DoD practice initiated in 1965 (PSU, 2005). This system reduced technical risk, but it made the whole process cumbersome. It worked well for NASA and Cooper emphasized that NASA did manage to put a man on the moon in less than a decade using the system – but it wouldn't work for the companies which were influenced by uncertain market conditions (Cooper, 1994). It is also made obvious that the NPI process is closely related to Project Management. The project leader drives the project from stage to stage, gate to gate (Cooper, 1990).

One of the most recognized decision-stage models is the Stage-Gate System developed by Cooper. The main difference from the PPP model is that the Stage-Gate System is multi-functional and consists of parallel activities, carried out by people from different functional areas (Cooper and Kleinschmidt, 1993). Cooper's Stage-gate systems recognize that product innovation is a process and, like other processes, can be managed. Therefore he proposed a generic model for managing new products development, improving performance (Poolton and Barclay, 1998). Stage-gate systems simply apply process-management methodologies to the innovation process, dividing the innovation process into a predetermined set of stages, themselves composed of a group of prescribed, related and often parallel activities (Cooper, 1990). Usually stage-gate systems involve from four to seven stages and gates, depending on the company or division. A typical system is shown in **Figure 2**.

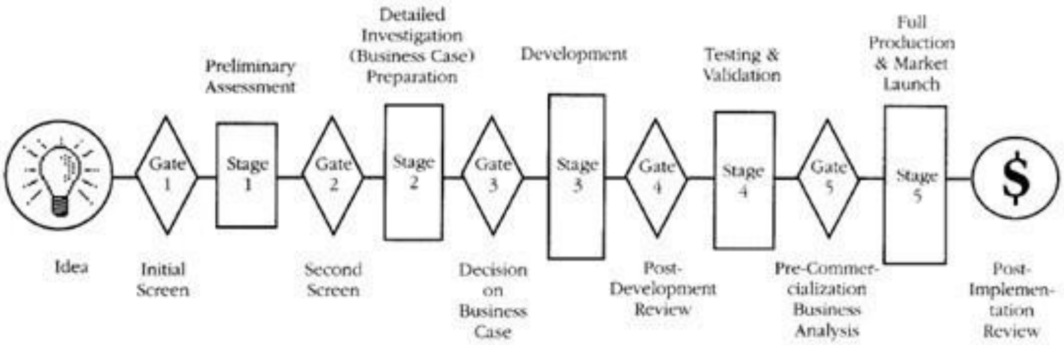

Figure 2. An overview of a Stage-Gate System (Cooper, 1990)

Each stage is usually more expensive than the preceding one. Concurrently, information becomes better and better, so risk is managed. The entrance to each stage is a gate; these gates control the process, much like quality control checkpoints control the production process. In the same way each gates is characterized by a set of deliverables or inputs, a set of exit criteria, and an output. The inputs are the deliverables that the project leader must bring to the gate. The criteria are the items upon which the project will be judged, the hurdles that the project must pass to open the gate to the next stage. The outputs are the decisions taken at the gate, usually in the form go/kill/hold/recycle, and the approval of an action plan for the next stage (Cooper, 1990). Not all stages are mandatory, in fact there are at least two or three categories of projects, ranging from small projects, driven by a single customer request, to major projects, involving heavy expenditures (Cooper, 1990). Although stage-gate systems may vary in the number of stages and gates, depending on the company, each seeks to manage risk and increase efficiency by implementing a strict development process model, during which the key questions are addressed in the beginning of the process (Veryzer, 1998).

Then, Ulrich and Eppinger elaborated a new stage-gate process model composed of six phases **(Figure 3)** Each ones comprises a series of activities and feedback processes **(Figure 4)**. Their key idea is the conception of product development process as “the set of activities beginning with the perception of a market opportunity and ending in the production, sale, and delivery of a product” (Ulrich and Eppinger, 2000).

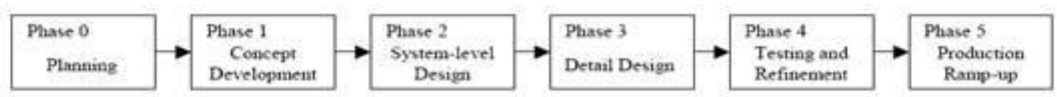

Figure 3. The Product Development Process (Ulrich and Eppinger, 2000)

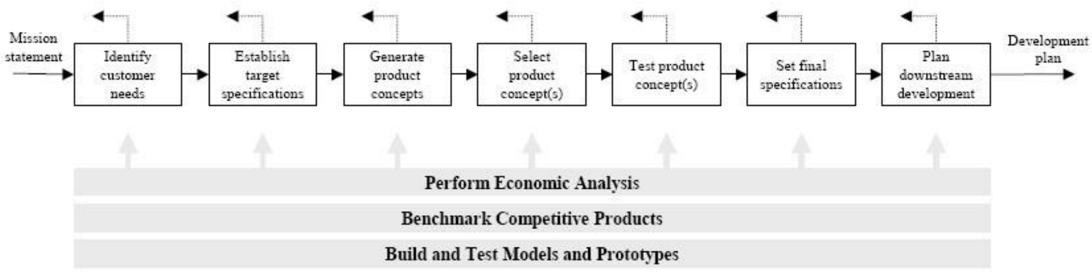

Figure 4. The Front-end Activities[2] Comprising the Concept Development Phase (Ulrich and Eppinger, 2000)

Wheelwright and Clark (1992) added organizational issues to Ulrich and Eppinger’s procedural models. This way to proceed is respectively represented in **Table 1** and **Table 2**, where are indicated the general activities each functional department has to take during each phase of product development.

[2] Front End Activities: (Khurana and Rosenthal, 1998) note that the Front End includes product strategy formulation and communication, opportunity identification and assessment, idea generation, product definition, project planning and early executive reviews, which typically precede detailed design and development of a new product.

Table 1. The Generic Product Development Process (Ulrich and Eppinger, 2000)

Planning	Concept Development	System Level design	Detail design	Testing and refinement	Production Ramp up
Marketing	Collect customer needs. Identify lead users. Identify competitive products.	Develop plan for product options and extended product family.	Develop marketing plan.	Develop promotion and launch materials. Facilitate field testing..	Place early introduction with key customer.
Design	Investigate feasibility of product concepts. Develop industrial design concepts. Build and test experimental prototypes.	Generate alternatives product architectures. Define major subsystems and interfaces. Refine industrial design.	Define part geometry; choose materials; assign tolerances; complete industrial design control documentation.	Reliability testing; life testing; performance testing Obtain regulatory approvals. Implement design changes.	Evaluate early production output.
Manufacturing	Estimate manufacturing cost;. Assess production feasibility.	Identify suppliers for key components. Perform make/buy analysis. Define final assembly scheme.	Define piece part production processes. Design tooling; define quality assurance processes. Begin procurement of long lead tooling.	Facilitate supplier ramp up; define production and assembly processes; train work force; refine quality assurance processes..	Begin operation of entire production system.

Table 2. Functional Activities under Cross- Functional Integration (Wheel Wright and Clark, 1992)

Functional Activities	Concept Development	Product Planning	Detailed design and development		Commercial preparation	Market Introduction
Engineering	Propose new technologies. Develop product ideas. Build models and conduct simulations.	Choose components and interact with suppliers. Build early prototypes and define product architecture.	Do detailed design of product and interact with process. Conduct prototype testing.	Refine details of product design	Evaluate and test pilot unit. Solve problems.	Evaluate field experience with product.
Marketing	Provide market based input. Propose and investigate product concepts.	Define target customer's parameters. Estimate sales and margins.	Conduct customer tests of prototypes.	Conduct second phase customer tests. Establish distribution plans.	Prepare for marketing roll out. Train sales force and field service.	Fill distribution channel.
Manufacturing	Process and investigate process concepts.	Define process architecture. Conduct process simulation.	Do detailed design of process design and develop tooling and equipment.	Test and try out tooling and equipment.	Build pilot unit in commercial process. Refine process on pilot experience. Train personnel.	Ramp up plant to volume targets.

Further evolution of Stage-Gate model was given by Cooper itself in 2008. Named the “Spiral Development” (Cooper, 2008), and seen in **Figure 5**. This way to operate tries to surmount the typical problems characterizing the traditional linear process models described above: project teams needs accurate information right at the time, but it takes months to design and develop a product that agrees all the specifications. Meanwhile, customers or users don’t really know what they want until they see it, especially in case of very innovative products; they often changes their mind as products evolve. Maybe the project team doesn’t understand user preferences, or also market could shift or a competitive product could be introduced(Cooper, 2008). Thus it is often enough to give something rapidly to the user, something he can see, touch and feel to obtain a response to his expectations. So the idea of spiral development, practiced by smart development teams, as dealing with the need to get mock-ups or prototypes in front of customer early in the process, and seek immediate feedback, then used to generate the next and more accurate product version. This model also considers smart-and-fast failures. In fact, this way to operate is relatively inexpensive even if the first few spirals often result in negative responses. According to Cooper (2008) this is not a problem and it should be very important to revise, rebuild and test again via the next spiral.

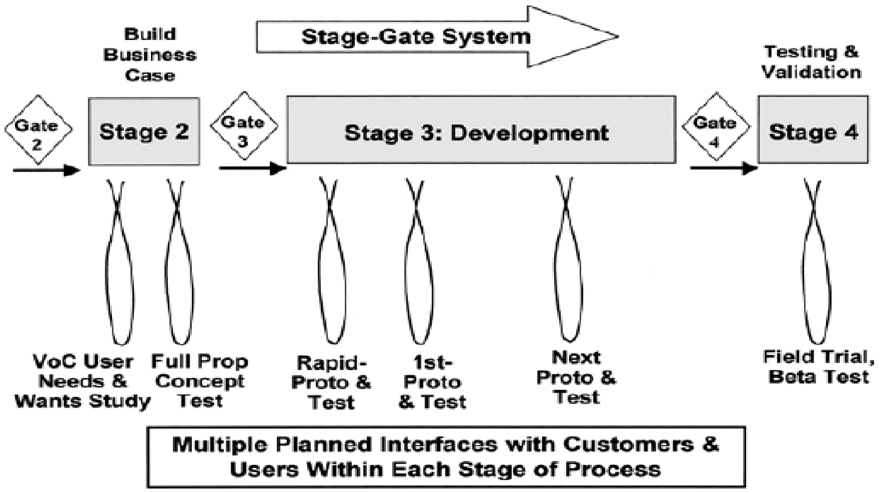

Figure 5. Spiral Development as a Series of "Build-Test-Feedback-Revise" Iterations (Cooper, 2008)

The first loop must be the voice-of-customer study assumed early in Stage 2, where project team members visit clients to better understand their unmet and implicit needs, troubles and benefits required in the new product (For this part, we will describe in section 4.1.4). At this point, the project team probably has very little to illustrate the customer; and that's the way it should be: the purpose of this visit is to listen and watch, not to show and tell. The second spiral, marked "full proposition concept test", should be where the project team give a representation of the proposed product. On the basis of the type of product and business, this representation can be a computer-generated virtual prototype, a hand-made model or mock-up, an extremely basic prototype, or even a few computer screens for new software. The product evidently does not work at this early stage, and sometimes is only two-dimensional, but it is sufficient to provide the customer a feel for what the product will be and perform. Interests, tastes, preferences and purchase intents are hence recognized even before the project become a formal development project. Feedback is required, and the needed product revisions are made. Moving into the Development Stage within weeks the project team creates the next and more complete version of the product, possibly a rough model or a quick prototype. Designers test it with customers, and again they search for feedback, then used to rapidly revise and build the first-working prototype; and after that the process flows to Spiral #3, #4 and so on. In this way each following adaptation will be closer to the final product, and at the same time, more similar to the customer's ideal. These loops look exactly like spirals, hence the name "spiral development."

The first concept of spiral development, described by Barry Boehm (1988) as an iterative waterfall in which each iteration allow to increasing software capability, is showed in **Figure 6**. The process evolves through four quadrants:

1. *Determine objectives;*
2. *Identify and resolve risks;*
3. *Development and test;*
4. *Plan the next iteration.*

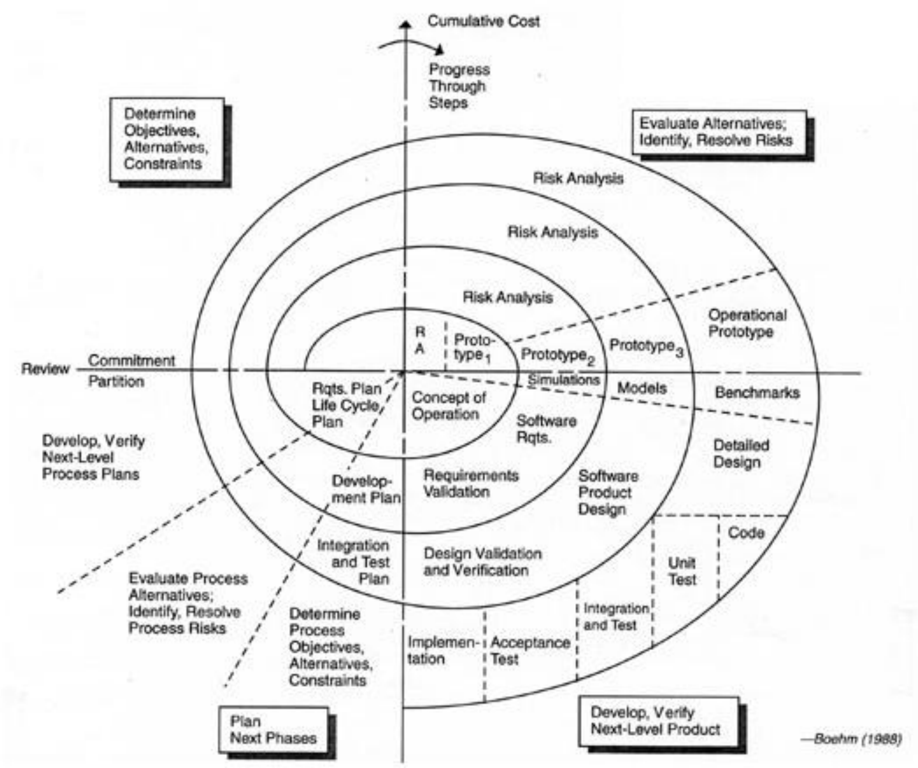

Figure 6. Spiral Development (Boehm, 1988)

Brown and Eisenhardt (1995) illustrate three different streams of product development research, which evolved from dissimilar sources and focused on quite different aspects of product development. Nevertheless, they also suggest complementary and sometimes overlapping insights into product development process. From these reflections they seek to develop an integrative model (Brown and Eisenhardt, 1995). The first stream of PD research explained is product development as rational plan, which is represented in **Figure 7**. This rational plan viewpoint highlights that successful product development is the effect of (a) careful planning of a superior product for an attractive market and (b) the execution of that plan by a competent and well-coordinated cross-functional team that operates with (c) the blessings of senior management. Just place a product that is well planned, put into practice, and properly sustained will be a success. The focus in this stream is on determining which of many independent variables are connected with the financial success of a product- development project.

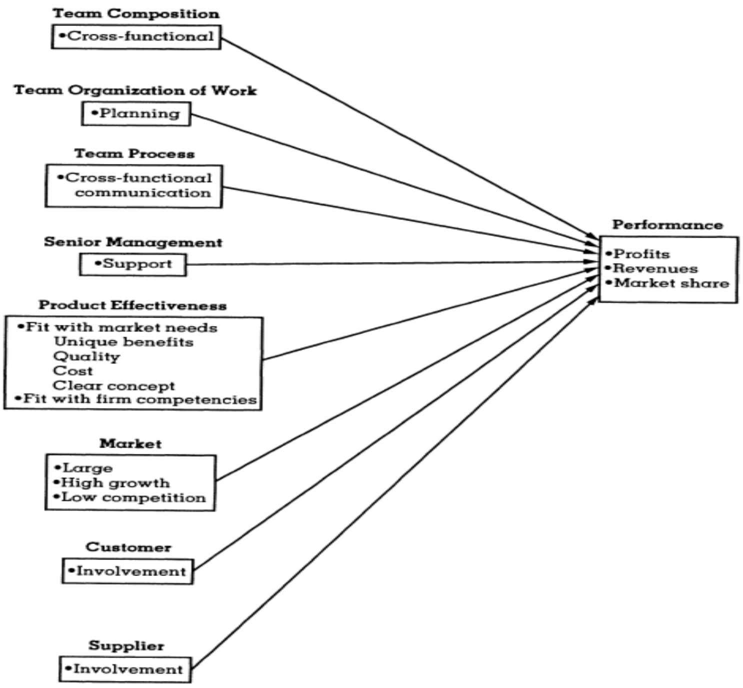

Figure 7. Rational Plan Model of Product Development (Brown and Eisenhardt, 1995)

A second stream of PD research centers on communication is shown in **Figure 8**. This research stream has evolved from the pioneering work of (Allen at MIT, 1977). The fundamental principle is that communication among project team members and with outsiders inspires the performance of development teams. As a result, the better members are related with each other and with key outsiders, the more winning the development process will be. In dissimilarity to the first point of view, this stream is closely focused on one independent variable-communication. Consequently, these work emphasize depth, not breadth as in the rational plan, by looking inside the "black box" of the development team. They harmonize the rational lens by including political and information-processing aspects of product development.

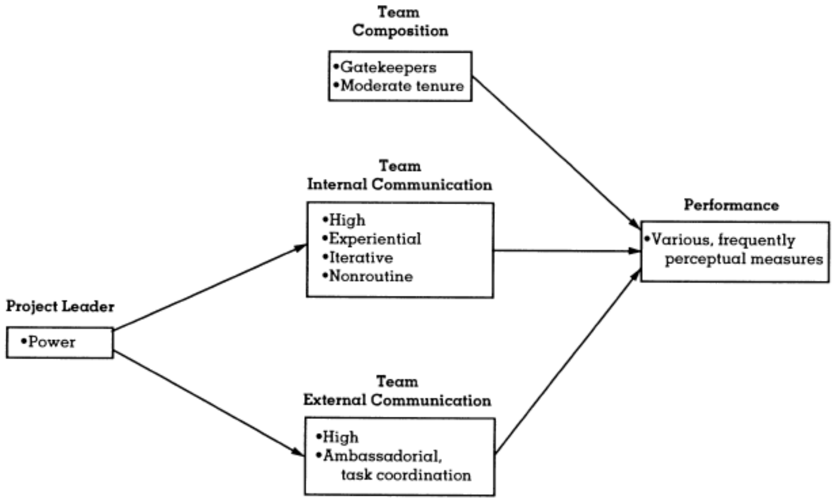

Figure 8. Communication Web Model of Product Development (Brown and Eisenhardt, 1995)

A third flow of study involves the disciplined problem-solving perspective **(Figure 9)**. This stream evolved from researches of Japanese product-development practices in the mid-1980s (e.g., Imai, Ikujiro and Takeuchi, 1985; Quinn and Tully, 1985). In this case, successful product development is perceived as a balancing perform between somewhat independent problem solving by the project team and the discipline of a strong leader, valid top management, and an overarching product vision. The result is a quick, productive development process and a high-quality product concept. This stream of research visualizes successful product development as disciplined problem solving. That is, successful product development involves relatively autonomous problem solving by cross-functional teams with high communication and the organization of work according to the demands of the development task. This point of view also emphasizes the role of project leaders and senior management in giving to problem solving a disciplined product vision. There is an accent on both project and senior management, on the one hand, to supply a vision or discipline to the development efforts and thus, on the other hand, to provide autonomy to the team. Consequently, this stream depicts product development as a balancing act between product vision developed at the executive level and problem solving found at the project level. In contrast to the rational plan stream, this stream is more specific about the effective organization of work and is more focused on the development process and product concept than on the financial success of the product. In contrast to the communication web viewpoint, this stream has a broader scope and considers the role of suppliers and senior management in addition to project leaders and teams.

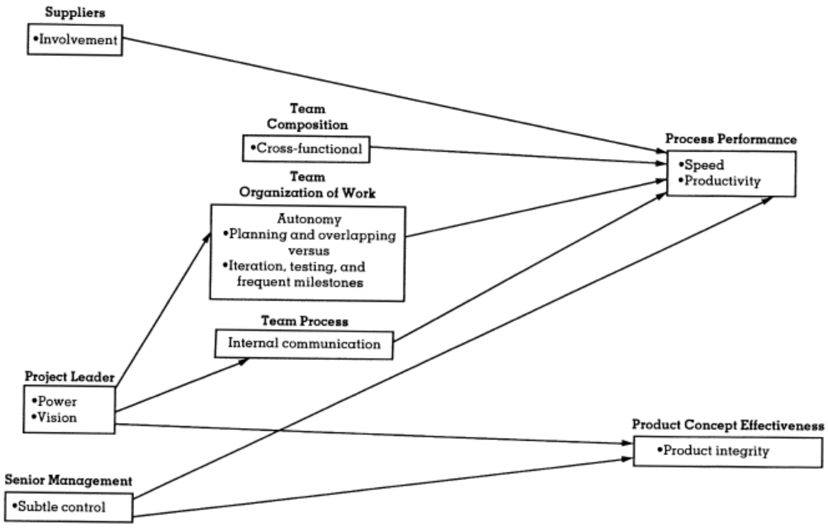

Figure 9. Disciplined Problem-Solving Model of Product Development

Finally, Brown and Eisenhardt combine these three streams of research into a solely model of factors affecting product-development success **(Figure 10)**. The categorizing idea behind the model is that there are numerous players whose actions affect product performances. In particular, it is stated that (a) the project team, leader, senior management, and suppliers influence process performances (i.e., speed and productivity of product development), (b) the project leader, customers, and senior management affect product effectiveness (i.e., the fit of the product with firm competencies and market needs), and (c) the combination of an efficient process, effective product, and generous market structures the financial success of the product (i.e., revenue, profitability, and market share). Underlying these relationships are the theoretical underpinnings that have been recognized from the combined research streams. Therefore, process performances are driven by the quantity, assortment, and problem-solving organization of information and by the resources accessible to the team. Product effectiveness is driven by the input of leaders, senior management, and customers into the formation of a clear product vision (a less well understood process).

Both product effectiveness and process performance influence the financial success of the product.

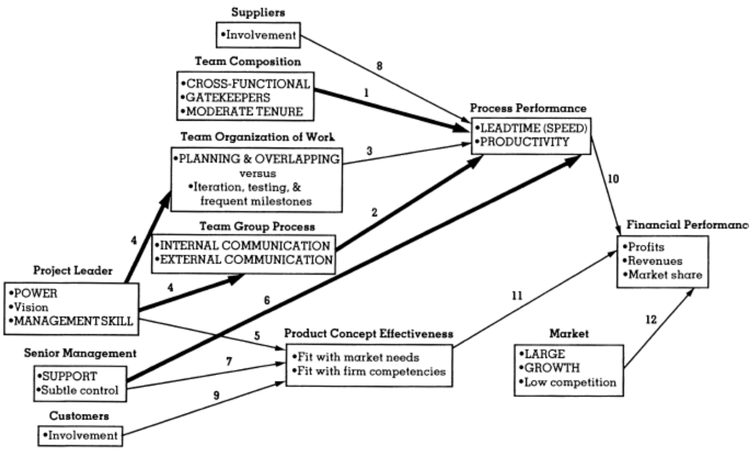

Figure 10. Factors Affecting the Success of Product Development Projects (Brown and Eisenhardt, 1995)

Sharify asserts that product design and development needs to be seen as a collaborative process (Sharify, 2001). In recent years, customers' need for the new product is changing rapidly. This means that companies have to become more agile and response-able in order to address the changing needs of customers and consumers. Therefore, the role of organization of NPD is significant. The new product design and development is no longer an isolated activity undertaken by either one discipline or a single organization. The nature and type of interaction and collaboration between different actors during the product development phase often influences the nature of the final product and its subsequent manufacture. In a global and competitive context many organizations are forced to rethink their approaches to the design and development of new products. There are different ways which organizations can choice regarding the process and extent of collaboration. For example, Lean NPD, Knowledge based NPD. During last years it has been often heard about "lean thinking", "TOYOTA" approach, JIT technique, concurrent engineering, etc. But, what does the word "lean" really mean? We will introduce it in the following section.

2.1.2 Lean Thinking

2.1.2.1 Lean Introduction

Nowadays, the concept of “Lean” is becoming more and more popular, but what the “lean” really is? The following introduction will give you a general idea.

Lean manufacturing, lean enterprise, or lean production, often simply, "lean," is a production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination. Working from the perspective of the customer who consumes a product or service, "value" is defined as any action or process that a customer would be willing to pay for.

(Womack, James, 1990)

Lean Thinking is a business system pioneered by Toyota in the twenty years immediately after World War II and is now rapidly diffusing to every corner of the world (Womack, Jones and Ross, 1990). Lean Thinking proposed an approach to operations management featured by the focus on waste and production excess removal and represented a substitute model to that of capital-intense mass production (Hines and Holweg, 2004).

Before lean manufacturing, mass production system was developed in the early twentieth century and one of its main representatives was Henry Ford. This model, characterized by high skills workers and simple but flexible tools used to meet customer requests, gradually spread and replaced craft production. The mass producer applies to skilled professionals only for the design of products, made by unskilled or semiskilled workers monitoring expensive, single-purpose machines. The high cost of change over cause the production of standardized products at high volume. Moreover, the high cost of machineries and their intolerance to be interrupted drive the mass producer to add many buffers to have a smooth production; that involve extra suppliers, extra workers and extra space. The outcome is that customers get lower costs but at the expense of variety and through work methods that most employees find boring and dispiriting (Womack, Jones and Ross, 1990). Opposed to mass production, in the late 40s, Eiji Toyoda and Taiichi Ohno introduced a different way to do things. Lean Manufacturing is a combination of the advantages of craft and mass production, avoiding the high cost of the former and the rigidity of the latter. Lean producers utilize teams of skilled workers at all levels of the company and highly flexible and increasingly automated machines to produce volumes of products in huge variety. In comparison with mass production, lean manufacturing approach uses less of everything: half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time (Womack, Jones and Ross, 1990).

"Lean" is the soul guiding the whole Toyota Production System (TPS), since 1960s when Eiji Toyoda and Taiichi Ohno started to formally apply it. Thanks to TPS Toyota, which despite 1973 oil crisis increased its earnings, was able to continue increasing its market share and performed better than western competitors. In the last two decades, many researchers have studied TPS and have documented various principles and practices used by Toyota (Womack and Jones; Liker; Sobek, Liker and Ward), the following paragraphs will try to describe these concepts.

2.1.2.2 Lean Five Principles

The core of Lean thinking philosophy is constituted by five principles which are suggested for disposing of waste. Here below a brief description is given:

1. *Specify Value.* Gather the value for the ultimate customer. Provide the costumer with the right product, for the right place, at the right time (Womack and Jones, 1996).
2. *Identify the value stream.* Eliminate all the non-value-added activities, minimize all necessary non-value added ones and make the value added

activities flow (McManus, 2004). Value Stream Mapping can be applied to analyze the process flow.

3. *Make the value flow.* Make the remaining value creating steps flow. The common work organization is distributed by functions and departments; thus it is thought that a greater control and efficiency are achieved. But this structure damages the continuity of flow. Continuous flow is achieved mainly through interventions that enable radical change in a short period of time. To achieve this maybe only some little actions are necessary: for example with small “continuous improvement teams” (kaizen) very good results could be achieved. Also the organization chart should change (Bonfiglioli, 2001).
4. *Let the customer pull the process.* Let the consumer pull the product; design and provide what the customer needs, when he needs it, without relying totally on demand forecasts. Sell one, make one (Womack and Jones, 1996).
5. *Pursue perfection.* Never relax until reaching the perfection, which is the delivery of pure value instantaneously with zero Muda[3] (Soderborg, 2008). There is no end to the process of reducing time, space, cost and mistakes (Womack and Jones, 1996).

2.1.2.3 Lean Wastes

According to Womack and Jones (2004), Lean ideas are the single most powerful tool available for creating value and eliminating waste in any organization (Womack and Jones, 2003). Lean production is the elimination of waste with the goal that all steps in a process add value from the customer’s perspective (Soderborg, 2008).

Taiichi Ohno was the person to enclose the seven common categories of wastes. These categories were later analyzed and acknowledged by Liker (2004).

The seven *waste* categories are (**Figure 11**):

[3] Muda: Muda is a Japanese term for "waste", as used in lean manufacturing and agile software development.

1) Overproduction. *Producing more items than actually required by costumers, these results in wastes such as overstaffing, storage and transportation costs because of excess inventory.*
2) Waiting (time on hand). *Workers just serving to watch an automated machine or having to stand around waiting for the next processing step, tool, supply, part, etc., or simply having no work because of stock-outs, lot processing delays, equipment downtime, and capacity bottlenecks.*
3) Unnecessary transport or conveyance. *Carrying work in process (WIP) long distances, creating inefficient transport, or moving materials, parts, or finished goods into or out of storage or between processes.*
4) Over processing or incorrect processing. *Making unnecessary steps to process the parts. Inefficiently processing due to poor tool and product design, causing unnecessary motion and producing defects. Waste is generated when providing higher-quality products than is necessary.*
5) Excess inventory. *Surplus raw material, WIP, or finished goods causing longer lead times, obsolescence, damaged goods, transportation and storage costs, and delay. Also, extra inventory hides problems such as production imbalances, late deliveries from suppliers, defects, equipment downtime, and long setup times.*
6) Unnecessary movement. *Any wasted motion employees have to perform during the course of their work, such as looking for, reaching for, or stacking parts, tools, etc. Also, walking is waste.*
7) Defects. *Production of defective parts or correction. Repair or rework, scrap, replacement production, and inspection mean wasteful handling, time, and effort (Liker, 2004).*

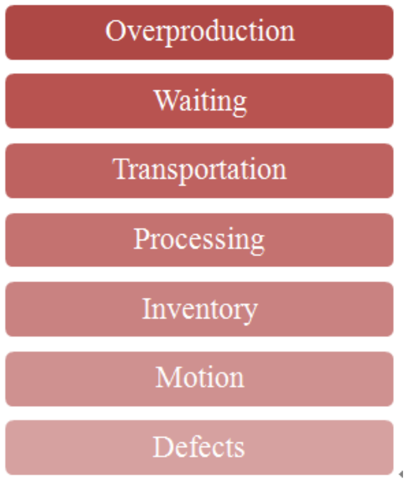

Figure 11. The Seven Wastes (Liker, 2004)

In addition to the original Taiichi Ohno's categories of waste, Liker, Womack and Jones added the eighth waste category.

The eight waste added by Liker is "Unused employee creativity". It refers to the losing time, ideas, skills, improvements, and learning opportunities by not engaging or listening to the employees (Liker, 2004). Womack and Jones, proposed the eighth waste as "good and services that do not meet the costumer's needs" (Womack and Jones, 2003).

Using lean thinking and principles analysis means to identify value added activities and eliminate those activities that fall in the categories of waste. Liker (2004) classifies all work activities into 3 groups:

- Value added activities. All the activities identified during the process that: transform information, material or reduce uncertainty; the customer wants to pay for; are done right the first time.
- Required non-value-added activities. They don't have the features of a value-added-activity, but they cannot be eliminated because of law requirements, company mandate, current technology, current process or other compelling reasons.
- Non-value-added activities. Activities directly ascribable to one of the waste category (pure waste).

Figure 12 illustrates a practical example; it shows that a large part of time is spent on non-value-added activities. Moreover, **Figure 12** shows a visual idea of the process as a flow of material, from raw components to finished parts and a flow of the processes needed to realize them.

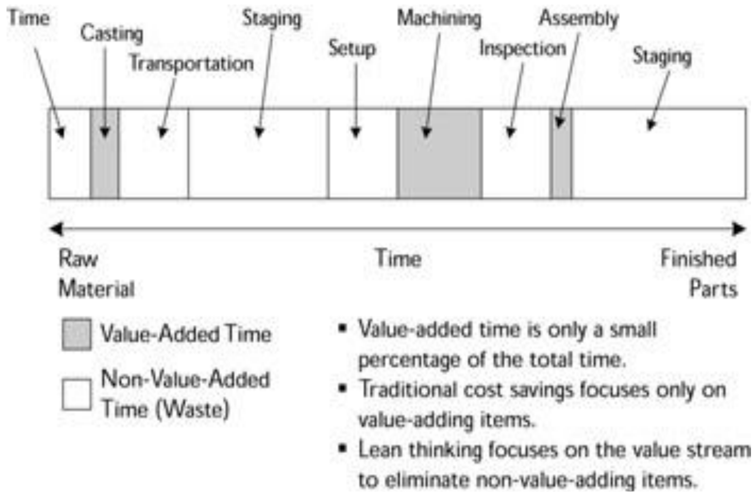

Figure 12. Waste in a Value Stream (Liker, 2004)

Customers only care about value-added activities and they do not want to pay for the non-value added activities. Also for the producer eliminating the non-value added activities can reduce the cost which will make the product more competitive.

To accomplish goals expressed by lean principles and eliminate lean wastes, a set of specific tools and techniques are introduced which will be described on the paragraph below.

2.1.2.4 Lean Tools and Techniques

In this section, a set of lean tools and techniques will be introduced; companies can implement them (or some of them) in order to accomplish the objectives made by lean principles and eliminate wastes.

The most common tools are shown below:

- *Continuous improvement/kaizen*. It refers to activities that continually improve all functions of a business, from manufacturing to management and from the CEO to the assembly line workers. By improving standardized activities and processes, Kaizen aims to eliminate waste; it is a fundamental tool to pursue continuous improvement.

- *Group technology or Cellular Manufacturing (CM).* A production which is focused on a component or on a product part allows to reduce transport, waiting and process time. The main objective in the design of a CM is to create machine cells, identify part families, and allocate part families to machine cells so that the inter-cellular movement of parts families is minimized (Heragu, 1994).
- *Kanban*. It is a Japanese word meaning “visible sign". It enables to synchronize product flow among cells through a label system that authorizes withdraw and production.
- *Labour balancing*. It is a tool to control that it is being produced only what is asked for. Production smoothing and Takt Analysis are useful in order to obtain a good trade-off between throughput time in the cell and delivery time of the product. Takt time is substantially the production rhythm (Net available time to work/ Total demand) and production flow should be follow it because takt time represents the maximum time available to produce a piece in order to satisfy the demand.
- *Single Minute Exchange of Dies (SMED).* The SMED application consists in identifying and separating external setup elements from internal ones, shifting external elements to external elements, preparing and implementing improvement projects for conversion simplification of both internal and external elements (Agustin and Santiago, 1996).
- *Step change/kaikaku*. It removes every activity that is classified as a waste and defines targets for improvement and whenever it’s possible for elimination of necessary non-value-added activities (Reeb and Leavengood, 2010).
- *Poka-yoke*. Poka-yoke literally means “mistake proofing.” Poka-yoke devices can perform three useful operations in defect prevention. These operations are as follows: warning, control and shut down (Bayers, 1994). This method aims to get a zero-defects process and eliminate quality inspections.

- *Supplier development*. Organization need to actively develop links with suppliers and working closely with them for mutual benefit as intimated by Bicheno (1999) and Henderson et al. (1999).
- *Supplier base reduction*. Further attempting to reduce the number of suppliers with which a company is committing, with the aim of having few close relationships and long lasting suppliers.
- *Value Stream Mapping (VSM).* VSM is a tool to support Value Stream Analysis (VSA). VSA is a method for examining a process according to the lean principles. In particular McManus and Millard (2002) define VSA as "a method by which managers and engineers seek to increase the understanding of their company's development efforts for the sake of improving such efforts". VSM thus can be simply stated as the method by which the outcomes of Value Stream Analysis are depicted or illustrated. In fact, it allows describing a highly complex real system in a less complex 2D format. This simplification of the system facilitates insight and understanding and provides a common language of communication for the insight. There are two tasks for VAM. First, mapping the current state of the material flow and information flow of a process and applying lean tools and techniques to obtain an improved future state vision of it. To develop the future state, non-value-added activities are identified and lean tools are applied to eliminate these activities that are pure waste and improve that which do not add value but are necessary (McManus and Millard, 2002). It will be applied in **Chapter 5**.
- *Total Productive Maintenance (TPM).* This is aimed at improving the reliability, consistency and capacity of machines through maintenance regimes as dwelled on originally by Ohno (1988).

From the above literature review, we get a general idea of lean thinking, wastes, principles, tools and techniques, how can we use these into new product development. In next section the application of lean in the real practice and how lean works in the new product development will be introduced.

2.1.3 Lean New Product Development

2.1.3.1 Introduction to Lean New Product Development

Each product goes through a life cycle that includes several phases, from the market introduction, to the growth, and maturity, until decline. Nowadays, this cycle is becoming shorter and shorter because customers ask for new products more and more innovative and efficient. To meet this market need the companies have to focus on the new product development. Companies try to optimize the process as much as possible, by making it quick, efficient and effective. However, only few companies lead the new product development process well. Among them, Toyota is the most famous and successful one without doubt. One explanation for the success of Toyota is their ability to bring products to market faster and with less effort than their Western competitors (Clark, Kim B., Chew, W. Bruce and Fujimoto, Takahiro, 1987). In fact, there is much more opportunity for competitive advantage in product development than anywhere else (Morgan and Liker, 2006). In the book The Toyota Production Development System, Morgan and Liker (2006) explain that in today's competitive market, excellence in new product development is rapidly becoming more of a strategic differentiator than manufacturing capability. There are two reasons justifying this sentence. First, whereas the performance gap in manufacturing is closing, the gap between best-in-class and the rest of the automobile industry in product development is increasing. Secondly, as Toyota has clearly demonstrated, manufacturing capability to impact vehicle sales performance is inherently limited. While a strong manufacturing system can affect quality and productivity, the ability to impact customer-defined value as well as vehicle investment and variable cost is clearly much greater early in the product's development process and decreases as the development program proceeds toward launch. Furthermore, manufacturing has little role in the initial selection of component suppliers, that has a huge impact on overall vehicle cost and quality. Today lean manufacturing is no longer the exclusive competitive advantage of organizations: in the automobile industry, the number of vehicle models available to North American consumers has increased dramatically. Conversely, then number of unique vehicle platforms has decreased substantially. Consequently, to be successful and remain competitive, automakers must now offer a much wider variety of vehicles and introduce new vehicles more often while using fewer platforms (Liker, 2006). According to a Merrill Lynch (2005) analysis in the automotive industry, new model introductions over the last five years have grown at a tremendous pace, with more than 60 new vehicles being introduced each year in the United States between 2003 and 2005. Dealing with this trend, many industries have been moving to platform engineering. For example, Intel recently made this a strategic priority, moving to platform of integrated chip sets to provide for different customer segment.

It can be easily derived that developing new products faster than competitors do is a formidable strategic weapon to succeed in increasingly turbulent markets. Although the techniques used to accomplish such high product development performance have existed for some time, they were later drawn together under a common heading: the concept of Lean product development.

In facts, most of companies still make use of traditional approach to Product Development. The traditional launch strategy is forecast driven and is based on anticipatory logistics (push), as is shown on the **Figure 13** bellowing.

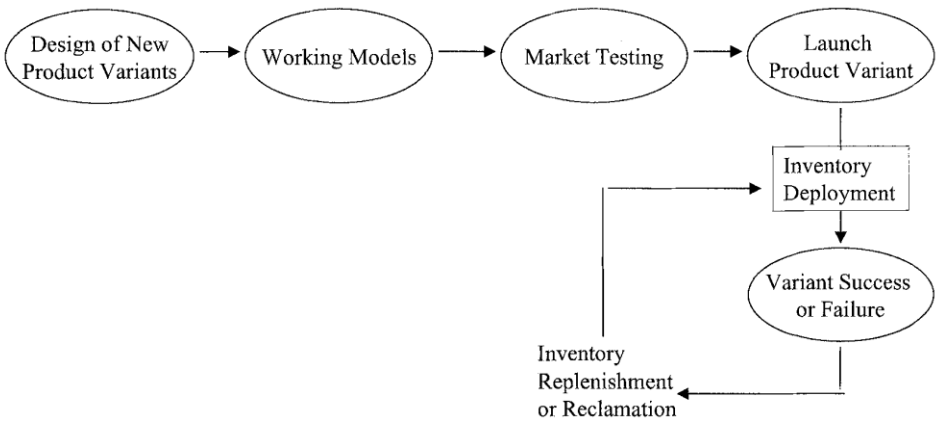

Figure 13. Traditional new product development process (Bowersox, Stank, Daugherty, 1999)

However, the lean new product development strategy is based on response-based logistics (pull) and supply management. **Figure 14** shows it.

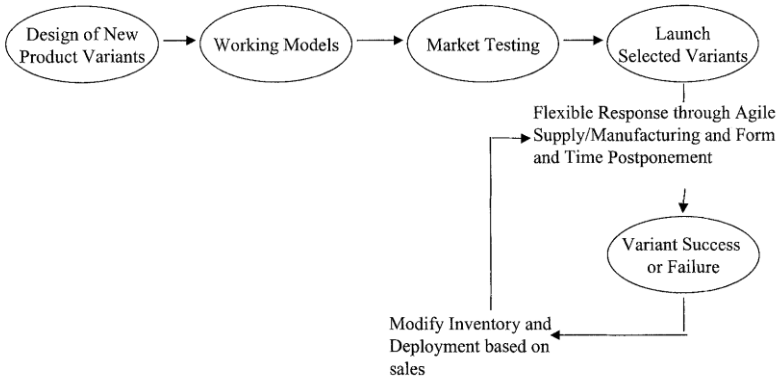

Figure 14. New product development process with lean launch (Bowersox, Stank, Daugherty, 1999)

The application of lean in New Product Development processes can lead to great advantages, some of them are given below:

- *Enabling the company to develop products faster and with fewer engineering hours than the competitors.*
- *Manufacturability of products improvement, thanks to the emphasis on collaboration between different areas within the company.*
- *Production start up difficulties prevention, thanks to a conscious effort to use quality as a guiding principle through the whole development.*
- *Increase of technological sophistication of products and development process acceleration, due to the extensive use of suppliers as expert developers (Karlsson and Åhlström, 1996).*

The Lean Aerospace Initiative (LAI)[4] gave one of the definitions of Lean New Product Development which indicates that Lean Product Development has three objectives, each one referring to a specific area of improvement:

- *Creating the right products.* That means creating product architectures, families, and designs that increase value for all enterprise stakeholders.

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[4] Lean Aerospace Initiative (LAI): LAI is a national consortium of Industry, Government, Labor and Academia, formed in 1993 whit the aim to help the acceleration of aerospace lean transformation.

- *With effective lifecycle and enterprise integration.* Using lean engineering to create value throughout the product lifecycle and the enterprise.
- *Using efficient engineering processes.* Applying lean thinking to eliminate wastes and improve cycle time and quality in engineering (McManus, Huggerty and Murman, 2007).

For conducting the lean product development process, a series of tools, principles and methods are applied. Among them, set-based concurrent engineering is wide used technique and is verified by the success of Toyota's application of this method, on the following section, we will introduce set-based concurrent engineering to you in detail.

2.1.3.2 Set-Based Concurrent Engineering and Lean New Product Development

Concurrent Engineering is a systematic approach to the integrated concurrent design of products and their related processes including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life from conception through disposal including quality, cost, schedule and user requirement.(Winner et al. 1988)

Institute of Defence Analysis Techniques such as Concurrent Engineering (CE) have been implemented and have been quite successful in improving NPD in terms of time, cost, quality, or a combination of these three; key features of concurrency which strongly relate it to NPD are the parallel scheduling of design and development activities and project-oriented organizational structures with strong cross-functional co-ordination (Abetti, 1994; Galbraith and Kazanjian, 1986). But CE is a much broader concept, developed in Western product development environments that encompass all functions in the product development life cycle, not just engineering (Fleischer and Liker, 1997).

Set-Based Concurrent Engineering (SBCE) proposes several different feasible solutions at the same time based on the concurrent engineering concept, we can analyze and select the most suitable solution according to the situation. SBCE was created by Toyota, and it is referred as well as "The second Toyota paradox" following the first paradox which is its production system, that includes delivering just-in-time (Ward, Liker, Cristiano, & Sobeck, 1995). It is a technique used by Toyota engineers for the design of a new product, which is different from traditional American way, decisions about details on the designs are delayed as much as possible while several possible solutions are explored (Ward, Liker, Cristiano & Sobeck, 1995). Kennedy (2003) and Sobek (1999) point out that in the Toyota approach of set-based design, the key feature is that all of the knowledge (including knowledge of what did not work) is captured and may be reused in future projects. It can be easily derived that applying Set-Based Concurrent Engineering with parallel evaluation of multiple subsystem alternatives and minimal design constraints is an effective base for lean product development (Baines, 2006).

The differences between CE and SBCE is: CE focuses on improving integration of development functions, using a number of formal tools and organizational mechanisms, to improve the quality, cost, and delivery; nevertheless working with concurrent activities and thus overlapping phases in a development effort is a very intricate matter (Karlsson, 1996). While with a set-based approach, designs converge rather than evolve. Sets of possibilities are communicated, thus instead of carrying out a series of meetings in which a design is critiqued and modified several times as done in point-based design; designers, manufacturing representatives, supplier representatives, etc., bring to the table sets of possibilities and compare them to find intersections of feasibility. In the case of set-based approach, truly parallel design work is possible since decisions downstream are always compatible with those upstream. Trade-offs between alternatives from all functional perspectives is given greater consideration, and they are heard early in the process where decisions have the greatest impact. The process can be much quicker, and requires less frequent and prolonged communication, and less attention to design process structure (Jeffrey K. Liker, 1996). SBCE casts a wider net at the start, and then more gradually eliminates weaker solutions. Design participants develop sets of solutions in parallel and relatively independently. As the design process progresses, they gradually narrow their respective sets of solutions based on additional feedback from product and manufacturing engineers, testing, customers, and others (Bernstein, 1998). The example given below (**Figure 15**) illustrates the key characteristics of SBCE (Set-based Concurrent Engineering).

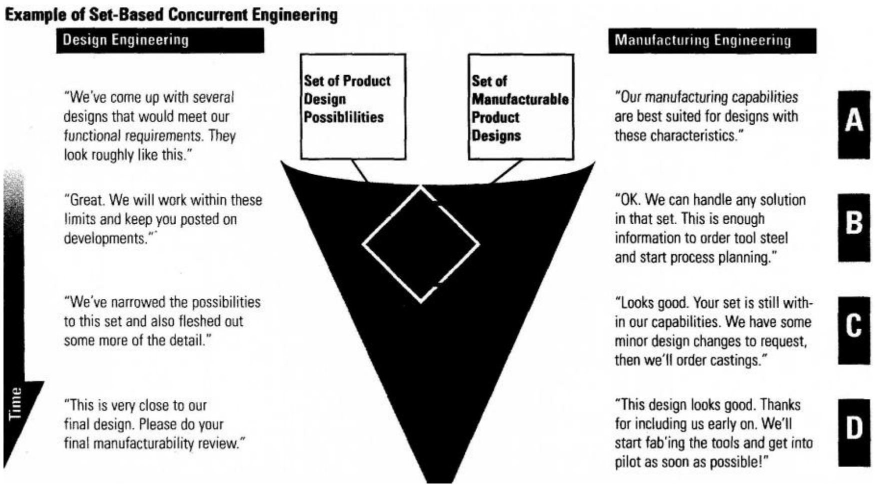


Figure 15. Example of Set-based Concurrent Engineering (Sobek, Liker and Ward 1998)

After knowing one of the most effective and useful lean product development techniques-SBCE, we will introduce another important topic "Lean Principles Application in NPD", which are also critical for the success of the NPD.

2.1.3.3 Lean Principles Application in NPD

The literature shows that the application of Lean principles to New Product Development is possible. Morgan and Liker (2006) think that lean manufacturing can be described as a set of tools that eliminates waste and creates flow of materials through a transformation process. Lean product development can be easily described in the same way, underling furthermore three elements: value, flow and conversion. Moreover, both lean manufacturing and lean product development are based on the importance of appropriately integrating people, processes, tools and technology to add value to the customer. However, McManus, Haggerty and Murman (2007) point out that the product development process relies on information rather than on physical material, its output is the specification of a product and not the product itself. Most product development processes act on a mix of jobs, of greater or lesser difficulty or complication. Javier and Alarcón (2002) also state that the process of product development can be conceptualized as a flow of information, as shown on **Figure 16** below; the principle of waste elimination translated into the design process lends to waste reduction through minimizing the amount of time before information is used. Value generation arises from capturing the customer's requirements and transmitting these accurately in the overall design process. The relationship between these two perspectives is to make the value flow.

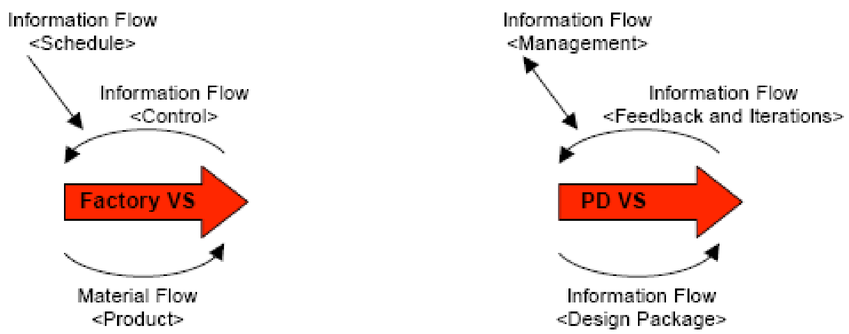


Figure 16. Material and Information Flow (Rother and Shook, 1999)

Figure 17 shows the comparison between traditional method and after applying lean to engineering processes. We can see from the figure that after application lean principles into engineering, the cycle time and standard deviation of the time are both reduced remarkably.

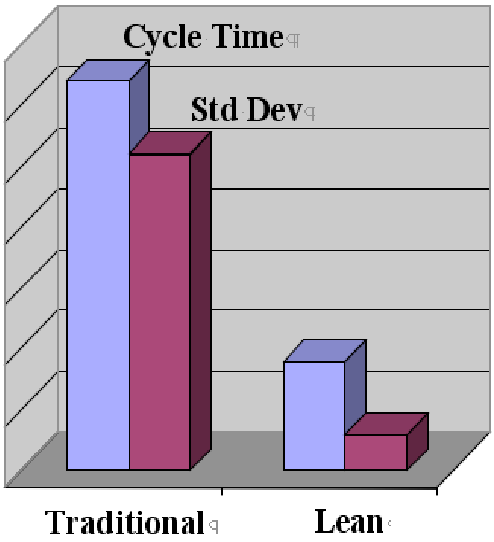


Figure 17. Results of Applying Lean to Engineering Processes (McManus, 2005)

Based on the work done before, McManus (2005) introduced the five lean principles to New Product Development, as is shown on the **table 3** below.

Table 3. Applying the lean five steps to engineering (McManus, 2005)

	Manufacturing	Product Development
Value	Visible at each step, defined goal Harder to see, emergent goals	Harder to see, emergent goals
Value Stream	Parts and material	Information and knowledge
Flow	Iterations are waste	Planned iterations must be efficient
Pull	Driven by takt time	Driven by needs of enterprise
Perfection	Process repeatable without errors	Process enables enterprise improvement

- Value. Especially if the process is underway, is harder to see, and the definition of value added is more complex (McManus, Haggerty and Murman, 2007). The typical value proposition for NPD is the ability to perform error-free and cost-effective production of the product satisfying the needs of the customer (Oppenheim, 2004).
- Value stream. Consists of information and knowledge, not as the easy-to-track material flows of the factory. Due to uncertainties or interdependencies the flow may be branched or iterated, anyway this can be beneficial, as opposed to production flow.

- Flow. Seamless movement through value-creating steps (Womack and Jones, 1996). As already mentioned, the key product of NPD activities is information. To implement the principle of 'flow' in NPD, an organization should be able to control information flow. The aim should be to reduce delay, to encourage process information in parallel wherever possible, to continuously add information value as activities progress from one to another, and eliminate non-value added information. To satisfy the "flow of value" principle, process and organization structures should focus on improving integration of NPD functions. Pull. Acting only to satisfy customer needs, rather than forcing, or pushing, a product upon the marketplace (Womack and Jones, 1996). According to Haque and Moore (2004), to achieve this, the essential is the control on the information coming on downstream and on the customer, too. Moreover the program plan (including resource plan, communication plan, work breakdown structures, and organization breakdown structure) should be managed by a strong leader and developed with the involvement of all the teams that are critical to the milestones achievement. In so doing, upstream activities should produce and decide only that information that is requested by downstream.
- Perfection. It is very hard to reach, as simply doing the process very fast and perfectly with minimal resource used; efficient product development process is simply an enabler of better enterprise performance and better products.

All the listed principles include some common factors in the achievement of their purpose: the presence of a project manager and team working, an accurate management of the flow of information and the use of technology as an enabler. In order to realize these purposes, we need supporting tools and techniques to help us. In the next section, we will introduce you some lean tools and techniques which are also named "lean enablers".

2.1.3.4 Lean Enablers for Lean NPD

Developing new products faster, cheaper and with higher quality require applying some technique (Karlsson & Ahlstrom, 1996). In fact, implementing the lean five principles is not enough for having a lean product development process; there are several tools that a company should put into practice as well. These tools are called Lean Enablers since they facilitate the implementation of lean thinking. It must be noted that in this case the term “enablers” implies tools, methodologies, logical path, processes, principles, and so on. A brief description of the most famous ones is provided below.

- **LAMDA.** It is a description of Toyotas learning cycle that takes place within the PDCA (plan-do-check-action) cycle. The five steps are:
  - Look: Go see for yourself.
  - Ask: Get to the root cause of the problem.
  - Model: Use some kind of analysis simulation or prototypes.
  - Discuss: Communicate with mentors, developers of interfacing subsystems, etc.
  - Act: Test your understanding experimentally.

The foundation on which LAMDA stands is the first two letters; look and ask. According to Kennedy (2008), the idea of going to the source of the problem, and thoroughly investigate it before starting to think of a solution is not being practiced to a satisfactory extent in western industry (Kennedy, 2008).

- **A3-Reports.** If LAMDA is the learning process, the A3 reports are its documentation. It is a powerful tool and establishes a concrete structure to the implementation of Toyota management system (Sobek and Smalley, 2008). The purpose of the reports is to get a short summary of the problem which offers a more visual presentation that easily can be used for communication and knowledge transfer rather than a large report where the most important points can be lost in the large amount of information. It is worth noticing that the most important is that the information is presented in a condensed and visual way. They are so called because information is disclosed on an A3 sheet.

Toyota has developed four minor variations of A3 reports for different applications (Liker and Morgan, 2006):

- Proposal: This kind of A3 has a theme, used when a new project of some kind is at hand. It normally contains an introduction to the opportunity, a proposal of how to use it and a schedule of when to do it.
- Status: This report presents the status of a project. It gives the objectives of the project and how it is currently doing according to the time plan in critical areas. It brings up the problems left to resolve and what the future plans are.
- Informational: These reports are used to share information of some kind, for example about competitors or suppliers. At Toyota, this is the only A3-report that is not fully standardized; it is left to the writer to form the structure.
- Problem-solving: Toyota uses Deming's PDCA-cycle throughout the company, and in this kind of report, the cycle is always the heart. It contains a systematic description of the problem, a detailed root-cause analysis, what the countermeasures are and how they should be implemented.

➢ **Team Integration.** This is a complementary concept to the cross-functional team one. It is a focus on integration of activities instead of co-ordination. An integrated team will achieve improvements in performance by developing the right culture and adopting the behaviors needed to support and reinforce that culture. This in turn leads to the eliminations of waste, duplication and unnecessary processes and procedures. The team is integrated as a result of the physical proximity that arises when individuals are working together in developing a new product.

- **Visual planning.** It is a tool to represent projects, problems and any other issue. It provides a physical representation of the problem, usually by a large billboard and several post-it attached to it. The goal is to have the whole problem exposed in a unique place with a logical illustration of the actions to be carried out, the people involved and the time line. It provides a global and immediate vision of the project status and evolution.
- **Obeya Room.** It is a room where cross functional teams visualize knowledge through A3-reports or other visual presentation posted over the wall, analyze progress and get an overall view of the status of the project.
- **Quality Function Deployment (QFD).** QFD, originally developed in Japan, is a systematic approach to design based on a close awareness of customer desires, coupled with the integration of corporate functional groups. It consists in translating customer desires into design characteristics for each stage of the product development (Rosenthal, 1992). It is a set of planning and communication routines, that focuses and coordinates skills within an organization, first to design, than to manufacture and market, goods that costumers want to purchase and will continue to acquire. The foundation of QFD is the belief that products should be designed to reflect customers' desires and tastes; for this purpose, marketing people, design engineers and manufacturing staff must work closely together from the product conception (Hauser and Clausing, 1988). QFD involves the conversion of the "voice of customer" into a set of characteristics which the organization can use to assign priorities and make objective trade-off decisions. Generally the requirements are weight in terms of their relative importance from a customer's perspectives. Once this has done, the team needs to identify the engineering attributes that drive the performance of the product. Below (**Figure 18**) is an example of the application of QFD method for customized toys which follows 7 steps:

    1) Identify customer needs

    2) Define the priorities of the needs

3) Translate customer needs into technical requirements

4) Relate the customer needs to the technical requirements

5) Define interrelationships between the technical requirements

6) Conduct an evaluation of the competitors' products or services

7) Select critical technical requirements to be deployed in the design and pro duction process

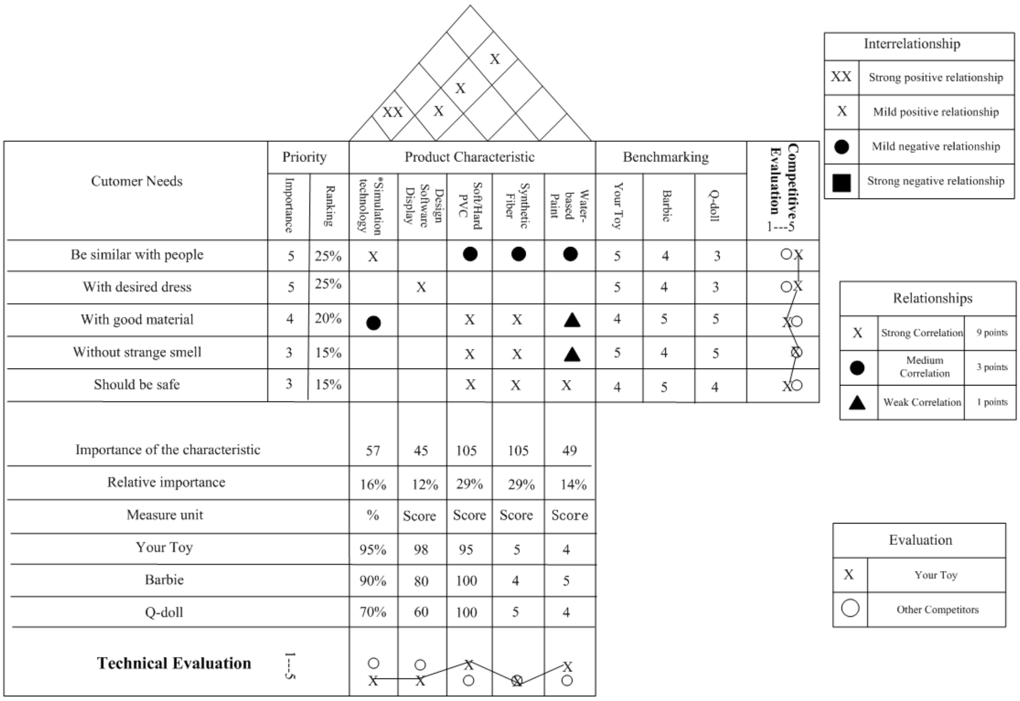


Figure 18. Example of QFD

- **Design for X.** Design for X method integrates manufacturing considerations into the design process. This practice was inspired by the successful Design for Assembly (DFA). As time went by, more and more researches recognized that not only assembly and manufacturing constraints, but also other life-cycle issues such as disassembly, recyclability, etc. concerns need to be considered during the design process. Therefore, there are many applications of these approach, all grouped under the general name of Design For-X (Kuo, Huang and Zhang, 2001). Such as the following ones.
  - **Design for Assembly (DFA).** It is based on the premise that the lowest assembly cost can be achieved by designing a product in such a way that it

can be economically assembled by the most appropriate assembly system. Therefore, during the design phase must be considered the two main elements that affect assembly costs: the total number of parts and the ease of handling, insertion and fastening of the part. So in the DFA method, the basic alternatives for the designer to reduce the cost of assembly are either to avoid certain operations altogether or to simplify them. Although various DFA approaches have been developed since the late 1970s, the basic guidelines remain the same: to reduce the number of parts and ensure the ease of assembly.

- **Design for manufacturing (DFM).** It refers to the selection of appropriate processes for the manufacture of a particular part based upon the matching of the required attributes of the part and various process capabilities. It concerns raw material and process selection, modular design, standard component usage, multi-use part development and others. These applications can be efficiently carried out through CAD/CAM systems, that are equipped with an integrated cost estimation function.
- **Design for quality.** Since neither inspection and statistical quality control can offset poor design, it’s better already in product design phase to take account of the quality aspect. This can be done designing a product to meet customer requirements, designing a robust product that can counter or minimize the effects of potential variation in manufacture of the product and the product’s environment and continuously improving product reliability, performance and technology to exceed costumer expectation and offer supervisor value.

- **CAD/CAM technologies:** CAD means computer aided design, which is a kind of computerized data bases and facilitates the standardization of parts. In this way it helps to minimize the variety of fittings, thereby reducing design time and manufacturing complexity. CAM, computer aided manufacturing, it enhances accuracy, reliability, and efficiency, and allows the automation of ancillary tasks such as materials handling and tube cutting and debarring.

- **Six Sigma.** It is an organized and systematic method for strategic process improvement and new product and service development that relies on statistical methods and scientific method to make dramatic reductions in customer defined defect rates (Linderman, Schroeder, Zaheer and Choo, 2003). This technique arose in Motorola, is characterized by rigorous measurement and control and is focused on systematic reduction of process variability from all sources of variation: machines, methods, materials, measurements, people, and the environment (Murman et al. 2002). Six sigma aims to attain predictable, repeatable and proficient processes and defect free production, through a rigorous data collection, use of statistical analysis and depth management training (Oppenheim, Murman and Secor, 2010).
- **Chief Engineer**: The Chief Engineer (CE) listens to the customer and then determines what functions need to do to address the customer's desires, so this role is probably the most critical one in the company. The chief engineer (CE) at Toyota has a significant role in the development. And usually they have strong technical skills that enable them to effectively lead and coordinate the technical work of engineers, designers, and other developers assigned to their projects. Their most important responsibility is to integrate the work of the development team around a coherent and compelling vision for the product.

From the previous description, we already know that new product development is no longer a standalone activity undertaken by a single discipline or a single organization. NPD contains amount of activities and need cooperation among different departments. The very beginning processes of NPD such as idea generation, product definition and project evaluation are essential for the success of NPD as it can affect the whole process. In the next paragraph, we will go deep into predevelopment processes analysis, which is also called Front End.

2.2 Lean Front End

2.2.1 The concept of Fuzzy Front End

(1) Introduction of Front End

In literature, Front End can also be called Front Loading or 0 stage. It will be called FFE in this research. During the FFE an organization formulates a product concept and determines whether or not it should invest resources to develop the idea (Moenart, 1995). Murphy and Kumar (1997) define the predevelopment stages as consisting of idea generation, product definition and project evaluation. Khurana and Rosenthal (1998) note that the FFE includes product strategy formulation and communication, opportunity identification and assessment, idea generation, product definition, project planning and early executive reviews, which typically precede detailed design and development of a new product.

Some scholars also think that the FFE begins when an opportunity is first considered worthy of further ideation, exploration, and assessment and ends when a firm decides to invest in the idea, commit significant resources to its development, and launch the project (Cooper 1993; Khurana and Rosenthal, 1998; Smith and Reinertsen, 1992). Jetter(2010) reports that uncertainties concerning the market, technology, environment, and resources are inevitable during the generation of new ideas, and only when the level of uncertainty is below a threshold value, the go/no-go decision can then be finalized.

Finally, Zhang and Doll (2001) reveal that uncertainties arise from customer requirements, competition, and changing technology; and the fuzziness involved in the FE is explained as follows (Zhang and Doll 2001):

- Customer: the fuzziness of product portfolio, requirements, demand quantity, and life cycle;
- Technology: the fuzziness of supply, specification and materials;

- Competition: the fuzziness of product development and technology adopted by competitors.

As we can see there is no widely accepted definition of the Fuzzy Front End, but from all of those definitions from the scholars, we can catch some key workds like "uncertainty", "early stage" and "idea development". Also some scholars defined the FFE by phases. For example:

The Fuzzy Front End is defined by all activities that precede the more formal and well-structured NPD process (Koen et al.2002). It concerns the stages from Opportunity Identification to Concept Definition, under conditions of high market and/or technological uncertainties and low availability of valuable information. As is shown in **Figure 19**.

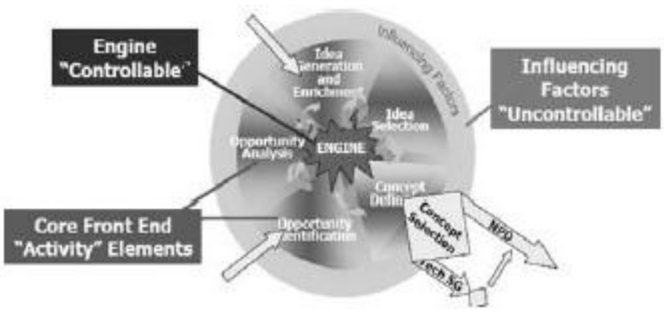


Figure 19. The new concept development(NCD) model(Koen et al.2002)

The FFE activities include pre-phase zero (idea generation), phase zero (assessment of market, technology and competition) and phase one (product definition, project justification and action plan) of phase review or stage-gate system (Cooper, 1997; Khurana and Rosenthal, 1998; Moenaert et al., 1995).

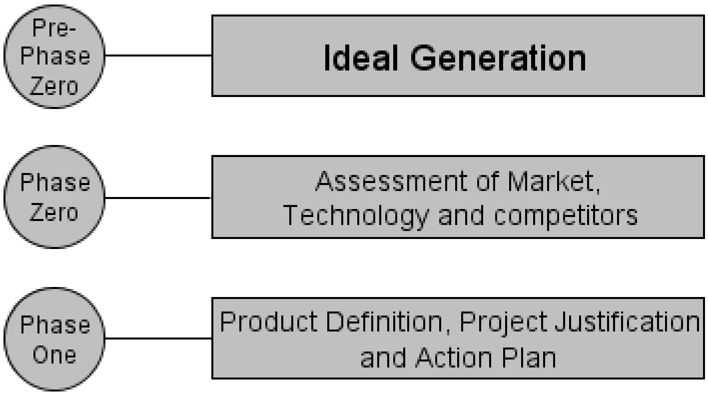


Figure 20. The phases of FFE activities

While Griffin (1997) divides the predevelopment phase by the “concept generation stage”; which begins when the idea for the product first surfaces and the “project evaluation stage”; which starts when the product strategy and target market have been approved and the project has been given a “go” to develop specifications.

(2) The Importance of FE

Past research has found that NPD activities carried out at the fuzzy front end of the NPD process were among the most important new product success factors for a wide range of products (Cooper and de Brentani, 1991; Moore, 1987; Rosenbaum, 1992). The importance of the FFE lies in the fact that effectively performing front end activities can contribute directly to the success of a new product (Cooper, 1988; Dwyer and Mellor, 1991). The FFE also is a "place" where one can find several low cost opportunities to achieve large improvements in time-to-market (Smith and Reinertsen, 1998).

As already highlighted at the beginning, the fuzzy-front-end of the NPD process is very important for the success of new products, it is at the same time highly uncertain (Herstatt et al., 2004). Past research has already suggested various ways of reducing some of the uncertainties associated with the fuzzy-front-end of the NPD process. However, difficulties occur in studying the FFE as it is dynamic, often unstructured, and has traditionally been characterized by low levels of formalization (Murphy and Kumar, 1997). Many firms acknowledge a serious weakness in the predevelopment steps of their product innovation process (Khurana and Rosenthal, 1997).

(3) The structure of Front End

According to the literature, it is said that every NPD process has a FE in which products and projects are defined. However, the ways product ideas are generated, developed, and assessed varies greatly (Koen et al.2002).

In view of this fact, a need emerges to move from a sequential process model to a non-sequential relationship model (Koen et al.2002) and with it the need for tools to help structuring and decision-making.

2.2.2 Models for Front End

In this research several mostly cited FE models are introduced.

Clark and Wheelwright Model

The Clark and Wheelwright model (Clark, Wheelwright, 1992) shows four front-end activities: Technology Assessment and Forecasting, Market Assessment and Forecasting, Development of Goals and Objectives and the Aggregate Project Plan. The first three activities involve the identification of product opportunities at the front-end; therefore. However, the concept generation and project selection components are only partially fulfilled by the Aggregated Project Plan.

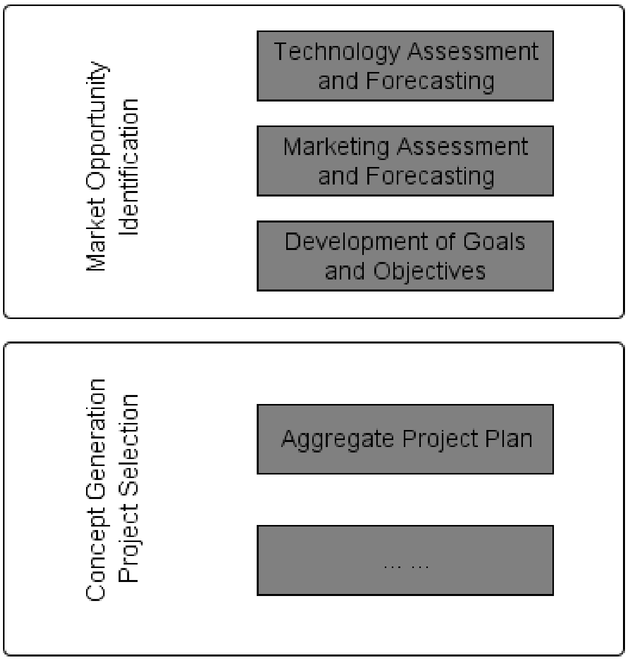


Figure 21. *Clark and Wheelwright Model*

Cooper Model

In a glossary of PDMA (Product Development and Management Association,2006) , it is declared that the Fuzzy Front End commonly consists of three tasks: strategic planning, concept generation, and especially, pre-technical evaluation. This definition derives from an old conception about this topic that was first popularized by Smith and Reinertsen (1991) and Cooper (1988). They explain the first phases of NPPD as a four step process in which ideas are created (I), subjected to a preliminary technical and market evaluation (II) and combined into rational and logical product concepts (III) which are lastly valuated for their strength with existing product strategies and portfolios (IV). Then, in 1995, Cooper and Kleinschmidt proposed their representation.

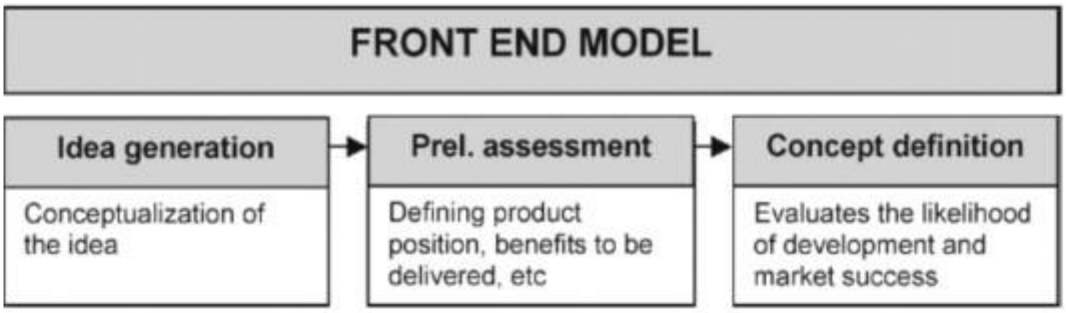


Figure 22. Predevelopment activities according to Cooper and Kleinschmidt(1995)

The Cooper model considers a front-end comprising three activities: Discovery, Scoping and Build Business Case; and three gates: Idea Screen, Second Screen and Go To Development. The identification of product opportunities is supported by the Discovery activity, the Concept Generation by Scoping and Build Business Case, and lastly, Project Selection is provided by the Gates. Hence, this model is a good front-end reference model. The only characteristic that makes this model less advantageous is the low level of details in some activities and the lack of tools and examples, which would better support its application.

The model of Koen et al

The model proposed by Koen et al. suggests five front-end activities: Opportunity Identification, Opportunity Analysis, Idea Generation and Enrichment, Idea Selection and Concept Definition (Koen et al, 2001). This model adopts a new organizational structure among its activities, including that the front-end is a flexible process. The first and second activities support product opportunity identification and the next three represent the concept generation. The last component, which is the project selection, is not clearly presented in this proposal. Nevertheless, it is considered during the execution of idea selection and concept definition activities, but it is not described sufficiently to support front-end development. Regarding its explanation, some detailed information and examples of tools are missing from this model, which may make it difficult to use as a reference for implementation.

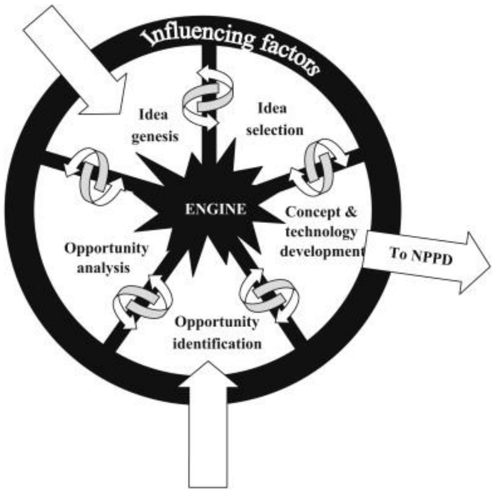


Figure 23. The model of Koen et al

The Crawford and Di Benedetto Model

The Crawford and Di Benedetto model presents three front-end activities: Opportunity Identification and Selection, Concept Generation and Concept/Project Evaluation. In addition, this model places three Gates after each of its activities: Direction, Initial Review and Full Screen. This model comprises one activity for each component of the front-end, i.e., Opportunity Identification and Selection for product opportunity identification, Concept Generation for concept generation and Concept/Project Evaluation for project selection. Additionally, this model includes tools and examples of how to implement activities. (Crawford and Di Benedetto, 2008)

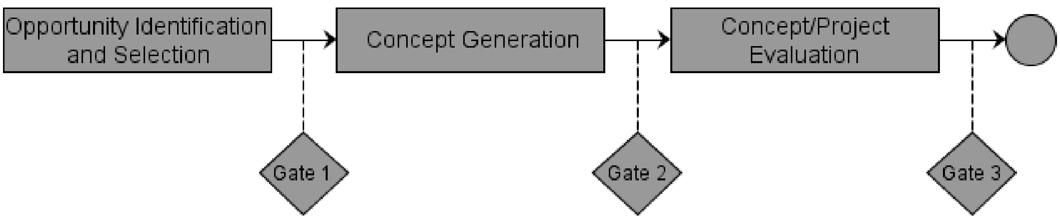


Figure 24. The Crawford and Di Benedetto Model

A Conceptual Model

Husig, Kohn and Poskela (2005) proposed a conceptual model (**Figure 25**) of Front-End Process which includes early Phases of Innovation Process that is structured in three phases and three gates:

Phase 1: Environmental screening or opportunity identification stage, in which external changes will be analyzed and translated into potential business opportunities.

Phase 2: Preliminary definition of an idea or concept.

Phase 3: Detailed product, project or concept definition and Business planning.

The gates are:

Gate 1: Opportunity screening;

Gate 2: Idea evaluation;

Gate 3: Go / No-Go for development. The final gate conducts to a dedicated new product development project.

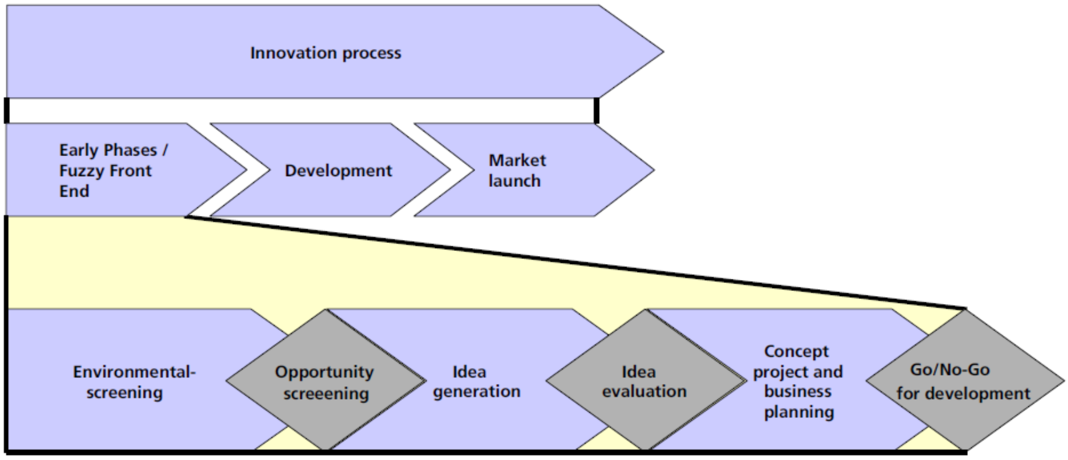


Figure 25. Front-End Model by Husig, Kohn and Poskela (2005)

Thus, in order to realize high FFE performance, it is important to understand the nature and the outcomes of this pre-development process. Outputs of FFE are:

- mission statement,
- customer needs,
- details of the selected concept,

- product definition and specifications,
- economic analysis of the product,
- the development schedule,
- project staffing and the budget,
- business plan aligned with corporate strategy.

A schematization of inputs/outputs made by Nobelius and Tryggare (2002) are shown in **Figure 26**.

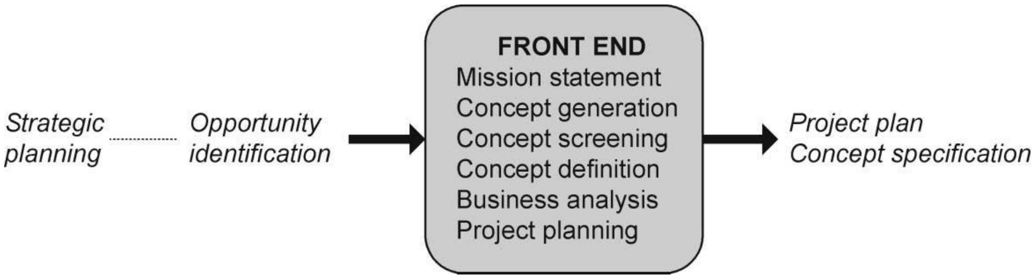


Figure 26. A synthesized input, activities, and output description of the Front End

(Nobelius and Tryggare, 2002)

The outcomes of the Fuzzy Front-End process become the inputs of the New Product Development Process. Since NPD process is already been studied a lot and also combined with the concept of lean. As the initial part of NPD process, we think to explore a way to apply the lean concept also in the FFE part could be a very interesting topic. Therefore, after the former introduction of the FFE, we will put more effort on introduction of Lean Front End.

2.2.3 Lean Front End

Why applying lean concept in Front End process will be very important? Applying strategic lean thinking and implementing an effective lean front-end technology solution can help streamline the entire range of opportunity-to-order processes and enable companies to realize measurable process improvements and results. By understanding how lean theories are used in the FFE part and how it affecting the FE by introducing and understanding the business case of Toyota.

(1) Toyota Lean Concept

Toyota Production System is developed in 1933 by Toyota Motor Corporation. In the western world it is well known as Lean Production System and this system is used widely now in every industrial field(Toyota.com, 2012).

There are two major pillars of Toyota Production System. One is Just-in-Time system and other is Kaizen. Just-in-Time system means producing only what is needed, in necessary quantity and at necessary time.

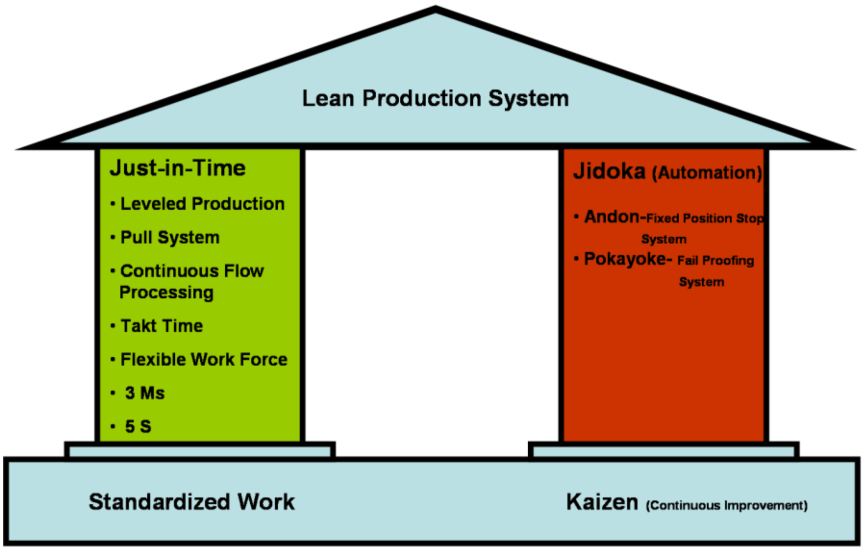


Figure 27. Toyota Production System

There are seven elements of Just-in-Time system:

- Leveled Production
- Pull System
- Continuous Flow Processing
- Takt Time
- Flexible Work Force(Shojinka)
- 3 MS(Muda, Mura, Muri)

- 5Ss(Sifting, Sorting, Sweeping, Spick-n-Span and Sustenance)

Among those elements, we understood that some are clearly revealing the concept of lean which could be used in the Front End phase. For example:

(2) Pull System

Pull System is the corner stone of JIT. The whole concept is based on customer demand. This demand is known as “pull” that runs in backward direction. In other words, production activities begin as a result of the pull generated by the customers in the form of order confirmation by them. This concept perfectly explained why we need to capture customer value in the Front End phase and why it can make the process lean.

(3) Continuous(Smooth) Flow Processing

Continuous or smooth flow processing means arranging work inside each process to flow smoothly from one step to other. The concept developed by Toyota is original used to reduce or even eliminate the inventory. In this case it will eliminate the waste of inventory cost if there is a defect of the products. Here we would like to “borrow” this concept for explain the cost of time and value because of the unsmooth communication. Since communication process would be a very important part of the Front End.

(4) Muda

The meaning of Muda in English is “non-value added”. Toyota use this concept to carry on continuous improvement by keeping searching the processes or activities inside the production process which are non-value added, in another word, wastes. This can be reflected also in Front End phase. When there are too much waiting for proceeding the next step or miscommunication or repeated work which is not necessary and value added.

From the introduction of Toyota Production System above, we can see that some lean thinking of Toyota Motor Company can guide us to develop a lean process related to Front End.

(5) Itzack Model

Since Lean Front End is a very new concept, we have not find a clear definition in literature. But some scholars already started to explore on this new way. Here we quoted a Model to explain Lean Front End by Itzack Ben-Levy. (Itzack Ben-Levy,2010)

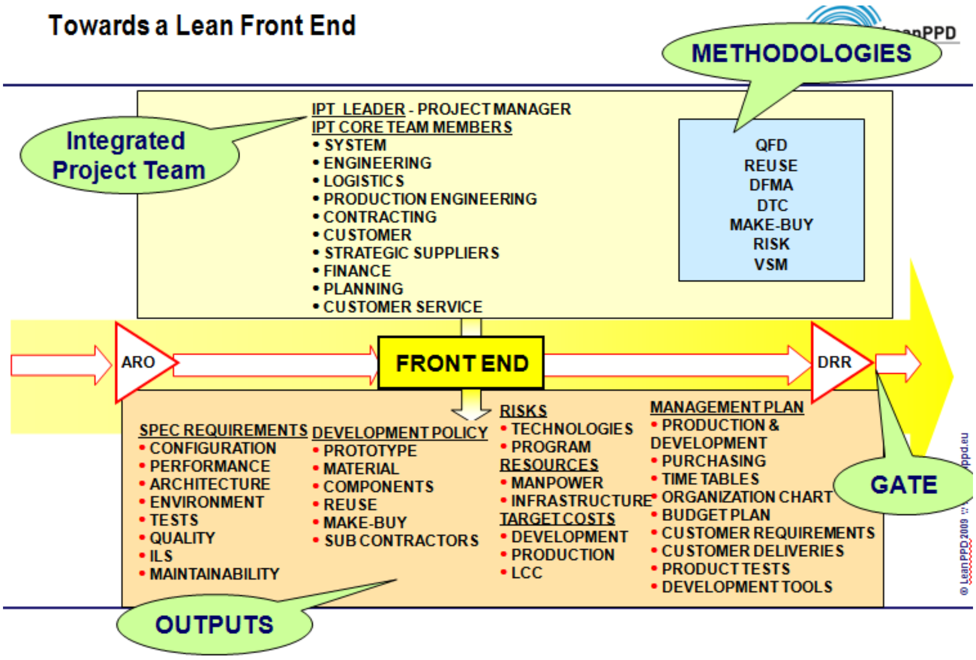


Figure 28. Itzack Lean Front End Model

In this model four aspects are explained:

A) Integrated Project Team

Inside one project team, a sum of various roles is included. For example, we have project manager, people from engineering, logistic, production, finance, planning and so on. Also customers considered as a party of team member because a lot of co operations and communications are needed in Lean Front End phase.

B) Methodologies

Also some tools are embraced in this Lean Front End model. For example, FMEA, QFD, VSM and so on, as we already explained before.

C) Gates

There are two gates are introduced in this model. ARO (Receipt Of Order) is the gate before processing Front End activities, while DRR (Design Readiness Review) is the one when the whole activities of Front End are finished. So it reveals that in the Lean Front End phase, it includes all activities after receiving the order from customer and ending with the designer’s review.

D) Outputs

The output of Lean Front End phase includes six aspects. They are specific requirements, development policy, risk, resources, target costs and management plan. Also by specifying all these requirements, good information documentation is achieved.

To sum up, lean philosophy of Toyota system and Lean Front End model from Itzack together gave us a promising vision of Lean Front End study and one step more laid a foundation for the further studies on this topic.

There are different ways organizations can choose to control to make the NPD successful. However, it is obvious that managing such complex relationships and continuous communication in a rapidly evolving context, cannot just be left up to fate. And, nothing can be controlled and guided without the right information and an accurate knowledge on the issues. Therefore, the next paragraph is dedicated exactly to the crucial topic of Knowledge Management for Lean Product Development and Front End.

2.3 Knowledge Management for Lean New Product Development and Front End

2.3.1 Introduction to Knowledge Management

Nowadays, change and evolution are intrinsic elements of an enterprise and the interdependencies of different actors presume the involvement of all people in the process (Pawar and Sharifi, 2002). Therefore, it becomes essential to share and transfer experiences and knowledge between people within the organization. And this knowledge should be well-managed. Managing NPD is a challenging, complex process. Also in order to be competitive, companies need to launch new products faster than their competitors and this is why senior managers perceive NPD as a key competence (Harmsen, Gruner, and Bove, 2000). To develop this competence, it is crucial to learn from the old NPD project and apply this experience to subsequent projects. NPD generates a vast amount of knowledge on organizational processes as well as technical knowledge on products (Cohen and Levinthal, 1989). Finally, new product development (NPD) is a complex activity that is dependent on knowledge and learning.

In the 1990's, the executives and scientists starts to talk about Knowledge management (KM) as a recognized field and KM is still a fuzzy concept, with a range of definitions and opinions on what really the core is. Joseph M. Firestone,White Paper (1998) think that The Knowledge Management Process (KMP) is an on-going persistent interaction among human-based agents who aim at integrating all of the various agents, components, and activities of the knowledge management system into a planned, directed process producing, maintaining and enhancing the knowledge base of the KMS. Knowledge Management is the human activity within the KMP aimed at creating and maintaining this integration, and its associated planned, directed process. Later, Wendi Bukowitz and Ruth Williams (2000) point out that knowledge management is the means by which a company generates wealth from its knowledge, or in other words from its intellectual capital. This abundance of riches can take a number of forms: cost reduction and cash-flow improvement by means of cycle acceleration, better customer satisfaction, increased capacity to innovate…Since those years, knowledge is increasingly being considered as the resource, rather than a resource (Nonaka and Takeuchi, 1995). All other resources, such as facilities, employees, machines and intellectual property are valuable because of the knowledge embodied in them. The western world has gone from an industrial age to a knowledge age, where knowledge is the key to success and the focal point of attention (Söderberg and Alfredson, 2009).

"Where is the wisdom we have lost in knowledge? Where is the knowledge we have lost in information?" (T.S. Eliot, 2000). An important issue of KM is the distinction between knowledge and information. The difference is illustrated in **Figure 29**.

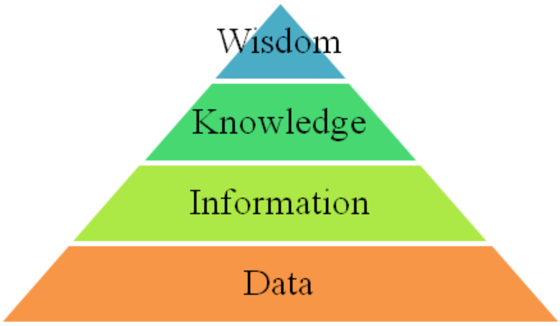


Figure 29. The knowledge pyramid

The bottom of the pyramid consists of data, i.e. information in its raw form that could be statistics or even ones and zeroes. When the raw data is interpreted and organized, it moves up a notch and becomes information that assumes particular sense within a specific context (Vercellis, 2006). But it's when the information and its consequences are understood, that it becomes knowledge. When all knowledge in a field comes together, and an understanding of the big picture and the interaction between different knowledge fields comes out, wisdom is achieved. Traditionally, the focus of product development has been on the two lines on the base, but it can be argued that it's advantageous to try to reach the top two lines in the pyramid (Davenport and Prusak, 1998).

Knowledge is in the literature divided into two different types: tacit knowledge and explicit knowledge (Nonaka & Takeuchi, 1995). Explicit knowledge is "knowing about", i.e. facts and theories. Tacit knowledge is "knowing how", i.e. skills in how to do things. The primary difference between those two is the transferability. Explicit knowledge can more easily be documented and spread throughout an organization via for example reports or illustrations. Tacit knowledge on the other hand, can only be acquired through practice, which makes the transfer of tacit knowledge between people costly, uncertain and time consuming. In **Table 4**, the two types of knowledge are put together with another dimension, namely the level of knowledge, i.e. if it's on an individual level or an organizational level (Grant, 2008). The more important knowledge is the tacit one, created through active generation and organization of experiences, and the part of it that can be expressed through numbers and letters are only the tip of the iceberg (Nonaka & Takeuchi, 1995).

Table 4. Two different levels of explicit knowledge and tacit knowledge (Grant, 2008)

	Individual	Organizational
Explicit	• *Facts* • *Scientific knowledge*	• *Databases* • *Intellectual Property*
Tacit	• *Skills* • *Know-how*	• *Organizational Routines*

Grant (2008) gives an overview of the subject of knowledge management explicitly considering Information Technology proposed by **Figure 30**. He indicates that there are two types of knowledge and two types of knowledge processes. The two types of knowledge are the ones presented earlier: tacit knowledge and explicit knowledge. The two types of processes are the generation of knowledge and its application. From **Figure 30**, we see that the generation knowledge process consists of knowledge creation including research, and knowledge acquisition which contains benchmarking, training, recruitment and Intellectual Property (IP) management. The other process is knowledge application, which involves six processes: knowledge integration, sharing, replication, storage and organization, sharing and replication, measurement and identification. In particular, Grant identifies the storage of knowledge as critical to efficient use of existing knowledge (Grant, 2008). The focus lies on creating easy-to-use databases that facilitate storage, transfer, organizing, access, and communicating knowledge. Moreover Grant put a lot of emphasize on the use of Information Technology. He also points out that explicit knowledge is transferred more easily through IT-systems, while the tacit is not that easily transferred.

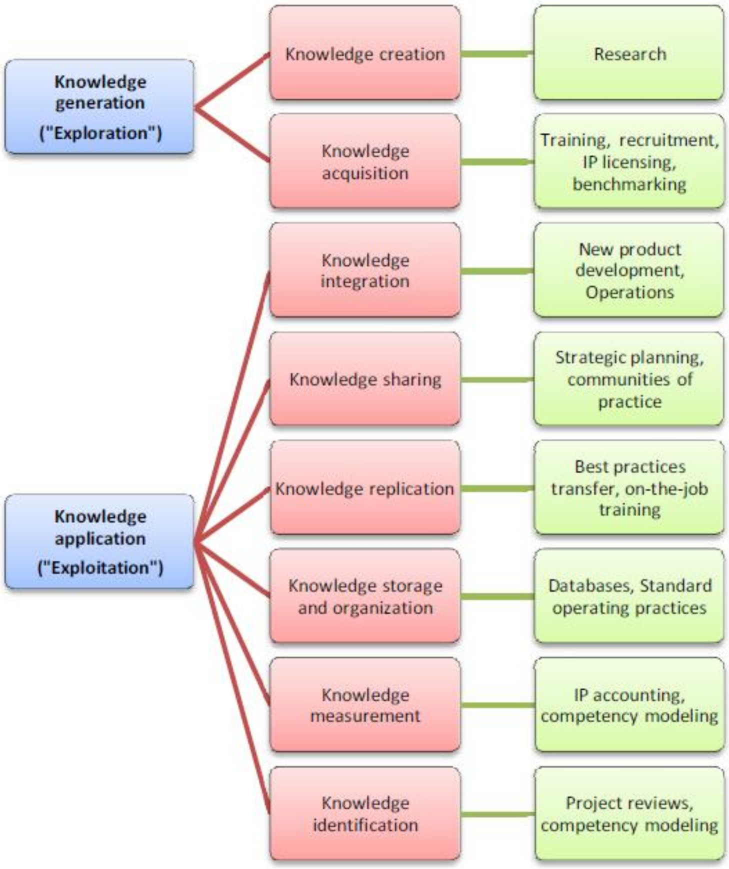


Figure 30. Knowledge processes within the organization (Grant, 2008)

After knowing what knowledge management is, the importance of knowledge management, and knowledge management processes, we will go deep into analysis of knowledgement management for lean new product development and front end on next paragraph.

2.3.2 Knowledge Management for Lean New Product Development and Front End

2.3.2.1 Importance of Knowledge Management for New Product Development

Top managers recognize that new product development is a core competence (Harmsen et al, 2000) and the “product innovation literature… has progressively highlighted the importance of knowledge management as the main source of long-term competitive advantage" (Corso et al, 2001). It is widely recognized that research and development (R&D) is the function of the business that is most dependent on knowledge and "nowhere is organizational learning more critical" (Lynn, 1998).

New product development generates vast amounts of knowledge—not only about the product and technology but also knowledge about the processes used by the NPD teams (Cohen and Levinthal, 1989). To constantly improve NPD, organizations depend on the ability to learn from previous projects (Gupta and Wilemon, 1996; Nonaka and Takeuchi, 1995; Wheelwright and Clark, 1992). If organizational learning occurs, it leads to a change in the way in which subsequent problems are investigated (Michael and Palandjian, 2004), it helps to avoid the repetition of mistakes (Tidd et al, 2001), and supports knowledge retention (Jensen and Sandstad, 1998). Learning can be said to have occurred when an organization uses knowledge to solve or prevent problems and this can lead to competitive advantage (Ambrosini and Bowman, 2001). There is a broad agreement that because NPD is a knowledge-intensive activity, particular mechanisms are needed to stimulate the creation and transfer of knowledge (e.g. Mehra and Dhawan, 2003). Research generates knowledge on technologies, whereas new product development (NPD) teams convert such knowledge into innovative products. If NPD teams learn from previous projects, then product innovation can be faster (Saban, et al, 2000), and mistakes that were made in the past can be avoided (Tidd, et al, 2001). Consequently, applying knowledge management into the lean NPD is quiet important.

2.3.2.2 Knowledge Management for Lean New Product Development and Front End

Here we will give a short description of the relationship of Lean NPD and Front End (FE), detailed discussion about FE has been conducted in **section 2.2**. Murphy and Kumar (1997) define the predevelopment (Front End) stages as consisting of idea generation, product definition and project evaluation. Khurana and Rosenthal (1998) note that the FE includes product strategy formulation and communication, opportunity identification and assessment, idea generation, product definition, project planning and early executive reviews, which typically precede detailed design and development of a new product. We can see that FE is an important part of NPD, it is difficult for us to speak FE without NPD, and vice versa. So in the following discussion of Knowledge for Lean NPD and FE, we will exploit knowledge in these two processes together.

Two very great problems in new product development are loopbacks and lost knowledge. Toyota has found methods that deal with both of these problems. **Table 5** illustrates some differences between a structure based company and knowledge based, and it is taken from a Michael Kennedy work (Kennedy, 2008).

Table 5. Two development environment attribute (Kennedy, 2008)

Attribute	Structure-based	Knowledge-based
Operational Focus	Planning and Control	Learning and Doing
Progress	Task Completeness	Knowledge
Basis for Personal Evaluation	Compliance	Knowledge/Expertise
Improvement Focus	Task Efficiency	Learning Efficiency

The second column (structure-based) is a good representation of many western companies that are using the traditional structured way of organizing (Kennedy, 2003). According to Kennedy (2003), the focus on Toyotas way of developing means that the demand for structure is low but the demand for knowledge is high.

In the NPD process there might be different kinds of knowledge needed to be collected and archived. Li Shaobo and Xie Qingsheng (2002) show a product knowledge representation architecture which is summarized on **Figure 31**. In the figure, boxes within boxes denote compositional relationships: an artifact (here means knowledge, information, or learning) is composed of sub-artifacts, functions, and form, behaviours; form is composed of a combination of geometry and material knowledge, etc. One of the benefits of this kind of representation is that it supports design at earlier stages of the product development process by allowing designers to maintain the representation of a product at multiple levels of abstraction simultaneously.

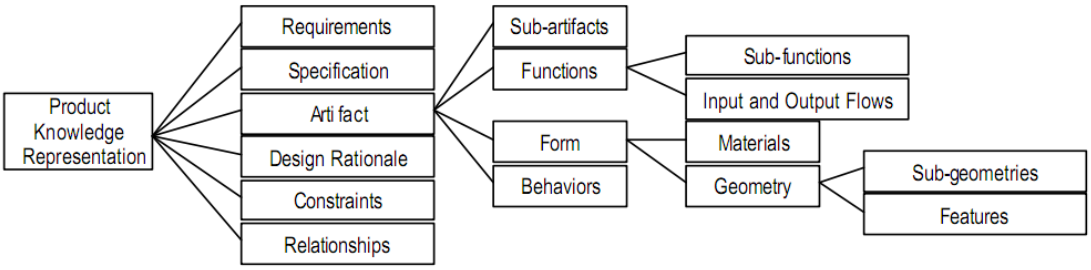


Figure 31. Product Knowledge Representation (Li Shaobo and Xie Qingsheng, 2002)

Combining what we reviewed before, we can know that knowledge in NPD mainly includes the product design information and the information derived from design information. Design is considered to be a critical link among the new product development processes. We will take a deep analysis of KM for design.

Design information includes the formal information such as engineering document, calculation expressions, CAD data, and other informal information such as measurement and tolerance of design, scheme selection, market information, market forecast, gist of decision-making, and so on. The result includes the knowledge recreated by product design, such as experience and rules. Information knowledge includes consumer advices, individualization demand, market direction, and so on; design parameters include applied standard, technique parameters and technical requirements, etc; engineering material knowledge includes handbook, catalog, standard, etc; rules include all what is created by field experts and knowledge engineers during their cooperation (Simon Szykman and Ram D. Sriram, 2001). These information are shown in **Figure 32** below.

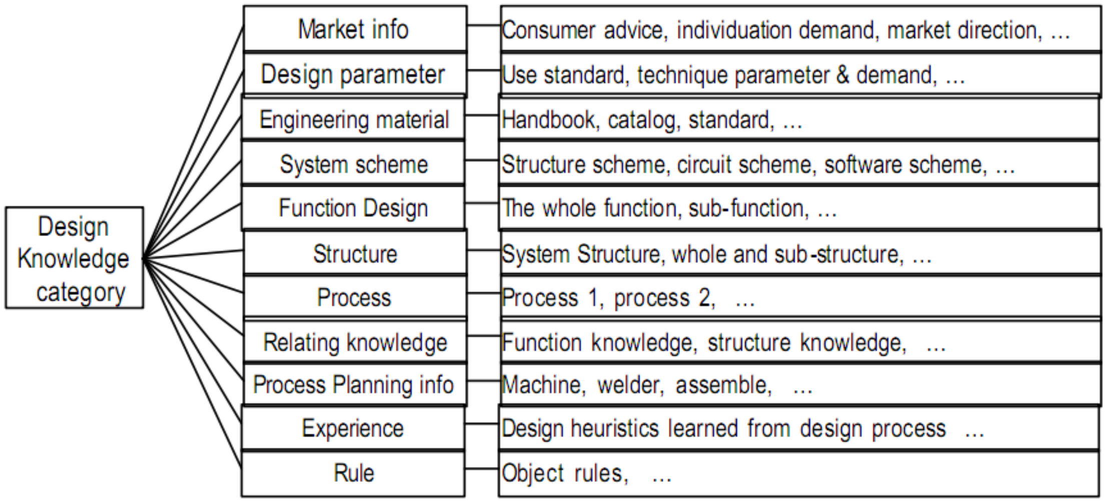


Figure 32. The design knowledge category (Li Shaobo and Xie Qingsheng, 2002)

Also knowledge management in product development covers a broad spectrum of activities and operations at many levels, from the individuals to the whole enterprise and between enterprises (as in virtual organizations). Until the late 1990s, knowledge management is mostly viewed as the behavior of an enterprise. It is clear now that the wealth creation potential of knowledge must be recognized, and policy initiatives are needed for the knowledge-based economy. Additionally, effective knowledge management can only be achieved through a holistic approach, addressing not only technological solutions, but also people, processes and links of core business activities (Angel Salazar, 2003). **Table 6** depicts some of the key elements of knowledge management across these two dimensions—KM at different organizations is one of the dimensions, the other dimension is KM at holistic level.

Table 6. Elements of Knowledge Management in Product Development Integration System

	Policy / Strategy	**Processes / Methods**	**People / Skills**	**Technology**
Intra-Enterprise	Collaborative associations	Collaboration methods and standards	Skills development	E-business networks
Enterprise	Knowledge-based product development integration system	Best practice, KM processes	Self-study, E-learning	Knowledge-based PDM System
Teams	Tasks and outcomes	Virtual working	Team roles	Collaborative workspace
Individuals	Career / life planning	KM specialties	Professional development	ICT/Internet proficiency

A large accent in lean new product development is put on creating, capturing and reusing knowledge. Kennedy (2003) describes the knowledge value stream in **Figure 33**, where the captured knowledge from all previous projects represents a foundation on knowledge base used to develop products faster and with higher quality avoiding redundancy in the knowledge work. But this is only a part of what he calls knowledge-first product development, where the main development is done in the knowledge value stream.

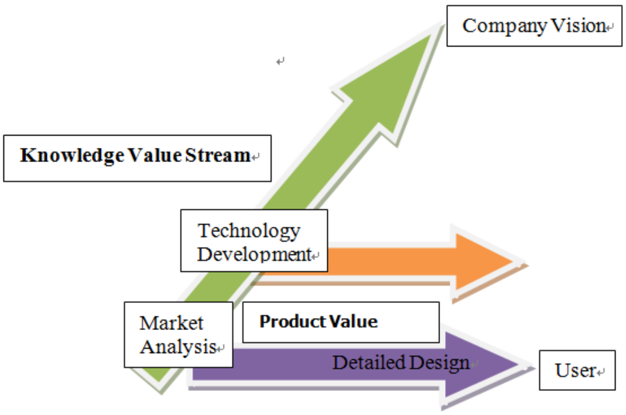


Figure 33. The Knowledge Value Stream (Liker, 2008)

The knowledge value stream is close to what other companies might call predevelopment (front-end which we will introduce in **section 2.2**) and at Toyota, this is where 90 per cent of the development work is being done. This means that Toyota never have to invent new technology in the projects, but always know at the start of one that they have a "baseline solution", that can meet all the specifications. Simply put, they make sure that they have all the necessary technology before even launching a project. The big advantage here is that Toyota never has to go into a project with unknown technology, and therefore they are avoiding a large portion of uncertainty in the product development projects. An interesting remark here is that the persons responsible for the knowledge value stream is the functional managers that build the knowledge within the function, while the product value stream is owned by the Chief

Engineer[5] developing the product itself (Kennedy, 2008).

There are some tools used to improve Lean NPD which are properly referred to knowledge in design process. We will introduce these tools on the next paragraph.

2.3.2.3 Tools for Knowledge Management

There are several knowledge management tools that a company can introduce and put into practice. Here we will take a brief description of the most important tools which are focused on the analysis of knowledge in Lean NPD and Front End.

- ***Trade-off Curves***. This is a basic, yet powerful tool, largely used by Toyota in its product development. It is simply an X-Y chart that serves as a visual model for the relationship between two combinations of variables that predict the performance of a system. For example, durability of the smell and fragrance are two combinations of variables for evaluating the performance of a perfume. Trade-off curves document the organization's current understanding about design decisions that are likely to work and the ones known to fail. They map out safe regions where designs have worked in the past, and the unsafe or unknown regions where the technical risk may reach unacceptable levels. In this way, they organize design data into knowledge that can be reused across products. These trade-off curves are used during development to ensure that design decisions take advantage of the best available knowledge. **Figure 34** is an example from Toyota that Kennedy (2008) uses for back pressure versus noise reduction on an exhaust system. We can see from the figure that the combinations of back pressure and noise reduction will be feasible if it locates above the curve, the design will be infeasible if it locates under the curve.

[5] Chief Engineer: The chief engineer at Toyota is first and foremost a technical expert who has a large input in the car's architecture. He is responsible for the project from concept to market, but he is mostly recognized by his experience, his technical and communication skills. He summarizes his vision for the car in a concept paper which leads into the system design phase.

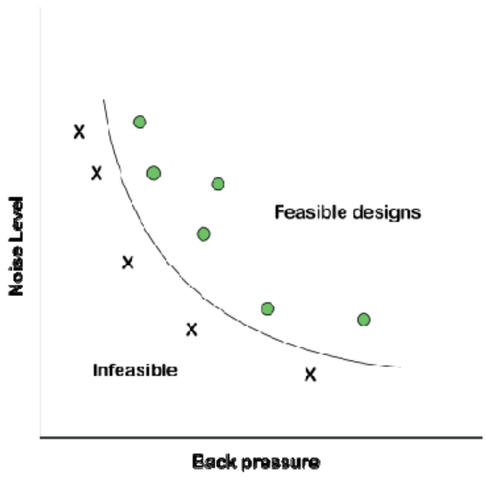
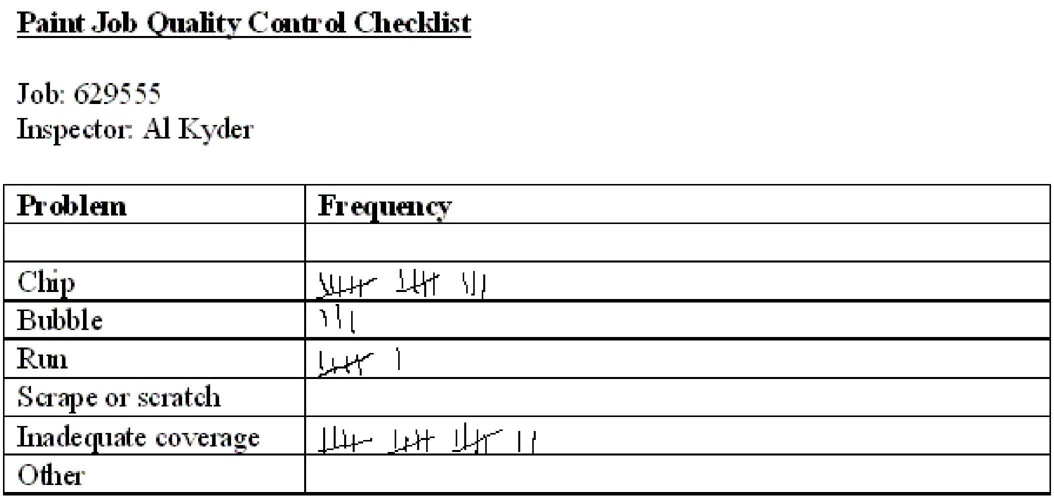


Figure 34. An example of Trade-off curve (Kennedy, 2008)

- ***Check-sheets.*** Check-sheets are another essential tool for collecting knowledge in Toyota. They can be seen as a map of the existing knowledge in a definite area, for example a car door. Liker refers to them as checklists and as simple reminders of things that should not be leaved out when designing something (Liker and Morgan, 2006). He also says “Ideally, engineering checklists are an accumulated knowledge base reflecting what a company has learned over time about good and bad design practices, performance requirements, critical design interfaces, critical to quality characteristics, manufacturing requirements as well as standards that communize design”. As well as with A3 reports and trade-off curves, the owners of the check-sheets are the functional groups, which are also responsible for updating and spreading the knowledge in the company (Liker and Morgan, 2006; Kennedy, 2008).

Here we have an example from Ishikawa Kaoru, 1996. This (**Figure 35**) is an example used in process quality control. This sheet records information about the type and number of paint flaws on items coming off a production line. When printed, the right column would have been blank. Subsequently, marks have been made in the right column as Mr Kyder inspected the output of job 629555. It can be seen that "inadequate coverage" is the most common flaw, occurring 17 times.



Paint Job Quality Control Checklist

Job: 629555
Inspector: Al Kyder

Problem	Frequency
Chip	卌 卌 ǀǀǀ
Bubble	ǀǀǀ
Run	卌 ǀ
Scrape or scratch	
Inadequate coverage	卌 卌 卌 ǀǀ
Other	

Figure 35. An example of check sheet (Ishikawa Kaoru, 1996)

Until now, we have already known what knowledge management is and knowledge management for Lean NPD and Front End. On the following chapter, Knowledge management concept will be applied to our practical model.

Chapter 3 Customer Value Creation

From Chapter 2, we have already known that New Product Development is more and more important for companies' competitiveness. Customer as an essential participator of NPD should be treated seriously. Because only if we can meet with customer's real needs and requirement, we can reduce the rework waste, make the NPD go ahead efficiently. The first section of this chapter gives an overview of the conception of customer value and some significant models of customer value which help to distinguish and capture customer value. Then, we highlight the importance of customer value to Lean NPD. The second section introduce an innovative technique—TRIZ which will be helpful for customer creation.

3.1 Customer Value

3.1.1 Concept of Customer Value

First, some frequent quoted definitions are presented on the list below to show a general idea of customer value.

Any definition of value must account for the inclusion of total benefits, including direct and indirect benefits derived from attributes and consequences, that arise from partner (seller-buyer) activities and behaviours, less total direct and indirect costs, and be determined from the customer perspective.

(Simpson et al., 2001).

A customer's perceived preference for and evaluation of those products attributes, attribute performances, and consequences arising from use that facilitate (or block) achieving the customer's goals and purposes in use situations.

(Woodruff, 2001)

The trade-off between the quality or benefits they perceive in the product relative *to the sacrifice they perceive by paying the price.*

(Monroe, 1990)

The emotional bond established between a customer and a producer after the customer has used a salient product or service produced by that supplier and found the product to provide an added value.

(Butz and Goodstein, 1996)

A perceived trade-off between the positive and negative consequences of product use (Woodruff and Gardial, 1996)

Dumond (2000) summarizes the common themes about customer value that it is ‘‘linked to the use of product or service’’, ‘‘perceived by the customers rather than objectively determined by seller’’, and ‘‘usually involves a trade-off between what customer receives, and what he or she gives up to acquire and use a product or service’’. Then, customer value is the summation of benefits minus the sacrifices that result as consequence of a customer using a product or service to meet certain needs. This definition moves away from the notion that value is something inherent to the product or service toward the notion that value is determined in the context of customer use (Bounds, 1994).

Definitions of customer value above reveals a diversity of the concept. However, most of the definitions have something in common that we will call "common threads". And we will summarize here in order to get a first global idea of the customer value concept.

First of all, value is perceptual and this is probably the most universally accepted aspects of the concept. Indeed, some authors even use the terms "perceived value" or "value judgments" to refer to customer value. That means the consumer's evaluation of the value of a product or a service is not an objective process but is influenced by a perceptual distortion of reality, and that might be the main reason why, after all, it is so hard to find a universal definition to this concept.

Another widely shared opinion is that value is situationally and temporally determined. Thus, the perceived value of a product can be expected to vary across different types of purchase situations. Moreover, even for the same type of purchase situation, the value of a product can change over time based upon the customer's past experiences or satisfaction. It was agreed that a reduction in perceived value over time is the most common outcome of multiple experiences, leading to brand or supplier switching.

Other areas of consensus are the following ones: customer value is linked to the use of a product, making it different from personal or organizational values, which are more enduring values; also, customer value is something perceived by customers rather than objectively determined by a seller; finally, it is generally a trade-off between what the customer receives (e.g. quality, benefits, worth, utilities) and what he or she gives up to acquire and use a product (e.g. price, sacrifices) (Dumond, 2000).

On the other hand, we can also identify some areas where the concept diverges. For example, the definitions differ as to the circumstances within which customers think about value; they may consider value at different times, such as when making a purchase decision or when experiencing product performance during or after use, which correspond to different judgment tasks.

Going beyond the definitions and ideas we get until now, next section we will present several most frequently used theoretical models of customer value which will be useful on finding and capturing the customer value.

3.1.2 Theoretical Models of Customer Value

Although the definitions of Customer Value are diverse and dynamic, there are scholars who summarize some useful models to help us master and categorize the customer value. One of the most famous models is built by Khalifa (2004). Khalifa builds customer value models based on the categorization. According to Khalifa's definition, customer value can be grouped into three categories: value components model, utilitarian or benefits-costs ratio model, and means-ends model. Though these models were (to some extent) different, they were not mutually exclusive but overlapped with each other. Taken separately, each model is incomplete in itself and its usefulness is limited, because each category emphasizes certain dimensions of the concept and pays little attention to others.

1. Value components model, value is interpreted as the performance or physical characteristics of the product:

■Must-be present;

■Are expected to be present;

■Delight the customers if the characteristics are present.

A model belonging to this category of value components model and certainly the most famous one is the Kano's model of customer perception of value. It includes three components of value: dissatisfiers (must be), satisfiers (more is better), and delighters (exciters). **Figure 36** is a representation of the effects of each of these components on customer satisfaction. A quick description of the notions of dissatisfiers, satisfiers and delighters then follows the figure.

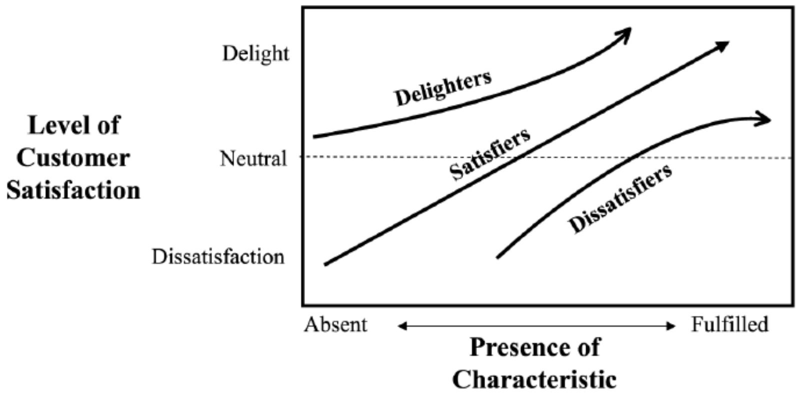


Figure 36. Kano's model of customer perception (Khalifa, 2004)

(1) **Dissatisfiers** are characteristics or features that are normal to a certain business industry, which are generally taken for granted, and that the customers have come to expect. Since they are expected to be there, their "presence" only brings customers up to neutral but their absence annoys them. They are sometimes called

basic or must-have needs. These needs drive customer defection and attrition if they are not met.

(2) **Satisfiers** are expected features and they are explicitly requested by customers. They typically meet performance related needs and they add value for the customer. Customers are disappointed if these needs are poorly met but have increasing satisfaction (and perhaps even delight) the better these needs are met. These features are often considered the minimum standards to stay in business. However, it is important to note that very often, what is originally a satisfier then becomes a dissatisfier. Customer expectations generally rise and once an organization establishes a desired level of customer value, failure to maintain that level can be dangerous.

(3) **Delighters** are new or innovative features or characteristics that customers do not expect and they surprise them in a good way. They innovatively solve a latent need of the customer and add value that is beyond the customer's expectations or desires, at least on a conscious level. For example, offering a babysitting service by a cinema operator will delight movie-loving parents with small children. Since they are unexpected, there is no negative effect if they are absent; but when present they have a positive effect.

2. Utilitarian model, customer value is the difference (or ratio) between total benefits and total sacrifices.

For example, Treacy and Wiersima (1995) consider customer value as *"the sum of benefits received minus the costs incurred by the customer in acquiring a product or service"*. Huber, Herrmann and Hennerberg (2007) suggest that the costs of obtaining the perceived benefits are usually the major concern of buyers. And Monroe (1990) defines customer-perceived value as "the ratio between perceived benefits and perceived sacrifice":

$$\text{Customer perceived value} = \frac{\text{Perceived benefits}}{\text{Perceived sacrifice}}$$

Formula 1. Customer perceived value by Monroe (Monroe, 1990)

In this formula, the perceived sacrifice includes all the costs the buyer faces when making a purchase: purchase price, acquisition costs, transportation, installation, order handling, repairs and maintenance, risk of failure or poor performance. The perceived benefits are some combination of physical attributes, service attributes and technical support available in relation to the particular use of the product, as well as the purchase price and other indicators of perceived quality.

Generally, when developing a utilitarian definition of customer value, authors specify which costs (monetary and non monetary factors) have to be taken into account. However, even if it is commonly agreed that benefits include tangible and intangible attributes of the product/service offering, there is very rarely a clear explanation of what is intended by those "benefits". To fill in this gap, other authors tried to develop categorizations of benefits. One of the most comprehensive definitions is made by Holbrook (1994) which described eight types of customer benefits or value:

- Efficiency: Value resulting from manipulating something as a means to a self-oriented end;
- Excellence: Personal satisfaction associated with the admiration of the characteristics of an object because they provide a means to an end;
- Politics: Value resulting from manipulating something as a means to the other-oriented end of achieving a favourable response from someone else
- Esteem: Value arising from the contemplation of one's own status or prestige as reflected in the opinion of others;
- Play: Value derived from the pleasure of engaging in some activity;
- Aesthetic: Value achieved by admiring something not as a means to an end but because it provides value in itself;

- Morality: Value achieved by doing things because they are the “right” things to do, not because they gain us favour with others;
- Spirituality: Doing things because of the value of faith or religious ecstasy.

Utilitarian models are broader than the value components models and more complete. They consider customer value in a longer time horizon perspective and include almost all elements of customer activity cycle. However, they do not pay much attention to the dynamics of value building and destruction; they seem to be static rather than dynamic. They do not link benefits and sacrifices with customer ends, values and purposes.

3. Means-ends model, Means-ends models are based on the assumption that customers acquire and use products or services to accomplish favourable ends: Means are products or services, and ends are personal values considered important to consumers. The means-ends theory, in other words, postulates that linkages between product attributes, consequences produced through consumption, and personal values of consumers underlie their decision making processes.

Woodruff (1997) attempts to consolidate the diverse means-ends oriented definitions, proposed: “Customer value is a customer’s perceived preference for and evaluation of those product attributes, attribute performances, and consequences arising from use that facilitate (or block) achieving the customer’s goals and purposes in use situations”. Woodruff emphasizes that value stems from customers’ learned perceptions, preferences, and evaluations. His model shown in **Figure 37** demonstrates that moving up and down of the customer value hierarchy and explains both desired and received value and suggests that customers conceive desired value in a means-end way. Starting at the bottom of the hierarchy, customers learn to think about products as bundles of specific attributes and attribute performances. When purchasing and using a product, they form desires or preferences for certain attributes based on their ability to facilitate achieving desired consequence experiences, reflected in value in use and possession value, in the next level up in the hierarchy. Customers also learn to desire certain consequences according to their ability to help them achieve their goals and purposes (i.e., the highest level). Looking down the hierarchy from the top, customers use goals and purposes to attach importance to consequences. Similarly, important consequences guide customers when attaching importance to attributes and attribute performances. The customer value hierarchy describes received value equally well. Customers evaluate products using the same desired attribute, consequence, and goal structure that they have in mind at that time. Further the customer's use situation plays a critical role in evaluation as well as in desires. If the use situation changes, the linkages between product attributes, consequences and goals and purposes change as well. For example, a customer's value hierarchy for Internet services used at work may look quite different with the hierarchy for those services used at home for entertainment.

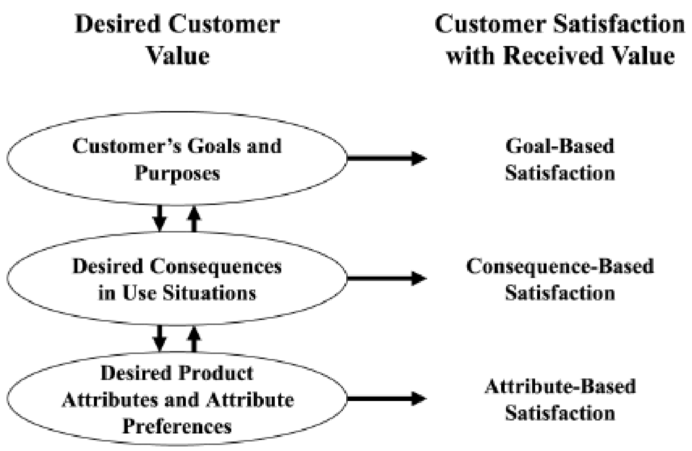


Figure 37. Woodruff's means-ends model of customer value (Woodruff, 1997)

The means-ends model of customer value fills a gap in the literature by being able to explain why customers attach different weights to various benefits in evaluating alternative products/services. They also take into account the negative consequences of certain product/service attributes but fail to pay sufficient attention to the sacrifices a customer is likely to bear in acquiring, using, or disposing of the product/service (whereas utilitarian models pay more attention to these elements).

For the new product development, one of the most important principles is to produce what the customer wants. So it is very important to follow the voice of customer and match with the customer value. After knowing the concept and models of customer value, we will go further on the topic of customer value based on lean new product development, on the following section.

3.1.3 Customer Value Based Lean New Product Development

From the modern management perspective, maximizing customer value is the key to surviving fierce competitions in the business world. Hence, many companies actively engage in developing new products. By delivering value through new products, companies satisfy customers and generate profits (W.H.Ip, B.C. Chen, C.W. Lau, K.L. Choy, S.L. Chan, 2008). When developing new products it is important for design teams to understand customer perceptions of consumer products because the success of such products is heavily dependent upon the associated customer satisfaction level. The chance of a new product's success in a marketplace is higher if users are satisfied with it (Elsevier Ltd, 2009). The comments above indicate that it is important to consider the customer value when new product development process is conducted.

In practice, Robert A. Slack (1999) comes up with a model which is focused on the way to consider customer value in new product development process, which is particularly important for the success of NPD. We will introduce the model in detail below.

Robert Slack (1990) defines that "Value is a measurement of the worth of a specific product or service by a customer, and is a function of (1) the product's usefulness in satisfying a customer need, (2) the relative importance of the need being satisfied, (3) the availability of the product relative to when it is needed and (4) the cost of ownership to the customer."

This model is thus part of the utilitarian models, and, according to Slack's work, value is defined as being directly proportional to the product of the need for an object (or service) and the ability of this object to satisfy this need, and it is inversely proportional to the cost of the product or service. He gives the following equation:

$$\text{Customer Value} = \frac{N * A * f(t)}{C}$$

Formula 2. Customer value equation for a given requirement or function by using utilitarian models (Robert A. Slack, 1999)

Where:

- ▪ *N* = the importance of the need of the product or service. The value of N is fully determined by the customer.
- ▪ *A* = the ability of the product or service to satisfy the customer need. The value of A is determined by how well the new product development process is executed.
- ▪ *f(t)* = the availability of the product or service to the customer, relative to the customer need date.
- ▪ *C* = the cost of ownership, is a function of product and service attributes as well as the efficiency of the new product development process.

In the context of complex systems development, a given product may have a multitude of needs or requirements with specific individual importance. The above **Formula 2** therefore could be used to evaluate value for a given requirement or function, or it could be used to evaluate the aggregate value of the product. The generalized aggregate value equation takes the form:

$$\text{Customer Value} = \frac{\sum(N * A) * f(t)}{C}$$

Formula 3. Aggregate customer value by using utilitarian models (Robert A. Slack, 1999)

A, the ability of the product to satisfy the customer need, can be viewed in terms of probability: it increases as the product progresses through the new product development process until the verification that the requirement has been accomplished, at which point it would be a maximum. A product which has demonstrated by test the ability to meet a requirement has eliminated the risk associated with this requirement and is of greater value to the customer than a product which has an element of risk associated with meeting this same requirement. The ability of the product to satisfy a customer need can be related to risk by the following simple relationship:

$$A = 1 - R$$

Formula 4. The ability (A) of the product to satisfy a customer need when relating to risk (Robert A. Slack, 1999)

Where:

- ▪*A* = the probability for a specific product to meet a specific customer requirement
- ▪*R* = risk, the probability that a specific product does not meet a specific customer requirement.

With the above **Formula 3** and **Formula 4**, a relationship between value and risk in the new product development process is given by:

$$\text{Customer Value} = \frac{\sum[N * (1 - R)] * f(t)}{C}$$

Formula 5. Aggregate customer value considering risk by using utilitarian models (Robert A. Slack, 1999)

The denominator of this equation, C, cost of ownership, is equivalent to the total life cycle cost of the product and includes acquisition costs and support, operations and retirement costs. This implies that to maximize customer value in the new product development domain all of these costs have to be considered during development decision-making processes.

After knowing what customer value is and its importance to Lean NPD, it is necessary for us to find useful tools and techniques to translate and create these values into new product development process of companies. TRIZ and Voice of Customer (VOC) are techniques which can help to capture and create customer value. We will introduce TRIZ to you on the next paragraph. VOC will be introduced and applied in **Chapter 4**.

3.2 Customer Value Creation through TRIZ

From the previous chapter we can see that the customer value is not easy to create and also the concept is hard to translate in reality. It is common that some key covariates in a regression model, such as marketing mix variables or consumer profiles, are subject to missing. The convenient method that excludes the consumers with missing in any covariate can result in a substantial loss of efficiency and may lead to strong selection bias in the estimation of consumer preferences and sensitivities (Yi Qian, 2011). To solve this problem, one interesting and innovative way is to apply TRIZ to customer value creation.

3.2.1 Concept of TRIZ

TRIZ (Teoriya Resheniya Izobratatelskikh Zadatch) is the Russian acronym for Theory of Inventive Problem Solving, originated in Russian more than 50 years ago (Altshuller G., 1984). It is well-established system of tools for problem solving, idea generation, failure analysis and prevention. TRIZ has been developed based on more than 1500 person-years of research and study over many of the world's most successful solutions of problems from science and engineering, and systematic analysis of successful patents from around the world, as well as the study of the psychological aspects of human creativity.(Kai Yang,2008)

The basic concept of TRIZ is the resolution of a contradiction (S.D.Savransky, 1996). Dr. Genrich S. Altshuller, the creator of TRIZ, started his investigation of invention and creativity in 1946. After initially reviewing 200,000 patent abstracts, Altshuller selected 40,000 as representatives of inventive solutions. In the course of the study, Altshuller noticed a fundamentally consistent approach used by the best inventors to solve problems. At the heart of the best solutions, as described by the patents, existed an engineering conflict, or a "contradiction.” The best inventions consistently solved conflicts without compromise (Matthew Hu, 2000).

According to Souchkov V.V's notes about TRIZ, there are 5 levels of solutions for industrial problems (Souchkov, 2009).

Level 1 indicates a quantitative system change that is realized by altering some parameters within the adopted conceptual solution; for instance, the continuously growing heat sinks. .

Level 2 indicates a qualitative system change by improving an existing sub-system within the same structure combination (i.e. without changing the product architecture).

Level 3 indicates an innovative system change by realizing an invention. The product or system is fundamentally improved and contradictions are resolved.

Level 4 and 5 finally indicate a pioneering invention and the discovery of a new scientific principle, respectively. For our study, where the focus is on resolving interface conflicts, these two levels of solutions are not directly pursuit.

According to these 5 levels explained above, Tidd J., Bessant J., Pavitt K. (2005) made a research to see the ratios of these different levels of industrial solutions by using TRIZ. They found out that 32% of industrial engineering solutions are acquired by routine design (Level 1). However 63% of industrial engineering solutions are solved by Level 2 and 3 solutions. Finally, the last 5% of solutions are of Level 4 and 5. In other word, if routine design fails- 93% of all solutions are of levels 2 and 3. Hence, the conflict resolving strategies are formulated according to the effects of Level 2 and 3 solutions.

TRIZ is a combination of methods, tools, and a way of thinking. The ultimate goal of TRIZ is to achieve absolute excellence in design and innovation Tidd J., Bessant J., Pavitt K. (2005) (Mann 2002). The researchers developed a four-step process of problem-solving according to the key philosophical elements of TRIZ.

(1) Problem Definition

This is a very important step in TRIZ. If you define the right problem and do it accurately, this represents 90 percent of the solution. The problem-definition step includes the following tasks:

- ◆ Function analysis: This includes function modeling and analysis of the system. This is the most important task in the "definition" step. TRIZ has very well-developed tools for function modeling and analysis.
- ◆ Technological evolution analysis: This task looks into the relative technological maturity of all subsystems and parts. If a subsystem or part is technically "too" mature, it may reach its limit in performance and thus become a bottleneck for the whole system.
- ◆ Ideal final result: The ideal final result is the virtual limit of the system in TRIZ. It may never be achieved but it provides us with an "ultimate dream" and will help us to think "out of box."

(2) Problem Classification and Tool Selection

TRIZ has a large array of tools for inventive problem solving; however, we must select the right tool for the right problem. In TRIZ, we must first classify the problem type and then select the tools accordingly.

(3) Solution Generation

In this step, we apply TRIZ tools to generate solutions for the problem. Since TRIZ has a rich array of tools, it is possible to generate many solutions.

(4) Evaluation

In any engineering project, we need to evaluate the soundness of the new solution. TRIZ has its own evaluation approach. However, other non-TRIZ methods might also be used at this stage, such as axiomatic design and design vulnerability analysis. As **Figure 38** showed, in a simplified TRIZ process, it includes mainly five steps:

- ◆ Define the problem
- ◆ Reduce problem to its basic constituents
- ◆ Examine for contradictions

◆ Evaluate alternatives

◆ New solution

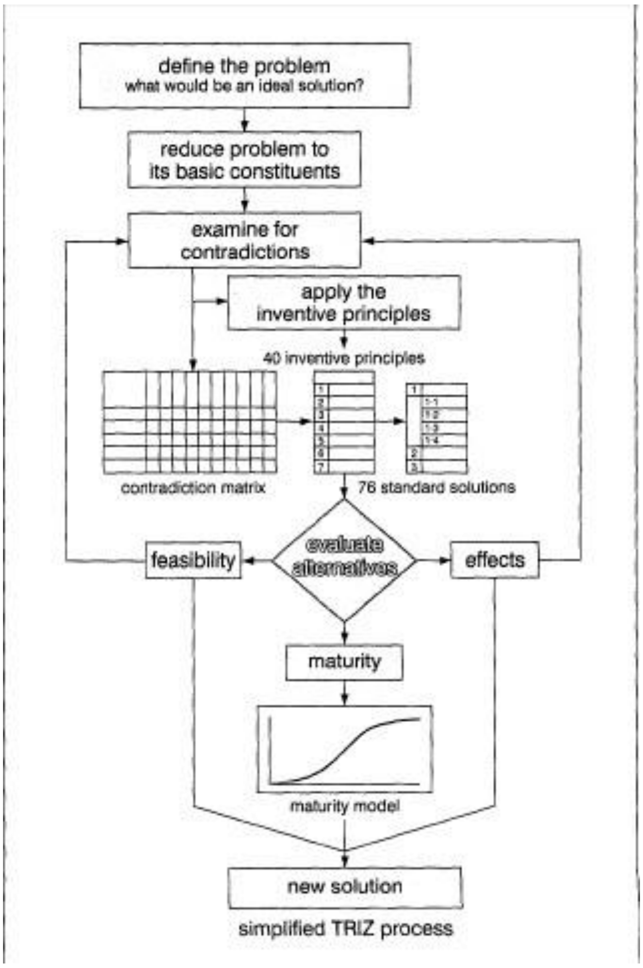


Figure 38. The simplified TRIZ process (Alan Webb, 2002)

Therefore as the literature revealed, we can see to solve the contradictions without making any compromise is the main goal of TRIZ methodology. Therefore to understand what is TRIZ contradiction matrix and how it works is very important to understand the TRIZ concept. Here is a simplified example of TRIZ contradiction matrix.

		CHARACTERISTICS	Characteristic that is getting worse						PRINCIPLES	
			1	2	…	…	…	39		
Characteristics to be improved	1	Weight of a mobile object		-	…	…	…	35,3 24,37	Segmentation	1
	2	Weight of a stationary object	-		…	…	…	1,28 15,35	Extraction	2
	…	…	…	…		…	…	…	…	…
	14	Strength	1,8 40,15	40,26 27,1	…		…	29,35 10,14	Asymmetry	4
	…	…	…	…	…	…		…	…	…
	39	Capacity / Productivity	35,26 24,37	28,27 15,3	…	…	…		Inert Environment	39
									Composite Materials	40

Figure 39. A simplified example of TRIZ contradiction matrix

From this example, we can see from the table above, there are 39 different characteristics. Some of them can improve the problem solving while some of them make the problem get worse. So the comparisons are made between every two of the characteristics and in the intersection part the numbers which present the principle of problem solving method are put. For example, for solving the conflict of characteristics of 14 and 1, we have problem solving principle 1,8,40 and 15. After we can check from the right side to see what is the principle behind the number. For example, principle 1 means "segmentation". So we should think about to classify the problem to solve it.

By the introduction of TRIZ methodology before, we can conclude that TRIZ helps the company design new product in a more creative and valuable way. It is also very helpful for helping business organization to capture customer value. This will be explained more in details in the next chapter.

3.2.2 Capturing Customer Value through TRIZ

The customer is the only reason why businesses exist; therefore an understanding of what the customer actually requires is an essential element of the strategy of a lean organization (Albert E, 2005). Therefore, when it comes to a problem like designing a more comfortable car seat, although TRIZ can allow us to hear the 'Voice of the System' and consequently be able to generate hundreds of possible future evolution jumps, these ideas alone are far from sufficient. What is also necessary if we are to genuinely create a better car seat (or any other product or service) is an understanding of what any given customer wants and needs at any given point in time (Mann, D.L., 2006). In developing any product or service, creative design combined with the right customer value position will usually bring huge success in the marketplace. Creative design can make your product the "first of its kind" in the marketplace, and it can make your product difficult for competitors to copy (Kai Yang, 2008).

The Theory of Inventive Problem Solving (TRIZ) is an effective methodology that can help companies and product development people improve their creativity. Without innovation, a company's products or services become commodities. This can be very dangerous for the company and require a change in strategy to survive (Cynthia A. Montgomery & Michael E. Porter, 1991). Commodity products are usually the purview of the lowest cost producer. The nature of TRIZ is to shortcut the creative process, and to effectively reuse the knowledge base developed in similar inventions in order to avoid reinvention. According to Russo and Regazzoni, the main benefit of TRIZ in providing guidelines that have a general value and provide detailed prescriptions to increase product sustainability. TRIZ is an indispensable tool for any customer-value-centric company (Russo, D., 2009).

- Improving the Fuzzy Front End for Continuous Innovation Incorporating TRIZ

In order to release novel and valuable products, a crucial aspect for a company is the efficiency of its product development cycle from the so-called fuzzy front end to the detailed design (Gaetano Cascini, 2006). The product conceptualization phase plays a fundamental role in the New Product Development cycle since, in order to develop a successful product in competitive and globalized markets, customer requirements need to be carefully investigated during the Front End design and the product platform planning. (Yan W., 2005).

The Fuzzy Front End is critical for great invention and innovation. It is usually considered as the Concept and Feasibility Stages of an overall product development process (Donald Coates, 2010). Unfortunately it has become vogue for many companies and experts to have a stage gate product development process that focuses on stages after the invention is created (Christopher Meyer, 1993). These systems do little if anything to help the Fuzzy Front End. In fact engineers have been directed at times with good intentions to ignore the front end and focus on the development stages of a stage gate process. The belief was that fast cycle time was the key (Cooper, 2006). The lack of a documented system in the Fuzzy Front End is maybe why it got its name. The Fuzzy Front End needs more structure which can help its consistency. The result of no system can be, “garbage into development is garbage out” (Donald Coates, 2010). This can seen clearly in the below **Figure 40** which is a classical product development process with Fuzzy Front End.

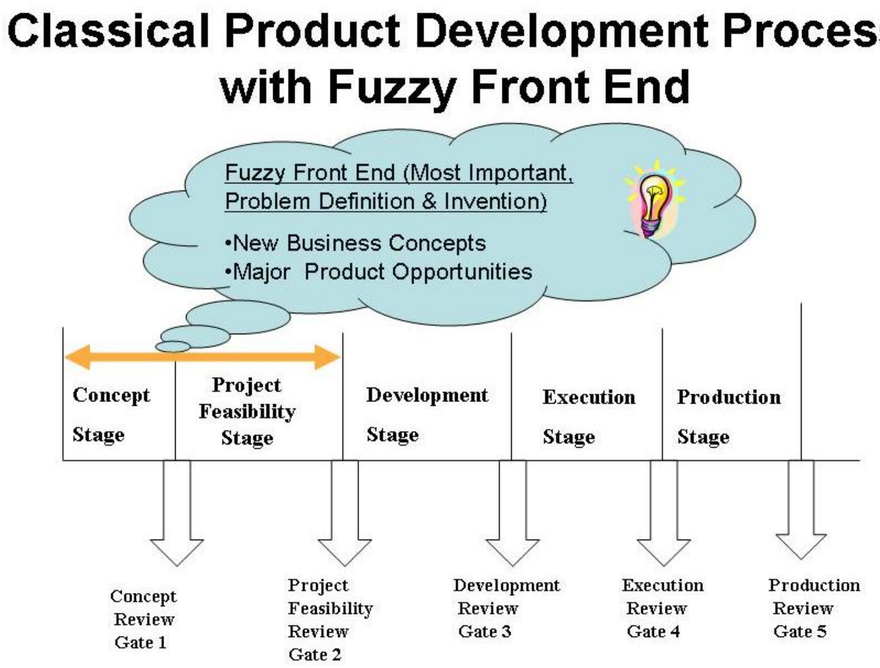


Figure 40. Invention Starts at the Fuzzy Front End of the Development Process

Therefore, Donald proposed a holistic front end Innovation Process Model that embraces elements of what others have proposed but prescribes these elements in a new system. The four elements are:

a)Identify and solve the tough problems. This is arguably the most important part of the Innovation Process Model (IPM). Truly it separates the "good from the great" solutions, since no solution or a weak solution leads to little innovation. Although there are many problem solving techniques available, TRIZ offers a powerful approach that could be at the top of every inventor's repertoire.

b)Perform good business analysis. This determines the link from the technical domain to the socioeconomic domain as Chesbrough has written. A good invention can fail without a solid plan for entry and performance into the social world (Henry Chesbrough, 2011).

c)Perform god business planning. This is different from the short term business analysis and looks at the longer term survival of a company. It uses data generated from many sources including the business analysis to develop multifamily planning for consistent innovation.

d)Provide good environment for innovation. The environment can improve the productivity for invention and innovation through a stimulating physical environment, to management vision and resource support, and to psychological support.

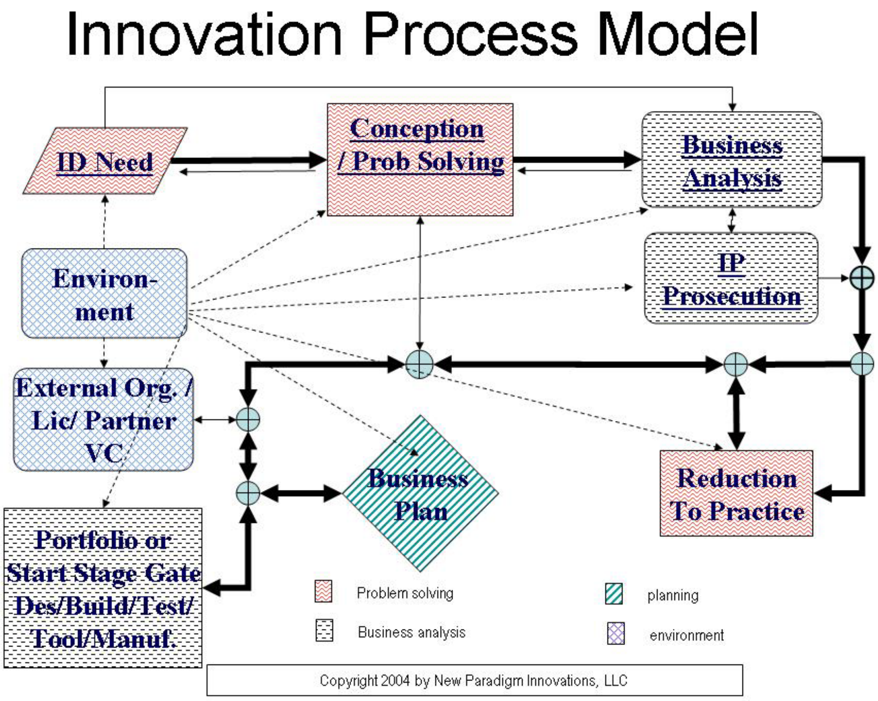


Figure 41. Innovation Process Model Diagram

The IPM is basically a clockwise circle of activities as shown in **Figure 41**. The first element of four is the process of Problem Solving. In this first element, the identification of a customer need (ID in the diagram), the conception of a solution (Conception/Problem Solving), the discovery of a valuable solution, and the reduction to practice are considered part of the overall problem solving element. The potential solutions need to have utility. They need documentation for a quality definition, analysis, and solution but also for subsequent consideration by the business. For novel and non obvious solutions, the inventor should write an Invention Disclosure (considered part of the Problem Solving element). The Invention Disclosure is a witnessed statement of the concept. This will establish an invention date if a patent is recommended.

As can be seen, TRIZ is rated highly for both problem identification and problem solving in this model. It contains methods to identify a more ideal solution, solve contradictions without compromise, disassemble the problem into the key problems, and identifies the most powerful solution methods and is therefore a key to this process of innovation.

From the above literature review, we have got enough knowledge about NPD, Lean NPD, tools and techniques for the success of Lean NPD. Also customer value and customer value creations which are essential factors for NPD. So on next chapter, we will combine this knowledge and our innovation to build our Model—Lean Front End Framework.

Chapter 4 Proposed Model- Lean Front End Framework

In this chapter, a model is proposed to formalize the information, objects and methodologies that should be managed in the Front End phase of New Product Development. The construction of this model is based on the literature study of the general business process and also empirical analysis of several specific companies. The model is used to analyze the practical problem in a real business case in the next chapter. And it turned out to be a successful model which can be promoted and widely applied.

The Lean Front End model comprehensively described the three key elements inside the Front End phase—what activities are included, which parties are involved, and what kind of methodologies/tools can be used. This model is constructed with two phases which involved three parties and five kinds of methodologies/tools used. More in details, two phases are concept development & feasibility analysis phase and technical marketing phase; three parties refer to customer, marketing department and design team; while six methodologies/tools are VOC, FMEA, AHP, TRIZ and QFD. In the literature we already explained why the usage of these methodologies/tools can show or realize the concept of "lean" in Fuzzy Front End phase.

4.1 Framework of Lean Front End Analysis

4.1.1 Introduction of Model

As mentioned before in Literature Review, increased attention has been paid to the Front End of product development. The Front End phase has been indicated as the most important part in product innovation because quality, costs, and timing are mostly defined during the Front End phase but at the same time as the greatest weakness according to the literature. At this early stage, the effort to optimize is low and effects on the whole innovation process are high. In fact, Front End activities may reduce deviations during the following development phase (Birgit Verworn, 2002).

The empirical research of Monica Rossi (2010) also showed us some lights to process the analysis of Fuzzy Frond End. In her research, a questionnaire was made to investigate all the subjects involved in the whole business process of a company in order to gather data to carry out an analysis of waste. As **Figure 42** showed, the result turned out that the most severe wastes among in total thirty kinds (see attachment 1) of wastes are three:

- Time loss for reworks or revisions which are 123 due to change priorities, information, data and/or requirement.
- Time spent with incomplete/incorrect/inappropriate/unreliable information, data, and requirements are 124.
- Time used for developing parts/products which already been designed before, without using existed projects are 125.

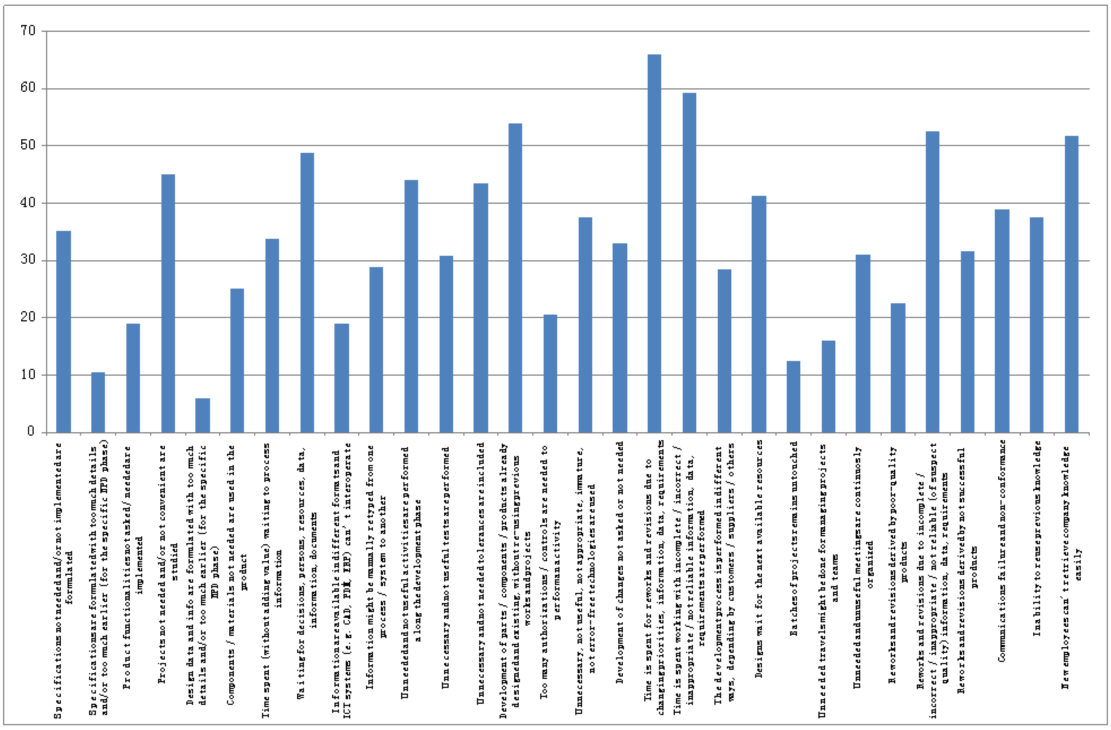


Figure 42. 30 types of wastes in Company S (Monica Rossi, 2010)

We can see both literature and empirical research triggered us to go in deep of the New Product Development process and explore the ”mystery” of Fuzzy Front End phase. In this study, we want to follow the track of other scholars' study of Lean New

Product Development process in the past literature and explore the emerging studying field of Fuzzy Front End by introducing Lean thinking into this stage.

Another issue seems to be extremely relevant when talking about Front End: how many parties are involved in the Front End phase? As literature has revealed to us, in Front End activities the foundation elements such as strategic orientation, concurrent engineering, and so on cut across projects, and form the basis for project-specific activities. For a specific project, the team should focus on the team vision building to ensure strategic fit of project, shared purpose, and a clear project target. So we considered that the whole functional subjects before manufacture should be all involved in the Front End phase as a project team. Therefore, it is very necessary to introduce some knowledge about the structure of an organization in order to lay a foundation for further construction of model.

A business is normally organized by its functions, for example, marketing department, production department, accounting department and so on. For the large business they might have a number of businesses within the whole group. This would be coordinated by a Head Office, where all the major decisions are made. (Business Mate.Org,2012) For the single business, the organization is settled by the central functions. There are several types of business as listed below:

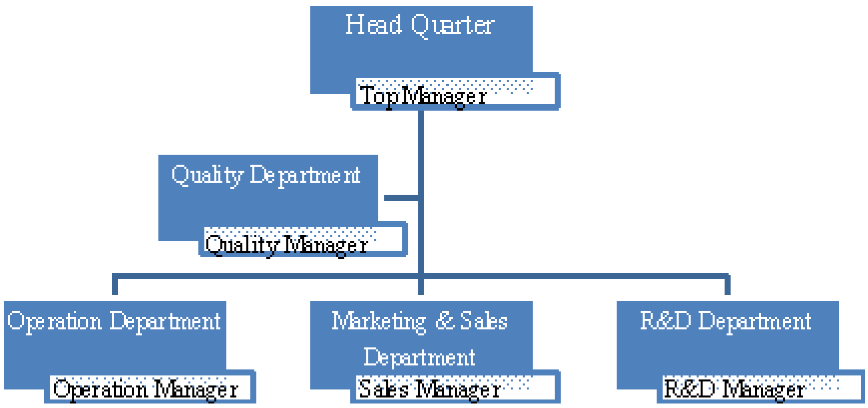


Figure 43. Example of A Business Structure

(1) Product Oriented-The functions are organized around the product. For example, a business like ICI, who are the UK's leading chemical manufacturer, a

product manager would have a team of functions who would answer to them, like accounting, marketing and production.

(2) Geographical Oriented-A hierarchy might be split according to different places that the product is sold into. For instance a business may have a Far Eastern division of its business, which would take into account the different cultural and supply differences of the region.

(3) Market Oriented- The organization is based on market segments. So an airline business like British Airways could concentrate on long haul, short haul, holiday maker, business clients and freight. (Business Mate.Org. 2012)

Here, we adopted the Market Oriented business organization to carried on further develop. As well-known, nowadays more and more companies focused on customer value and market requirements because of the rapidly changing of market and continuous updating product series. And to capture customer voice in a quicker and right way is also the focus of this research. We summarized the departments and roles a company may have as following.

Table 7. The departments of a business organization

Department	Role
Accounting	Provides a detailed record of the money coming in and going out of the business and prepares accounts as a basis for financial decisions.
Human Resource	Deals with all the recruitment, training, health and safety and pay negotiations with unions/workers.
Production	Makes sure that the production plans are met on time and products of the right quality are produced.
Design	Carries out function analysis of the products.
Purchasing	Buys all the raw materials and goods required for production.
Sales	Deals with all aspects of selling to customers.
Marketing	Carries out marketing research, organizes advertising and product promotion.
Logistic	Delivers final products to customers.

Therefore, we identified the basic and essential departments inside a marketing oriented business organization. By specifying this, we are aimed to lay a foundation for the further analysis of the functional structure which will be involved in the early stage Fuzzy Front End.

4.1.2 The Model Framework

Based on the former statement, the model is developed in order to generalize and better analyze the problems in real cases. In this model the phrases before manufacture are described, they are concept & feasibility phase and technical marketing phase. In each phase, we also identified what kind of information is needed, who are involved in this phase and how we can execute the activities in order to perform better according to the concept of Lean Front End. In the following paragraph, we will go through every concept in this model for better understanding.

The Lean Front End model comprehensively described the three key elements inside the Front End phase—What activities are include, which parties are involved, and what kind of methodologies/tools can be used. This model is constructed with two phases which involved three parties and five kinds of methodologies/tools used. More in details, two phases are concept development & feasibility analysis phase and technical marketing phase; three parties refer to customer, marketing department and designer team; while six methodologies/tools are VOC, FMEA, AHP, TRIZ and QFD. In the literature we already explained why the usage of these methodologies/tools can show or realize the concept of "lean" in Fuzzy Front End phase.

Two Phases:

In this framework we divided Fuzzy Front End process into two phases-Concept development & feasibility analysis phase and Technical marketing phase. By defining the phases, we lined out what kind of activities are include in the Fuzzy Front End phase. More detailed explanation is as below, as shown in **Figure 44**.

(1) Concept development & feasibility analysis phase

In this phase, ideas for new products is obtained from basic research, for example, Market and consumer trends, company's R&D department, competitors, focus groups, employees, sales people, trade shows and so on. Five different Front End elements are included (Koen et al, 2001):

- Opportunity Identification

In this element, large or incremental business and technological chances are identified in a more or less structured way. Using the guidelines established here, resources will eventually be allocated to new projects which then lead to a structured NPD strategy.

- Opportunity Analysis

This element is done to translate the identified opportunities into implications for the business and technology specific context of the company. Here extensive efforts may be made to align ideas to target customer groups and do market studies and/or technical trials and research.

- Idea Genesis

The idea genesis is described as evolutionary and iterative process progressing from birth to maturation of the opportunity into a tangible idea. The process of the idea genesis can be made internally or come from outside inputs, for example, a supplier offering a new material/technology, or from a customer with an unusual request.

- Idea Selection

The purpose of idea selection is to choose whether to pursue an idea by analyzing its potential business value.

- Concept Development

During this part, the business case is developed based on estimates of the total available market, customer needs, investment requirements, and competition analysis and project uncertainty.

(2) Technical marketing phase

For a long time, even until nowadays, most of the business has been split into two main forces: the technical people and marketing people. The separation of these two functions brings some drawbacks to a business organization. For example, marketing people get contact with customers directly. In another hand, the technical people are only focused on the realization of features what the customers want. And they get this information from the marketing department without direct contact with customers. The problem is without technical background the marketers cannot explore the customers' need in an optimal way or they cannot understand very well what the customers really want and whether the customers’ need can be achieved by current technology. Instead the designers sit in their office and build a product based on their "fantasy". In a long term, this kind of communication "disability" will harm the development of the new product development. In this case, it is very important to develop a sought of organization to bound these two functions together. That is why technical marketing came into our eyes. It is a specific and niche area which taps on the synergy of both sets of these expertises in order to achieve a project success and customer win. Technical marketing can be broadly split into two phases:

- In-bound Marketing

The first phase in which marketing is needed to help define the product/R&D/technology road map.

- Out-bound Marketing

The second phase helps push the product out to the market. An area where engineers with a technical background can especially value-add if they are equipped with the right kinds of marketing skill sets as needed in a hi-tech industry for this job function.

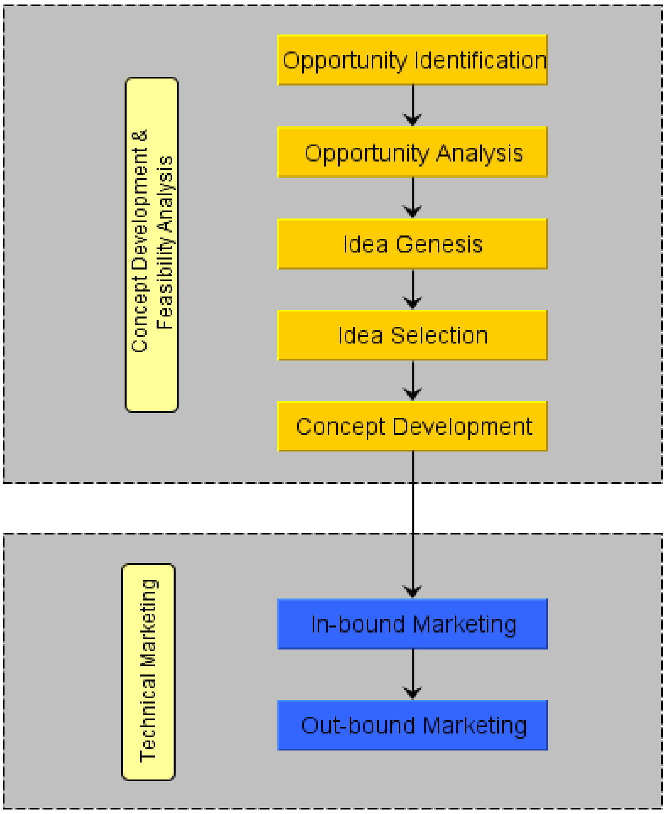


Figure 44. Activities of two Fuzzy Front End phases

Three Parties:

In this framework, we also explained what contents are involved in the Fuzzy Front End phase by defining three parties-WHAT, WHO and HOW. WHAT means what kind of information is needed; WHO means which people are involved; and HOW means which methodologies/tools could be used to analysis this phase.

(1) WHAT

In this part we explained what kind of information is needed in the Front End phase.

First during the concept development & feasibility analysis process, the most important information we need are to capture what is the customer's real needs, both for the open market and specific customers (customized products). This information can be collected through several different channels: Directly customer investigation, for example, questionnaire, survey, interview, or focused group. It can be also revealed by customer complaints, past products design experiences from design department, new features from R&D department. Another channel is marketing analysis which the information can be got from competitors, market trends and so on.

Second in the technical marketing part, obviously the task is transferring customer needs into specific product feature design. So there are three procedures of information 'evolutions'. At very beginning, design department should receive the customer requirement documents from marketing department. And then design specification documents should be released based on the customer requirements. The last step is going through the detailed design after the design specification is settled.

(2)WHO

In this part we identify all the subjects/departments who are involved in the Front-End process according to which phase (concept development and feasibility analysis or technical marketing) they belong to and what kind of information should be assigned to. There are six subjects involved in the whole FE process:

- Customer

Customer also called buyer, is a party that receives or consumes products and has the ability to choose between different products and suppliers. It is the party outside but also the input to the business entity. The only reason of a business ran is to serve the market. Therefore customer plays a key role to the successful of the business. In another word, also as literature showed us, to capture customer value, define it, well represent it and communicate it is the most important part of the Front End process.

- Marketing Department

This is the party who has the directly contact with customers inside the organization. Marketing involves a range of process concerned with finding what consumers want, and then providing it for them. This involves four key elements, which are referred to as 4P's (the marketing mix) (Peter M. Banting and Randolph E. Ross, 1973)- the right product, the right price, the right place and the right promotions.

The marketing department must act as a guide and lead the company's other departments in developing, producing, fulfilling and servicing products or services for their customers. Communication is vital here. The marketing department should have a better understanding of the market and customer needs, but should not act independently of product development or customer service. Technical department should be involved, and there should be a meeting of people with different background, whenever discussions are held regarding new product development or any customer-related function of the company.

- Design Team

Design team gives form to products, spaces and messages and satisfies the functional, psychological and aesthetic needs of users. Design is systematic, as it involves the analysis of problems in our physical environment, and the transformation of findings into appropriate and usable solutions. Designers do not directly communicate with customers but they receive the information from marketing department and translate the customer requirements first into technical specifications, then into detailed design. Depending on the company design department can be composed of different departments, expertises, functions, such as:

  - Test Engineer

A test engineer is a professional who determines how to create a process that would test a particular product in manufacturing, quality assurance or related area, in order to assure that the product meets applicable specifications. Test engineers are also responsible for determining the best way a test can be performed in order to achieve 100% test coverage of all components using different test processes.

Ideally, a test engineer's involvement with a product begins with the very early stages of the design phase, which refer to product requirement document and marketing requirement document. By working as a member of Front End team, test engineer makes sure that the product can be readily tested and built.

- Software & Application Department

This party may exists in some business organizations, especially those manufacture enterprises who is focused on B2B business by designing and producing parts or products. In this case, the test of the parts/products does not only concentrate on the quality of product itself but also the usability or compatibility as one part of the function of final user case. So in the technical marketing phase, software & application department has to work with design teams together to develop the detailed design features.

- Manufacture Department

Manufacture is the functional area responsible for turning inputs into finished outputs through a series of production processes. This party does not participate in the Front End process. It is the department who execute the output of the former phase by moving to production phase.

(3) HOW

In this part we selected some methodologies or tools could be used in each phase. To use the right tools is very important in the phase of problem identification and problem solving because by them we can analysis the situation better and specify the problem and then solve them in the right way.

Table 8. Merhodology / Tool in Lean Front End Phase

Methodology / Tool	Description	Use Phase
VOC	The methodology to understand what the customers really want and to transform their needs into quality criteria.	Concept Development
FEMA	Aims to analysis of potential failure modes within a system for classification by the severity and likelihood of the failures.	Feasibility Analysis
AHP	The Analytic Hierarchy Process is a structured technique for organizing and analyzing complex decisions, particularly applied in group decision making.	Feasibility Analysis
TRIZ	The theory includes a practical methodology, tool sets, a knowledge base and model-based technology for generating new ideas and solutions for problem solving.	Feasibility Analysis
QFD	To transfer customer needs (after critical to quality) into design specifications. Aims to eliminate such wastes by identifying customer needs properly in the first place.	Technical Marketing

4.1.3 Involved Methodologies/Tools

In this chapter we would like to introduce better the methodologies/tools mentioned before by specifying how is going to use those tools, how to use them and why we use them. Moreover, based on these methodologies/tools we developed two matrixes which combined several methods together. In the following we will explain better why those two matrixes we developed are very useful and how to use them.

(1) Voice of Customer (VOC)

Voice of customer is used in business to describe the in-depth process of capturing a customer's expectations, preferences and aversions. Specifically, the voice of the customer is a market research technique that produces a detailed set of customer wants and needs, organized into a hierarchical structure, and then prioritized in terms of relative importance and satisfaction with current alternatives. VOC studies typically consist of both qualitative and quantitative research steps. They are generally conducted at the start of any new product, process, or service design initiative in order to better understand the customer's wants and needs, and as the key input for new product definition, QFD (Quality Function Deployment) and the setting of detailed design specifications.

Generally speaking, there are four steps of identifying VOC:

(1) Identify customers

Usually, when we are speaking about customers, there are two types of customers related, external customers and internal customers. To identify the object is a very important starting point.

(2) Collect and analysis data

There are several ways to collect information from customers, for example, telephone interview, face to face interview, email survey and focus group.

(3) Generate a key list of customer needs (Critical to Customers)

This phase is mainly to understand what customers want in their language base on the analysis of the data collected from the former step.

(4) Transfer CTC to CTQ (Critical To Quality)

The last step is to convert the Voice of Customers finding into Critical to Quality or Critical Customer Requirements so they can be used to measure the success of our process improvements.

It is critical that the product development team is highly involved in this process. They must be the ones who take the lead in defining the topic, designing the sample (for example, the types of customers to include), generating the questions for the discussion guide, either conducting or observing and analyzing the interviews, and extracting and processing the needs statements.

VOC can be used by the project team in the concept development phase at the very beginning of the project to capture the customer needs and transform it into the critical points for quality.

(2) Failure Modes and Effects Analysis (FMEA)

FMEA is an inductive failure analysis used in product development, systems engineering and operations management for analysis of potential failure modes within a system for classification by the severity and likelihood of the failures. A successful FMEA activity helps a team to identify potential failure modes based on past experience with similar products or processes or based on common sense logic, enabling the team to design those failures out of the system with the minimum of effort and resource expenditure, thereby reducing development time and costs. Because it forces a review of functions and functional requirements, it also serves as a form of design review to erase weakness (related to failure) out of the design (Forest Grove, Weber System, 1978).

There are three elements to precede FMEA:

- Occurrence (O)

To look at the cause of a failure and the number of times it occurs. This can be done by looking at similar products or processes and the failure modes that have been documented for them in the past. A failure cause is looked upon as a design weakness.

- Severity (S)

Severity is the impact of the failure, how much it impacts of the failure and how much it impacts the process.

- Detection (D)

Detection is the ability to detect the problem before it happens. When appropriate actions are determined, it is necessary to test their efficiency.

After all, the criticality of a failure mode is evaluated by Risk Priority Number (RPN) which is calculated as the formula below:

RPN=S*O*D

The RPN will be between "1" and "1000". Below is an example of FMEA work sheet for the toys' making process. From the **Figure 46** we can know that the processes with high RPN, such as, the customer ordering interaction process with RPN=512 should be focused and be improved.

METRIC OF THE FMEA PARAMETERS										
Scale / Parameters	1	2	3	4	5	6	7	8	9	10
OCCURENCE (OCC)	Impossibility of occurrence									Certainty of Occurrence
SEVERITY (SEV)	Minor severity									Major severity
DETECTION (DET)	Easily detectable									Not detectable

Figure 45. Matric of FMEA Parameters

					Evaluations							Results			
Process Steps	**Potential mode of failure (main defects)**	**Potential effect of failure**	**Potential causes of failure**	**Current control**	**SEV**	**OCC**	**DET**	**RNP**	**Recommended actions**	**Responsibility**	**Actions taken**	**SEV**	**OCC**	**DET**	**RNP**
CUSTOMER ORDERING	Interaction	Lower similarity of the toy	Wrong expression of the customer; misunderstanding of the designer	Encourage the communication between customers and designers	8	8	8	512	2 designers responsible for one customer; enriching interaction methods	Designers; marketing department	2 designers responsible for one customer	6	3	3	54
PROCUREMENT	Stocks	Late delivery	Insufficient stock	Inventory management	7	4	2	56	Inspe 正在查询... [illegible] inventory more frequently	[illegible]ement department	Inspection the inventory more frequently	5	2	2	20
DESIGN	Designers	Unsatisfactory toy	Designers lack of knowledge; designers cannot understand	Selection designers strictly	6	5	4	120	Training designers before working; 2 designers responsible for one customer	H&R department; direct manager	Training designers before working; 2 designers responsible for	4	3	3	36

Figure 46. Example of FMEA analysis for Toyes

The advantages of FMEA analysis are:

-Improve the quality, reliability and safety of a product/process

-Improve company image and competitiveness

-Increase user satisfaction

-Reduce system development timing and cost

-Collect information to reduce future failures, capture engineering knowledge

-Reduce the potential for warranty concerns

-Early identification and elimination of potential failure modes

-Emphasize problem prevention

-Minimize late changes and associated cost

-Catalyst for teamwork and idea exchange between functions

-Reduce the possibility of same kind of failure in future

-Reduce possible scrap in production

FMEA can be used by the project team in feasibility analysis phase in order to evaluate the possible risk of the product/process.

(3) AHP

The Analytic Hierarchy Process (AHP) (Saaty, Thomas L, 1980) is a structured technique for organizing and analyzing complex decisions. It has particular application in group decision making, and is used around the world in a wide variety of decision situations. Rather than prescribing a "correct" decision, the AHP helps decision makers find one that best suits their goal and their understanding of the problem. It provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions.

There are four steps of using this methodology:

- First, users of the AHP decompose their decision problem into a hierarchy of more easily comprehended sub-problems, each of which can be analyzed independently. The elements of the hierarchy can relate to any aspect of the decision problem-tangible or intangible, carefully measured or roughly estimated, well-or poorly-understood-anything at all that applies to the decision at hand.

- Second, once the hierarchy is built, the decision makers systematically evaluate its various elements by pair wise comparison (comparing them to one another two at a time), with respect to their impact on an element above them in the hierarchy. In making the comparisons, the decision makers can use concrete data about the elements, but they typically use their judgments about the elements' relative meaning and importance. It is the essence of the AHP that human judgments, and not just the underlying information, can be used in performing the evaluations.

- Third, the AHP converts these evaluations to numerical values that can be processed and compared over the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse capability distinguishes the AHP from other decision making techniques.

- In the final step of the process, numerical priorities are calculated for each of the decision alternatives. These numbers represent the alternatives' relative ability to achieve the decision goal, so they allow a straightforward consideration of the various courses of action.

Here is an example of how to use AHP:

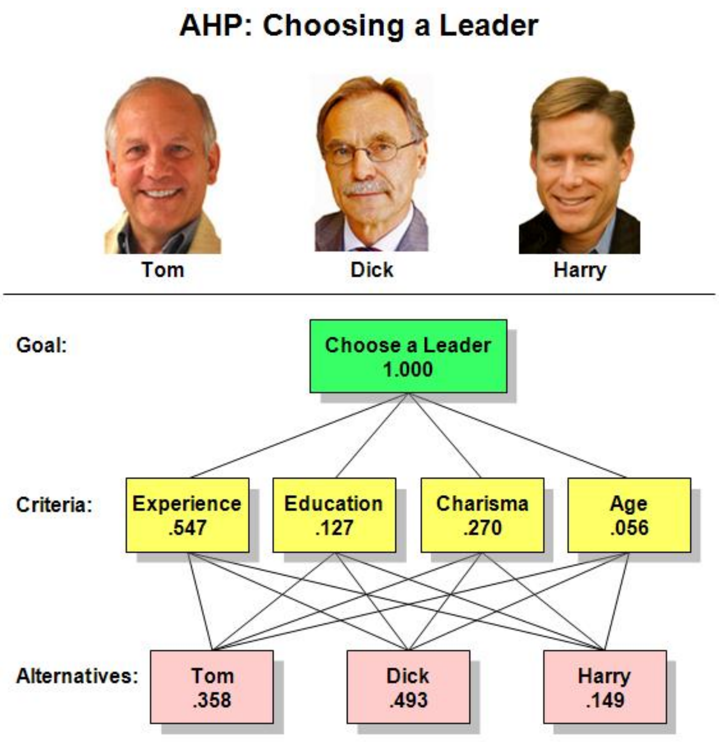


Figure 47. Example of AHP

This is a simple AHP hierarchy, with final priorities. The goal is to select the most suitable leader from a field of three candidates. The factors to be considered are Experience, Education, Charisma, and Age. According to the judgments of the decision makers, Dick is the strongest candidate, followed by Tom, then Harry.

AHP could be used in the phase of technical marketing phase by design department in order to understand better the importance of several of features or functions.

(4) TRIZ

TRIZ is a "problem-solving, analysis and forecasting tool derived from the study of patterns of invention in the global patent literature" (Hua, Z.; Yang, J.; Coulibaly, S. and Zhang, B., 2006). In English the name is typically rendered as "the theory of inventive problem solving". It presents a systematic approach for analyzing the kind of challenging problems where inventiveness is needed and provides a range of strategies and tools for finding inventive solutions. In the process , the analysis of the contradiction, the pursuit of an ideal solution and the search for one or more of the principles which will overcome the contradiction, are the key elements which is designed to help the inventor to engage in the process with purposefulness and focus.

One of the tools is contradiction matrix in which the contradictory elements of a problem were categorized according to a list of 39 factors which could impact on each other. The combination of each pairing of these 39 elements is set out in a matrix (for example, the weight of a stationary object, the use of energy by a moving object, the ease of repair etc.). Each of the 39 elements is represented down the rows and across the columns (as the negatively affected element) and based upon the research and analysis of patents: wherever precedent solutions have been found that resolve a conflict between two of the elements, the relevant cells in the matrix typically contain a sub-set of three or four principles that have been applied most frequently in inventive solutions which resolve contradictions between those two elements.

TRIZ could be used in the phase of technical marketing by design team. The aim is to facilitate design in a more innovative and systematic way.

(5) QFD

Quality function deployment (QFD) is a "method to transform user demands into design quality, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and component parts, and ultimately to specific elements of the manufacturing process"(Dr. Yoji Akao,1966). QFD helps transform customer needs (the voice of the customer) into engineering characteristics (and appropriate test methods) for a product or service, prioritizing each product or service characteristic while simultaneously setting development targets for product or service.

There are seven steps to carry out QFD:

1) Identify customer needs

2) Define the priorities of the needs

3) Translate customer needs into technical requirements

4) Relate the customer needs to the technical requirements

5) Define interrelationships between the technical requirements

6) Conduct an evaluation of the competitors' products or services

7) Select critical technical requirements to be deployed in the design and production process

QFD is used in the phase of technical marketing by designer team. The aim is to transform the customer request (critical to quality) into the design specification (critical to design).

Therefore, based on the interpretation before about "two phases" and "three parties", we structured the Lean Front End framework as following **Figure 48.**

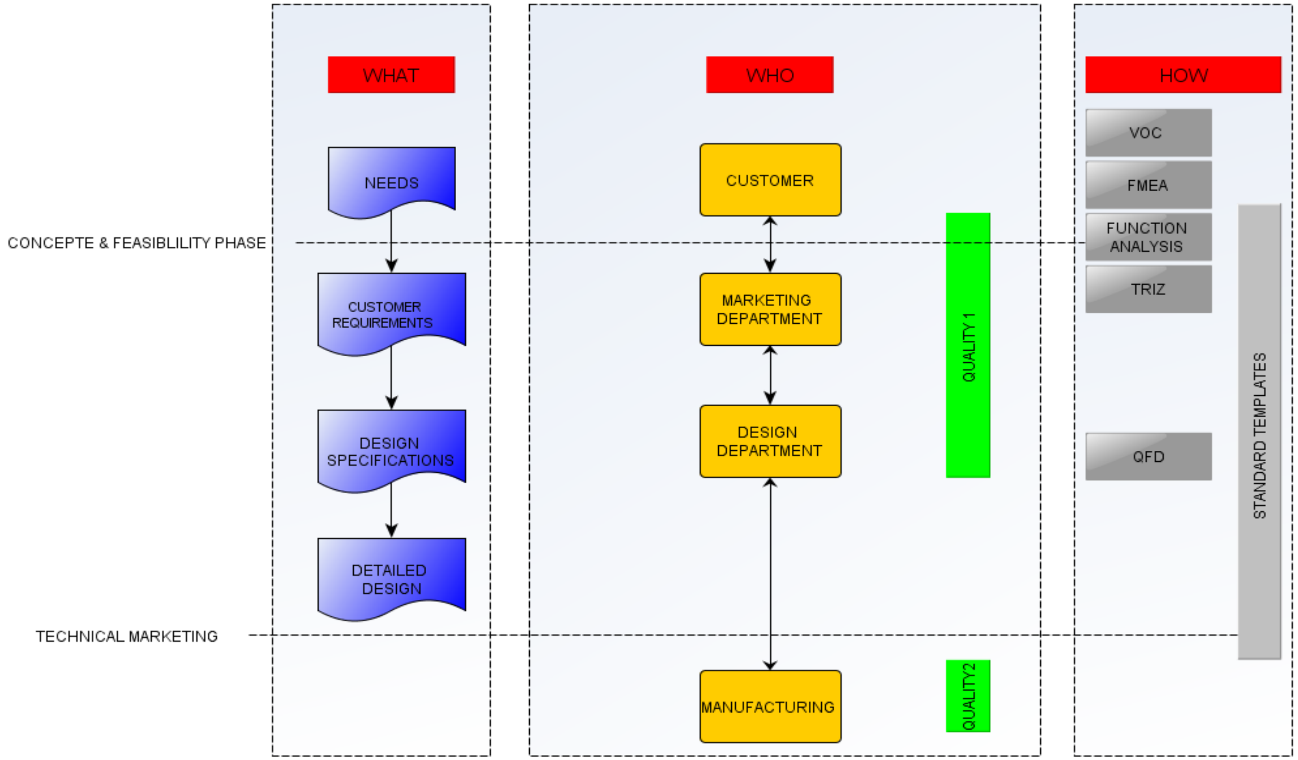


Figure 48. Lean Front End framework

4.1.4 VOC Matrix & Function Analysis Matrix

According to the methodologies/tools introduced before, in the end we developed two matrixes in order to carry out the concept development and function analysis. The VOC Matrix is based on the theories of voice of customer and TRIZ. The aim of this matrix is to find out what the customer really wants and capture the value for them. While the Function Analysis Matrix is derived from simplified AHP in order to understand among all the functions in one product which are those more important compared to others.

These two matrices have different targets. For the VOC Matrix it is more open market oriented. It means by using this matrix we intend to gather information from a big population of the market. While the Function Analysis Matrix is more tailored customers oriented. We use this matrix to evaluate the specific needs of one customer and satisfy his needs by customized product. The following description gives detailed explanation about these two matrices.

(1) VOC Matrix

In this matrix, several aspects have to be valued. In the column of "Function", we filled in the functionality of a product which is a transfer of VOC. Also what are the values for customer according to the product can be filled in. Here we took an example of USB pen. From the VOC and QFD analysis we learn that for a USB pen customer cared about the function of "USB", "Body Color", "Ink Color" and "Size of Point" most. So we put these four characteristics on the ‘Function’ column. The "Importance" of the function to the customer value is numerically valued with a weight from 1 to 5, where ‘1’ means less important, ‘3’ means more important, ‘5’ means much more important. Weight of each function is determined by market department depending on the investigations’ statistics for collecting customer needs. From the matrix, we can see that to be a USB pen, the importance of ‘USB’ function is much more important, so the weight for ‘USB’ function is 5. The information of "Satisfaction" of existing products is gathered by questionnaire or survey or interview conducted by marketing department to customers. The matrix below indicates that the customer satisfaction to 'USB' function of the existing product is only 10% which is very low. The value of "Satisfaction" of expected future products is an estimated one from the hypothesis based on the importance of the function to customer satisfaction, customer satisfaction to the existing product, market trend, current technology level of company and so on. Instead this information should from inside the company. The example shows that customer satisfaction to the 'USB' function can be improved to 20% after certain implementations and efforts. "Potential Market" is a value which can be gained from marketing department. This value is based on the market surveys and analysis. We can see that the potential market for the'USB' function is 30% which means if we can do better on this function, we will catch a certain amount of customers. Strategy is a kind of comprehensive analysis to tell us whether it is worthy of investment. If the market is mature or there is no possibility for us to improve the customer satisfaction under the current technology, that means this market is not so much interested and the strategy No. should be low. Vice verse if the market is new or growing rapidly and we still have a lot of space to improve our customer satisfaction, it would be better to put effort on this market and the strategy will be highly improved.

Table 9. Example of VOC Matrix

Function	Importance (1-5)	Satisfaction (existing products)	Satisfaction (expecting products)	Potential Market	Strategy No.
USB	5	10%	20%	30%	100%
Body Color	1	100%	100%	4%	40%
Ink Color	3	90%	95%	5%	60%
Size of Point	1	90%	100%	6%	65%

Importance Scale:

1= Less Important

3= More Important

5= Much More Important

The important scale is given by the marketing department based on the judgment of customer preference from the data of marketing research by which the information from the customers are got.

(2) Function Analysis Matrix

Here we use AHP to evaluate the different functions of a product by making one to one comparison. Still we took the USB pen as an example. The designers and marketers are asked to cooperate to fill the first part of this table by making comparison according to what the customer really wants. After this evaluation, designers will communicate with marketers about the result and later customers will be asked to check the weight of the each function with marketers to see if it is what he really wants. If it is agreed by the customer, the design team can go on to real design. If not, more communication is needed between customer, marketing people and designers in order to improve the initial plan and find out what the customer really wants. Here we try to propose a project team with different talents instead of the long communication channel because it obviously facilitate the transform of information in a more effective and efficiency way.

By the example we had, we will try to explain you the function analysis matrix. The first part of the matrix is to identify functions important for a USB, which is reflected on **Table 10** that the result after communication between designers and marketers is that “USB”, “Body Color”, “Ink Color”, “Size of Point” are the critical features for a USB pen. Then we should determine the interaction importance among the functions, here weights are applied, take the effect of “Body Color” to “USB” for example, the weight is 1/3, which means “Body Color” function is not important comparing with “USB” function. After the evaluation, we can get a sum of the weights for each function. For example, the calculation result of “USB” function is 9.33 which is the sum of the second line of the matrix. Then based on the calculation, we can get a weight percentage for each function, where a higher weight percentage means this function is more important for the customer. So we can see from **Table 10** that the most important function for the customer is USB (40%) and Size of Point (34%) while the Body Color (11%) and Ink Color (14%) are not so important.

Table 10. Example of Function Analysis Matrix

Function	USB	Body Color	Ink Color	Size of Point	Calculation	%
USB	1	3	5	1/3	9.33	0.40
Body Color	1/3	1	1	1/3	2.66	0.11
Ink Color	1/5	1	1	1	3.2	0.14
Size of Point	3	3	1	1	8	0.34

Importance Scale:

1= Less Important

3= More Important

5= Much More Important

4.1.5 Information Documentation

Another important issue in the Front End process is knowledge management. Think about it, we may do a great job of exploring what is customer value and we are able to design and produce the customer want. But we achieve this goal by a very time-consuming and resource-wasting process. In this way we are not provide the best solution both for the company and the customers because for the business we waste time/money and we are not able to do the job in the most effective way while for the customer they need to pay more for the non-value added activities. So to have the proper tools are necessary but not sufficient, without recording and communicating and transmitting the right information, the process will not be successful. Therefore, how to organize information is another crucial issue in Front End process.

Also as we cited the research of Monica Rossi (2010) before, we can see that the most server wastes among in total thirty kinds of wastes are three:

- Time loss for reworks or revisions due to change priorities, information, data and/or requirement.

- Time spent with incomplete/incorrect/inappropriate/unreliable information, data, and requirements.
- Time used for developing parts/products which already been designed before without using existed projects.

They all related the impropriate documentation of information/knowledge. So to develop several standard templates for marketing department, design team and other involved parties are very important for a better performance of Front End process.

Templates are needed in each phases among the whole process of Fuzzy Front End. To be more specific, when marketing department contact with the customers, the documentation in a standard way will be very important because it will facilitate the mutual communication. For example, a check list can be developed to require the information from customers-what kind of product the customer wants? And what are the features or characteristics of this product favored by the single customer? In the phase of design and test, a thought of checklist also could be done to check if all the features which the customer requested are all satisfied. Also in this phase, the documentation of knowledge of the existed projects can be very helpful for the future projects. Because in this way the reference can be taken from the past project if the same features or works have been before. In this way the repetition will be avoided furthermore time and cost can be saved.

For example, we developed a customer contact template as below.

Customer Contact Template

Date: 04-07-2012
Recorder: Dante

Code: 2012
Customer Name: Shake Spear
Product Required: USB Pen

Product Feature Check List

USB	16GB☑	8GB	No preference
Color	Red	Black	No preference☑
Point	0.7cm	0.5cm☑	No preference
...	...	...	...

Figure 49. Customer Contact Template

In the template above, some main information are included. For example, the time of this documentation happened, who is the recorder of this document, who is the customer and what kind of product the customer selected. Moreover, it also showed main product features and what is the customers' selection. This kind of documentation is very useful for the future market analysis to understand what the general requirements for this kind of product are. And also it will facilitate the customer tracking by following and analyzing the purchase of the same customer in different period.

4.2 Lean Front End Framework Implementation Roadmap

In this chapter a roadmap is designed to give an instruction the usage of Lean Front End Framework. Following the interpretation of the structure and the content of the model, here by this chapter we devoted our effort on guiding the reader to implement this model into practices by introducing several steps of using Lean Front End Framework. There are four steps to follow:

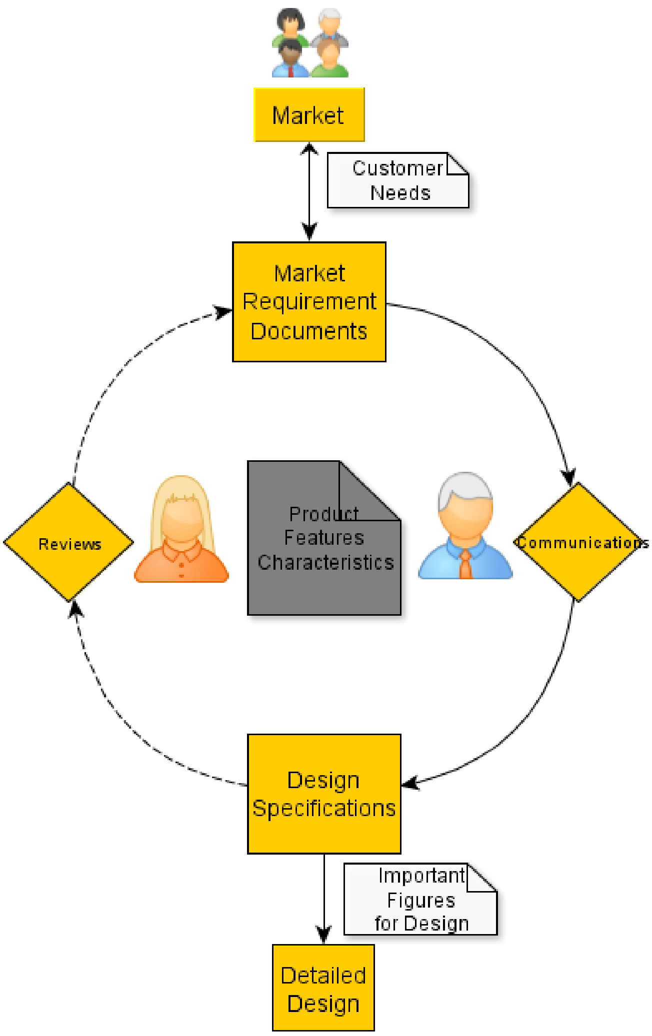


Figure 50. Road Map of Model Implementation

(1) Recognize Customer Needs

In order to capture customer value and correctly communicate inside Lean Front End project team, the first step is to identify customer needs, in another word, what the customers really want.

The methodology we can used to recognize the customer needs is VOC. By the large base of customer survey and satisfaction investigation, we can get a large range of customer preference of the products, including outlook, performance and so on. For customized product, the customer need can be directly obtained by interview with single customer.

(2) Create MRD (Market Requirement Documents)

The aim of this stage is to target the key elements or characteristic of customer requirement, furthermore, formalize it into Market Requirement Document.

The methodologies can be used in this stage is two matrixes which have been developed in this research. For the open market, the VOC matrix can be used to identify what are the critical characteristics the customers really want; For serving the customized market, we introduced another matrix-Function Analysis Matrix. By using this model, the specified customer will be asked directly the importance of the functions of the products he/she wants.

(3) Translate MRD into DS(Design Specifications)

In this phase, the target is to translate the market requirements into design specifications. This is a very important stage for a New Product Development process because it demonstrated if the project team has already understood the customer requirements in the right way. And it has directly impact on the specific design in the further step.

The tool can be used in this phase is QFD (Quality Function Deployment). As been introduced before, this tool is used to translate customer requirements to design specifications. But perfectly understanding the customer needs is not an easy job to do and it cannot be done for one way communication. In this case, the communication cycle is created to show the real situation of this stage.

As showed in the **Figure 50** before, two loops have been described related to this double direction communication. The first loop is between marketers and designers inside the project team, they have several times of communication and review until it achieves a satisfaction level for concluded the Design Specification for both parties. The second loop is between customers and marketers which is outside the project team. It means during the mutual communication between marketer and designer, the customers will also be asked for further information according to the feedback which the marketer gets from designers. This kind of communication cycle can promise the result of the Design Specification which is strictly following the desire of customers. To get all the teams members involved and developed a barrier-free communication channel are the main strength of Lean Frond End methodology.

(4) Carry on Detailed Design

This is the last step of carrying out Lean Front End model, which means after the formalized specification of design. The designers can go in deep to work on the detailed design.

In this stage information documentation is very important since specified design is a kind of knowledge which has been developed by the designers inside the company which can be used repeatedly in the future. Even if the project is not the same in the future, part of the existed documented design can be still used as a reference. So to develop some kind of template to record the information is highly proposed during this part.

After four main steps of Lean Front End framework is the new product manufacture which is the next phase of New Product Development.

4.3 Validation of the Model

In order to test the quality of the model, we applied this model to a real business case. It turned out the model is very applicable to solve the real problem in the industrial world.

4.3.1 Introducing the model to real business case

A project study associated with this research has been done with S company, which is a world-wide semi-conductor producer. And it is also the continuing study of New Product Development process but one step forward; we focused only on Front End activities.

(1) Why S company

We chose S company because it is a very mature manufacturing company with a very complementary business process. And the company has a strong motivation to improve and involve in academicals studies by cooperating with scholars. A serious previous study has been done to evaluate the business process of the company. And the problem of early stage of product development has been identified which laid a very solid foundation for the further study. In a word, all those conditions favored both of the parties to carry on this study.

(2) How the project is proceeding

- Periodical meeting

During this research, we frequently visited S company to gather information and understand the situation. A once-a-week project meeting with quality managers of the company has been carried on in order to communicate what has been done and what we need to do in the future. Meanwhile, the meetings inside the company between quality people and other departments which are involved in the study have been carried on in order to deep analysis the real situation inside the company.

- Interview

We also interviewed the people from different departments who are related to this research. For example, people from Marketing department, Design team, Test engineering department and Software & Application department. This kind of face-to-face interview is very important to help us to understand the daily routine of their jobs and how they communicate with each other. By this we tried to find out the existing communication problems and the flaw of current business process.

- Questionnaire

Besides, an on-line questionnaire is made to ask all the employees to evaluate their jobs and how they feel about the current situation and what they think can be changed/improved, for example, "How many times did you start to work without the right information". Thanks to this questionnaire we gathered sufficient and reliable data to precede the analysis of missing documentation.

(3) What has been done during the project

- As-is BPF & VSM

During the project, we draw out the whole BPF (Business Process Flow) under the instruction of quality managers of the company and the information we gathered. After the analysis of the whole process and discussion with them, we targeted the problem at the early stage of product development, which means the Front End stage. Base on this judgment, the more detailed VSM (Value Stream Map) of initial marketing phase has been drawn.

- Improved VSM of FE phase

Based on the as-is situation of the company, we proposed an improved value stream map after the analysis of the process. The repeat loop which does not create value has been eliminated. So does the activities which are logically wrong or waste too much time and resources instead of creating small value.

- Introducing the usage of two Matrix

Meanwhile, the VOC Matrix and Function Analysis Matrix have been introduced to the company for early product concept development and feasibility analysis.

- Developing templates for information documentation

The other important part knowledge management is also under the discussion with the company. Therefore, several templates with different aims have been developed in order to proceed better knowledge management of the business process.

4.3.2 The result

After six months' testing and realization, the result is quite inspiring. According to the customer satisfaction investigation and some indicators revealed by the company the model we provided are capable to offer a better way to solve the real problem related Front End phase in New Product Development process. The detailed procedure and results will be exposed in the next chapter.

Chapter 5 Empirical Research

In the previous Chapters we developed a framework to carry out Lean Front End analysis. The next step is to understand how the model built can be useful for business organization in the real world. In order to do this, an empirical research has been undertaken. The aim of this part of research is to testify the usability and adaptability of the model to real business case.

The empirical research has been carried out with a world-wide company, S Company, who already has a long term cooperation of study with Politecnico di Milano.

5.1 Company Background

5.1.1 Introduction

(1) About S Company Company

S Company was created in 1987 by the merger of two long-established semiconductor companies. The group has approximately 50,000 employees, 12 main manufacturing sites, advanced research and development centers in 10 countries, and sales offices all around the world.

S Company is one of the world's largest semiconductor companies with net revenues of US 9.73 billion in 2011. Offering one of the industry's broadest product portfolios, S Company serves customers across the spectrum of electronics applications with innovative semiconductor solutions by leveraging its vast array of technologies, design expertise and combination of intellectual property portfolio, strategic partnerships and manufacturing strength.

S Company is the world leaders in many different fields, including semiconductors for industrial applications, inkjet pinheads, MEMS (Micro-Electro-Mechanical System) for portable and consumer devices, MPEG decoders and smart card chips, automotive integrated circuits, computer peripherals and wireless.

The company has particular strengths in Multimedia, Power, Connectivity and Sensing technologies and its sales-which includes wireless business conducted via S Company- Ericsson, the 50/50 Joint Venture with Ericsson-are well balanced among the industry's major sectors: Telecom (24%), Automotive (20%), Consumer (11%), Computer (14%), Industrial (10%) and Distribution (21%). S Company has a strong focus on delivering solutions that help enrich people's lives, make society work better, and protect the planet. The company's world-class products and technologies serve to:

- Enable the convergence of multimedia and communication in smart consumer devices that help people interact anywhere, anytime;
- Increase energy efficiency all along the energy chain, from power generation to distribution and consumption;
- Provide all aspects of data security and protection;
- And contribute to helping people live longer and better by enabling emerging healthcare and wellness applications.

Since its creation, S Company has maintained an unwavering commitment to R&D. Almost one quarter of its employees work in R&D and product design and in 2011 the Company spent about 24% of its revenue in R&D. Among the industry's most innovative companies, it owns over 21,500 patents and pending patent applications. Their concentration on technology and research makes this research possible and undergo smoothly with a very cooperative spirit.

(2) About Product

During the research, we picked the Product Development Process of one product called Spear100 among a huge range of product type as our object of analysis.

The Spear100 is a member of the Spear family of embedded MPUs for network devices. It offers an unprecedented combination of processing performance and aggressive power reduction control for next-generation communication appliances.

This product targets cost and power sensitive networking applications for the home and small business as well as telecom infrastructure equipment, with lowest overall leakage under real operating conditions. The device integrates ARM's latest generation ARMv7 CPU cores, C3 security coprocessor, and advanced connectivity interfaces and controllers as shown in the picture below.

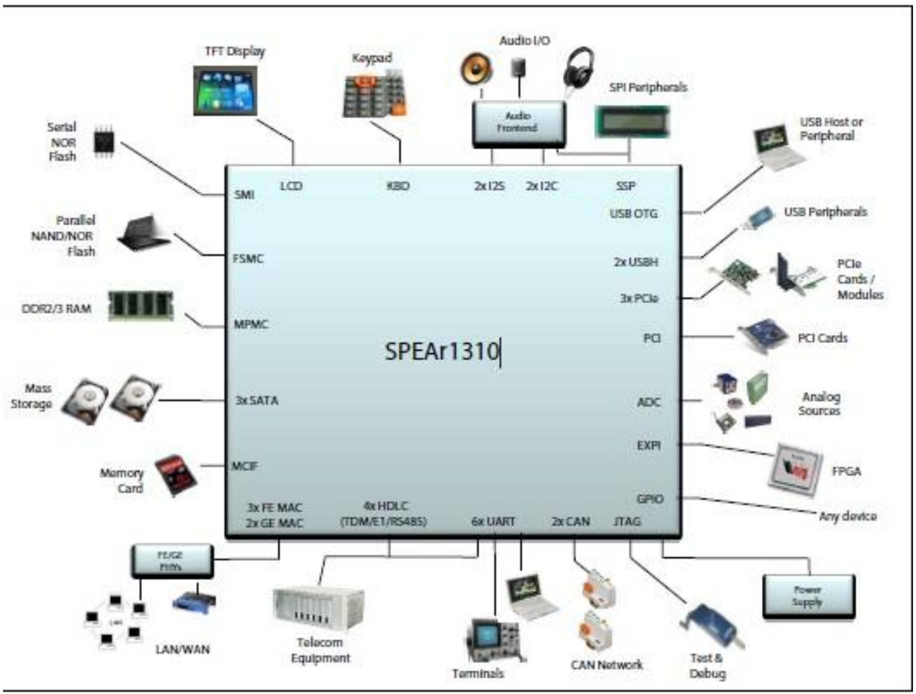


Figure 51. The connectivity of Spear100 system

The Spear100 internal architecture is based on several subsystem logic blocks that are interconnected through a multilayer interconnection matrix. The switch matrix structure allows different subsystem data flows to be executed in parallel improving the core platform efficiency.

High performance master agents are directly interconnected with the memory controller to reduce memory access latency. The overall memory bandwidth assigned to each master port can be programmed and optimized through an internal, weighted round-robin arbitration scheme.

5.1.2 Research Objectives

In this chapter we tried to apply the methodologies and tools which have been introduced in the former chapter into a real business case which related to Front End phase in New Product Development process. The next step is to understand how the Model built can be implemented in the real organizations. In order to do this, an empirical research has been undertaken. The aim of this part of research is to testify the usability and adaptability of the theory to real business case.

The research has been developed in three steps:

- Analysis the current VSM of the Initial Marketing phase. This work has been done by interviewing the stuff from related departments like marketing, design, testing, software and application department. The aim of this work is to identify what are the non-value added activities in another word waste in this phase.
- Improve VSM of Initial Marketing phase. After the investigation and evaluation from the previous activity, in the phase we tried to analysis the problems and provide solutions to improve the VSM of this phase. This work has been done by meeting with the quality managers and the result is accredited by both parties after careful discussion.
- Apply the Model. In this part, we described how the model was used in the business case. There are several steps has been follow as in the Model, for example, VOC Matrix, Function Analysis Matrix and Documentation Development.

5.2 Application of the Model in Initial Marketing

Here we adopt the concept of "Initial Marketing" from the S Company. In the company Initial Marketing has been defined as the phase from Customer Requirement to Design, which we found the same with what have been studied in this research of Front End phase. So the Model we developed should be applicable in this empirical research. More specific in this business case, we have to considered more functions inside design department, more in detail, the design department, test engineer and software & application department are included under the big "view" of function of design, as can be seen in **Figure 52**. This issue has already been referred in the chapter 4 when we built the model where we pointed out that the model is built in a general way but according to each specific company the situation may have slightly difference.

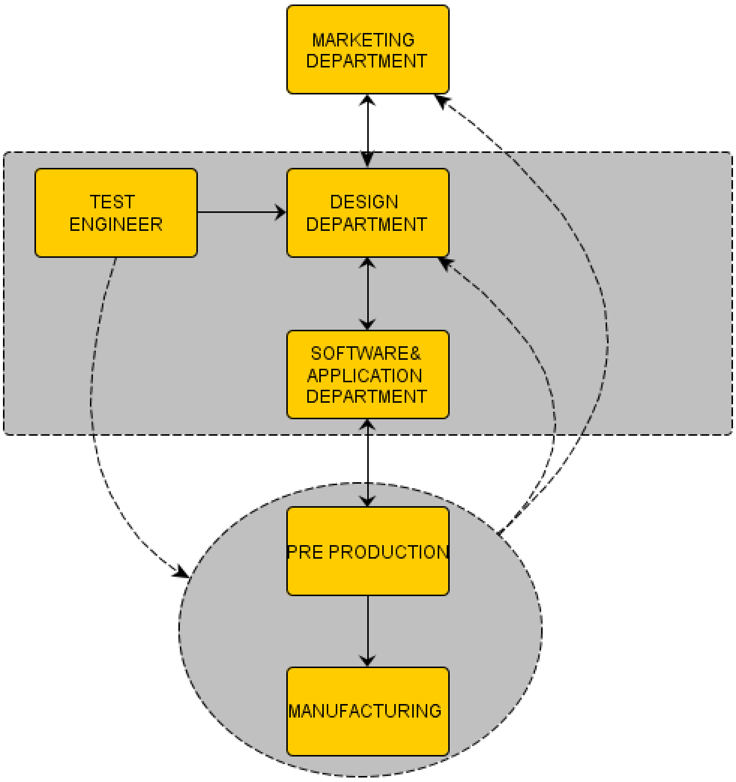


Figure 52. Function structure of S company in Initial Marketing phase

5.2.1 Analysis the Current VSM of Initial Marketing

Before analyzing, we will have a brief introduction about the product development process of S Company.

1. S Company Product Development Process Description

✓ **PURPOSE**

The product development process describes the way products are developed within the product groups in agreement with customer requests and S Company manufacturing / technology capability. The product development process targets to satisfy the customer expectations in term of time to market. This means for internal purpose "time to volume". This process describes not only the semiconductor development but all the developments linked to the system development to offer the total applicative solution to customers, including application, software and system integration.

- ✓ **SCOPE**

This process is applicable to all new products developed within S Company covering product development until Mat 30[6]. All activities above Mat 30 like product sustaining are covered in S Company Quality Manual.

- ✓ **S Company Product Development Process Description**

The product development process is a set of interrelated activities dedicated to transform customer specification and market or industry domain requirements into a semiconductor device and all its associated elements (package, module, sub-system, application, hardware, software and documentation), qualified respecting S Company internal procedures and able to be manufactured using S Company internal or subcontracted technologies. The whole product life is managed, through product maturity levels defined in the SOP 2.6.7[7]. SOP 2.6.7 determines how S Company products must be handled in terms of transition control from design, through production to termination. SOP 2.6.7 defines also the business rules that apply to all maturity stages.

2. Analysis the New Product Development Process of S Company

To prepare for the analysis of current state of S Company, we use Process Flow Chart to help us get the big picture of S Company' s general new product

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[6] Mat 30: Maturity of product after the PQC is signed. PQC is Product Qualification Certificate, document validating the product qualification and authorizing the manufacturing in volume.

[7] SOP 2.6.7: It determines how S Company products must be handled in terms of transition control from design, through production to termination. SOP 2.6.7 defines also the business rules that apply to all maturity stages.

development process, and using Value Stream Mapping to indicate current state of processes having lots non-value added activities.

- ✓ **Process Flow Chart**

Process flow chart is a type of diagram that represents an algorithm or process, showing the steps as boxes of various kinds, and their order by connecting these with arrows. This diagrammatic representation can give a step-by-step solution to a given problem. Process operations are represented in these boxes, and arrows connecting them represent flow of control. Data flows are not typically represented in a flowchart, in contrast with data flow diagrams; rather, they are implied by the sequencing of operations. Process flow charts are used in analyzing, designing, documenting or managing a process or program in various fields.

S Company shares some documents with us, including their new product development processes, products' introduction documents, Visio 2010 software, indicators and indexes of processes, quality management manual and so on. Based on the files they provided to us, first, we draw the big picture of general processes of new product development of S Company. As shown in **Figure 53**.

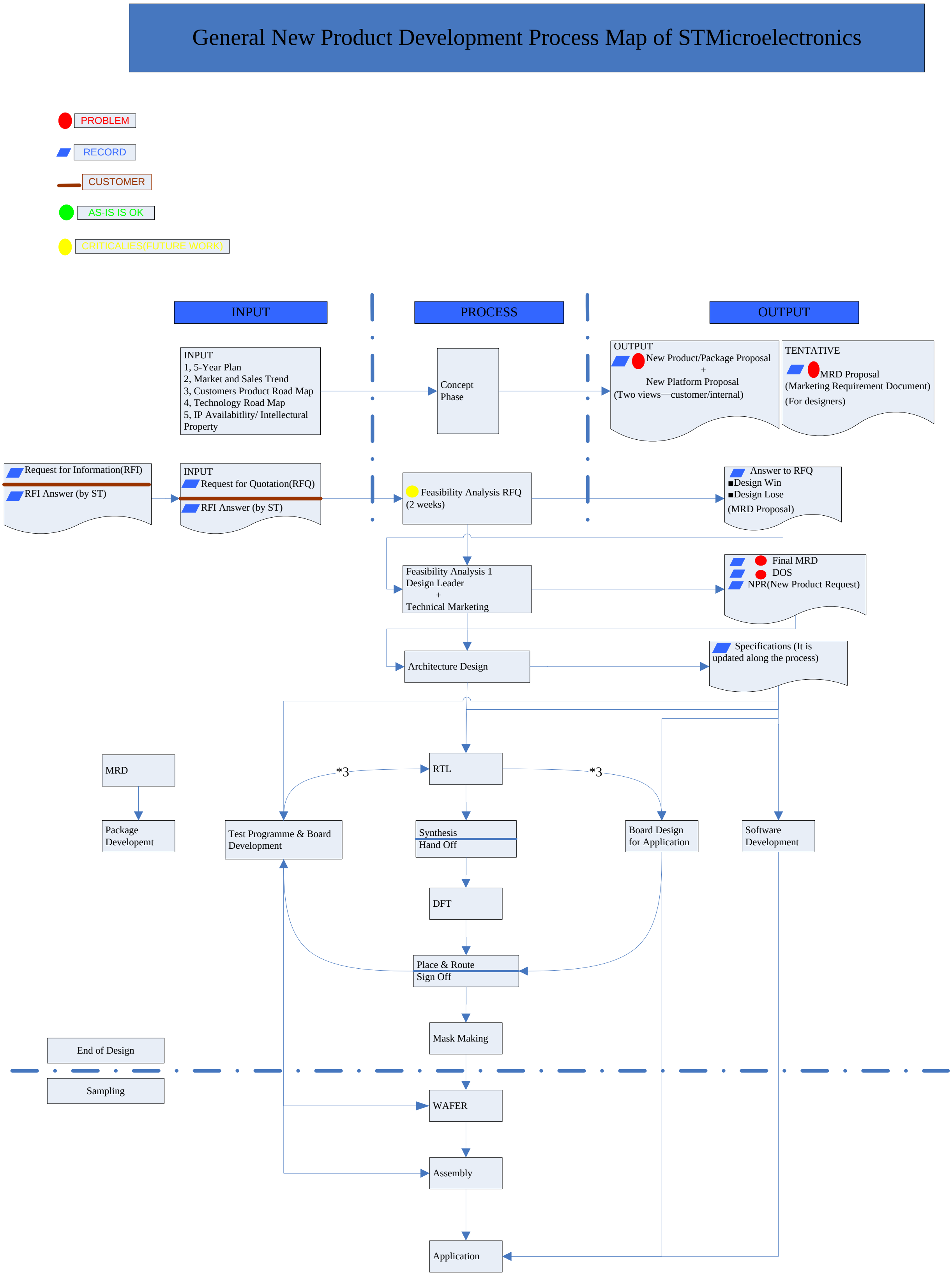

Figure 53. General New Product Development Process Map of S Company

From **Figure 53**, we can see that the process mainly contains the following steps: Project Management, Back-end design, Software design platform, Front-End Design, Architecture, RTL and Synthesis, Design for Testability, Place and Route, Documentation, Board Design and application, Software drivers, Technical Marketing, Product engineering and so on, which can be summarized into 3 modules: Marketing main process, Design main process, and Application software and documentation process.

The analysis of the general process has been done by interviewing the stuff from related departments such as marketing, design, testing and so on. The interviews are conducted according to the interview questionnaire (**Appendix**) we made based on the principle to identify the non-value added activities and their severity in the new product development process.

The interviews are conducted by S Company. After interviews, S Company gave us the feedbacks and the results (**Figure 54**); they indicated us that the Initial Marketing process (Front End design with an uncertainty and none value added percentage 35%, Documentation with an uncertainty and none value added percentage 31%, Technical Marketing with an uncertainty and none value added percentage 32%) of S Company contains a large amount of non-value added activities and disconnections. So the following step we will focus on the analysis of Initial Marketing part.

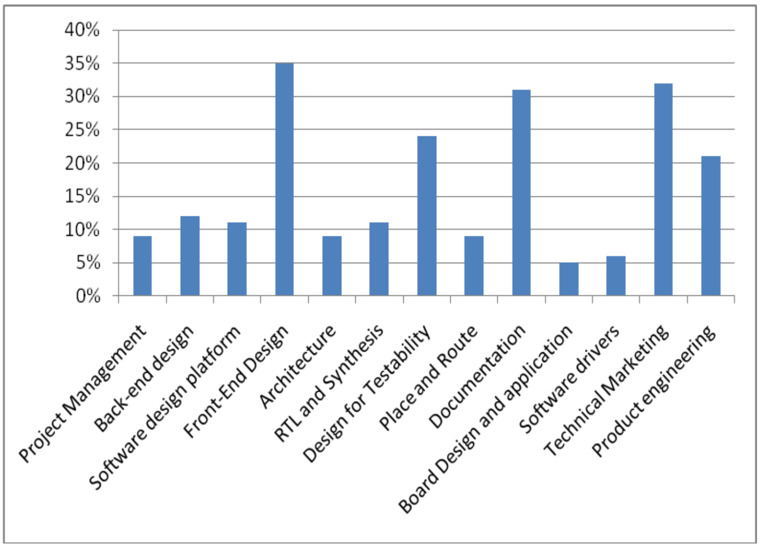

Figure 54. Interview Results to check the uncertainty and None Value Added activities percentage in the NPD process. (S Company, 2012)

✓ **Value Stream Mapping (VSM)**

Value stream mapping is a lean manufacturing technique used to analyze and design the flow of materials and information required to bring a product or service to a consumer. At Toyota, where the technique originated, it is known as "material and information flow mapping". (Rother, Mike; Shook, John ,2003).

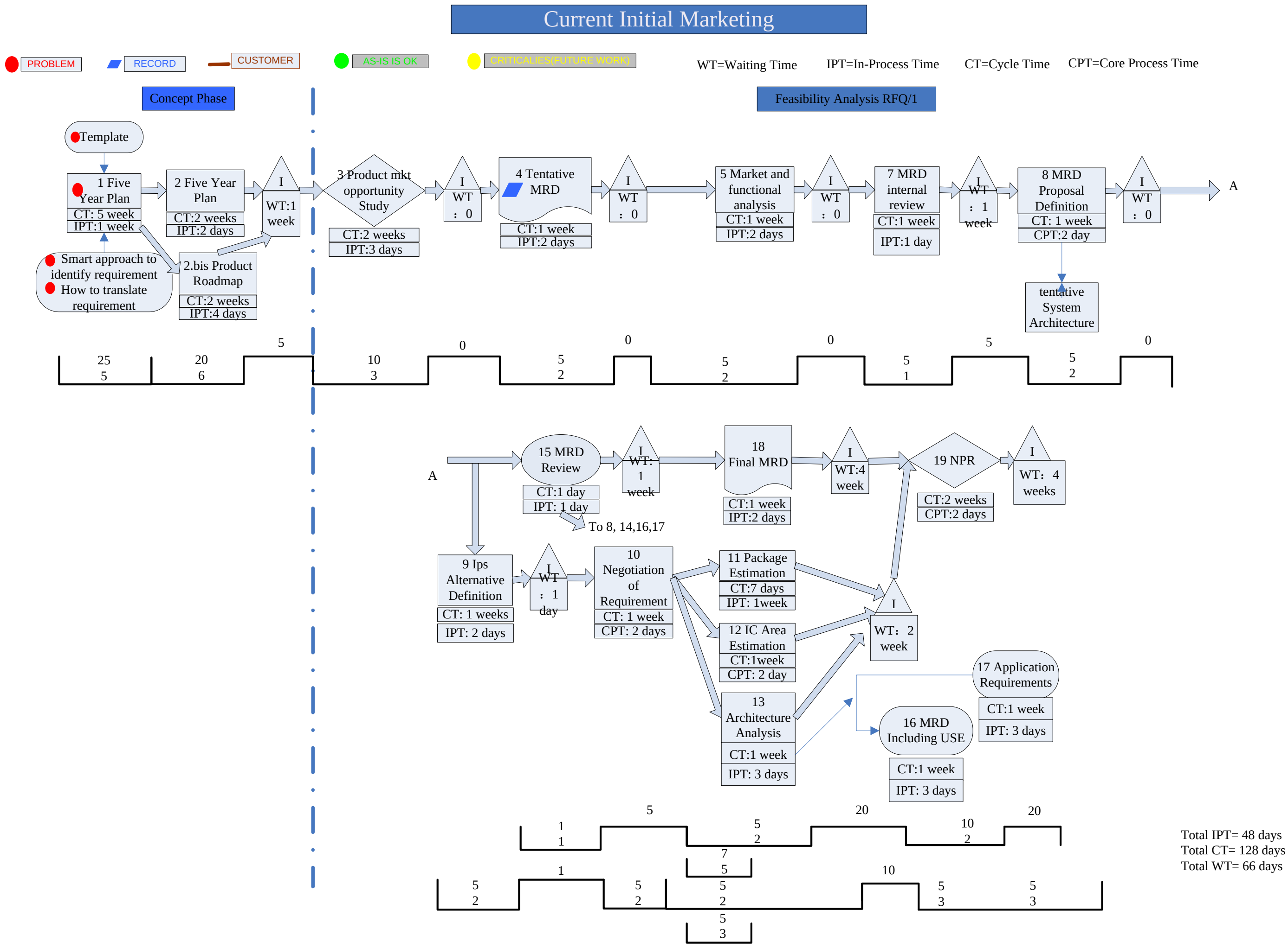

Figure 55. Current VSM of Initial Marketing

As we can see from the VSM of Initial Marketing of S Company, Total WT is 66 days, Total IPT is 48 days and Total CT is 128, which means the non-value added activities costs total 146 days (Total CT + Total WT – Total IPT), while the in process time is only 48 days.

The efficiency of the whole process is: Total IPT / (Total WT + Total CT) = 48 days / 194 days = 24.7%

The efficiency of activities is: Total IPT / Total CT = 48 days / 128 days= 37.5%

So next step, we will go deep into analysis the reasons for the inefficiency of initial marketing of S Company.

3. Evaluation Current State of S Company initial Marketing process

Focusing on the process flow of Initial Marketing part of the New Product Development Process of S Company, we find the following missing information and disconnections among process.

- **Missing Information:**
  - ✓ Templates for making the "Five Year Plan";
  - ✓ Approaches to identify and translate customer requirements;
  - ✓ Also need to do "Sales Trends & Performance" analysis when doing "Market and function analysis".
- **Disconnections:**
  - ✓ Disconnection between "Final MRD" and "Product Market Opportunity Study".

From VSM analysis, we summarized two categories of reasons for causing the inefficiency and wastes of Initial Marketing process of S Company.

- **Too Long or Unnecessary Waiting Time among different activities:**
  - ✓ The waiting time between "Five year plan" and "Product Market Opportunity Study" is 1 week;
  - ✓ The waiting time between "MRD[8]" review and "Final MRD" is 1 week;
  - ✓ The waiting time between "Package Estimation, IC Area Estimation, and Architecture Analysis" and "NPR" is 2 weeks;
  - ✓ The waiting time between "Final MRD" and "NPR[9]" is 4 weeks.
- **Huge inefficiency of activity implementation:**

[8] MRD: Market Requested Documents.

[9] NPR: New Product Request.

- ✓ The IPT (in process time) for making the "Five Years Plan" is 2 days, while the CT (cycle time) is 2 weeks;
- ✓ The IPT for making the "Product Market Opportunity Study" is 3 days, while the CT is 2 weeks;
- ✓ The IPT for doing the "MRD Internal Review" is 1 days, while the CT is 1 week;
- ✓ The IPT for making the "NPR" is 2 days, while the CT is 2 weeks;
- ✓ The IPT for making the "Product Roadmap" is 4 days, while the CT is 2 weeks.

5.2.2 Improved VSM of Initial Marketing

We proposed the following solutions corresponding the problems we detected by process flow chart and VSM in last paragraph. These solutions are also approved and practiced by S Company. They are listed below.

- ✓ Making templates for the "Five Year Plan";
- ✓ Proposing approaches to identify and translate customer requirements;
- ✓ Making "Sales Trends & Performance" analysis when doing "Market and function analysis";
- ✓ Making a loop to fix the requirements between "Final MRD" and "Product Market Opportunity Study";
- ✓ Make sure to transfer "Five year plan" information to "Product Market Opportunity Study" is within 2days;
- ✓ Reducing the waiting time between "MRD review" and "Final MRD" to be within 2 days;
- ✓ Promoting the information transporting from "Package Estimation, IC Area

Estimation, and Architecture Analysis" to "NPR" within 4 days;

- ✓ The waiting time between "Final MRD" and "NPR" should be controlled with 1week.
- ✓ Eliminating the none value added activities and time waste among "Five Years Plan" to make sure it can be finished within 4 days;
- ✓ Ensuring the process of making "Product Market Opportunity Study" to be conducted efficiently and finished within 4 days;
- ✓ To make sure to finish the "MRD Internal Review" within 2 days;
- ✓ To make sure to finish "NPR" within 4 days;
- ✓ The make sure complete "Product Roadmap" within 5 days.

Based on these change, we get the improved VSM of Initial Marketing, as shown in **Figure 13** below.

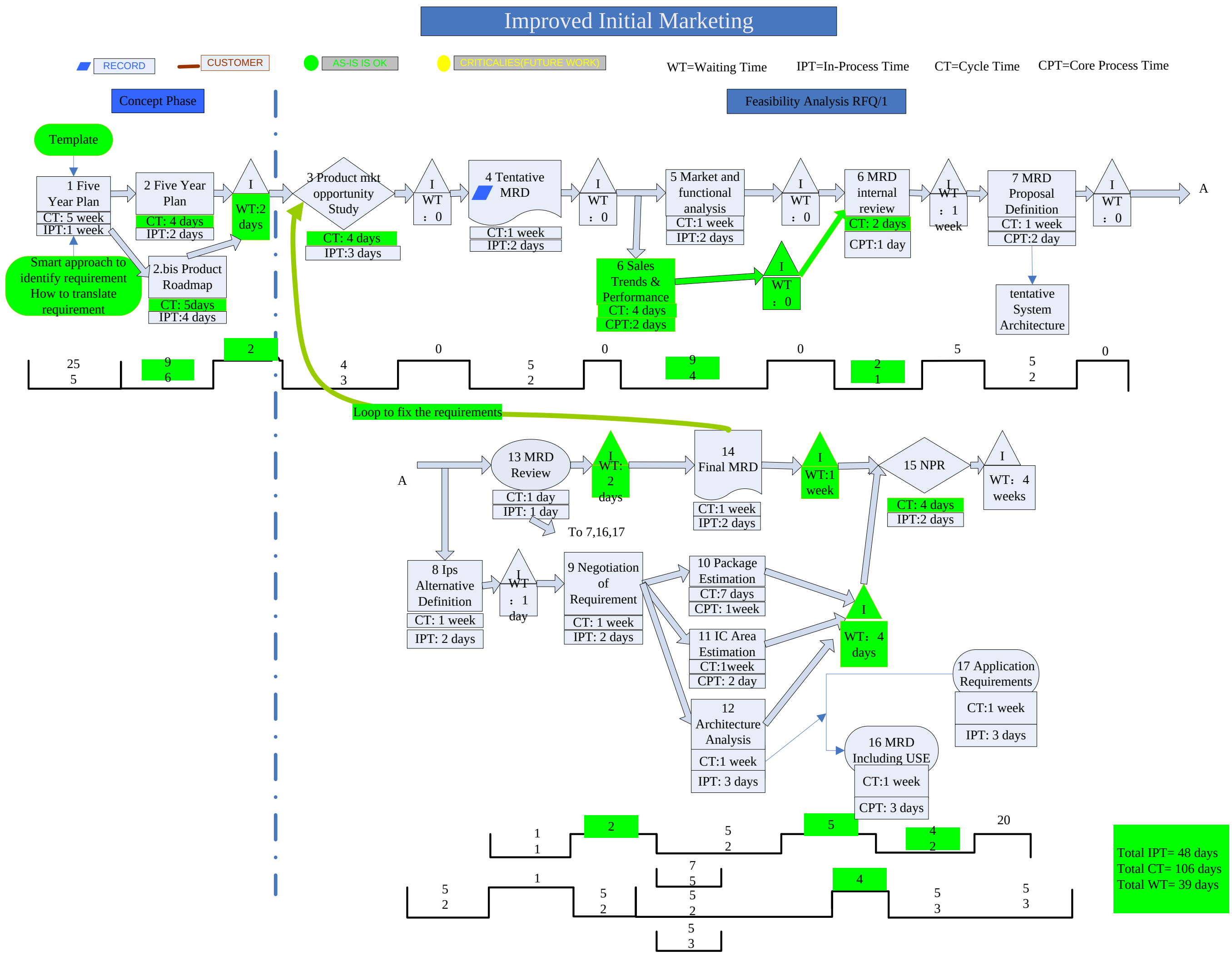

Figure 56. Improved VSM of Initial Marketing

As we can see from the Improved VSM of Initial Marketing of S Company, total waiting time is 39 days, total in process time is 48 days and total cycle time is 106. Then we can get the new efficiency after improvement.

The efficiency of the whole process after improved is: Total IPT / (Total WT + Total CT) = 48 days / 145 days = 33.1%

The efficiency of activities after improved is: Total IPT / Total CT = 48 days / 106 days= 45.3%

This means the efficiency of initial marketing is improved a lot after our actions on the process flow and timing.

5.2.3 Application of the Model

In the first part of this chapter we described the whole New Product Development process and more specifically we put more focus on the Initial Marketing phase (in another word, as we referred in Chapter 4-Front End phase). After using VSM to analyze the Initial Marketing phase, we evaluated the current situation of this early stage by pointing out several problems existed. They are mainly classified into two catalogers: To much time consuming and Un-smooth process flow. Furthermore improved VSM and flow chart of Initial Marketing phase are obtained after carrying out several ways to deal with the two issues mentioned before.

In this second part of this chapter, we are going to apply the Lean Front End framework we developed in the Chapter 4 in the real business world. The application will be proceeded mainly in three activities-VOC Matrixes, Function Analysis Matrix and templates development.

(1)VOC Matrix

Here we developed a matrix for evaluating the preferences of different product characteristics of open market for a new product Spear100 which is under developing inside the company S. We chose several product features to carry out the analysis as below.

Table 11. VOC Matrix of Spear 100 of S Company

Feature	Importance	Satisfaction (Existing Products)	Satisfaction (Expecting Products)	Potential Market	Strategy No.
2×ARM Cortex A9 cores	4	100%	90%	16%	2%
Shared 512 KB L2 cache	6	70%	80%	22%	19%
Accelerator coherence port	10	35%	100%	40%	100%
32KB Boot ROM	8	90%	85%	38%	26%
32KB Internal SRAM	3	82%	80%	14%	4%
Controller(FSMC) for external NAND Flash	5	71%	80%	15%	12%
Controller(SMI) for external serial NOR flash	2	66%	60%	8%	0%
2×Giga/Fast Ethernet ports	7	34%	85%	23%	52%
3×Fast Ethernet	9	100%	90%	35%	23%
3×PCle 2.0 links(embedded PHY)	1	23%	60%	3%	4%
3× SATA gen-2 host port	1	80%	60%	5%	0%
1×32-bit PCI expansion bus(up to 66 MHz)	6	77%	80%	21%	14%
2×USB 2.0 host ports	6	52%	80%	19%	28%
2× CAN 2.0 a/b interfaces	5	67%	60%	16%	4%
2×TDM/E1HDLC controllers with 256/32 time slots	4	90%	60%	13%	0%
Feature	**Importance**	**Satisfaction (Existing Products)**	**Satisfaction (Expecting Products)**	**Potential Market**	**Strategy No.**
TFT LCD controller, up to 1920×T1200,24bpp	7	60%	85%	25%	35%
Touchscreen I/F	10	70%	100%	42%	72%

9×9 keyboard controller	9	80%	90%	38%	43%
Memory card interface(MCIF) supporting SD/SDIO 2.0	9	80%	100%	36%	50%
Expansion interface	4	63%	60%	15%	5%
Security:C3 cryptographic accelerator	6	80%	80%	20%	12%
13×timers and 1×real time clock	5	99%	65%	18%	0%
2×high-performance 8-channel DMA controllers	7	80%	80%	23%	16%
10 bit ADC,up to 1 Msps, 8 inputs with autoscan capability	3	58%	60%	12%	4%
510+209 one time programmable (OTP) bits	5	79%	65%	16%	1%
JTAG-PTM (Debugging and test interface)	4	42%	60%	14%	13%
Power islands for leakage reduction	9	40%	90%	35%	77%
IP clock gating for dynamic power reduction	10	65%	100%	43%	78%

We can see from the VOC Matrix above that 28 different product features are under the investigation. The importance is scaled from 1 to 10 and those numbers are obtained from the market specialists who have done the marketing research about this new product so they already understood the market requirements and customer preference in a very good way. Satisfaction degree of existed products is from the customer satisfactory investigation from marketing department through interview, questionnaire or survey, while the satisfactory of future product is an estimation of company's ambition for the next generation of product. The indicator called potential market is used to see the importance of this feature in the market in the future. We also got this number from marketing department which is based on the prudent marketing research. At the end we calculated the strategy No. By considering all the factors above to get an idea of the percentage of effort it is still needed to put in each product feature to achieve both customer satisfaction and business strategy. It can also give us an idea of importance weight between different features. Here the result of calculation is automatically runed up/down to 100/0 if it is above 100 or below 0.

For example, the strategy No. of feature "Accelerator coherence port" is 100%. It means full effort is needed here to improve the performance of this feature. The reason is very obvious when we look at the other column. It is very important (the important No. is 10) and the current customer satisfaction is 70% (not very high) compared to the expected satisfaction is 100%. And it is a very important product feature for future (the potential market number is 40%). So the feature should be taken care of carefully in the future.

Another example, when we look at product feature "Controller (SMI) for external serial NOR flash", we can see it is not so important (the important No. is 2) and the current customer satisfaction is 66% which is higher than our expected satisfaction level (60%). And also it is not so important for the future (the potential market number is 8%). So we can fairly say that no more effort is needed to waste on this feature in the future.

This matrix helped S company to understand better what they should focus on in the future New Product Development when we talking about a series of product development.

(2)Function Analysis Matrix

In the next paragraph, we are going to explain how another matrix-Function Analysis Matrix in Lean Front End framework can be used in practice. This matrix is mainly used to evaluate the preference of product features for customized market. As shown in the table below.

Here we took an example of product request of a single customer. There are 5 key product features which can be seen in the table. The customer is asked to fulfill the number of importance by comparing each two product features. For example, if the feature "Accelerator coherence port" compare to "Touchscreen I/F" is much more important , so the comparative important number is given like "5". In the opposite way, if we compare the importance of product feature "Touchscreen I/F" to "Accelerator coherence port" should be "1/5".

After that we calculated the total value for each product feature by summing up all the comparative number for this feature. And the weight of each number compare to all the others can be calculated based on the evaluation of the last step. For example, we got the evaluation of "Accelerator coherence port" is "11.03" and the weight is "19%" which is the second important product feature compare to other four features which the customer wants.

This matrix is made to serve the customized market, in another word, to satisfy the single customer's demand by helping them to understand what are the important features that he/she really wants when he/she have to decide which is a preference during the design and product constraints.

Table 12. Function Analysis Matrix of Spear 100 of S Company

Function	Accelerator coherence port	2×Giga/Fast Ethernet ports	Touchscreen I/F	Memory card interface	Power islands for leakage reduction	IP clock gating	Calculation	%
Accelerator coherence port	1	1/3	5	4	1/2	1/5	11.03	19
2×Giga/Fast Ethernet ports	3	1	1/2	1	1/4	2	7.75	13
Touchscreen I/F	1/5	2	1	1/2	1/5	1/3	4.23	7
Memory card interface	1/4	1	2	1	3	1	8.25	14
Power islands for leakage reduction	2	4	5	1/3	1	4	16.33	28
IP clock gating for dynamic power reduction	5	1/2	3	1	1/4	1	10.75	18

(3)Templates

In this part, several templates are developed for Initial Marketing phase of S company in order to facilitate information documentation.. As already been explained in the chapter of Knowledge Management and Lean Front End Framework, information documentation is very important to understand what is going on of the project which is helpful for the current project management and also cut the repetition of the same work which is non-value added in the future.

Here we developed a check list for customer contact as an example. In these templates, some important information related to customer is documented. For example, what was the date of documentation, who recorded the information, who was the customer, what was the product, what was the product features that this customer favored and so on. This kind of check list can help the company understand what the real customer needs are and keep tracing the customers by their preference. In the future, S company will develop more templates also regarding to the communication result between marketers and designers, designers and test engineers and so on.

Table 13. Customer Contact Template

Customer Contact Template

Date:04-07-2012

Recorder: Mr. Unknown

Code:04072012S1

Customer:HP

Product:SPEAR100

Product Feature Check List

2 ×ARM Cortex A9 cores, up to 600 MHz	2×Giga/Fast Ethernet ports □
32+32 KB L1 instructions ☑	3 ×Fast Ethernet(for SMII/RMII PHY)
Shared 521KB L2cache □	3× PCle 2.0 links □
32KB Boot ROM ☑	3 ×SATA gen-2 host port ☑
32 KB internal SRM ☑	1 ×32-bit PCI expansion bus □
Controller for external serial NOR flash	1 ×USB 2.0 host ports ☑
2 ×CAN 2.0 a/b interfaces ☑	2 ×TDM/E 1 HDLC controller ☑
2 ×HDLC controllers for RS485 ☑	6×UARTs □
1 ×SSP port □	TFT LCD controller ☑
Touchscreen I/F ☑	9 ×9 keyboard controller ☑
Expansion interface ☑	13 ×timers and 1 ×real time clock ☑
JPEG HW codec □	10 bit ADC, up to 1 Msps, 8 inputs ☑
510+209 OTP bits ☑	JTAG-PTM □
Power islands for leakage reduction ☑	IP clock gating for dynamic power

Dynamic frequency scaling □	

5.3 Summary

In this chapter, two tasks were undertaken in order to realize the application of the Lean Front End model we developed:

First, analyzed the current business flow of Initial Marketing phase by using VSM and then improved the process by cutting wasting time, better re-organizing flow in order to achieve a more efficient and smooth Front End process of the company.

Second, based on the work before, we applied Lean Front End framework into this real business case. By developing VOC matrix, Function Analysis Matrix and one template for information documentation, we testified our model in a successful way.

Chapter 6 Conclusion

In this final chapter two tasks have been proceeded. First is to go through the chapters we have written before and conclude the research by pointing out what has been done in this thesis. Second is to identify the limitation of this research, explain the reason and then think about what is the next step of carrying out the research by looking at the future.

6.1 Results and Discussion

Along with the rapidly changing of the customer and shorter and shorter product updating cycle, the New Product Development has become a more and more important topic to not only industrial field but also the academical field. According to literature, NPD has several sub-processes. Many researches have been carried out to identify the whole NPD process and some models have been built to have a better view of the whole NPD process. But as the most important phase of NPD process, the area of Fuzzy Front End part still remained ambiguous. That is the initiation why the authors carried out this research.

Three aspects of work have been done in this research:

First of all, a deep and comprehensive literature review was carefully studied during this research, which covered the concepts used or mentioned in this thesis. On one side, standing in manufacturer's feet, to understand the Lean New Product Development concept is very important. Therefore we studied the concept and phases of NPD, lean thinking and knowledge management. And based on this we went in deep to focus on the literature of Fuzzy Front End, the relationship between FFE with NPD, FFE with knowledge management. On the other hand, taking the point view of customers, we took care also the literature which studied on customer value, Voice Of Customers and the methodology TRIZ which used to capture VOC. Based on this we tried to connect these two aspects by studying the relationship of customer value with

NPD and FFE with TRIZ. All these concepts are referred to our further studies. The firmed literature review laid a foundation to our further studies.

Second, the core part of this research is to develop a Lean Front End model to facilitate the business organization to carry out the Lean Front End management. Therefore, in the chapter 4, we spilled a lot of words on the construction of this model. In the model, by the order of business development phase from concept development & feasibility analysis to technique marketing, we identified all the parties who involved in the FFE phase(they are customers, marketing department, design team, testing engineer, software & application department), what kind of information they need(customer requirement, design specification and detailed design are needed) and which methodologies/tools can be used in analysis of FFE(VOC, FMEA, function analysis, TRIZ and QFD can be used). Two matrixes, VOC Matrix and Function Analysis Matrix are developed in the end. This model showed a general road to carry out the FFE analysis in a organized and lean way.

Another important part of this research is to testify the model we built in a real business case. In order to achieve this goal, a project with S company was proceeded on parallel with this research. We investigated the as-is situation of Initial Marketing phase of a new product(Spear 100) development process by interviewing the employees involved in this process, periodical meeting with quality managers, on-line questionnaire and so on. Thank to their cooperation, a current Value Stream Map of Initial Marketing phase was drawn. And based on this map and further discussion with them, we analyzed the existing problem (waste or non- value added activities) and proposed a improve Value Stream Map. On the other hand, we validated the two matrix we developed in the model, applied them in this case. The result is quite encouraging.

6.2 Limits and Future Researches

Although the research is completed in a very satisfied way, there are still some limitations about this study. For example, limited empirical research caused due to time and resource constraints. In this thesis, only one empirical research has been done in order to testify the model. And the result is very successful. But if we have more time and more companies available would be better, in that case the model would be tested by several different cases in different industrial field.

In this research we would also like to introduce a tool called trade-off curve in the FFE phase, more specifically in the design activity, as shown in the **Figure 57** below. Trade-off curve is a basic but very powerful tool that Toyota applies to a large amount in its product development. It is simply a curve showing the trade-off between two design characteristics, for example fuel consumption and engine size and is a base for decisions. Adopting this tool to the design process in FFE phase could be a great help for choosing the critical features which the customers want and optimizing the result between design cost and customer service. Due to the time constraint, the trade-off curve tool is not included in this research. But it will be a very promising study direction for the further researches.

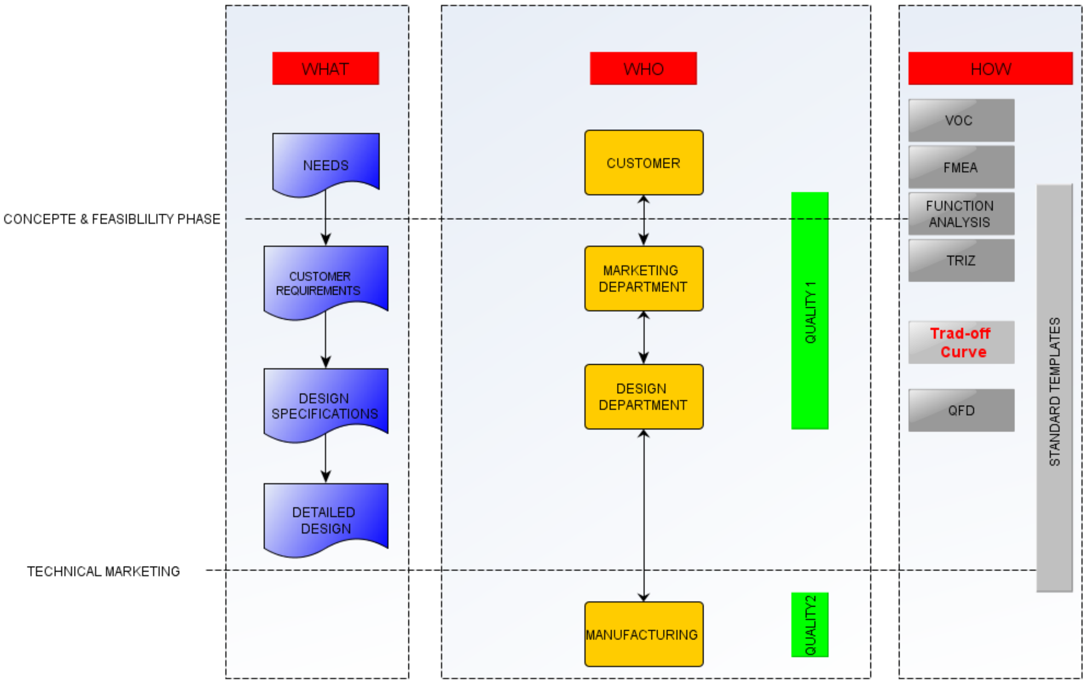

Figure 57. The future Lean Front End framework

Reference

[1]. A.Khurana, S. R. Rosenthal: Integrating the fuzzy front end of new product development; Sloan Management Review Vol. 38 (1997) No. 2: p. 103-120

[2]. A.Khurana, S. R. Rosenthal: Towards holistic "front ends" in new product development; Journal of Product Innovation Management Vol. 15 (1998) No. 1: p. 57-74

[3]. Abetti, P.A., (1994), "Impact of technology on functional roles and strategies", International Journal of Technology Management, Vol.

[4]. Agustin R.O. and Santiago F. – 1996 – Single-Minute Exchange of Die. Adavanced Semiconducto rManufacturing Conference and Workshop. ASMC 96 Proceedings pp.214-217.

[5]. Alan Webb,"TRIZ: an inventive approach to invention", Engineering Management Journal, 2002 p.117

[6]. Allen T. J. - 1977 - Managing the flow of technology. Cambridge, MA: MIT Press.

[7]. Altshuller, G.S., 1984, "Creativity as an Exact Science: The Theory of the Solution of Inventive

[8]. Problems", (original publication in Russian - 1979), Gordon and Breach Science Publishers, New York,United States of America

[9]. Ambrosini and Bowman, 2001-'Tacit knowledge': the variety of meanings in empirical research.

[10]. Anderson, David M. Agile Product Development for Mass Customization. Chicago: Irwin Professional Publishing, 1997.

[11]. Angel Salazar, 2003- The Influence of Organisational Size, Internal IT Capabilities, Information Technology and Management 4(2-3): 289-301 (*2003*).

[12]. Annacchino M.- 2006 - The pursuit of New Product Development: the Business Development Process. New York, 2006.

[13]. Business org. http://www.businessmate.org/Article.php?ArtikelId=184

[14]. Barry Boehm -1988 – A spiral Model of Software Development and Enhancement. 9. Bayers P.C. – 1994 - Using Poka Yoke (Mistake Proofing Devices) to Ensure Quality. Applied Power electronics Conference and xposition, 1994. APEC ’94. Conference Proceedings 1994. pp. 201-204.

[15]. Bicheno, J. (1999), “The new lean toolbox”, Picsie, London.

[16]. Bonfiglioli R.(2001), “Pensare Snello - Lean-thinking alla maniera italiana. Come costruire l’impresa snella e produrre di più con minori sprechi: 3 casi italiani di successo”, Franco Angeli Edizioni.

[17]. Booz, Allen and Hamilton, (1982), “New Product Development for the 1980s”, Booz, Allen and Hamilton Inc, New York, NY.

[18]. Bowersox D.J., Stank T.P. and Daugherty P.J. - 1999 - Lean Launch: Managing Product Introduction Risk Through Response-Based Logistics. Journal of Product Innovation Management, Vol. 16, pp. 557-568.

[19]. Brown S.L. and Eisenhardt K.M. - 1995 - Product Development: Past Research, Present Findings, and Future Directions. The Academy of Management Review, Vol. 20, Issue 2, pp. 343-378, April 1995.

[20]. Butz H.E., Goodstein L.D., “Measuring customer value: gaining the strategic advantage”, Organizational Dynamics, Issue 3, 1996

[21]. Christopher Meyer, Fast Cycle Time,: The Free Press a division of Simon & Shuster Inc, New York, 1993, p 50, pp 196-198

[22]. Clark, Kim B., Chew, W. Bruce and Fujimoto, Takahiro, Product Development in the World Auto Industry." Economic Activity, 729. 1987

[23]. Clark, K.B. and Wheelwright, S.C. (1993). Managing New Product and Process Development. New York: The Free Press.

[24]. Cohen and Levinthal, “Innovation and Learning: The two faces R&D” , The Economical

Journal, 1989

[25]. Cooper R. (1990), “New Products: what distinguishes the winners”, Research e Technology Management, Volume November/December, pp.27-31.

[26]. Cooper R.G. - 1994 - Third-generation new product processes. Journal of Product Innovation Management, Vol. 11, Issue 1, pp. 3-14.

[27]. Cooper, R., Edgett, S.J., (2008), “Maximizing productivity in product innovation”, Research Technology Management, March.

[28]. Cooper, R., Edgett, S.J., (2008), “Maximizing productivity in product innovation”, Research Technology Management, March.

[29]. Corso et al, 2001, Information technology adoption for service innovation practices and competitive advantage: the case of financial firms.

[30]. Crawford, C.M. and Di, Benedetto, A. (2003). New Products Management,7th ed., New York: McGraw-Hill/Irwin.

[31]. Cynthia A. Montgomery, & Michael E.Porter, Strategy: Seeking and Securing Competitive Advantage, Published by Harvard Business Press, 1991 p. 307

[32]. Davenport T.H. and Prusak L. - 1998 - Working Knowledge: How Organizations Manage What They Know. Cambridge, MA: Harvard Business School Press.

[33]. Brentani, U. 2001. Innovative versus incremental new business services:Different keys for achieving success. Journal of Product InnovationManagement 18 (3): 169–87.

[34]. Donald Coates, Improving the Fuzzy Front End of Product Development for Continuous Innovation Incorporating TRIZ,2010

[35]. Ehmke C., Boehije M. - 2005 - Business Planning and the Stage-Gate Process. Purdue University, 2005

[36]. Fleischer, M., and Liker, J., (1997), “Concurrent engineering effectiveness: integrated product development across organisations”, Cincinnati: Hanser Gardner Publications.

[37]. Formoso, C., Tzortzopoulos, P., Jobin, M., and Liedtke, R., (1998),.‘‘Developing a protocol for managing the design process in the building industry.’’, Proc., 6th Annual

[38]. Conf. Int. Group for Lean Construction, International Group for Lean Construction.

[39]. Gaetano Cascini, Paolo Rissone, Federico Rotini, Davide Russo, Systematic design through the integration of TRIZ and optimization tools,Procedia Engineering 9 (2011) 674–679,2006

[40]. Galbraith, J.R., Kazanjian, R.K. (1986), “Strategy implementation: structure, systems, and processes”, West Publishing, St Paul, MN.

[41]. Grant R. - 2008 - Contemporary strategy analysis. Blackwell publishing.

[42]. Griffin, A. (1997). PDMA Research on New Product Development Practices: Updating Trends and Benchmarking Best Practices. Journal of Product Innovation Management 14(6):429–458.

[43]. Gupta e Wilemon (1996), “Accelerating the development of technology-based new products”, California Management Review, Volume 32, pp. 24-44.

[44]. Haque B. and Moore M.J. - 2004 - Applying lean thinking to new product

[45]. introduction. Journal of Engineering Design.

[46]. Harmon R. R., Laird G., “Linking marketing strategy to customer value: implication for technology marketers”, Innovation in technology management: the key to global leadership, PICMET, 1997

[47]. Hauser J.R. and Clausing D. - 1988 - The house of quality. Harvard business review, May-June 1988, pp.63-73.

[48]. Henderson, B., Larco J.L. and Martin S. - Lean Transformation: How to Change your Business into a Lean Enterprise. Oaklea Press, Richmond, VA.

[49]. Heragu S.S. – 1994 - Group Technology and Cellular Manufacturing. IEEE Transactions On Systems, Man, And Cybernetics, Vol. 24, No. 2.

[50]. Herstatt, C.,Verworn, B., Nagahira, A., 2004. Reducing project related uncertainty in the “fuzzy front end” of innovation: a comparison of German and Japanese product innovation

projects. International Journal of Product Development 1 (1), 43–65.

[51]. Hines P., Holweg M. and Rich N. – 2004 - Learning to evolve. A review of contemporary lean thinking. International Journal of Operations & Production Management, Vol. 24, No. 10, pp. 994-1011

[52]. Huber F., Herrmann A., Hennerberg S.C., “Measuring customer value and satisfaction in services transactions, scale development, validation and cross-cultural comparison”, International Journal of Consumer Studies, N°31, pp 554-564, 2007

[53]. Imai K., Ikujiro N. and Takeuchi H. - 1985 - Managing the new produc development process: How Japanese companies learn and unlearn Harvard Business School Press.

[54]. Itzack Ben-Levy, LEAN Product Development (LPD) ,SAE International2010

[55]. Javier, J. and Alarcon, L., (2002), "Achieving Lean design process: improvement methodology". Journal of Construction Engineering Management.

[56]. Johnson J. e Baldwin J. (1996), “Business strategies in more and less innovative firms in Canada”, Res Policy, Vol.25, pp. 785–804. 49. Joseph M. Firestone,White Paper (1998)

[57]. Kai Yang, Hongwei Zhang, "Enhancing Robust Design with the Aid of TRIZ and Axiomatic Design", International Conference on Axiomatic Design, ICAD ‘2000, Cambridge,June 21-23, 2000.

[58]. Karlsson, C., and Ahlstrom, P., (1996), “The difficult path to Lean product development”, Journal of Product Innovation Management, Vol. 13.

[59]. Kennedy, M. N., (2003), “Product development for the lean enterprise”, Midpoint Trade Books.

[60]. Kennedy M.N. - 2008 - Ready, set, dominate. Oaklea Press, Virginia.

[61]. Khalifa A. S., “Customer Value: a review of recent literature and an integrative configuration” Management Decision, Vol .42, N°5, pp 645-666, 2004

[62]. Kaufman J.J., “Value Management: Creating Competitive Advantage, Best Management Practices Series”, Crisp Publications, Menlo Park, CA, 1998

[63]. Kuo T., Huang S.H. and Zhang H.C. - 2001 - Design for manufacture and design for 'X': concepts, applications, and perspectives. Computers & Industrial Engineering Vol. 41, Issue 3, pp. 241-260, December 2001.

[64]. Li Shaobo and Xie Qingsheng, E-HUB integration to facilitate collaborative manufacturing information system, (2002)

[65]. Liker J.K. - 2004 - The Toyota Way 14 Management Principles from the World's Greatest Manufacturer. McGraw-Hill.

[66]. Liker J.K. and Morgan J. - 2006 - The Toyota product development system: integrating people, process, and technology. Productivity Press.

[67]. Linderman K., Schroeder R.G., Zaheer S. and Choo A.S. - 2003 - Six Sigma: a goal-theoretic perspective. Journal of Operations Management, Vol. 21, pp. 193–203.

[68]. Mann, D.L., Bridoux, D., 'Evolving TRIZ Using TRIZ and NLP', paper to be presented atTRIZCON2002, St Louis, April, 2002.

[69]. Mann, D.L., 'The Space Between Generic and Specific Solutions', TRIZ Journal, June 2006.

[70]. Matthew Hu, Kai Yang, Shin Taguchi,Enhancing Robust Design with the Aid of TRIZ and Axiomatic Design,2000

[71]. McManus H. (2004), "Product Development Value Stream Mapping (PDVSM Manual)", Beta Draft Cambridge, MA: Lean Aerospace Initiative, Massachusetts Institute of Technology.

[72]. McManus H. (2005), "Product development Value Stream Mapping (PDVSM) manual", MIT Lean Aerospace Initiative, Cambridge.

[73]. McManus H.L., Haggerty A. and Murman E. - 2007 - Lean engineering: a framework for doing the right thing right. The aeronautical journal, pp.105-114, February 2007.

[74]. Mehra, K. & Dhawan, S. K.,2003. Study of the process of organizational learning in software firms in India. Technovation,23:121-129.

[75]. Michael, S.C. and T.P. Palandjian (2004), "Organizational learning in new product introductions," Journal of product innovation management, 21, 268-76.

[76]. Monroe K.B. , “Pricing: Making profitable Decision”, McGraw-Hill, New York, NY, 1990

[77]. Moore, J. F. 1993. Predators and prey: A new ecology of competition.Harvard Business Review 71 (3): 75–86.

[78]. Moore, J. F. 1993. Predators and prey: A new ecology of competition.Harvard Business Review 71 (3): 75–86.

[79]. Moore, J. F. 1993. Predators and prey: A new ecology of competition.Harvard Business Review 71 (3): 75–86.

[80]. Moore, J. F. 1993. Predators and prey: A new ecology of competition.Harvard Business Review 71 (3): 75–86.

[81]. Morgan J.M., Liker J.K., “The Toyota Product Development System: Integrating People, Process And Technology”, NY: Productive Press, 2006

[82]. Murman E.M., Allen T., Bozdogan K., Cutcher-Gershenfeld J., McManus H., Nightingale D., Rebentisch E., Shields T., Stahl F., Walton M., Warmkessel J., Weiss S., and Widnall S. - 2002 - Lean enterprise value: Insights from MIT‟s Lean Aerospace Initiative, Palgrave, Hampshire, UK.

[83]. Murphy S.A. and Kumar V. - 1997 - The front end of new product

[84]. development: a Canadian survey. R&D Management, Vol. 27, pp. 5-15.

[85]. Nonaka I. and Takeuchi H. - 1995 - The Knowledge Creating. New York

[86]. Ohno T. - 1988 - Toyota production system: beyond large-scale production. Productivity Press, Cambridge, Massachusetts.

[87]. Oppenheim, B. W. (2004), "Lean product development flow", Systems engineering, Vol. 7, no. 4.

[88]. P. Koen, G. Ajamian et al.: Providing clarity and a common language to the “fuzzy front end”; Research Technology Management Vol

[89]. Pawar K.S. and Sharifi S. - 2002 - Managing the product design process: exchanging

knowledge and experiences. Integrated Manufacturing Systems, Vol. 13, Issue 2, pp. 91-96.

[90]. PDMA. http://www.pdma.org/npd_glossary.cfm

[91]. Poolton J. and Barclay I. - 1998 - New Product Development From Past Research to Future Applications. Industrial Marketing Management, Vol. 27, pp. 197–212.

[92]. Qingyu Zhang, William J. Doll, (2001),"The fuzzy front end and success of new product development: a causal model", European Journal of Innovation Management, Vol. 4 Iss: 2 pp. 95

[93]. R. C. Cooper, E. J. Kleinschmidt: New products: The key factors in success; American Marketing Association, United States 1990

[94]. R. C. Cooper, E. J. Kleinschmidt: Screening new products for potential winners; Institute of Electrical and Electronics Engineers IEEE engineering management review Vol. 22 (1994) No. 4: p. 24-30

[95]. R. C. Cooper: Predevelopment activities determine new product success; Industrial Marketing Management Vol. 17 (1988) No. 2: p. 237-248

[96]. R. K. Moenaert, A. De Meyer, W. E. Souder, D. Deschoolmeester: R&D/Marketing communication during the fuzzy front-end; IEEE Transactions on Engineering Management Vol. 42 (1995) No. 3, p. 243-258

[97]. Reeb J.E. and Leavengood S. – 2010 - Introduction to Lean Manufacturing. Oregon Wood Innovation Center, October 2010, pp. 1-7.

[98]. Reinertsen, D.G. (1999). Taking the Fuzziness Out of the Fuzzy Front End. Research-Technology Management 42 (November–December):25–31.

[99]. Rossi M. – 2010 – Tools and Methodologies for Improving New Product Development Process. www.politesi.polimi.it

[100]. Roberts E. (1962), “The Dynamic of research and development”, Massachusetts Institute of Technology.

[101]. Robert G. Cooper, “Formula for Success in New Product Development”, Working Paper No.

23, Product Development Institute 2006.

[102]. Rother M. and Harris R. - 2003 - Creating Continuous Flow. The Lean Enterprise Institute, Brookline, Massachusetts.

[103]. Saren, M.A., (1984), "A classification and review of models of intra-firm innovation process", Research and Development Management, Vol. 14.

[104]. Sharma A., Krishnan R., Grewal D., "Value creation in markets, a critical area of focus for B2B markets", Industrial marketing management, Vol. 30, N° 4, pp 391-402, 2001

[105]. Smith, P.G. and Reinertsen, D.G. (1991). Developing Products in Half the Time. New York: Van Nostrand Reinhold.

[106]. Sobek, D.K., II, Ward, A.C., and Liker, J.K., (1999), "Toyota's principles of set-based concurrent engineering", Sloan Management Review, Winter.

[107]. Sobek, D.K., II, Ward, A.C., and Liker, J.K., (1999), "Toyota's principles of set-based concurrent engineering", Sloan Management Review, Winter.

[108]. Soderborg N. - 2008 - Lean Product Development. WCBF Design for Six Sigma Conference Las Vegas, Nevada, February 10, 2008.

[109]. Söderberg B. and Alfredson L. - 2009 - Building on Knowledge: Ananalysis of knowledge transfer in product development. MASTER'S THESIS CHALMERS UNIVERSITY OF TECHNOLOGY, Göteborg, Sweden

[110]. Tidd J., Bessant J., Pavitt K., 2005, "Managing Innovation TRIZ Tools", www.managinginnovation.com/tools/TRIZ.pdf.

[111]. TOYOTA. http://www.toyota.com.au/

[112]. Treacy M, Wiersima F.,"The Discipline of Market Leaders", HarperCollins, London, 1995

[113]. Ulrich K. - 1995 - The role of product architecture in the manufacturing firm. Research Policy, Vol. 24, pp. 419-440.

[114]. Ulrich K. and Eppinger S. - 2000 - Product design and development. Irwin McGraw-Hill,

New York, NY.

[115]. Ulrich K., Eppinger S. e Filippini R. (2004), “Progettazione e sviluppo prodotto”, 2a edizione, McGraw-Hill.

[116]. Vercellis C. - 2006 - Business Intelligence, modelli matematici e sistemi per le decisioni. McGraw-Hill.

[117]. Veryzer R.W.Jr. - 1998 - Discontinuous Innovation and the New Product Development Process. Journal of Product Innovation Management, Vol. 15, Issue 4, pp. 304–321, July 1998.

[118]. Ward A., Liker J.K., Cristiano J.J. and Sobek II D.K. - 1995 - The second Toyota paradox. How delaying decisions can make better cars faster. Sloan Management Review, Spring 1995.

[119]. WILLIAMS, RUTH L.; BUKOWITZ, WENDI R. “Manual de Gestão do Conhecimento”. Porto Alegre: Bookman, 2000.

[120]. Wheelwright, Steven C. and Kim B. Clark. Revolutionizing Product Development: Quantum Leaps in Speed, Efficiency, and Quality. New York: The Free Press, 1992.

[121]. Winner, R.I., Pennel, J.P., Bertend, H.E., and Sulsarczul, M.M.G., (1988), “The role of concurrent engineering in weapon system acquisition”, IDA Report R-338, Alexandria, VA: Institute for Defence Systems Analysis.

[122]. Womack J.P., Jones D.T. and Roos D. - 1990 - The machine that changed the world. Rawson Associates, New York.

[123]. Womack J.P. and Jones D.T. - 1996 - Lean thinking: banish waste and create wealth in your corporation. Simon & Schuster, New York.

[124]. Womack J. e JonesT., (2003), "Lean solutions: how companies and custoers can create value and wealth together", The Free Press, New York.

[125]. Woodruff R.B., "Customer value: The next source for competitive advantage",Journal of the Academy of Marketing Science, 1997

[126]. Woodruff R.B., Gardial S.F., "Know your customer: New approaches to understanding customer value and satisfactio", Cambridge, MA: Blackwell Publishers, 2001

Appendix

Survey Questionnaire

New Product Development (NPD) process analysis

◆ **General Information**

Company Name	
Name	
Department	
Position	
Email	
Telephone	
Filling date	

◆ **Questions**

1. Do you have a formal new product development (PD) model (visual representation of the PD process, including the various stages, activities, mechanisms and supporting tools) and is it effective in guiding the PD operations? (select one option)

Options		**Effectiveness**		
		Not Effective	Somewhat Effective	Very Effective
◇	There is currently no PD model	⊙	⊙	⊙
◇	The current PD model is developed by a central organization that administer its implementation, but it is not followed	⊙	⊙	⊙
◇	The current PD model is developed by a central organization that administers its implementation, and it is followed	⊙	⊙	⊙
◇	The current PD model is developed, and maintained by decentralized groups that administer its implementation in their respective areas	⊙	⊙	⊙

2. Do you have flexibility in how you do your job? (Or is it mandatory to comply to a process, that you do not have ownership of?) (select one option)

Options	
◇	Engineers must complete defined tasks in the order of process documentation
◇	Engineers must complete defined tasks in process documentation but the order is flexible
◇	Engineers understand their responsibilities and are provided with company best practice information and complete key deliverables in accordance with project deadlines, but process documentation is not imposed on them

3. Is there a technical leader who is responsible for the entire development of a product from concept to launch? (select one option)

Options		Effectiveness		
		Not Effective	Somewhat Effective	Very Effective
◇	No technical supervisor has responsibility for the entire development of a product	⊙	⊙	⊙
◇	A project manager (non-technical) has responsibility for the entire development of a product while an engineer or a group engineers share some responsibility	⊙	⊙	⊙
◇	A chief engineer with a team of engineers have responsibility for the entire development of a product	⊙	⊙	⊙

4. Every specification is a compromise between what customers want and what can be provided. How is a product specification stabilized in your product development process? (select one option)

Options	
◇	Specification provided early on by customer or central organization and must be adhered to
◇	Specification provided early on, but subject to engineering alterations
◇	Specification grows through continuous interactions along the stages of PD as the product understanding matures

5. How do you select the design solution that will be developed? (select one option)

Options	
◇	We only produce one design solution for each product
◇	We identify multiple solutions, and select the one that most closely matches the

	design specification
◇	We identify multiple solutions, and select the solution that has the lowest development costs
◇	We design multiple solutions for each product/component, and rule them out as more information becomes available (due to prototyping, testing, integration etc.)

6. How are your current processes and work methods reviewed/improved? (select one option)

Options	
◇	Processes are not regularly reviewed
◇	Processes are reviewed at regular intervals by experienced company members or a central organization, but improvement suggestions are rarely incorporated
◇	Processes are reviewed at regular intervals by experienced company members or a central organization, and there is a formal mechanism to capture improvement suggestions
◇	Engineers are encouraged to make improvement suggestions at any time and there is a formal mechanism to capture suggestions, but engineers are not confident that good ideas will be incorporated
◇	Engineers are encouraged to make improvement suggestions at any time and there is a formal mechanism to capture suggestions, and there is evidence that good ideas are regularly incorporated

7. Do your suppliers provide you with multiple alternatives for a single part (component)? (select one option)

Options	
◇	Suppliers provide one part (solution) based on a detailed design specification that we provide
◇	Suppliers provide one part (solution) based on a detailed design specification that we provide
◇	Suppliers provide multiple solutions for most parts and we work with them to develop the solution
◇	Suppliers inform us on developments in what they can provide and we together develop multiple solutions and progressively eliminate weak solutions as the product design solution matures

8. How are projects currently initiated, and the does the product development process flow? (select one option)

Options	
◇	Project initiation is dependent on customer requests and projects often run late
◇	Project initiation is dependent on customer requests, but projects rarely run late
◇	Projects start at regular intervals, but do not have consistent standard durations
◇	Projects start at regular intervals, have consistent standard durations, and are

	composed of multiple project types (e.g. facelifts, major modes, redesign/breakthrough), but projects do run late
◇	Projects start at regular intervals, have consistent standard durations, and are composed of multiple project types (e.g. facelifts, major modes, redesign/breakthrough), but projects are always on time

9. Which of the following tool/techniques have you formally implemented and utilize as an aid during the design of the product?

Tools/Techniques	**Frequency of use**			**Effectiveness**		
	◇	Sometimes	Always	Not Effective	Somewhat Effective	Very Effective
Design for Manufacture Assembly	◇	⊙	⊙	⊙	⊙	⊙
FMEA (Failure Modes Effective Analysis)	◇	⊙	⊙	⊙	⊙	⊙
TRIZ (Theory of Inventive Problem Solving)	◇	⊙	⊙	⊙	⊙	⊙
Value Analysis /Value Engineering	◇	⊙	⊙	⊙	⊙	⊙
Design to Cost	◇	⊙	⊙	⊙	⊙	⊙

10. During design do you consider incorporating error /mistake-proofing (features/elements/mechanisms) for the following:

User	**Incorporation**		
	Never	Sometimes	Always
End User	⊙	⊙	⊙
Prototyping	⊙	⊙	⊙
Manufacture	⊙	⊙	⊙
Assembly	⊙	⊙	⊙
Testing	⊙	⊙	⊙
Packaging	⊙	⊙	⊙
Storage	⊙	⊙	⊙
Distribution/sales	⊙	⊙	⊙
Delivery	⊙	⊙	⊙
Service/Maintenance	⊙	⊙	⊙
Recycling	⊙	⊙	⊙
Disposal	⊙	⊙	⊙

11. During concept selection which of the following criterions do you consider in reaching a final solution? (select applicable)

Criterions	**Considerations**		
	Never	Sometimes	Always
Function	⊙	⊙	⊙

Critical to quality	⊙	⊙	⊙
Durability	⊙	⊙	⊙
Technology	⊙	⊙	⊙
Cost	⊙	⊙	⊙
Performance	⊙	⊙	⊙
Safety	⊙	⊙	⊙
Sustainability	⊙	⊙	⊙
Ease of Manufacture	⊙	⊙	⊙
Portability	⊙	⊙	⊙
Enhanced Capability	⊙	⊙	⊙
Usability	⊙	⊙	⊙

12. What approaches do you use in assuring optimal values (as assigned in the design specification) are achieved in your final design?

◇	**Mathematical approaches**	◇	**None Mathematical approaches**
◇	Regression analysis	◇	Personal experience/understanding
◇	Multi-objective optimization	◇	Design Matrix
◇	Other:	◇	Other:

13. What sources do you use to ensure the following are considered your design? (Select applicable)

Sources / Factors	Rules	Design Standards	Inspiration	Innovation	Personal Intuition	Personal Experience	Design text books
Mistake-proofing	◇	◇	◇	◇	◇	◇	◇
Manufacturability	◇	◇	◇	◇	◇	◇	◇
Assembly	◇	◇	◇	◇	◇	◇	◇
Critical to quality	◇	◇	◇	◇	◇	◇	◇
Reliability	◇	◇	◇	◇	◇	◇	◇
Performance	◇	◇	◇	◇	◇	◇	◇
Sustainability	◇	◇	◇	◇	◇	◇	◇
Recyclability	◇	◇	◇	◇	◇	◇	◇
Innovation	◇	◇	◇	◇	◇	◇	◇
Ergonomics	◇	◇	◇	◇	◇	◇	◇
Cost	◇	◇	◇	◇	◇	◇	◇

14. From your personal experience, how important do you assess the following sources of Knowledge? (Select one each)

Sources of Knowledge	**Considerations**

	Not important	Important	Very Important	Essential for Competitive Advantage
Design Rules:	⊙	⊙	⊙	⊙
● **Heuristic Rules – Company own design rules**	⊙	⊙	⊙	⊙
● **Published Rules e.g. from Books**	⊙	⊙	⊙	⊙
● **Rules from supplier e.g. from Material Provider**	⊙	⊙	⊙	⊙
Design Standards	⊙	⊙	⊙	⊙
Capability of current resources	⊙	⊙	⊙	⊙
Capability of current process	⊙	⊙	⊙	⊙
Previous Projects	⊙	⊙	⊙	⊙
Tacit Knowledge (Expertise of Engineers)	⊙	⊙	⊙	⊙

15. How do you assess the importance of proven knowledge (e.g. test results) to support decision taking in product design and development? (Select one)

Not Important	**Important**	**Very Important**	**Essential for any decision**
⊙	⊙	⊙	⊙

16. Please estimate how much, in percentage, do you rely on knowledge from previous project when designing a new product? (Select one)

⊙	**100%**
⊙	**80%**
⊙	**60%**
⊙	**50%**
⊙	**40%**
⊙	**20%**
⊙	**0%**

17. How and which of the following data is stored at your company for a specific product during the entire product life cycle? (If used select one or multiple for storage)

No.	**Used**	**Data**	**Storage Form**				
			Paper Form	**PDM Database**	**ERP**	**Share Drive**	**Other**
1	◇	**QFD**	◇	◇	◇	◇	◇
2	◇	**BOM**	◇	◇	◇	◇	◇
3	◇	**Cost Calculations**	◇	◇	◇	◇	◇

4	◇	**Make or Buy**	◇	◇	◇	◇	◇
5	◇	**RFQ**	◇	◇	◇	◇	◇
6	◇	**Specifications Documents**	◇	◇	◇	◇	◇
7	◇	**CAD Drawings**	◇	◇	◇	◇	◇
8	◇	**FMEA**	◇	◇	◇	◇	◇
9	◇	**Test Reports**	◇	◇	◇	◇	◇

18. What is the role of cost estimation in product development? (You may select multiple options)

◇	**To target and reduce the overall development cost**
◇	To compare the cost of product/component alternatives
◇	To support taking through cost visualization
◇	Others (please explain)

19. Who is responsible for cost estimation in product design?

◇	**Finance personnel**
◇	Design engineers
◇	Cost engineers
◇	Others

20. What are the main challenges that you face in product development? (you may select more than one option)

	Options
◇	Products are not innovative enough
◇	We normally face cost overruns
◇	We are always overburdened with the quantity of work
◇	Downstream engineers passed optimized designs that require significant modification or redesign?

21. What are the main problems with your current PD model? (you may select more than one option)

	Options
◇	Too many sign-offs required (bureaucracy)
◇	Needs to be updated to meet changing demands
◇	Causes work to be delayed due to unnecessary tasks/activities
◇	Engineers are forced to spend time on lengthy documentation (reports)
◇	The model hasn’t been well communicated to employees

22. What challenges do you face with regards to knowledge capture and representation? (you may select more than one option)

	Options
◇	Often very time-consuming
◇	Incompatibility of knowledge formats between different software
◇	Unnecessary knowledge capture and over-crowded documents/figures/posters/databases etc.
◇	Engineers are forced to spend time on lengthy documentation (reports)
◇	Designers find it difficult to extract knowledge from previous projects

23. Do you think that mistakes in previous designs could have been prevented by the correct knowledge being provided at the right time? (select one option)

None	◇	◇	◇	◇	◇	**All**