# A LEAN APPROACH TO PRODUCT DEVELOPMENT IN SMALL AND MEDIUM MANUFACTURING ENTERPRISES

IN

NEW ZEALAND

A Thesis presented

in partial fulfilment of

the requirements for the

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*Dedicated to my Beloved Gurudeva:*

*Sri Sri Paramahansa Yogananda*

# ABSTRACT

Product Development (PD) is a multifaceted and challenging process, more so in Small and Medium Enterprises (SMEs) due to issues such as the resource constraints, high dependency on suppliers and the modern day competitiveness. For countries such as New Zealand, where 99.54 % of firms belong to the SME category, the significance of improving the PD system is enormous. These firms have to ‘do a great deal with very little’. The various PD management solutions that have been successfully deployed in large companies require “alterations” or customisation for application in SMEs. The research work presented in this thesis addresses the growing interest in the application of a distinctive best practice, one of the most recent, and promising solutions to product innovation in SMEs: (Toyota’s) ‘Lean Product Development System’.

The Lean philosophy has proven time and again as a holistic system to enhance efficiency of the entire supply chain by optimising all internal processes; in addition to bringing about responsiveness to external environment. According to studies conducted by prominent research institutes across the world, Toyota’s excellence is equally seen in its PD as in manufacturing, where projects take half the time of its US equivalents, with four times the productivity, and consistent top quality. In line with the industry trend in exploration of Lean system to PD across the world, this study focuses on:

"Evolving a broad framework for PD that incorporates Lean principles for application in Small and Medium Enterprises."

In-depth action research within a SME environment showed that Lean Product Development Systems is one solution that provides ideal balance of being a systems based, process oriented, interactive expert managed approach with a clear customer / value focus for these firms. Aspects such as flexibility of engineering infrastructure, the CAD/CAM proficiency, flat organisation structure aiding better communication, and the continuous learning attitude prevalent within SMEs corresponds closely to that in Toyota, and were identified to be great enablers for Lean deployment. On the other hand, few areas were found to pose challenges to the Lean approach within SMEs: including resource scarcity, the dependency on suppliers, and lack

of concept reuse, among others. On the whole, the findings have led to the development of a customized framework for Lean innovation in SMEs that addresses the knowledge, people, process, leadership, management, and planning elements, topped with measures to minimize effects of the identified obstacles.

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# INTRODUCTION

# CHAPTER1. INTRODUCTION

## 1.1 Background of the study

Manufacturing industries play a major role in the global economy. Among the various internal functions of a manufacturing company, Product Development (PD) is chiefly responsible for recognising market opportunity (i.e. customer needs) and fulfilling that need by the research and development of new products (i.e. product innovation and design). New Product Development (NPD), also termed as 'Product Development' (PDMA website, 2006) refers to the "overall process of strategy, organization, concept generation, product and marketing plan creation and evaluation, and commercialization of a new product". Specifically, the PD 'process' has been defined as 'a set of activities beginning with the awareness of a market opportunity and culminating in production, sale, and release of a product' (Ulrich & Eppinger, 2008, p.2). In other words, PD creates 'value' that ultimately flows to the customer, flowing through other organisational functions such as production, sales and marketing, and delivery (refer Figure 1). Thus, a "PD value stream" creates two types of value: the manufacturing systems and usable knowledge (Ward, 2007).

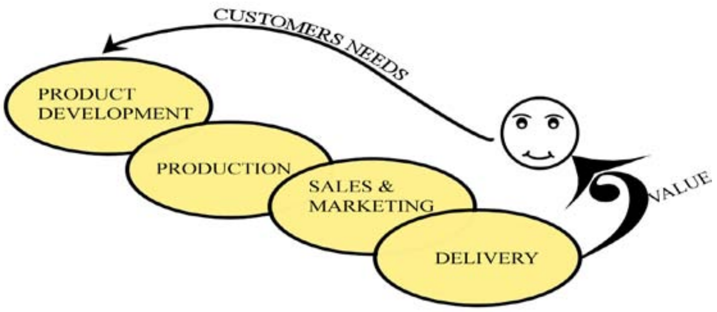



**Figure 1: Vital functions of a manufacturing firm**

The process of the physical transformation of products i.e. manufacturing (production) has received much attention with respect to improvement initiatives. Best practices such as Lean principles, Six Sigma, etc., have been applied for several years to manufacturing for significant improvements

(Womack and Jones, 1996; Liker and Meier, 2006; Fiore, 2005). Consequently, the performance gap between competitors in the manufacturing domain has reduced, making PD as the next domain of core competency (Morgan and Liker, 2006). The question now is how world-class best practices such as 'Lean thinking' can be applied to PD to enhance its effectiveness within the organisation.

## 1.2 Application of Lean philosophy to Product Development

The PD function is multidimensional by nature. A great deal of research has been done, and continues on each dimension; some examples include the study on the importance of strategy for guiding PD function and projects (Crawford, 1983), PD performance (Booz-Allen and Hamilton, 1982), PD process (Cooper and Kleinschmidt's, 1986; Cooper, 2008), collaborative project management with supplier involvement (Wang *et al.,* 2008), organisation culture to facilitate radical innovation (McLaughlin *et al.,* 2008), knowledge acquisition for PD (Zhen *et al*., 2008), etc.

The famous study by McKinsey & Co (as cited by Vesey, 1991) indicates that high-tech products that reach the market six months late, but on budget earn 33% less profit over 5years, in contrast to, products that beat competition by six months to gain profits by nearly 12%. This clearly shows that the companies developing products on budget, but in shorter times, develop a commercial advantage with increased flexibility. However, to date, research shows that PD faces several challenges to meet this time, cost and quality targets, such as trade-offs between managing customer and technical requirements, dynamic market preferences, difficult design decisions, time pressures and cost of development (Ulrich and Eppinger, 2004; Fiore, 2005).

The application of Lean philosophy to PD has been an emerging area within research and industry circles in the recent past, owing to its success in manufacturing. As Womack (1996) describes, a 'Lean' system focuses on defining *value* from the customer's perspective and aligns company's resources to make this value *flow* to the customer at the right price and time. In order to sustain this internal environment (in spite of external variability), the Lean organisation '*continuously improves*' or does *kaizen* (refer glossary, p.218). This 'holistic' thinking of 'Lean' encompassing the long-term philosophy, the right process, the people and partners, and continuous solving of root problems (Liker, 2004) presents immense potential to optimise PD (Figure 2).

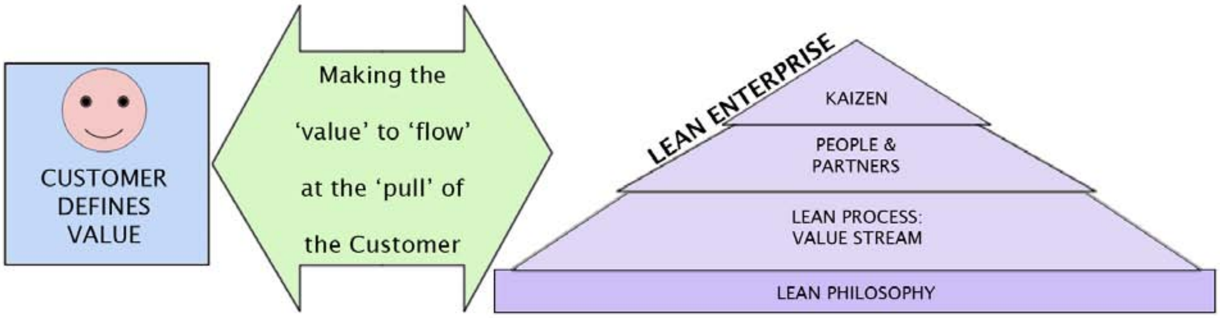



**Figure 2: The 'holistic' enterprise approach of Lean thinking**

Thus, a Lean Product Development System (LPDS) aims to constantly generate innovative products, at the optimum speed, quality and cost that delights customers. Specifically, Lean PD establishes world-class techniques such as set-based concurrent engineering, 'chief engineer' system (refer glossary, p.218), responsibility based planning, and expert engineering workforce (Kennedy, 2003) in order to create a flow within the PD value stream to effectively eliminate the problems (referred to as 'wastes') that affect PD efficiency (Ward, 2007). In a nutshell, the difference between a traditional PD and Lean PD system is the ploughing of resources upfront in the process, i.e. it commits resources to the front-end for intensive research instead of fire fighting later in the process due to development loop backs.

## 1.3 Significance of the study

As mentioned earlier, several companies across the world (including NZ) have applied Lean Manufacturing techniques, but to expect that speed-to-market can be achieved by optimising manufacturing alone is wishful thinking. The application of 'Lean' has hence moved upstream from manufacturing to PD.

The Lean Product Development System has been researched for the past two decades and much literature has been published on the theoretical aspects of this system (Clark and Fujimoto, 1991; Ward *et al.*, 1995; (Nobeoka, 1995; Sobek and Ward, 1996; Sobek II, 2002; Kennedy, 2003; Ballé and Ballé, 2005; Reinertsen, 2005; Morgan & Liker, 2006; Ward, 2007), since its first revelation by Womack (1990). Many companies are struggling to adopt this idealistic model into the present chaotic PD system successfully. Only recently, a small amount of research on the application of LPD outside Toyota has emerged (Haque and Moore, 2004; Baines *et al.*, 2007; Schuh *et al.*, 2008). These publications showed the piecemeal approach taken toward LPD implementation in large organisations (such as the automotive sector, and aerospace industry) by interpreting the Lean Manufacturing tools to PD, or the application of 5 basic Lean principles. The 'how to make the transition' question was addressed first in 2003, and then in 2008, when Kennedy *et al.*, published findings of a holistic LPD implementation in two companies (Fisher & Paykel Appliances, NZ and Teledyne Benthos, North America). It becomes obvious that the literature in all the above cases is focused on large companies, with no documentation on whether LPD can be applied to Small & Medium Enterprises (SMEs).

Hillary (2000) explains that the definition of a SME varies across the world with respect to the industry sector and country. For example, in the European Union a company with 50 to 250 employees is defined as a SME, whereas Australia defines it as firms with less than 200 employees. However, the International Chamber Of Commerce (ICC) defines a SME as having 100 to 2000 employees. In New Zealand, firms with less than 100 employees belong to the SME category (NZ statistics, 2007), and firms with an employee count greater than 500 are called large firms. For the purpose of this research, companies with 50 to 250 employees will be termed as SMEs.

For small economies, such as New Zealand that benefit largely from firms with less than 100 employees (which constitute more than 99% of all businesses, account for about 60% of employment and offer 40% of the total value added output; as per Ministry of economic development, 2007); the need to optimise the PD function is obvious and critical. These SMEs are unique entities; they are highly innovative (as NZ firms have an economic freedom score of 82: 2009 Index of Economic Freedom), with PD characteristics such as informal and truncated processes, resource scarcity, unstructured environment (management and organisation), etc. (Kerr, 1994; March-Chorda et al., 2001; Owens, 2007).

Thus, although the best practices of PD have found success in both large and SMEs, application of holistic solutions such as Lean Product Development (that is famed for its role in Toyota's success) is under-researched till date. In spite of the modern day economic challenges, if micro-economies such as NZ have to benefit from PD efficiency, its more obvious than ever before that this research is indispensable.

## 1.4 Statement of the problem

The main question addressed in this research work is whether ‘Lean Product Development’ systems are applicable to SMEs.

Therefore, the aim of the research can be stated as follows:

**"To evolve a broad framework for Product Development that incorporates Lean principles for application in Small and Medium Enterprises."**

As this study requires a live PD environment for collection of context-rich data, a manufacturing company (from SME sector) was chosen from NZ (the fifth most innovative country in the world according to the survey by 2009 Index of Economic Freedom). A moderately long study period at this SME would help to understand the PD environment, to analyse results from testing the LPD tools, and obtain feedback on the perceived positives and negatives of the LPD model. Ideally, a study conducted with large companies implementing LPD would be added bonus; the doubts and questions that emerged due to gaps in the literature could be addressed with help of this supporting case study.

Accordingly, the objectives of the research are as follows:

1. To understand the application of ‘Lean’ to Product Development and to comprehend details of the approach taken for its deployment in large companies.
2. To examine the current Product Development practices in Small and Medium Enterprises.
3. To propose a ‘Lean’ solution for Product Development in Small and Medium Enterprises that would help them to overcome obstacles in delivering high-quality innovative products.

## 1.5 Thesis structure

The literature reviewed on Lean Product Development, the methodology adopted, the case studies conducted, the findings and results that address the aim and objectives are described in the remaining chapters of this thesis report. Some of the highlights are summarised below:

- Chapter 2: Review of Lean Product Development

  Provides an overview of best practices in product innovation, the characteristics of PD in NZ SMEs, and the various aspects of Lean and Lean Product Development (the principles, cornerstones of LPD implementation). The present study also addresses gaps in literature this research.

- Chapter 3: Research Methodology

  Reiterate the aim and objectives of the research, the methodology adopted to fulfil the aim, the study scope and plan, the details of main and supporting case studies, and finally lists the data collection questions.

- Chapter 4. Study of Lean Product Development deployment at a large New Zealand Company A

  Provides insight on the journey of a large manufacturing company into a holistic Lean Product Development System, explains major findings of the case study conducted on LPD deployment, and the various challenges for implementing Lean approach in Product Development.

- Chapter 5: Main Case study- Data collection and analysis of findings from SME Company B

  Portrays data collected on overall SME business environment (market and organizational aspects), its Product Development system (process, people, leadership, knowledge systems), and the typical challenges faced during Product Development at the SME (such as supplier and customer integration).

- Chapter 6. Design of a Lean approach to company B’s Product Development process

  With the help of LPD literature and valuable inputs from Company B, a generic LPD model for SMEs was designed and tested partially at Company B on its applicability.

- Chapter 7: Discussion

  Based on the initial results from Company B and similar feedback from another SME, the LPD model has been enhanced to suit the SME environment. A discussion on findings and its applicability to various aspects has been discussed with a probable roadmap for implementation.

- Chapter8: Conclusions

  In the end, a comprehensive account of the major findings of the research has been described. It also highlights the significance of this study and the various possibilities for future research.

CHAPTER 2

# REVIEW OF LEAN PRODUCT DEVELOPMENT

# CHAPTER 2. REVIEW OF LEAN PRODUCT DEVELOPMENT

PDMA website (2006) defines Innovation as "A new idea, method, or device" and "the act of creating a new product or process which includes invention as well as the work required to bring an idea or concept into final form." Although, innovation can be referred to creation of products (Product Development) as well as ideas, services, mechanisms, processes, 'Product' innovation is the most common of them.

New Product Development (NPD) refers to the "overall process of strategy, organization, concept generation, product and marketing plan, creation and evaluation, and commercialization of a new product" (PDMA website, 2006). In a broader sense, it not only comprises of this chain of activities (i.e. PD process), but also includes the overall product strategy, the people organization, knowledge creation, and the leadership. Success in Product Development is achieved by treating it as a holistic system of complex interrelated value adding functions; where the goal is customer satisfaction achieved through good quality, timing and cost of products. Although studies have shown that growth and survival of both large and small firms depend on continuous innovation, the pathway to achieving this for small firms is not clear (Mosey, 2005). Further, in the case of SMEs, the various aspects of product strategy, management, market intelligence, opportunity identification, supplier integration, etc. has strong bearing on each other, making it is very clear that any future research on Product Development in SMEs (across industry types and nations) should be 'holistic'.

The following sections provide an overview of product innovation practices across the world, and in New Zealand with a focus on SME sector to bring forth the literature published on 'systems' or 'holistic' solutions for Product Development.

## 2.1 Product Development process models

Product Development 'process' may be defined as a series of steps that begin with inception of an idea ("awareness of a market prospect"), followed by making or designing the product and finally launching the creation i.e. "culminating in production, sale, and release of a product" (Ulrich and Eppinger, 2004; Ulrich & Eppinger, 2008).

Most of the research on Product Development has focused on the Product Development 'process'; such examples include the Phase (Stage) gate model (Cooper, 2001), the activity networks flowcharts (PERT/CPM) (Elmaghraby, 1995), Queuing models (Taylor and Moore, 1980), Design structure matrices (Steward, 1981; Eppinger, 2001; Browning, 2003), System Dynamics (Ford and Sterman, 1998), Input-Process-Output or IPO (Fricke *et al.*, 2000), Business process modelling (Arkin, 2002), value stream mapping (McManus and Millard, 2004), among others. These models have been useful for companies to focus on the value-added activities, to provide transparency and visibility to internal and external stakeholders, to ensure good decision making, to aid planning, scheduling and managing of the Product Development activities, etc. (Browning *et al.*, 2006).

Earle (1971) was one of the pioneers in the field of Product Development (Kerr, 1994). She defined the following steps for PD process: Planning, literature review, detailed study of market, study of process and product, development of prototype, development of production plan, planned production and marketing, organising, and launch. (Figure 3)

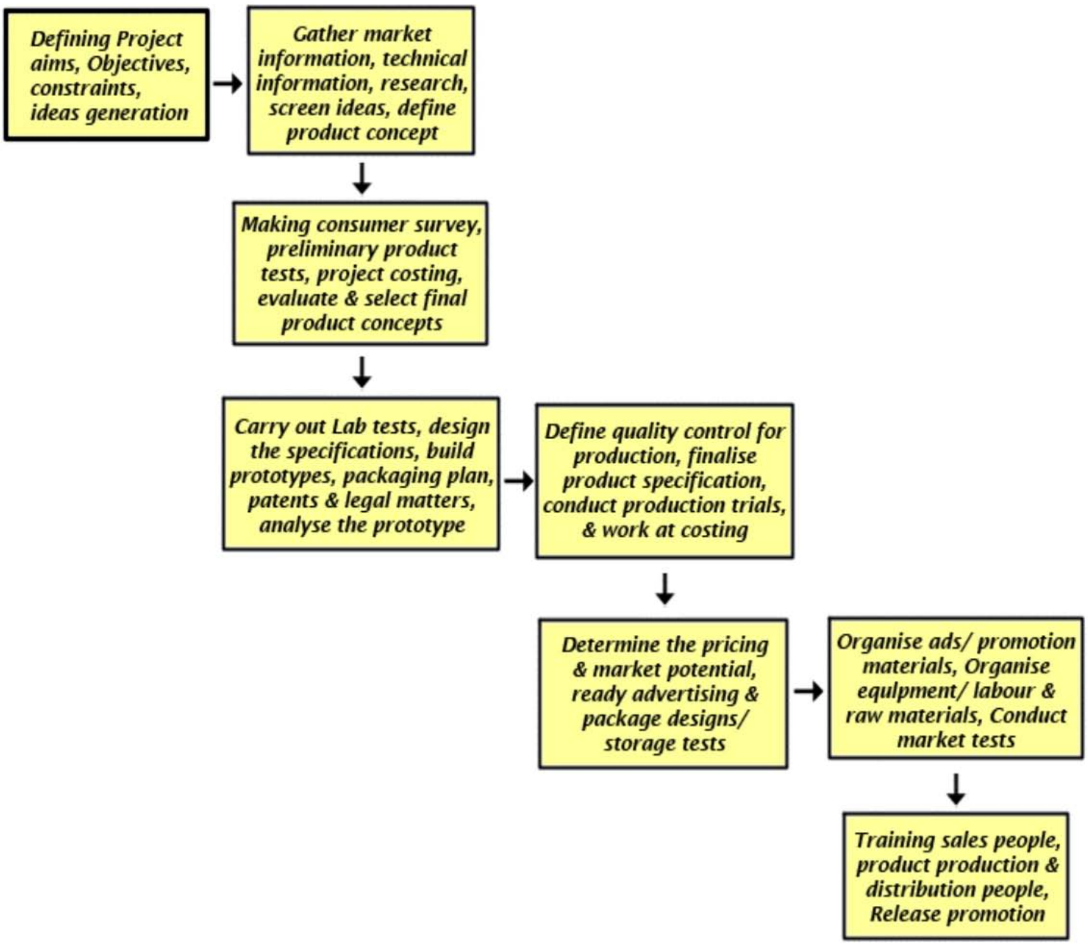



**Figure 3: Illustration of Earle's Product Development Process (1971)**

This model also included features such as 'Go/ No-go decisions' for obtaining verification of new product viability after each step; and the importance of new product 'planning and strategy'.

In 1983, Cooper also described a similar model that proposed a more systematic approach for managers to carry out the PD process efficiently. The steps were idea generation; initial screening, preliminary market assessment, preliminary technology assessment, concept, development, testing, trial and launch. Later, Cooper (1990) put forth the 'Stage Gate system', which became popular with most PD practitioners across the world. This task based stage-gate process consists of the idea, preliminary assessment, product definition, validation, commercialisation and post-commercialisation review stages, with decision-making gates after each stage (Figure 4).

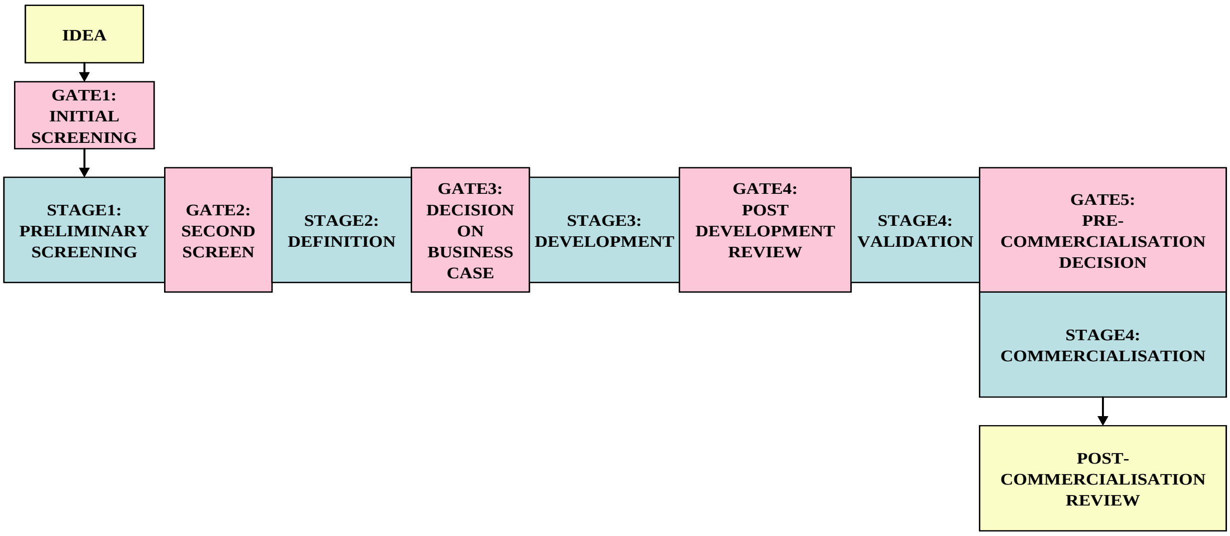



**Figure 4: Illustration of Cooper's Stage Gate process (1990)**

Innovation as such can categorised into two types based on the outcome: accidental Discovery (that leads to 'new-to-the-world' products), and iterative Development (that leads to creating of derivative products) (PDMA website, 2006). Although these two types have different requirements (such as percentage innovativeness and risk involved), the process steps can be generalised to a large extent, and hence most of the models proposed are generic in nature.

Product developers across the world use several techniques to carry out each of the steps in a PD process. Kerr (1994) examines some of these techniques with the help of Cooper's PD process steps.

Techniques for Idea generation stage:

- Focus groups, research, brainstorming, attribute analysis, gap analysis, lateral thinking, employee's suggestions, manager's ideas, observations, and customer requests.

Techniques for Initial screening *gate*:

- Scoring methods using criteria and weights, group evaluation, internally by manager.

Techniques for Preliminary Assessment stage:

- Market assessment: Information from competitors, market shares, market size, customers, product positioning.
- Technical assessment: Government regulations information, patents information, capability analysis, engineer's assessment, drawings and specifications.

Techniques for Detailed market research / Definition stage:

- Concept testing, conjoint analysis, competitive products and prices.

Techniques for Decision on Business case *gate*:

- Costs and sales forecasts, ROI (Return on Investments), payback period.

Techniques for Prototype Development stage:

- Physical construction tests, field tests, technical tests, expert evaluations, customer evaluations.

Techniques for Validation stage:

- Trial production run, test markets

Techniques for Commercialisation stage:

- Cost review, production ramp-up, advertising, promos, launch

The above-mentioned techniques help to conduct the activities during each of the specific stages, for investigating solutions, assimilating data, testing, and creating solutions. As Sharda (2007), explains everyone is capable of being creative; but most people do not exploit their full creative potential, as they do not have a clear process to guide and sustain the flow of their 'inventive juices'. Creativity is a "mental extreme sport"; therefore, innovators need to train themselves to do it well. It requires "pulling unrelated things together"; and providing training on techniques and tools (methods) that show engineers and designers how to combine knowledge from different fields to enhance their creativity. Case studies show several benefits of using the above-mentioned PD techniques and by training PD personnel in creativity programs (Kropp, 2004); some examples are listed below:

1. 3M – gained more than $4 billion from new products within four years of undertaking training.
2. Sysco Corporation – led to an increased sale of 25-30 percent after sales participation in this training.
3. Flextronic's cost reduction program has resulted in over $35 million US.

Popular examples of Creativity Programs include Lateral thinking, Problem solving techniques, Out-of-the box Thinking, Group problem solving technique like 6 thinking hats etc.

Thus, one of the important ways to increase creativity is by using creativity programs that inculcate and enable ordinary employees to improve their Productivity and come out with ideas, which they would otherwise not even think feasible (Kropp, 2004). The Six Thinking Hats technique, for example (put forth by of Edward de Bono, 1985) can be used for exploring different perspectives towards a multifaceted situation or challenge. Using an analogy of coloured hats (white, red, black, green, yellow, blue) that represent various perspectives on a subject, this technique is designed to help individuals to purposely take up analysis from different angles, which may be very diverse from the one that they might most naturally presume. For example, a white hat would relate to an observer with neutral, focused on information available and objective facts, whereas the black hat represents a judgemental and critical viewpoint. The key benefits of Six Thinking Hats method are freedom of expression, providing a framework for the process of thinking; enhance decision-making by analysing multiple facets of a situation, among others. An example is shown in Figure 5.

Step 1: Present the facts of the case (**White Hat**)
Step 2: Generate ideas on how the case could be handled (Green Hat)
Step 3: Evaluate the merits of the ideas - List the benefits (Yellow Hat), List the drawbacks (**Black Hat**)
Step 4: Get everybody's gut feelings about the alternatives (Red Hat)
Step 5: Summarize and adjourn the meeting (Blue Hat)

**Figure 5: An example for the six hats of thinking (Edward de Bono, 1985)**

Examples of other innovation and creativity tools include Lateral Thinking, TRIZ (Theory of Inventive Problem Solving) etc. The TRIZ tools have been used successfully across the world to generate concepts and solving technical problems (Ulrich and Eppinger, 2004). It has also been very helpful to increase the value of intellectual property, strengthen patent applications, and get around competitive patents (Hipple and Reeves, 2001). Yang (2008) suggests that TRIZ can be applied to reduce reinvention as part of a company's value-based PD system, which also ensures strategic cost-time effectiveness. Overall, research and industry cases shows that the various tools used to enhance creativity and innovation (i.e. techniques for PD process) and hence may be applied confidently.

For the purpose of this research (and in this thesis), the PD definition by Ulrich and Eppinger (2008) and PD process shown in Figure 6 has been referred to as the 'standard' definition and the 'traditional' PD process respectively, as they are consistent and basic by nature.

| | | | | | |
|---|---|---|---|---|---|
| **PHASE 0:**<br>**PLANNING**<br>**(Marketing, design, manufacture)** | **PHASE 1:**<br>**CONCEPT DEVELOPMENT** | **PHASE 2:**<br>**SYSTEM LEVEL DESIGN** | **PHASE 3:**<br>**DETAIL DESIGN** | **PHASE 4:**<br>**TESTING AND REFINEMENT** | **PHASE 5:**<br>**PRODUCTION RAMP-UP** |

**Figure 6: The generic Product Development process with six phases (Source: Ulrich & Eppinger, 2008).**

A review of published literature on NPD process by Page and Schirr (2008) revealed that (over a period of 2 decades) the field has grown tremendously with more variables and complicated models being studied across the world. The focus has been on technical aspects of engineering such as components, features, performance, models and creative concepts. In spite of this, there is a major concern:

The constant focus on 'process' aspect of PD (such as the Stage Gate model), with minimal research on other success qualifications such as market and product characteristics.

## 2.2 Best practices and holistic solutions to Product Development

Krishnan and Ulrich (2001) explain that the concern of unbalanced research in PD has been addressed by researchers from other fields (such as marketing and operations) to bring out the customer / market fit aspects, the overall productivity, cost, supplier aspects and decisions of Product Development. Examples of studies on various PD aspects are listed below:

1. Assessment of customer needs by Shocker and Srinivasan (1979), Ramaswamy and Ulrich (1993);
2. Urban and Hauser (1993) on product strategy and planning;
3. Brown and Eisen Hardt (1995) on cross-functional and organisational framework for R&D;
4. Thomke and Bell (2001), Ulrich and Eppinger (2000) on PD testing;
5. Terwiesch and Bohn (2001) on production ramp-up; and
6. Michalek *et al.*, (2005) on marketing and engineering design.

These studies showcase the fact that the literature on PD has matured and specialised in providing good solutions to elements within PD (i.e. every individual decision). Further, some of the well-researched and popular PD practices (also termed as best practices) are as follows:

- Sound strategy for selecting R&D projects (Liesiö *et al.*, 2007),
- Fuzzy front end for PD (Reinertsen and Smith, 1991),
- Concurrent engineering (Sobek *et al*, 1999), (Hull and Collins, 2006),
- Customer involvement (focus) in PD (Rhea, 1992),
- Improved supplier collaboration (Clark and Fujimoto, 1991), (Handfield *et al.*, 1999),
- Adopting an overall R&D philosophy (Filson and Lewis, 2000),
- Team review of important decisions and Process optimisation (Cooper, 2008),
- Negating risk by acquiring and sharing knowledge (Rupak *et al.*, 2008),
- Development of product and processes simultaneously (Nevins and Whitney, 1989)

These PD practices have been able to benefit companies in abundance. For example, the product 'strategy' is responsible for making decisions on the company's new product / idea positioning in the market; which in turn guides selection of PD projects (new or derivative product). Based on this decision, the companies emerge as market leaders, or fast followers (imitators), etc. (The PDMA Handbook, 2nd Edition). Whereas, several studies on integration of suppliers in the PD process have shown to help companies gain a competitive advantage over others (Handfield *et al.*, 1999). Similarly, studies reveal a clear and categorical connection between a fuzzy front end and PD success due to its fine balancing feature of market and technological capability combined with high quality planning (Reinertsen and Smith, 1991).

Upon application of these individual solutions in industry, it has emerged clearly that unless good practices for individual elements are combined and applied as a system, PD will still deliver mediocre sub-optimal results (Negele *et al.*, 1999). Over a period of time, practical experience showed that linear rigid processes fail to handle today's dynamic, highly variable PD environment that faces increased global competitiveness. In many cases, companies tend to overuse rigid phase gate process (assumed to bring in more control) leading to severe delays in PD cycle itself (Reinertsen and smith, 1991). Moreover, the industry sector will look to benefit from adopting holistic models rather than solve issues that may arise over integration of these individual practices when adapted. As a result, new models with holistic viewpoints have emerged by including systems focus, customer involvement, modern techniques, supplier collaboration, etc. Models such as Next generation Stage Gate process by Cooper (2008), the Integrated Product Development model (IPD) and Toyota's Lean Product Development System (Ward, 2007) aim to optimize the entire function by employing best practices for each PD aspect, integrating them, and focusing on the value adding activities.

I. Next Generation Stage Gate process:

Cooper's Next Generation Stage Gate process has incorporated extra features to the standard stage-gate model (Cooper, 1990) using techniques such as Value Stream Mapping and continuous improvement (from Lean Manufacturing) to make the stage-gate process more flexible, adaptable and progressive. Subsequently, better decision-making, and an improved accountability with simpler and more effective gates have emerged. The Figure 7 shows key features of this 'Next generation Stage Gate' process.

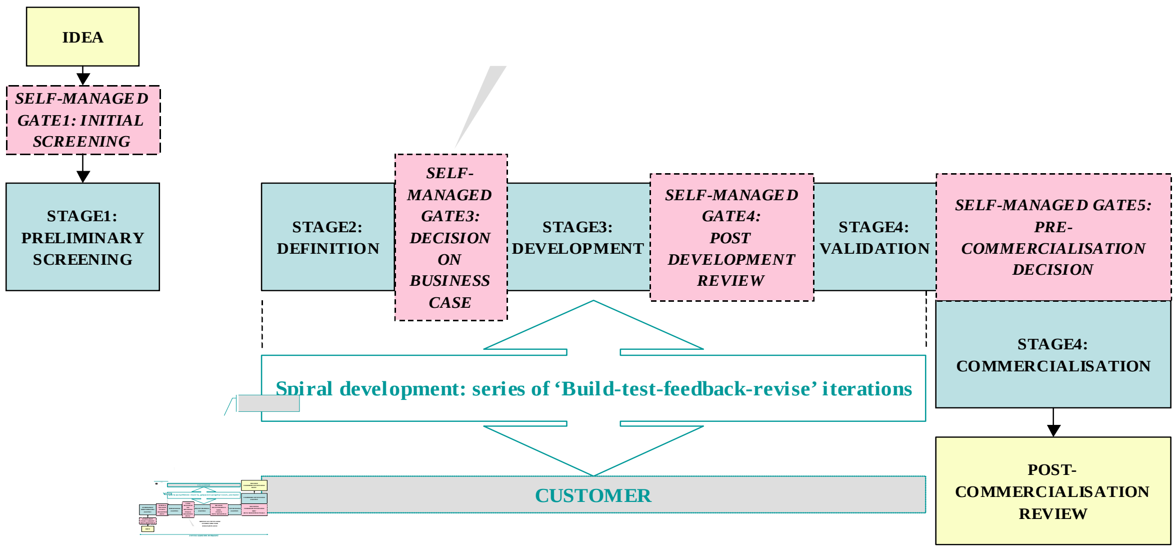



**Figure 7: Cooper's 'Next Generation Stage Gate' process (2008)**

Based on implementation experiences, Cooper adds that the users of Stage Gate system hurry into the implementation of additional tools from Six Sigma and Lean systems, which may jeopardise the entire system leading to problems such as bureaucratising PD, accountability, etc. Although, its effectiveness in optimising overall PD system is still not studied, it does not make any landmark changes to the PD paradigm. Based on this, there is all probability that PD will face similar problems as in the past.

II. Integrated Product Development process (IPD):

The Integrated Product Development process (IPD) encompasses several good practices of PD such as concurrent engineering, customer involvement, supplier involvement, use of cross-functional team including others (Rupak *et al.*, 2008). IPD has been one of the few very successful models for PD; in theory and practice (large companies), it has been proven a beneficial for cost, lead-time, quality and process effectiveness (Gerwin and Barrowman, 2002). The model is very responsive, flexible, iterative and effective. However, as IPD is a complex 'process management' system that tries to manage uncertainties, its features tend to encourage 'over-the-wall' approach providing no concrete solution to PD delays. Some of the drawbacks of IPD model include lack of discussion on nurturing technical knowledge within PD and the lack of understanding on cross-company (supplier-customer) co-ordination (Negele *et al.*, 1999).

III. Lean Product Development (LPD):

Lean Product Development (LPD) is a promising new paradigm that has emerged for Product Development, since its first revelation in 1990 by Womack. LPD is a comprehensive system of process, expert workforce, visionary leadership and responsibility based control system that works to ensure smooth flow of value to the customer (Kennedy, 2003; Ward, 2007).

It is well established in studies (Brown and Eisen Hardt, 1995) on success factors for PD (based on concrete research findings) that:

- Cross-functional well-balanced team with excellent communication (internal and external), Iterative well-planned realistic process scheduling, a visionary skilled leader, and top management commitment are proven and the most essential ingredients for PD project success.
- Business partner collaboration: Supplier and customer involvement in PD (early and highly disciplined) benefits PD.
- These above-mentioned criteria improve speed, productivity and effectiveness of PD, leading to a resounding market success and lasting financial performance.

These aspects happen to be addressed in the LPD model (Ward, 2007). Although, the only drawback of LPD is the unavailability of details on implementation of this system until recently, it is most likely that LPD is this “ideal” paradigm, an *intelligent* combination of world-class practices (key success ingredients) into an incredible *system* that ensures success. By and large only few “holistic” solutions found in literature have all elements required for PD success, and since Lean Product Development System has been under-researched, its success cannot be rated as yet.

## 2.3 Product Development in Small and Medium enterprises

Success in Product Development is measured in terms of innovativeness. But what earns profits to the company is eventually customer satisfaction owing to quality product delivered at the right time and right price. Perhaps, speed to market is more important to an emerging competitor as cost is to a mature market competitor (Reinertsen and Smith, 1992). But, irrelevant to the size of the business, survival and prosperity in the market is key crucial to a firm's existence, and all firms put-together make up the economy.

In small economies (such as Sweden and New Zealand), Small and Medium enterprises (SMEs) play an important role as they have maximum potential for growth and expansion (Agndal and Chetty, 2007). The definition of SMEs has come a long way since 1971, when it was termed as 'a small business with a relatively small market share, an entrepreneurial initiative with no formalised management system, and its existence as an independent entity in the industrial world' (Bolton report, 1971 cited by Kerr, 1994). But today, since SMEs have been able to increase their market share exponentially (in-case of niche market / specialised products/ service), and are increasingly associating with external agencies for partnership; the definition is mostly based on the 'Employee Count' (EC) in recent years. For example, firms with an EC of less than 500 are considered as a 'small' company in world terms, whereas, in NZ firms with EC less than 50 are considered as small (Devlin and Le Heron 1977; Bollard 1988, as cited by Kerr 1994).

Manufacturing SMEs have similar functions as large firms (PD, production, marketing, so on), but just with different characteristics. Although, past research on PD systems of SMEs have looked into the overall company environment, project selection, PD criteria, resources, process, and strategy (Cooper, 1983; Kerr, 1994; Filson and Lewis, 2000; Lawson *et al.*, 2006; Jong and Vermeulen, 2006; Owens, 2007; Verganti, 2008) etc. there is much potential for further research (Coetzer *et al.*, 2007). Important contributions have been made by organisations such as 'Organization for Economic Co-operation and Development' (OECD, 1982) on understanding the basic characteristics of SMEs. Most SMEs display requirement of loosely controlled organisation structures, informal roles and managerial styles due to its small and dynamic size, as compared to the large firms. Further, studies by Rothwell & Dodgson (2007) about SMEs highlighted the following:

1. Major inventions happen in small entrepreneurial firms that contribute significantly to the growth of the economy.
2. Enhanced internal communication exists within SMEs due to the flat organisational structure and limited staff working under a hands-on leadership.

3. Small firms suffer from resource scarcity (including skilled labour, venture capital and access to external information sources).

Bollard (1988) (as cited by Kerr, 1994) made similar revelations and suggested that increased contracting of design work and multitasking were the ways to overcome the internal resource problems. However, most studies have emphasised that small firms have an advantage of flexible, innovative structures that can help in making decisions at a faster rate. Studies by researchers across the world have confirmed that SMEs in various parts of the world share most of the above-mentioned characteristics (both positive and negative aspects) (Kerr, 1994).

A recent study conducted by Wickramansinghe and Sharma (2005) point out the obstacles faced by SMEs that prevent them from exploiting the world markets and to gain entry into new low-cost markets. The obstacles discovered were mostly internal aspects, such as unstructured Value Streams, low investments into infrastructure, marketing, technology and organisation hurdles. Constant research on SMEs continues with a strong focus on improving PD; some of these organisations involved include the 'Centre for Entrepreneurship, SMEs and Local Development' (part of OECD) and local bodies such as the 'New Zealand Centre for research into small and medium enterprises'. They continuously publish important findings on enhancing the role of SMEs in the global value chains, identifying and eliminating barriers to internationalization, and product innovation improvements (New Zealand Centre for research into small and medium enterprises, 2008); which has to be encouraged in order to allow SMEs participate better in the global economy.

### 2.3.1 Product Development in Small and Medium Enterprises within New Zealand

Innovation in NZ is a unique research topic in itself. The industry diversity in NZ is significantly different from the rest of the world and the products/ services are representative of this unique environment. Statistics NZ categorize companies as very small (EC<5), small (5<EC<50), medium (50<EC<100), large (100<EC<500) and very large (EC>500); with a SME population of 99.5% (refer Figure 8), which account for about 60% of employment and 40% of the value added output (Ministry of economic development, 2007) for NZ.

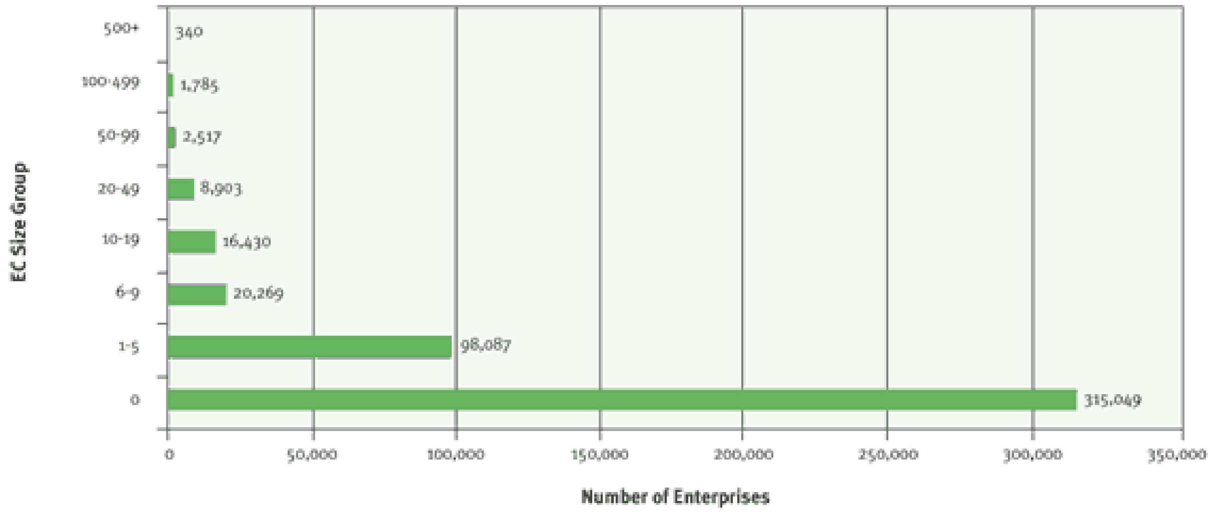



**Figure 8: Data on population distribution of companies (Source: NZ statistics, 2007)**

Although, the people in this region are known for their inherent creativity ('Kiwi-Ingenuity') and problem-solving attitude across the world, which has developed due to the availability of abundant natural resources added to the geographical isolation of the country (Campbell, 1999); studies reveal that PD problems are plentiful.

One of the earliest works on defining a PD process in NZ was conducted by Earle (1971); followed by studies Stuart and McCulloch (1980), Devlin (1984), Healy et al., (1987), Bollard (1988), among others (As cited in Kerr, 1994). Other Prominent researchers involved in studying this sector are Massey, Perry, de Bruin, Pech, and Cameron, McGregor and Tweed and Battisti (NZ Centre for SME research, 2009), in addition to Kerr (1994), Gomes (1998) and Ho (2001). These researchers have focussed on Product Development practices, the process, technology information acquisition behaviour, and knowledge creation, among others. Some of the important findings of these studies were in-line with findings across the world on small firms, such as:

- SMEs understand the high value of tacit based knowledge, but have no systems to capture it,
- Lack of knowledge on the various new PD techniques and tools being developed across the world,
- Firms are informal when they carry out the Product Development process,
- Firms rely heavily on external sources of information, and
- The major obstacle in conducting PD is resource scarcity (eg: budget, skilled people, etc.).

Research on PD processes within NZ SMEs reveal that even though most managers believed that standard PD process steps are logical and can be applied to SMEs; in reality these firms have very truncated PD processes, with several vital stages missing (Kerr, 1994). Most businesses reported that this lack of management resources, costs, and lack of skilled personnel have hindered the enrichment of product innovation (Statistics NZ 2005 report, 2007). Thus, the government, industry and academicians are inclined to provide encouragement, to suggest solutions for overcoming these problems. For example, the NZ government (through NZ Trade and Enterprise) has come forward since the late 1990s to support and grow the SME sector, by providing financial services, consultancy services, etc. with some positive results so far (Ho, 2001).

Thus, except for a few differences (such as the employee count), the SMEs within NZ and SMEs worldwide face similar problems and need a customised PD solution that encompasses all facets of product innovation. *In conclusion, since NZ SMEs face multi-dimensional problems, a holistic solution suiting their business environment is highly recommended.*

### 2.3.2 Holistic Solutions for New Zealand SMEs:

PD is a complex challenging process, even more in SME's due to the resource constraints, high dependency on business partners (suppliers, dealers, etc.) and modern day competitiveness (Wind and Mahajan 1997). Unfortunately, most of the PD models and practices are too complex for the application in Small and Medium Enterprises (SMEs) and require "adaptation" with several modifications (Vorbach and Perl, 2007; Wait *et al.*, 2008). Thus, it is unlikely that any particular practice or single solution model can realistically claim that it is a complete solution.

Customizing Product Development systems to assorted environments such as small entrepreneurial firms and varied industries to understand its relevance and applicability is one of the important suggestions made in most review papers on PD (Krishnan and Ulrich, 2001). Some of the good practices of PD such as knowledge sharing, a sound process, project selection models, etc. have been applied successfully in SMEs over a period of time, and an effort to customise them is also seen. For example, studies in different parts of the world (Rupak *et al.,* 2008) have revealed that collective knowledge of the development process can be built by improving a team's shared knowledge of customers, suppliers, and internal capabilities to reduce product design 'glitches' and improve Product Development time, cost, and customer satisfaction. These benefits are specifically important for successful PD in SMEs. Research has revealed that Knowledge-Based Engineering (KBD) has worked in SMEs (Sandberg, 2003) with benefits such as reduced lead-time, product optimisation, knowledge capture for future and more time for innovation, but has drawbacks such as time consuming implementation make it unsuitable for SMEs.

But success in PD is a sum total of optimum PD elements, acting like a jigsaw puzzle to provide superior performance. So, individual solutions such as those mentioned above are of little use. In addition, research studies on PD have revealed that SMEs carry out PD in a very different way. Since the PD processes in SMEs have been called 'truncated' with vital stages missing (Kerr, 1994), it shows that the working of PD in SMEs cannot be allied into any standard PD model; but a 'process' (or system) does exist in SMEs (although not documented: Browning *et al.,* 2006). A customized process / framework for innovation for SMEs, which is flexible, adapts easily to the people, leadership, management, planning, and other aspects of a SME are essential. Yet, there exists no comprehensive system built for SMEs to ensure seamless integration of all PD elements. The holistic models for PD such as Integrated Product Development (IPD) contain very good features and look promising for the application in SMEs. However, drawbacks such as lack of discussion on nurturing technical knowledge and the lack of understanding on cross-company (supplier-customer) co-ordination; can prove to be a major retard to SMEs upon implementation.

Thus, the following points can be summarised about PD solutions to SMEs:

- There is a need for Holistic Solutions that encompass the proven best practices, however
- The issues resulting from integration of the various best practices have to be avoided, given the problems faced by SMEs already.

Keeping this in mind, Vorbach and Perl (2007) proposed the innovation management model for SMEs that suggests a simple 3-phase process: idea generation, idea acceptance, and idea realization, with flexible feedback loops. Further, it proposes an 'innovation tool box' that contains a wide range of PD techniques (such as QFD, FMEA, Lead user concept, etc.) for each phase of the process. However, the following drawbacks can be identified for implementing this model in SMEs:

- The management and control of innovation system was a hindrance,
- The organization style in most companies was a mismatch to the PD process,

- Details of the knowledge management database was not revealed,
- Employee resistance to structure, and
- Lack of flexibility and openness.

SMEs across the world face several difficulties, including resource scarcity, limited support for innovation, technological uncertainties, poor market requirement definition, planning and strategy (Huang *et al.,* 2002) (Kerr, 1994) (Owens, 2007). Adding to this complexity is the fact that each Industry Domain / segment (Pharmaceutical, Engineering, Automotive, Electronics) have their own practices which are unique to their industry (March-Chorda *et al*, 2001). Yet, any industry essentially has the following common important factor in being successful (Jong and Vermeulen, 2006):

A. Value that they add to themselves, their customers, their business partners, employees and the society in general,
B. Timeliness of the innovation, time to market of the product, quality of the product and the competitive environment in which it operates.

Keeping the above important factors in mind, new age literatures focus on providing “frameworks” for innovation management rather than describing a ‘process’, an example for this is the ‘holistic innovation framework for SMEs’ by Wait *et al.,* (2008). Thus, it is important to look at holistic PD solutions that are ‘systems oriented’ as against ‘process oriented’, which can be developed into a framework for SMEs. Overall, since most of the best practices and solutions such as IPD have originated from Japanese companies, the focus repeatedly toward the most successful of them all: Toyota’s Lean Product Development or LPD.

## 2.4 The Lean Product Development System

As mentioned earlier, glimpses of success of the various key practices such as concurrent engineering, fuzzy front-end, flexible planning, constant learning, extensive supplier collaboration, customer focus, nurturing knowledge, etc. are already found in the literature. Product Development organizations are multifaceted systems, because of the complexity of human beings, making the need for a systemic perspective even more critical (Morgan and Liker, 2006). LPDS encompasses all these best practices into one comprehensive system for Product Development, the details of which are described in the sections below.

One of the earliest publications that suggested a possibility of 'Lean' being applied to PD was 'The machine that changed the world' (Womack, 1990). It brought to light two important aspects: the 'chief engineer' system and the supplier collaboration. In the meantime, studies by Clark and Fujimoto (1991), and Fox (1993) published their findings on the superiority of the Product Development systems within Japanese auto companies. They recognised high performance characteristics such as PD consistency, organization structure, technical skills, problem solving process, culture, strategy, and quality consciousness. *Thus, it became clear that Japanese firms like Toyota had superior PD systems that needed further investigation.* Subsequently, details such as concurrent engineering practices, the chief engineer concept and built-in flow and standardisation (Womack *et al.*, 2003; Liker, 2004) were published. In addition, Toyota's conservative culture of innovation, importance given to voice of the customer, learning from competitor products and careful customisation of information technology (CAD, CATIA software) was made known. However, these studies looked at Toyota as the Lean Enterprise, and were not focused on Product Development in detail.

In the recent past, specialist studies within Toyota on the PD systems resulted in a series of revelations on its key principles, processes, tools and technology (Ward et al., 1995; Sobek, 1997). In addition, books by Michael N. Kennedy (2003), James M. Morgan and Jeffrey Liker (2006) and Allen C. Ward (2007), revealed all the fine details, dwelling on each aspect and relating them to modern day industry; of what is known today as the 'Lean Product Development System (LPDS)'. Only recently, purposeful publications on *Industry application of LPDS* such as Baines *et* al., (2007) Haque and James-Moore (2004), Schuh *et al.,* (2008), Slack (1999) and Kennedy *et al.,* (2008), etc.

have emerged. The sections below describe the principles (including processes, leadership, tools, and techniques) and finer details of Toyota's Product Development system (TPDS) or LPDS.

### 2.4.1 Defining value and performance for Product Development

'Value' is defined by customer-defined entity for a Lean enterprise. The definition of value within PD refers to the knowledge created during development, the innovation yield to satisfy customer needs, and development of manufacturing or operational Value Streams (Ward, 2007). Thus, the PD system is responsible for creating two Value Streams: the knowledge value stream and the product value stream (details are explained in Figure 19). The knowledge value stream runs across several product Value Streams and forms the backbone for innovative products (Kennedy, 2003).

The Product Development performance indicators are cost, quality, delivery and speed-to-market which reflect in the form of customer satisfaction. Most traditional companies focus on measuring only the project Return-On-Investment (ROI), project expenditure, and profit per product. Whereas, a Lean PD system uses ROI calculation with market share to manage development, project defect rate Figures to spur growth, and estimated probability of failure to measure success of sub-systems (Ward, 2007). Calculating the value-adding time for designers, learning cycle time, project lead times and 'Learning-to-cost' ratio are important performance measurement tools helping to assessing the company's innovativeness. The learning-to-cost-ratio helps to check both the knowledge value stream and the product value stream are interfaced and healthy.

### 2.4.2 Waste (Muda) in Product Development:

Waste or '*Muda*' (refer glossary, p.218) is defined as any activity that does not add value to the customer. The three categories of activities within a value stream (Liker, 2004; Ward, 2007) have been described as: -

1. Value adding activities: These are directly accountable for providing the value to the customer, the creation of solutions that can be made and delivered to the customers. For example: Creation of Bill of Materials (BOM) document.
2. Non-value adding activities: These are pure wastes in the system, which consumes resources without giving any returns. For example: Waiting for suppliers, wrong parts supply by supplier.
3. Non-value added, but required: These are support work required to sustain the value adding tasks, such as knowledge database management.

Unlike manufacturing, wastes in Product Development are often invisible and difficult to measure. Some examples of PD wastes are listed in Table 1 in the seven identified categories of DOTWIMP (refer Glossary, p.215):

| | CATEGORY | EXAMPLE OF PD WASTE |
|---|---|---|
| 1 | **D**EFECTS | Inaccurate information on customer needs & missing verification tests |
| 2 | **O**VER ENGINEERING | Redundant development, pushing data rather than pulling |
| 3 | **T**RANSPORTATION | Information incompatibility, communication failure, multiple sources causing confusion. |
| 4 | **W**AITING | Unavailable information, delays in tools and samples from suppliers |
| 5 | **I**NVENTORY | Knowledge captured but not reused, excessive information, poor database management, complicated retrieval of design data |
| 6 | **M**OTION | Reformatting of information |
| 7 | **P**ROCESSING | Too much iteration, excessive verification, and unclear criteria |

**Table 1: Examples of PD wastes in the seven (DOTWIMP) categories (Fiore, 2005, p.32)**

One of the foremost tools for waste identification, the Value Stream Mapping (VSM) tool has emerged as the favourite primary methodology to implement Lean Thinking, both within manufacturing and at the supply chain level (Hines and Rich, 1997; (Hines et al., 1998; Womack, 2006). Rother and Shook (1998, p.3) define a value stream as "all actions (both value added and non-value added) currently required to bring a product through the main flows essential to every product: (1) The production flow from raw material into the arms of customer, and (2) The design flow from concept to launch."

VSM is used to separate value-adding activities from the non-value adding ones in the process. In PD, it can also be defined as the flow of information and technical requirements in order to create design models or drawings (Fiore, 2005). Some of the key benefits of VSM are mentioned below (Rother and Shook, 1998; Fiore, 2005):

1 It helps to clearly map flow of value across the current process,
2 Establishes a baseline for further improvements, and defining the future state,
3 It uncovers wastes and non-value adding activities in the value stream,
4 It gives an overall picture with product and knowledge value streams for PD, and
5 Eliminates cherry picking of improvement projects.

Studies across the world have confirmed that these wastes are commonly found in most large and small companies. Application of Value stream mapping to Product Development in many cases, have been able to expose PD wastes such as information incompatibility, lacking required tests/verification, etc. in major US and UK aerospace companies (McManus and Millard, 2002; Haque and Moore, 2004). The wastes exposed are mostly interrelated, which shows that the waste elimination process should also be a systems approach.

After more than a decade's research in Toyota, Ward (2007) suggested that the most important waste of all is the 'knowledge waste'. This is linked directly to the definition of PD, which is to create value through knowledge. Further, the three categories of knowledge wastes and their associated wastes have been listed as follows:

I. Scatter: It refers to the activities that make knowledge useless by upsetting its flow and its effects include communication disruption, distraction of developers, overloading of resources and affecting future projects.

   The associated wastes of scatter are communication barriers and poor tools. Barriers to communication could be physical, social, skill or information by nature. These barriers prevent flow of knowledge. Some examples are formal rules, off-site production, etc. Poor tools are the result of written standard procedures that generate problems when practiced. Examples include standard task lists and inadequate understanding of responsibility for results.

II. Hand-off: A ‘hands-off’ waste occurs when knowledge, responsibility, action and feedback are separated within the PD. When these four elements are separated, associated waste such as useless information is created (example: power-point presentations), and an uneven integration that leads to waiting for important knowledge (example: design waits for specifications from marketing).

III. Wishful thinking: The ‘wishful thinking’ waste means making decisions based on assumptions and unproven data. Two typical examples are setting of specifications (a negotiation stuck between what customer wants and what nature permits), and selecting suppliers late in the PD process based on superficial understanding of their capabilities. Also, most knowledge gained during the development is wasted after a manufacturing launch; this may imply reinventing the wheel for the next project. Thus, the two associated wastes of wishful thinking are testing to specifications and discarded knowledge.

Overall, we can see that the ‘root’ cause for PD wastes is connected to knowledge. VSM would identify wastes that co-relate to this root cause, and a way to address them would be to ensure knowledge is not scattered, it is not discarded, and definitely not separated from the PD value stream.

2.4.3 Process, organization and culture that shape Lean Product Development System:

The development excellence at Toyota emerges from three corporate capabilities namely process, organisation and culture (Figure 9). These also define the company environment that is required for deploying and sustaining LPD. Further, the National Centre for Manufacturing Sciences: NCMS (based in the United States) has established that different paradigms exist within companies across the world and mapped them against process, organisation and cultural attributes (Kennedy, 2003). These maps or matrices offer a change management methodology and an assessment device for enabling paradigm shift from the traditional to the Toyota way in Product Development.

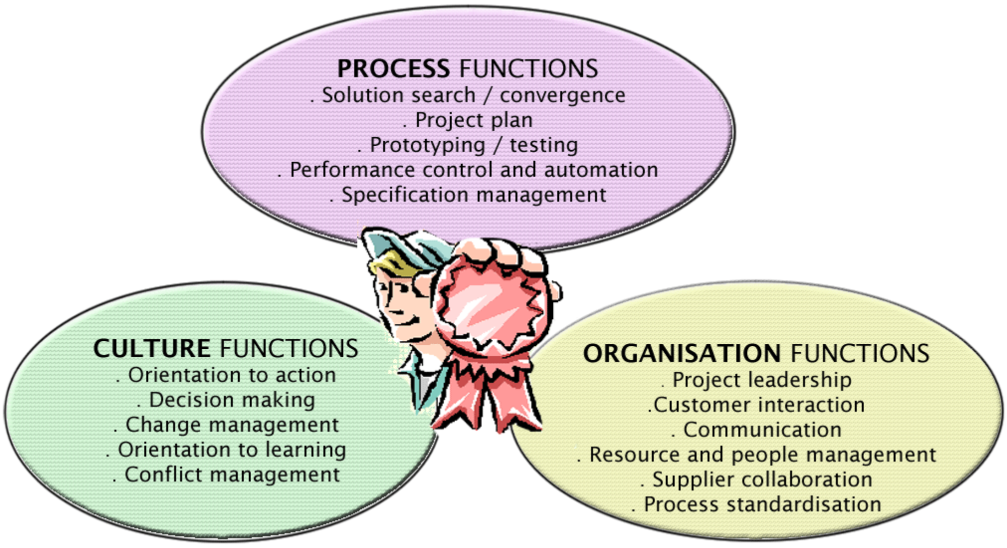



**Figure 9: Development environment for excellence (Kennedy, 2003)**

These assessments show that the paradigm characteristics in traditional companies and Toyota fall in two extreme categories. The fundamental difference is the basis of the engineering environment. Toyota focuses on the expertise of the workforce, learning, actual observations for status reporting and improvement by constant learning, whereas traditional companies focus more on structure, control, and adherence to schedules (Table 2).

| ATTRIBUTE | TRADITIONAL COMPANIES | TOYOTA |
|---|---|---|
| BASIS OF ENGINEERING ENVIRONMENT | Structure of the operational activities | Knowledge of the work force |
| OPERATIONAL FOCUS | Planning and control | Doing & learning |
| PROGRESS EVALUATION | Completion of actions | Go & see in 'Gemba' (actual workplace) |
| BASIS FOR PERSONAL REWARD | Completion to plan | Knowledge/ expertise |
| IMPROVEMENT FOCUS | Task efficiency | Learning efficiency |

**Table 2: Development environment differences between traditional industry and Toyota (Kennedy, 2003)**

Toyota's environment emerges from its 'core' or 'DNA' which is deeply rooted in the Japanese culture (Liker and Morgan, 2006). An example of this is the '*Kaizen*' tool, which has evolved from the '*Hansei*' (refer glossary, p.218). *Hansei* is the process of introspection and reflection that is cultivated in every child within the Japanese culture. The benefits of this include deep understanding of one's actions and the identification of areas for improvement, which form an integral part of 'Lean' thinking.

In order to retain and transmit this culture, the company uses the following four methods:

1. Appointment of co-ordinators to train new Toyota plants across the world,
2. Careful selection of new employees for compatibility with culture,
3. Influence on overseas Toyota employees when they visit the company in Japan, and
4. Mentoring by Chief Engineer during projects.

In addition, Ward *et al.,* (1995) suggests that Toyota has distinctive characteristics compared to its Japanese competitors such as Nissan, and in-fact much superior to all companies in the world. The reasons are many, but it is chiefly due to a combination of Japanese characteristics and geographic isolation of the company that 'Lean' was born at Toyota.

## 2.4.4 The Importance of Lean

As mentioned earlier, the Lean Product Development Systems is based on the 'Lean' thinking or the Lean philosophy that originated from the Japanese Automaker 'Toyota Motor

Corporation Ltd.' The term 'Lean' has been used to describe Toyota's excellent internal system that has made the company one of the best in the world today. The Lean philosophy focuses on *identifying value* and *eliminating waste* in central processes so that the entire supply chain becomes agile, flexible and efficient. The book "The Machine That Changed the World" by Womack *et al.*, (1990) discussed why Toyota seems to exceed their Western competitors in productivity and quality. This was followed by several other publications on 'Lean' (Womack and Jones, 1996) and Toyota by Emiliani (1998), Liker (2004), Emiliani (2004), Flinchbaugh and Carlino (2006), etc.

The 'Lean' approach is based on 5 basic principles, as illustrated in Figure 10.

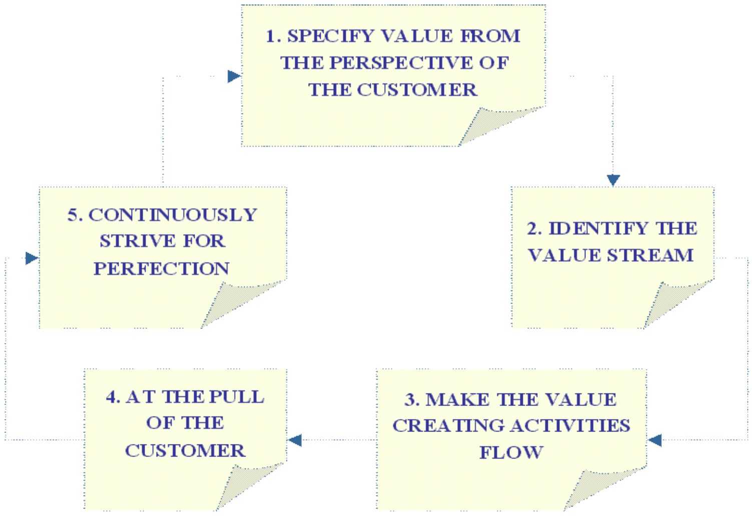



**Figure 10: The five Lean principles (Womack and Jones, 1996)**

According to Lean principles, the customer specifies ***'value'*** (a product or service) that satisfies their needs at the right price and time; and the '***value stream'*** is the set of tasks (mainly consists of solution development, physical transformation, and delivery) that is required to produce this value. Here, '***flow'*** is used to ensure the value added in every stage without encountering the obstacles or 'Muda' (waste) throughout the value stream. The fourth concept of '***pull'*** refers to the customer 'demand' for the product, which acts as a trigger to let the 'value' (product / service) flow through the value stream. The four elements of value, value stream, flow and pull work in harmony within a Lean enterprise. In order to sustain this internal environment in spite of external variability, the

Lean organisation must '***continuously improve'*** or do ***kaizen*** to move toward perfection (Womack and Jones, 2003).

Toyota identifies three areas that can harm the Lean system*: **Muda, Mura,*** **and *Muri***.

1 Muda refers to the seven wastes: over-production, defects, unnecessary inventory, inappropriate processing, excessive transportation and waiting, unnecessary motion (Ohno, 1988). The eighth waste is design of unwanted goods (Womack, 1996).

2 Mura refers to unevenness or variability in process and demand. Muda gets generated as a reaction to Mura.

3 Muri refers to overburden or excessive workload and it generally arises from Mura.

The five Lean principles form the basis for carrying out activities within Toyota, be it the Product Development, or manufacturing or Logistics.

The four-pillar model and Ohno's (1988) Lean temple are two popular analogies to describe the Lean approach. In 2004, Liker published the book 'The Toyota Way' which elaborates the details of the Lean system within Toyota. The **four main pillars** of Toyota's systems are:

1 Long-term philosophy to sustain the Lean enterprise,

2 Ensure the right process to produce the right results,

3 Adding value to the organisation by developing firm's people and partners, and

4 Continuously solving root problems to drive organisational learning.

These four pillars have been extrapolated into fourteen principles that form the basis of the popular 'Toyota Production system' (TPS) or 'Lean Manufacturing' (Liker, 2004), and to all functions within Toyota (as illustrated in Figure 11).

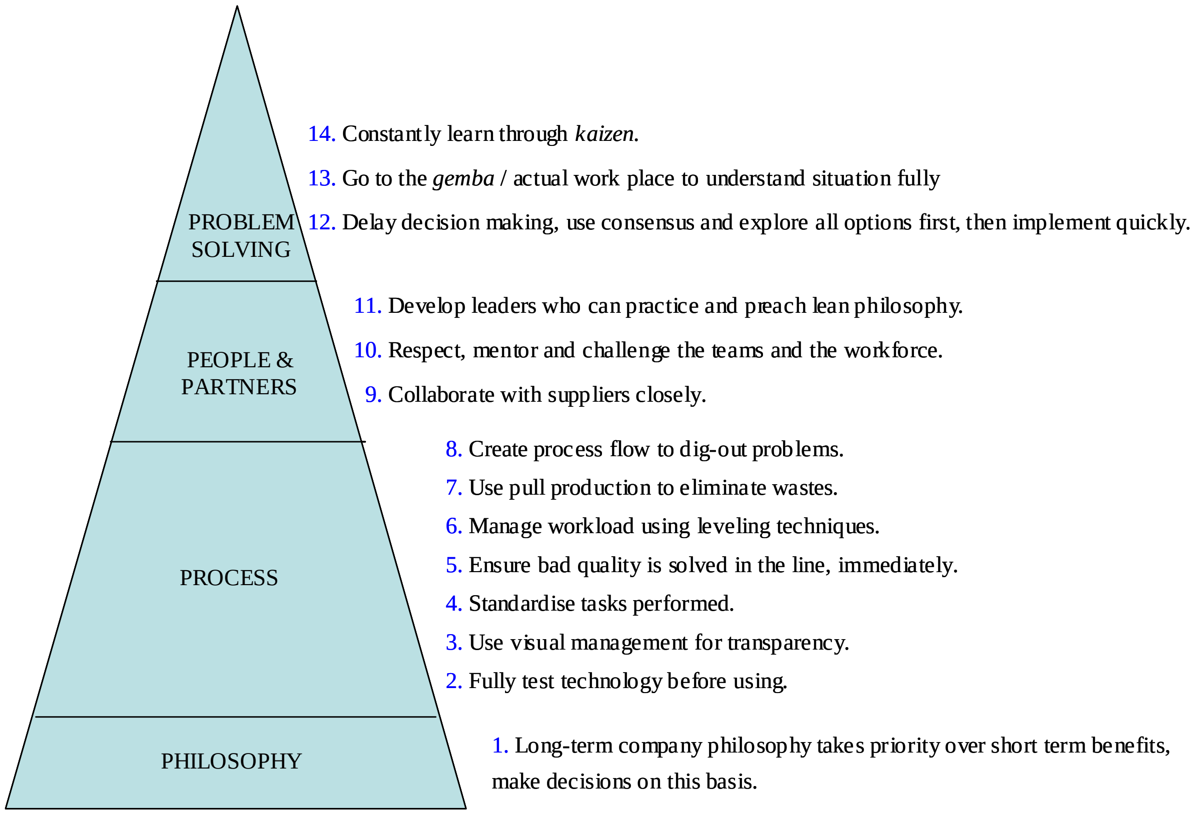



**Figure 11: The "4P" model of Toyota way (Liker, 2004)**

The elements of **Ohno's Lean Temple** (1986) are similar. The Lean temple or house contains standardised work, process and product robustness, supplier involvement and housekeeping as the foundation; Flow, pull system and workload levelling as the first pillar; Technological excellence, error proofing and visual control as the second pillar; and quality-cost-delivery form the roof of the temple (Ohno, 1986).

Researchers and practitioners have experienced that the Lean thinking has to be sustained if the success has to be permanent. Thus, Hines *et al.*, (2008) came up with the **Sustainable Lean iceberg model.** According to this model, *strategic alignment, leadership, behaviour and commitment* form the base on the iceberg that remains below waterline, and enables the visible elements of the iceberg (above waterline), such as tools, technology, techniques and process management (Figure 12).

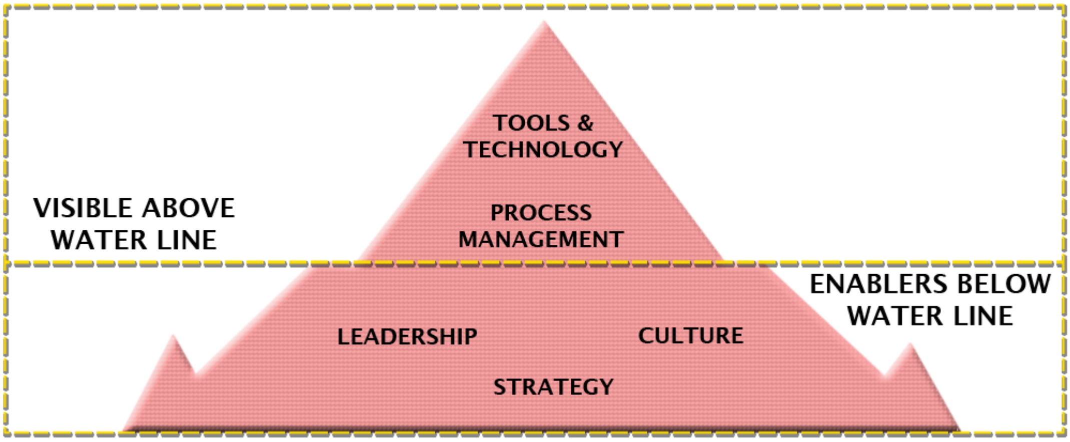



**Figure 12: The 'Sustainable Lean iceberg' model (Hines *et al.*, 2008)**

Toyota's Production System or TPS announced the Lean approach to the world, and has been used in several companies including world's largest automotive manufacturers such as Ford, General Motors and Chrysler (Womack and Jones, 1996; Liker and Meier, 2006; etc.). The benefits of TPS range from increased efficiency, quality with decreased cost and lead-time. Although the Lean thinking is not limited to just the manufacturing in Toyota, TPS is seen as the secret of Toyota's success. The reasons for this is perhaps:

1 TPS has been well understood and much has been written about it, compared to other Lean systems within Toyota.

2 It is the most logical first step towards establishing the Lean enterprise.

3 It contains simple and effective tools that can generate results within a short period of time.

Details of TPS has been excluded from the literature review of this thesis as it falls beyond the scope of the research topic.

Although, the application of 'Lean' thinking outside production was suggested by several publications Womack (1990), Liker (2004) and Magee (2007), minimal importance was given to them. Nevertheless, it has now been recognised that *speed-to-market* is achieved by *efficiency in both manufacturing and Product Development together* (Morgan, 2002). Efficiency within PD helps to balance world-class innovation with resource constraints, and therefore organisations are exploring the application of Lean in PD.

## 2.5 Lean Manufacturing and Lean Product Development

The focus transition from Lean Manufacturing to Lean Product Development can be understood in the light of the following events (Morgan and Liker, 2006):

- It has emerged as the "next domain of core competency",
- New era challenges such as increased customer demands, innovativeness, speed-to-market, ever-increasing demand for variety, quality, cost pressures and aesthetic accuracy can be met by optimising PD (where the actual birth of a 'manufacturing process' occurs in every company),
- Most companies have adapted the Lean Manufacturing practices with much success, and so the "performance gap between competitors in this domain has reduced",
- Extensive research has been carried out in the field of Lean Manufacturing, unlike Lean PD.
- NZ industry has adapted Lean Manufacturing for more than a decade, the time has come for the next step: build a 'Leaner' PD.

Application of Lean to a complex PD environment is probably more challenging, as Reinertsen (2005) explains: "Product Development in the 21st century has evolved into a complex, multi-dimensional, sequence of activities which involve a network of informed professionals spanning across different stakeholders of any organizations, business partners such as network of suppliers and vendors, competition location and demography influence an organization capacity to development new products". Some distinct characteristics of PD as opposed to manufacturing are illustrated in Table 3:

| Characteristics | Differences |
|---|---|
| Variability | PD has variability exists in 2 ways; one that creates value (Economic, Aesthetic) and one that destroys it (due to complexity). |
| Value flow | Product developers have to manage information flows as opposed to material products in a manufacturing scenario. |
| Value creation | In Product Development, innovative ideas, concepts and practices can develop in either path breaking ways or disruptive ways, as against the linear way in manufacturing. |
| Capacity versus demand | Risk taking for addition of economic value and time required are the important factors in Product Development phases in most organizations. |

**Table 3: Distinct characteristics of PD as against manufacturing**

Preliminary studies by Reinertsen (2005) on application of Lean tools to PD has led to an understanding of how these techniques can be applied to PD:

1 **Queue-management: -** In manufacturing, products in 'queue' are easily visible and are tracked via inventory. In PD, queues are intangible and difficult to measure in financial terms. Hence, ROI (return on investment) is viewed as important factor in queue-management here.

2 **Batch size reduction: -** Optimum batch size management is important for Lean Product Development. The factors such as market research and product specification influence batch size selection in PD.

3 **Flow: -** Project deliverables and their relationship to management reviews and testing are to be synchronized in a PD set-up.

4 **Rapid local adjustments**: -While special methods like '*Kanban*' (refer glossary, p.218) need to be adapted in manufacturing scenario for Rapid local adjustments; in PD, efficient task and resource management can be combined with special methods to achieve the same.

5 **Waste elimination**: **-** Lean Manufacturing bought the focus on broader view of waste than just labour and material. But, PD scenario offers a more holistic view for waste elimination.

In summary, Lean Manufacturing and Lean Product Development both focus on adding value to the customer and society by integrating people, processes, tools and technology efficiently (Morgan and Liker, 2006). Although this might give the picture that Lean tools (those in manufacturing) applied to optimise PD is 'Lean Product Development', but it is much more than that.

## 2.6 Popular descriptions and models of Lean Product Development

'Lean Product Development system' emerged as a result of extensive specialist studies conducted for understanding Toyota's Product Development. These specialist studies were conducted by 'Industrial and operations engineering' faculty and doctoral students at University of Michigan for over a decade. The publication "The Second Toyota Paradox" by Allen Ward, Jeffrey K. Liker, John Cristiano and Durward Sobek in 1995 is one of the most significant and foremost publications to the field of knowledge till date, which was followed by "Applying Lean Principles to Product Development" by James Morgan. Hence, these researchers have been referred to as pioneers in almost every publication on LPDS, for example Ballé and Ballé (2005), Kennedy

(2003), in addition to the various independent researchers within Japan such as Cusumano and Nobeoka (1998), Takeuchi and Nonaka (1995), etc.

Further, it has been observed that the understanding of the LPDS has improved over the last decade, with the help researchers and practitioners across the world. Additional applications oriented models (Ballé and Ballé, 2005), (Kennedy, 2003) have emerged on this topic, and are mostly adaptations of pioneering studies mentioned above. The field of study is constantly enriched today with renowned experts such as Don Reinertsen, Mike Kennedy, Ron Mascitelli, Tom Devane (and others) on the state-of-the-art and future directions (Management roundtable, 2007).

Since, Lean Product Development has emerged from Toyota, it is clear that pioneering studies, or firsthand research would be the closest to the real ‘Lean’ system that makes Toyota’s PD world class. Based on this obvious understanding, the following chapter details into the LPD model described by pioneers in order to provide an overview of this system.

### 2.6.1 Principles of Lean Product Development

Morgan (2002) presented one of the earliest interpretations of the basic principles of LPDS. These principles revolved round the “systems” approach of LPD; the importance given to customer needs, engineering rigour, problem solving techniques and cross-functional aspects, embedded continuous learning attitudes and a concurrent engineering set-up; which in totality ensured strategic flexibility and design reusability of PD system. Subsequently, these principles have been extrapolated into 13 process, people and tools-technology (Morgan and Liker, 2006).

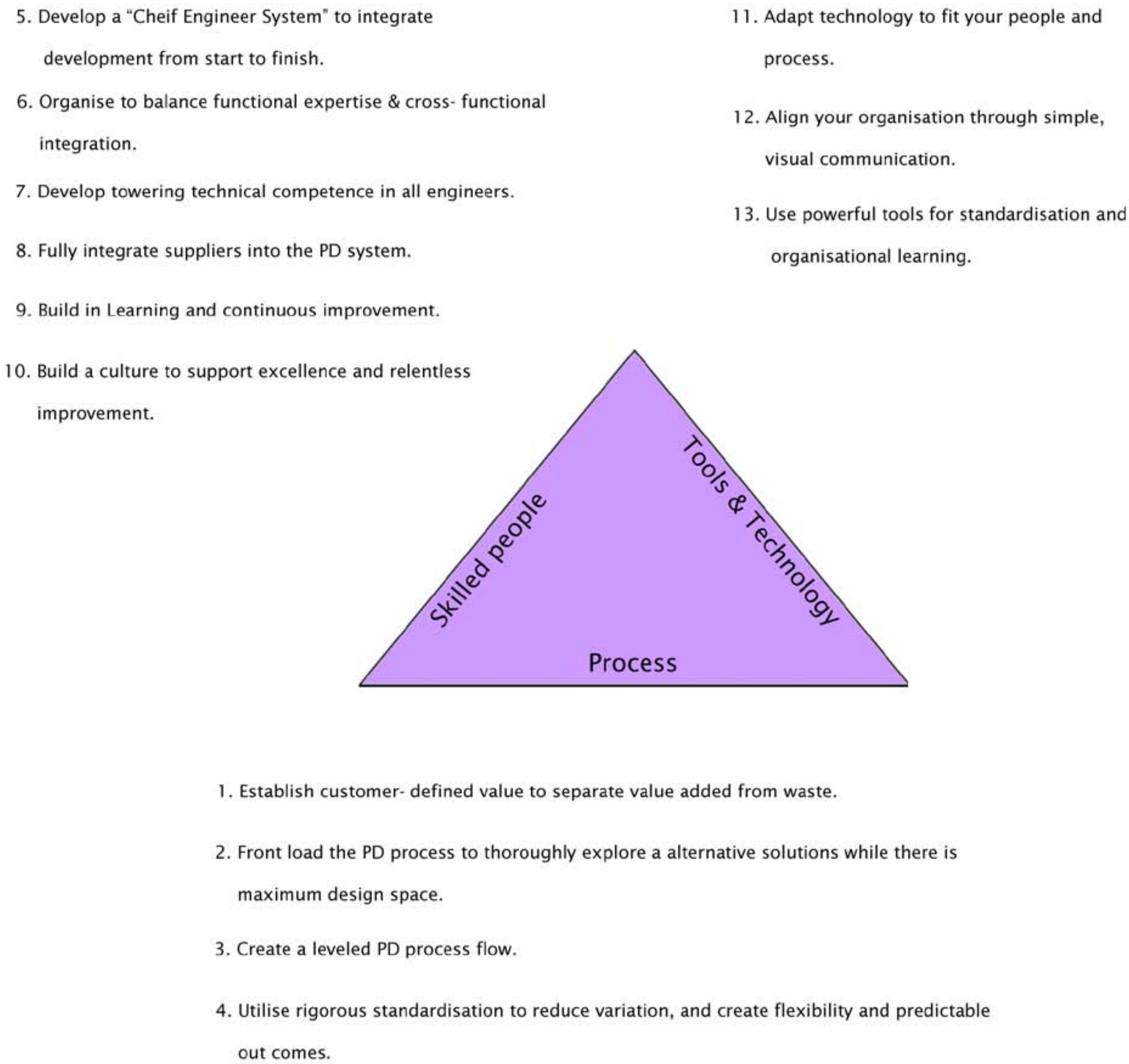



**Figure 13: Principles of Lean Product Development System (Morgan and Liker, 2006)**

As shown in Figure 13, the process, people and tools and technology principles put together form of the 'Lean system'. These aspects are "interdependent, overlap and work together in coherence" (Morgan and Liker, 2006). The process principles take care of eliminating non-value adding activities, ensure exploration of all design options to satisfy customer needs, establish a system with root-cause analysis capabilities in problem solving, and stabilise the workload using standardisation techniques. Meanwhile, the people principles set-up a chief engineer system in addition to strong functional teams, ensure engineers develop expertise continuously, align suppliers and establish a culture of constant learning. Finally, the tools and technology principles help to customise technology in order to fit the firm's processes and people systems, to enable effective communication and provide aids for standardisation and learning.

Toyota has been able to constantly develop top quality vehicles more rapidly, for less cost, and at a larger turnover than its competitors due to the practice of these Lean process, people, and tools-technology principles. The philosophy of customer focus, continuous improvement and integration of value streams has enabled PD excellence as much as it did for manufacturing systems.

### 2.6.2 The four cornerstones model of Lean Product Development

Allen C. Ward (1995, 1999, 2007) developed the 'four cornerstones' model of Lean Product Development. These four pillars of LPD are the Process- Set based Concurrent engineering, People- Expert engineering workforce, Leaders- System designer entrepreneurial leadership, and Control system- Responsibility based planning and control, which interact together for establishing value focus and creating profitable value streams to the customer, as shown in Figure 14. The four cornerstones model has been adapted for application by Kennedy (2003), also termed as four implementation pillars of Lean Product Development system.

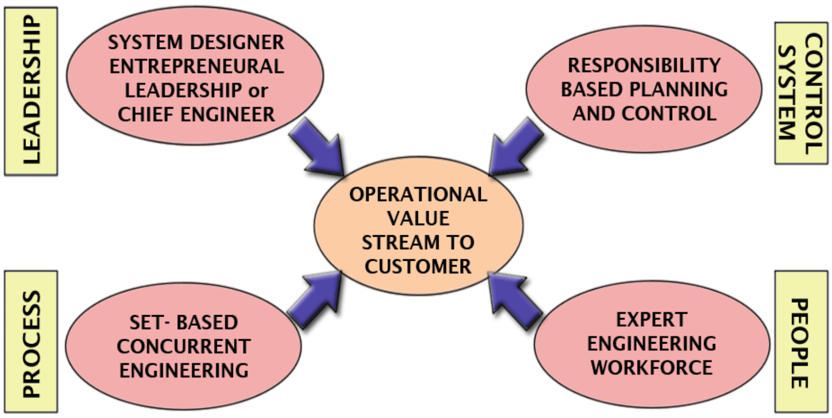
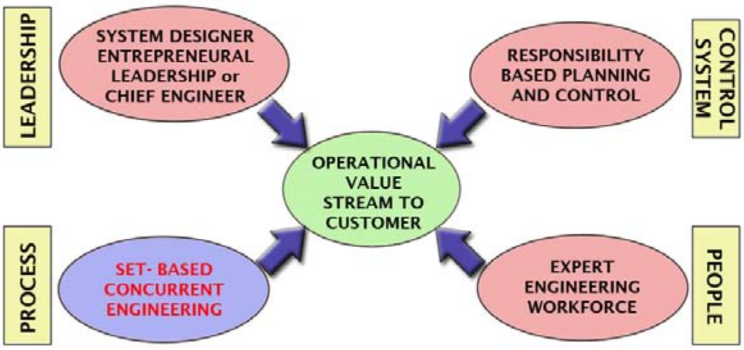



**Figure 14: Four cornerstones of the Lean Product Development System (Ward, 2007)**

Ward (2007) indicated that the Lean Product Development Systems cater to all the types of development, i.e. research (exploration of new ideas), strategic breakthrough (satisfying the customer needs by defeating competitors) and application projects (rely on existing knowledge). It uses *Set-based Concurrent Engineering* to search and arrive at optimal solutions with the help of the knowledge of the *expert engineering workforce*; manage the entire system by *distributed responsibility* and provide necessary leadership and technical decision making for the product with the help of the C*hief Engineer* system (Kennedy, 2003; Ward, 2007). Details of four critical elements are described below:

I. Set based concurrent engineering (SBCE):




Practitioners and researchers have always emphasized the exploration of multiple ideas in PD, examples include Pugh concepts and Wheelwright and Clark, Dubinskas, etc. that stress the need for a wide set and criteria based narrowing down to approach an optimum solution (Ward *et al.*, 1999). Similarly, set based concurrent engineering is a straightforward, growth, recurring cycle with the intention of achieving high originality in products and manufacturing systems; while eliminating risk using redundancy, vigour and knowledge capture (Kennedy, 2003). The process of SBCE is illustrated in Figure 15.

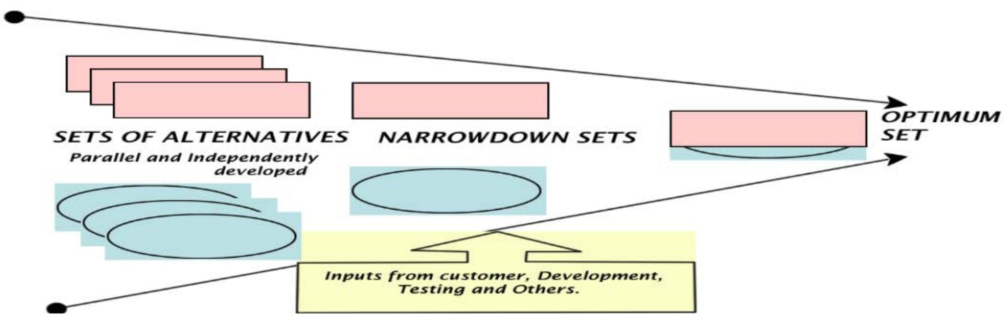



**Figure 15: Process of Set-Based Concurrent Engineering (Ward *et al*, 1999)**

One of the foremost experts on SBCE, Ward (Ward *et al.*, 1999) explained the principles of SBCE as follows:

1. Mapping the design space (applied at individual project level as well as the overall product systems): Includes defining feasible regions, designing / simulating the alternatives, analysing the trade-offs between alternatives and evaluating them using a matrix.
2. Integrating by intersection of feasible regions: Use of checklists to locate intersections, applying minimum boundaries while seeking conceptual sturdiness.
3. Establishing feasibility of the optimised overall system solution before committing: Includes narrowing down to details that aid selection of sets, ensure the selected sets are processed further without deviations and managing risks.

The SBCE process involves not only the design department, but also encompasses the suppliers. The exploration of some parts / sub-systems may be delegated to suppliers, who conduct SBCE for particular component within their company; while the main components are worked at within Toyota.

In Toyota's supplier circles, there is great regard for the company's practices. Studies conducted by Morgan and Liker (2006) found that suppliers rank Toyota highly due to the following reasons:

1. "Toyota works with new / struggling suppliers to get up to speed,"
2. "Makes commitments to suppliers early in the PD process and makes good on promises,"
3. Makes contracts that are straightforward, and long-term,
4. Toyota balances focus on cost and on quality extremely well, as compared to the other automakers,
5. "Toyota honours the contracts – does not exploit suppliers for any reason."
6. "Treats suppliers respectfully, and respects the integrity of intellectual property."
7. Works as a team to achieve tight cost targets.

The knowledge of the engineering workforce and suppliers are the important factors for the success of SBCE. The process gets accelerated and costs reduce as knowledge and expertise increases within the functional departments.

SBCE targets wastes such as wishful thinking, testing to specifications and discarded knowledge. It helps to eliminate several problems faced by companies using the traditional approach. In a traditional set-up, Product Development teams select a single concept very early in the process based on 'gut' feeling and begin to make detail designs, leading to failures most of the time during testing. This focus on a single solution ('point-based) thus leads to unplanned loop backs; budget overruns and increased lead-time, among others. In SBCE, through testing of multiple solutions builds in a 'redundancy' factor that mitigates risk, and the choice of concepts are made after careful elimination using test results of all the concepts (Ward *et al.*, 1999; Kennedy, 2003).

Another important advantage of using the SBCE system is consistent capture of knowledge in reusable form. *Trade-off curves* (refer glossary, p.218) are used to perform this function for the LPD system. Trade-off curves are used to store relationship information or design decisions between two parameters within a subsystem, indicating the feasible and infeasible regions for design. These trade-off curves ensure that no innovative ideas are lost, and knowledge is available for forthcoming projects (Figure 16). Although, similar practices exist in PD (also called 'competitive map') for refining specifications by trading off between parameters such as cost versus performance, etc., these are rarely practiced within industry.

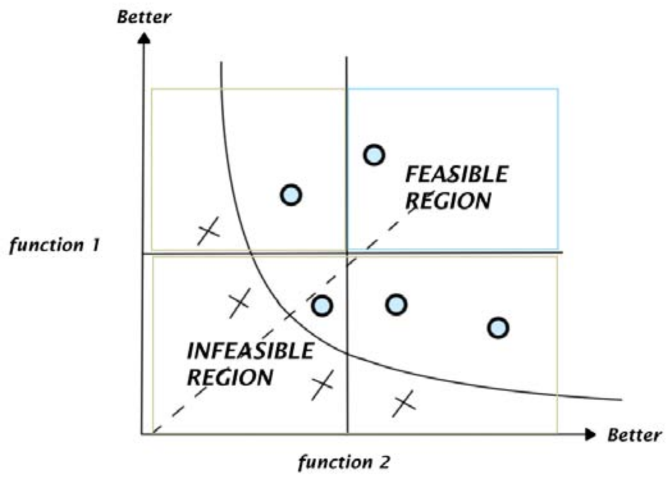
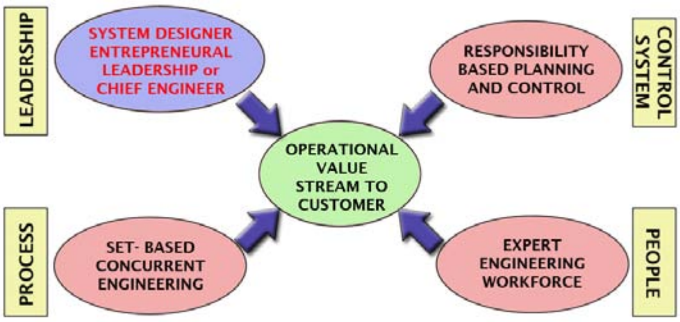



**Figure 16: Trade-off curve (Kennedy *et al.*, 2008)**

More importantly, set-based concurrent engineering has been called the "second Toyota paradox", which helps to delay decisions, exploring extensively using prototypes and coherent leading to better cars faster and cheaper (Ward *et al.*, 1995).

II. Entrepreneur system designers (ESDs) or 'Chief Engineer' (CE) System:




The ESD or the 'Chief Engineer' is the product champion with ultimate authority and responsibility of the entire PD process for a particular new Product Development. Within Toyota, there exists a clear role and responsibility separation between functional managers and chief engineers. The role of a functional managers is to support frontline engineers and designers, organise knowledge creation and help to build capability; whereas, the chief engineer or the project leader supports the top management by ensuring profitability with every project. Functional managers constantly negotiate with chief engineers for suitable resources, along with guiding CEs to take correct decisions (Ward, 2007). This kind of organisation structure helps bring about the most important balance between innovation and project management (Morgan and Liker, 2006).

The *purpose* of the ESD cornerstone is to develop the vision for the new product, ensure good timely decision-making and ensure cross-functional flow. The *criteria* for the selection of chief engineers were noted as technical expertise and experience, learning potential, good judgement, ability to connect technical and business realities, and ability to communicate their vision of product and value stream. The chief engineer (also called master designer) carries out the following four major *functions* (Ward, 2007):

1 Representing customers: This includes understanding 'completely' the needs of the customer (it is much more than just collecting needs via market research),

2 Negotiating for resources, agreeing on the vision: It involves talking to customers, suppliers, production, functional teams, marketers, etc. to communicate the vision for the new product.

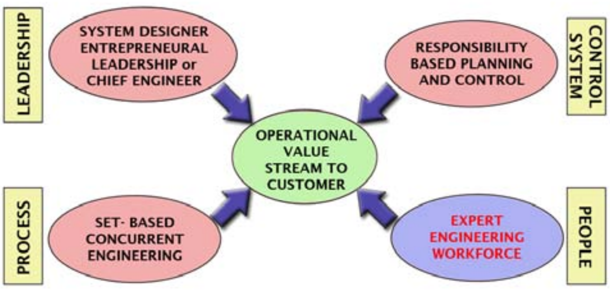
3 Ensuring profitability of the project while managing risk: It consists of evaluating decision options keeping in view the uncertainty involved and project profit. As a system designer, it is essential to bring about a win-win situation between the two aspects.

4 Designing the overall system: This function encompasses conducting field tests to simulate solutions, shape and innovate the overall system architecture, define technical philosophies, eliminate week links, and integrate knowledge.

Thus, within the Lean Product Development process, a chief engineer's *role* is to arrive at a product concept, gain approval from the management, and set the dates for key Integrating Events (IE) for picking the optimum solutions. An Integrated event (IE) (refer glossary, p.218) is the points within the Product Development process where the right set of alternatives from each sub-system (being developed by the functional teams using SBCE) is chosen. Although several of the project champion attributes are seen in the chief engineer concept, there are some key differences:

- A project manager is called as a project champion in many companies, and it is assumed his/her management skills are additional to the technical skills already existing in the individual.
- Gatekeepers of the PD (stage-gate) process are often called the project champions who make key decisions on the progress of the project.

III. Expert Engineering Workforce:

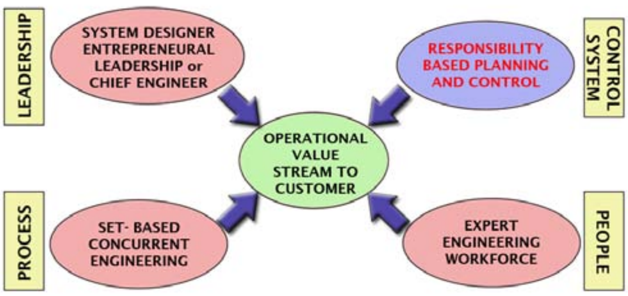



The 'people' aspect of Lean Product Development focuses on developing expertise and sound leadership within the system. The characteristics of the engineering and design workforce are as follows (Kennedy, 2003) (Ward, 2007), (Morgan and Liker, 2006):

- Ability to take responsibility of the entire project success, not just play a part in isolation. Every individual has full responsibility of controlling and delivering to the chief engineers requirements,
- Be a team player, contribute, teach others, listen, solve problems, and communicate well within the department and across departments,
- Ability to constantly learn, innovate and gain knowledge: The engineers and designers develop expertise by conducting rigorous tests in labs, practicing, publishing, discussing and taking up new challenges, and
- Training of engineers, supervisors and managers in a structured problem-solving approach that uses a tool called the A3 Problem-Solving Report (refer glossary, p.218), etc.

People at Toyota are subjected to three levels of training. Firstly, they are exposed to the company's basic processes, manufacturing set-up to let them understand and gain practical knowledge of PD's internal customer, i.e. the production (Ward, 2007). Then, the critical skills are communicated to the workforce. The skills such as understanding of Lean principles, speed of decision-making, etc. is provided through training and on-job mentoring. Finally, they are given responsibility to carry out work and also begin mentoring others. Thus, the engineers are expected to be experts in their areas, and the reward system is based on the knowledge and learning by these individuals.

IV. Responsibility based planning and control:




As discussed in the 'expert workforce' cornerstone of LPD, engineers and designers are experts; they not just create designs but are responsible for the final outcome as well. In summary, the teams of responsible engineering experts work under the supervision of the functional manager, who plays the role of providing environment, resources for the teams, insist and demonstrate ethical behaviour, communicate well, and lead the development toward success.

As per the responsibility based planning and control element, the designers are allowed to plan and monitor themselves based on the amount of work involved in meeting the chief engineer's requirements. As Ward (2007) explains, traditional companies face problems related to accountability in their PD systems because management (scheduling) and actual design work is carried out by different individuals (over-the-wall approach). This, however, does not undermine the importance of communication within PD but instead makes communication more efficient.

Communication is an important support for the engineering expert teams to carry out innovation. The various tools used within the LPD system are A3 reports, visual information, 'Obeya' (big room) meetings (refer glossary, p.218), etc. The purpose of these tools is to surface problems, communicate reality and arrive at consensus between the functional teams (functional manager and expert workforce) and the Chief Engineer. For example, A3 reports serve the following purposes (Shook, 2008):

- A document to capture learning, decisions, and preparation involved with solving a problem,
- Ease communication with people in other departments, and internal mentoring
- Give structure to problem-solving so as to capitalize on learning.

An A3 report is written after doing thorough investigation of the situation, using a PDCA (Plan-Do-Check-Act) type of cycle, also called the LAMDA (Look-Ask-Model-Discuss-Act) (Ward, 2007). The typical steps in an A3 report are study background, assess current situation, define goals/ targets, analyse, and evaluate alternative solutions, select and implement solution (Shook, 2008). This is central to Toyota's relentless improvement of operational performance. Much research has been done on the A3 reporting tool of LPD and the application of this tool within various organisations (Shook, 2008), (Sobek II & Jimmerson, 2006), etc. due to the simplicity of this tool.

On the whole, the two cornerstones of 'expert engineering workforce' and 'responsibility based planning and control' target the wastes such as 'hands-off', as they carefully combine responsibility, knowledge, action and feedback for innovation.

<u>Central focus: Operational value stream to customer using the four cornerstones:</u>


The four foundation cornerstones of LPD, that represent process, people, leaders, and control systems, are pulled together to create cadence, flow and an effective value stream to customer (Kennedy, 2003). Cadence can be related to 'TAKT' of Lean Manufacturing, i.e. a rhythm that helps to reduce variation, stabilise workload and aid continuous improvement. Flow ensures that knowledge is available at the right time, when the pull of the customer needs to be addressed (Ward, 2007). In addition, the supervisors guide the knowledge into value for customers while spreading expertise internally. The overall LPD system is effective by the use of simple cyclic tools such as the 3-step investigation process, the LAMDA cycle (refer glossary, p.218), etc.

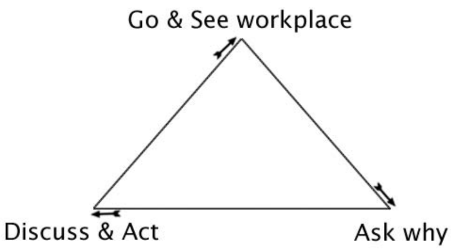



**Figure 17: The LPD investigation process (Ward, 2007)**

The investigation tool for example (Figure 17), helps to be aware of facts at any given point of time, and to react promptly to requirements. Since, the entire cycle of understanding customers, simulating solutions, making world-class products and learning from the feedback of customers is a continuous process, such tools are needed to guide the PD personnel. Another important tool is the **LAMDA** (Look-Ask-Model-Discuss-Act) cyclic investigation process. It is used to prepare A3 reports or Knowledge Briefs (KB) (Panchak, 2007). The LAMDA cycle (refer Figure 18) is based on the PDCA (Plan-Do-Check-Act) cycle, with an aim is to investigate every aspect of a particular problem or situation in detail (LOOK and ASK), followed by a representation and discussion on possible solutions (MODEL and DISCUSS), and finally the implementation of the solution (ACT) for completion of one cycle (Panchak, 2007).

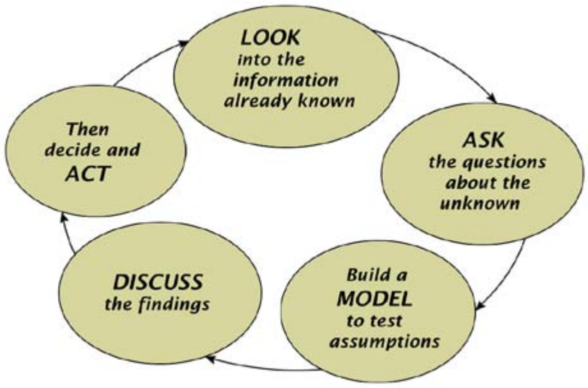



**Figure 18: LAMDA cyclic investigation (Panchak, 2007)**

LAMDA and other tools form the sound problem-solving system at Toyota. They aid constant learning (i.e. innovation) and are captured in standard A3 reports for the future.

In summary, a Lean Product Development System is generated by continuous capture and growth of knowledge with the help of Lean tools, which may or may not be independent of a particular project in R&D. This is the basis for the four cornerstones, which pull in together and create the necessary flow of value to customer, as illustrated in Figure 19.

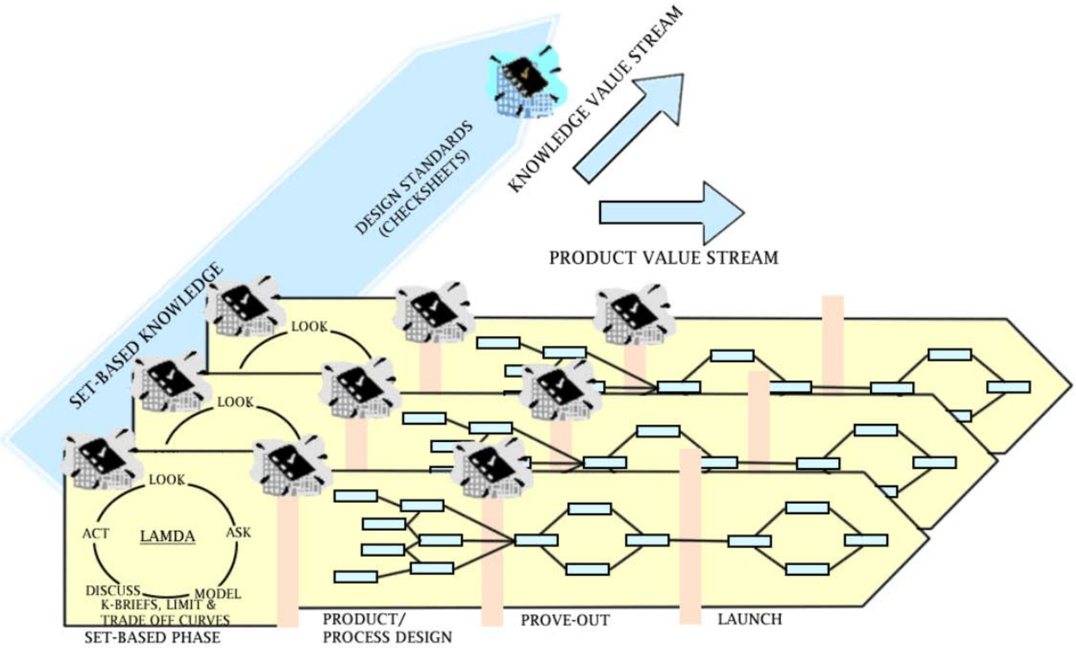



**Figure 19: Knowledge and product value streams (Kennedy *et al.*, 2008)**

Kennedy (2003) suggests that most companies are either unaware of the existence of the knowledge value stream or are unable to integrate the two value streams. At Toyota, the knowledge value stream (containing set-based knowledge, and design standards etc.) behave as a 'blood stream' which is responsible for providing 'nutrition' i.e. knowledge to product value streams at the right time and in right amounts. In turn, the knowledge value stream is constantly built and replenished from the set based engineering carried out in product value streams (Kennedy *et al.*, 2008).

Thus, we can see that the TPDS model proposed by Ward (2007) provides a holistic and detailed view of the system. It is a direct result of over a decade's dedicated effort for understanding all aspects of this 'Lean' system. This model has been built upon by Kennedy (2003, 2008) to understand the co-relation between traditional companies and Toyota.

### 2.6.3 Summary of differences between traditional companies and Toyota

It is not uncommon to see PD processes facing problems in traditional companies. The discussion below provides an overview of these problems in the light of the LPD system by comparing PD in large traditional companies and Toyota:

**Process:** According to traditional processes, designing a product and then testing for compliance to specifications is the way to PD. Whereas, within LPD, tests of new concepts are carried out to understand the basics of functions before designing the product. It can be viewed as a clear paradigm shift.

**People:** In traditional companies, focus lies on the management skills of the people rather than the technical expertise (Ward, 2007). Kennedy *et al.*, (2008) explain that only technical expertise will convert into innovation and ultimately earn money for the company, and not management skills. Self-management is the key to balance creativity with project management. Another important aspect is the integration of suppliers in PD; Toyota practices true 'partnership' and 'business collaboration' with suppliers.

**Leadership:** Traditional organisations have PD managers that perform a dual role: as functional managers (leading innovation) and chief engineers (choosing solutions from customer point-of-view). This suffocates either innovation or market needs, as they work against each other. Within Toyota, this balance is brilliantly managed using the CE system.

**Control systems:** PD systems with highly structured ways of working seen in traditional firms gives the top management a sense of control. The result is unplanned activities. The responsibility based planning and control system of LPD ensures that systems are responsive, flexible and adoptive to changes, as the basic nature of PD is 'variation'.

**Knowledge:** In traditional companies, the purpose of paperwork is management, control and bureaucracy. These elements are supporting the core innovation value stream. Problems arise in traditional companies as they lose their way (i.e. waste) trying to build complex systems (software, KMS, etc.) to manage supporting functions. At Toyota, documentation is encouraged only because it is directly related to the core innovation value stream i.e. technical expertise. The non-value adding but necessary paperwork is retained at minimum levels, suggesting strongly to PD personnel that "remember; customer does not pay for it".

## 2.7 Application of Lean Product Development outside Toyota

The Lean Product Development System has emerged as a new holistic solution for enhancing performance of PD. The details of this system have been well explained in the literature published so far, with an understanding of all its elements (best practices), its benefits and tools (as discussed in previous section 2.6). The industrial world is looking to benefit from these best practices evolved within Toyota in order to achieve business excellence. However, literature survey conducted as part of this research shows limited understanding of its application outside Toyota. The main reason for this is the newness of revelations on integration of individual LPD elements and hence, the piecemeal approach to implementation.

Some of the key studies on implementation conducted so far include the application of the five basic Lean principles to Product Development (Slack, 1999; Haque and Moore, 2004), understanding of application of the Lean Manufacturing tools such as Value stream mapping and waste identification in Product Development (McManus and Millard, 2002; Schuh *et al.*, 2008), implementation of key LPD techniques such as customer focus, and set-based concurrent engineering in the German industry (Schuh *et al.*, 2008), and a study on adoption and awareness of LPD practices in the UK industry (Baines *et al.*, 2007).

### 2.7.1 Case studies and examples of Lean Product Development:

I. A discussion by Slack (1999) on the significance of the five Lean principles and Lean terminology to innovation has led to ‘expanded PD customer value model’, wherein specific attributes of customer value: performance, cost and schedule and a link between value and risk are in constant tension. But this study falls in the category of theoretical frameworks, as there is no contribution to the industry application consequences.

II. A survey style study among German companies revealed that the application of some LPD techniques such as customer focus, set-based concurrent engineering, flexible resource allocation, project champion system and standardisation has led to a clear distinction between out-performers and under-performers in the industry (Schuh *et al.*, 2008). Further, based on this easy 3-step guiding theme for Lean innovation has been proposed: “structure early, synchronise easily, adapt securely”. In addition, the application of Lean innovation techniques to identify and eliminate waste is used systematically in only one-third of the German industry population (Schuh *et al.*, 2008). However, it is a drawback that other elements of LPD such as knowledge capture, etc. have either not been implemented or not been investigated in this case.

III. Baines *et al.*, (2007) conducted an extensive survey on the understanding of Lean principles within the UK industry, the extent of adaptation of LPD techniques, the consideration of ‘value’, ‘set-based’, ‘flow’ etc., the importance given to chief engineer system and knowledge capture. The key findings although included the overall LPD system implementation is in its embryonic stage, the automotive sector is leading in LPD implementation, followed by aerospace and lastly the general engineering. This clearly showcases that LPD concepts are fast penetrating, but the implementation lacks momentum in most cases as compared to Lean Manufacturing.

IV. A study in nine major aerospace companies in the US by McManus and Millard (2002) revealed that Value stream mapping (VSM) has been successfully adapted to identify waste in PD. Although other techniques such as Gantt chart, process map flow, system dynamics, etc. are also widely used; the recommended application is a combination of the above-mentioned techniques with VSM. The other aspects of LPD have not been covered in this study.

V. Haque and Moore (2004) suggested that although explicit application of the five Lean principles to Product Development by academia and industry is lacking, many companies have begun with implementation of the five Lean principles and the set-based concurrent engineering. Further, the study reveals that in most cases concurrent engineering as such could not work in isolation of Lean thinking. Also, application within two aerospace companies showed encouraging results such as clear waste identification, lead-time reduction, single-piece flow, and cost improvements.

VI. A study by Karlsson (1996) on LPD implementation reveals that even though several factors encourage LPD deployment, several hindrances also do exist. Some obstacles for the successful implementation of LPD have been discovered as:

- Executive overemphasis on PD in projects restricts efforts to attain organisational cross-functional integration,
- A linear operation and overview of the development process prevents teamwork in cross-functional environment.

In contrast, elements that support the transition to LPD include: close collaboration with a experienced customer, company progress schedules, top management commitment and expertise in workforce.

Some more literature relating to the application of LPD to industry include Value stream mapping of the PD process at Jaguar and Land Rover (Swain, 2005); implementation of waste analysis, visual control, standardization and continuous improvement at Rolls-Royce (Haque & Moore, 2004); application of VSM, single piece flow, kanban and KPIs at UK based small company (Haque & Moore, 2004), etc. While these provide informative insights on how Lean tools can be applied, they tend to show only specific tools of LPD and the Lean principles in general. Several other large automakers are in pursuit of implementing Lean to PD based on their experience with Lean Manufacturing. These have seen only partial success due to the piecemeal approach and the lack of a complete understanding of the Toyota LPD system, according to these authors.

In summary, we can see that several companies have benefited by application of Lean PD, making them better than before, but they realise that its not the ‘best’. A business does not realize Lean Product Development merely by implementing a few of the techniques. In other words, “a successful move toward Lean Product Development requires approaching these interrelated techniques as elements of a coherent whole" (Karlsson, 1996). Although literature shows that only in recent times the system has matured to the level of confident holistic application within other companies, there has been no generic guiding theme or framework for LPD implementation outside Toyota, until the books by Kennedy (2003), Mascitelli (2007), and Kennedy, Harmon and Minnock (2008) emerged. These books develop the pioneering model proposed by Ward (2007) further into a detailed transition methodology, tools and techniques that can be used, the challenges one may face, and an implementation plan (refer section 2.7.2 below).

### 2.7.2 Holistic approach to Lean Product Development implementation

The Lean Product Development System has thus emerged as one of the most logical, simplistic, and holistic models for optimising Product Development function. The implementation of Lean Product Development may present a difficult transition period (due to the drastic paradigm shift involved), hence requiring guidance. In addition, the results of implementing LPD emerge rather slowly, as compared to Lean Manufacturing.

According to Kennedy (2003), a major change initiative such as transformation from traditional PD to Lean PD can be done in two different ways (refer Table 4): the 'define and convince' method or the 'participative approach'.

| “DEFINE AND CONVINCE” | “PARTICIPATIVE APPROACH” |
|---|---|
| In this approach, an assigned expert / expert team define the change specifics, and convince the rest of the Organisation to follow the recipe for change. | In this approach, the leader defines the change goals & gives responsibility to the workforce to define details and execute the changes. Further, workshops are used for convergence of methodology and decision making, parallel to testing and learning of new concepts. Experts provide substantive knowledge. |
| Leaders here provide orders, participate completely and are very hands-on with details. | Leaders here trust the workers to move on with change, and then remain as participants of transition process- they learn and guide decisions. |
| This approach is recommended for small companies. | This approach is recommended for large organisations, as it ensures rapid buy-in. |

**Table 4: The two approaches to LPD deployment (Kennedy, 2003)**

Both the approaches have a common goal of ensuring an unambiguous paradigm shift, building a customised LPD solution, and ensuring that the Lean culture is incorporated with the help of visionary leadership. But since any change of this magnitude cannot be totally completed in one step, a quick transition with a continuous improvement cycles thereafter is recommended (Kennedy, 2003), as illustrated in Figure 20.

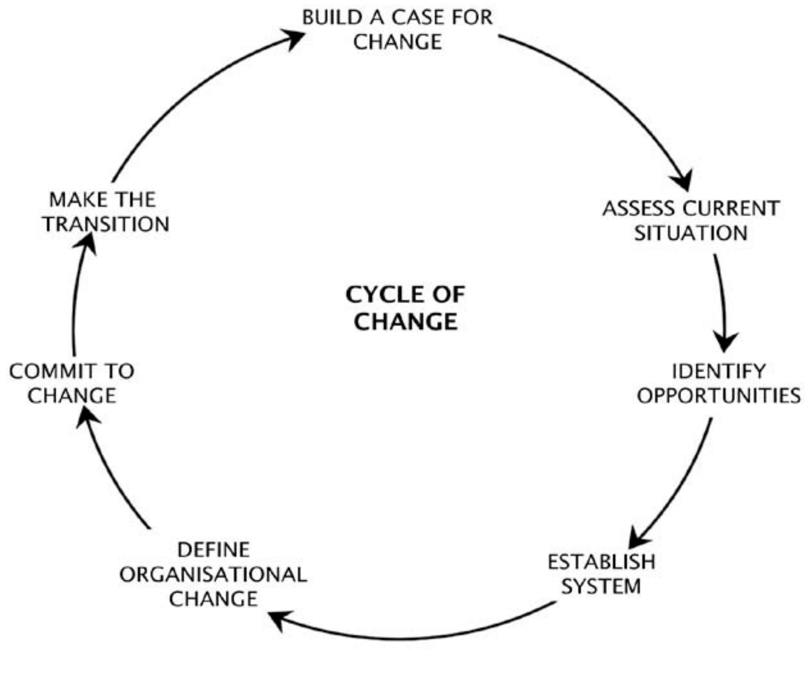



**Figure 20: The cycle of change recommended for LPD deployment (Kennedy, 2003)**

Ron Mascitelli (2007) set forth similar recommendations with more emphasis on careful selection of Lean tools for the company. For example, the suggested tools for phase one in majority of the companies would include “Obeya room” (refer glossary, p.231) meetings, visual planning boards, prioritising tasks and meetings, forming rules to eliminate wastes (such as replying to unnecessary e-mails etc.). In order to effectively progress, performance indicators such as project cost, schedule variance, time-to-market, return on R&D investment, productivity per employee, profit margins on each project, and available buffer capacity can be used. Overall, the phased deployment plan is illustrated in Figure 21.

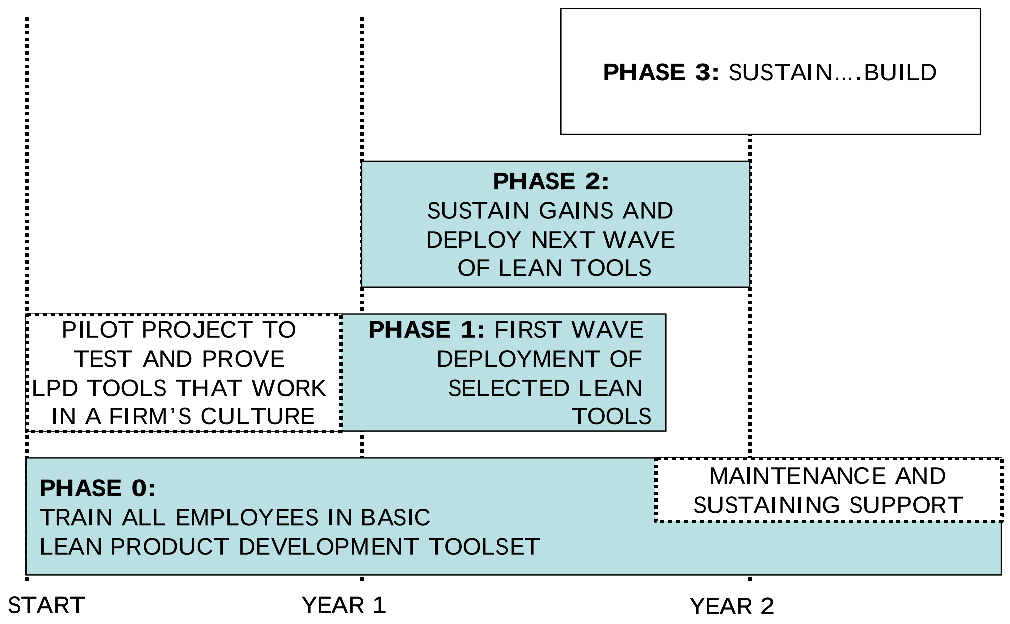



**Figure 21: A phased deployment plan suggested by Ron Mascitelli (2007)**

On comparison of the approaches suggested by two leading experts on industry application of LPD reveals the following (Table 5).

| | The Learning first product development: Kennedy (2003, 2008) | The Lean product development guidebook: Ron Mascitelli (2007) |
|---|---|---|
| *Overall Methodology:* | A continuous process of improvement after a quick deployment. | A continuous process of improvement after a phased deployment. |
| *Lean Tools recommended:* | The knowledge capture tools as used for PD in Toyota such as A3s, Trade-off curves, etc. | Tools from the overall Lean toolkit, including visual planning boards, etc, in addition to the knowledge capture tools. |
| *Reference to PD best practices:* | The model does not refer to / comment on other best practices in the field. | The model provides an overview of commonly used practices and discusses if it has positive or negative effect on LPD. |
| *Explanation of Lean concepts and steps:* | A comparison with traditional Organisation practices in terms of problems faced. | A comparison with traditional Organisation tools, structures and techniques. |

**Table 5: Comparison of the approaches suggested by two leading experts on industry application of LPD**

In summary, the approach discussed in Kennedy (2003) was found to be concentrated on the actual change required, rather than suggesting the exact recipe. It was mostly generic, with some added guidelines for transition in large firms. In contrast, the methodology suggested by Mascitelli (2007) is more specific to certain large organisations that currently have definite practices, wastes and behaviours in PD. The ease with which these two methodologies would work for different industry sectors (automotive, specialised manufacturing, etc.) and different sizes (small, medium, large) would determine the success of the models proposed.

Although several companies have taken up the implementation of Toyota's PD systems, such as include Kohler Company, Eaton Corporation, HP and Ford Motor Company (Panchak, 2007), the details of the implementation approach, methodology adopted, and the benefits received, are not published. In 2008, publications on two companies using Kennedy's approach to LPD emerged (Kennedy *et al.*, 2008), which are understood to be the only 'holistic' implementations. The companies involved were:

A. North American Company Teledyne Benthos and Teledyne Taptone, and

B. New Zealand based large company Fisher & Paykel Appliances Ltd.

These companies used the four cornerstones methodology as described by Kennedy (2003) (refer section 2.6.2). The plan for change, and the tools as described in this book, was used in these companies. Since the implementation approach here was experimental by nature, it would be extremely useful for researchers and practitioners to look into the findings that are described in these two case studies.

**I. US-based company Teledyne Benthos implements Lean Product Development:**

In 2007, Patricia Panchak published details on journey of a small North American company, Teledyne Benthos into Lean Product Development, followed by Kennedy *et al.,* (2008). The company had experienced, long serving employees guiding the PD with the help of their knowledge and experience, although there was no process in place. Product Development faced problems such as increased lead times, costs, and increased competition. Although the stage-gate system was helpful in shortening the lead times and getting some of the design specs right; it was unable to eliminate expensive loop backs, deviations in specs with respect to cost-size-payload requirements and launch delays, etc. The basis for adopting Lean PD system was the following three aspects discussed in Kennedy (2003):

1. Reverse the sequence of design and testing by doing thorough testing first before designing,
2. Customer interests / requirements can be best understood by an engineer, not the sales and marketing people, and
3. It is very essential to capture the knowledge during every Product Development cycle.

Based on these three aspects, the deployment of the 'Learning first Product Development (LFPD)' (Kennedy, 2003) was taken up in two stages. The first step was to spread the knowledge, gain consensus, and deploy simple tools; followed by integration of all the Lean tools and practices (Panchak, 2007; Kennedy *et al.*, 2008). The goal was to improve productivity to twice as much.

Stage I of LFPD deployment: Ground work

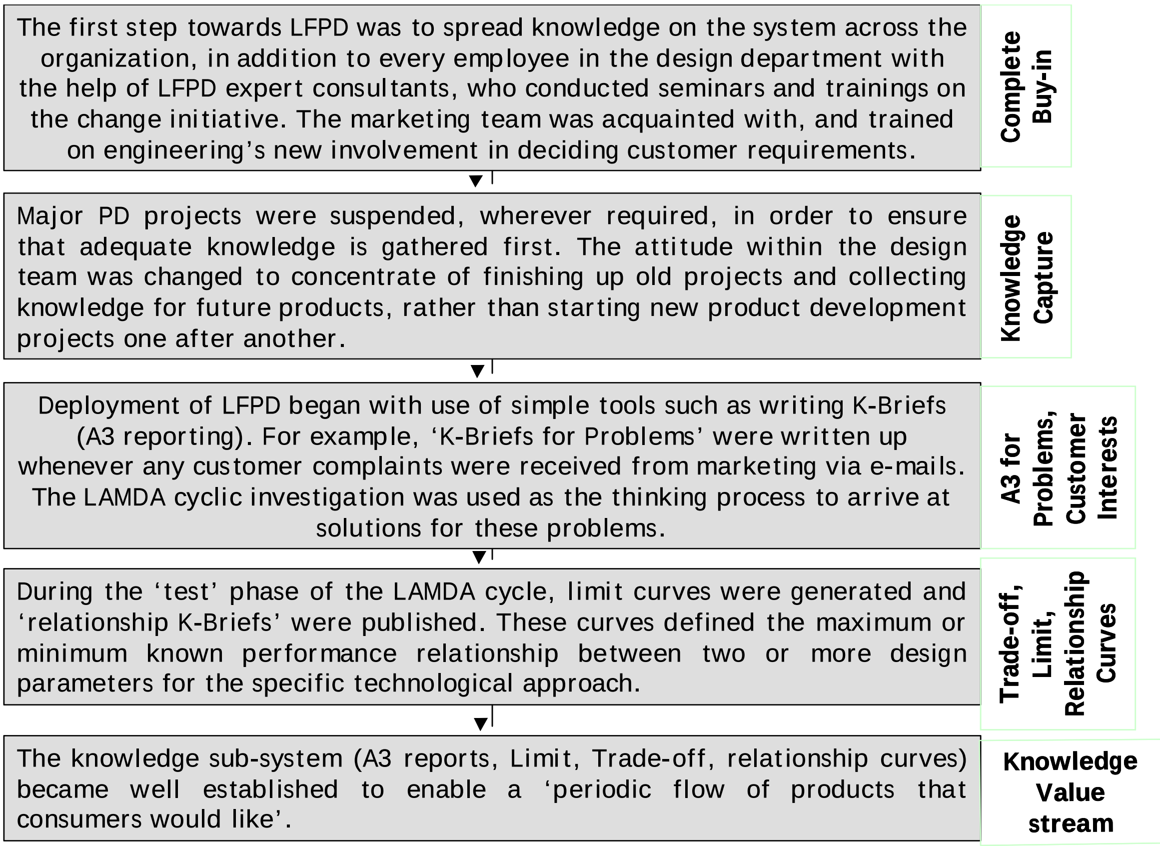



**Figure 22: The initial LPD deployment steps at Teledyne Benthos (a representation of published details)**

Thus, the first stage of LFPD deployment reveals that the consultants and the company took steps to set-up a sound knowledge value stream for the company's Product Development (Figure 22). The understanding is derived from the fact that the knowledge acts as a life line/ blood stream at Toyota and nourishes the product / project value streams of the company at present and future times (Ward, 2007).

The following example shows the depth of understanding and the successful implementation of LPD tools (such as use of LAMDA and customer interest A3) as discussed in the literature (Panchak, 2007): For an up gradation project, the team firstly visited customers of the existing version of the product to determine preliminary specs (*Look and Ask*). In the next step, they built a test jig that can be used by the design team to test the theories of design parameters. Design engineers then ran experiments on these test jigs to collect data for limit curves (*Model*). Further design/test iterations were carried out, debated within functional teams to understand the physics behind all interfaces (*Discuss*). Finally, based on the limit curves, a 'Product Proposal K-Brief' was written up and knowledge gained ensured that the new product exhibits critical interest parameters without any costly add-ons (*Act*). Final prototyping put the tested components together, embodying all the parameters from the knowledge curves, and it proved to work together in one device (*Proof of Concept Build*).

Stage II of LFPD deployment: Making it work:

Once the knowledge value stream was built, the Lean process was designed by using project integration, beta-builds, and limit / trade-off curves (Figure 23), where the knowledge value stream worked as the underlying layer for the product value stream.

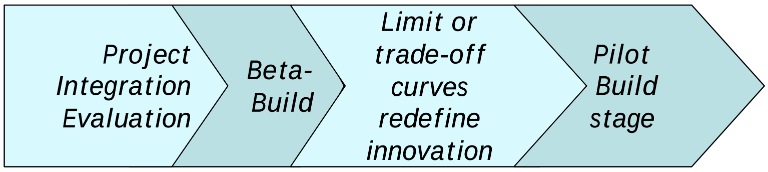



**Figure 23: Critical elements of the LFPD system at Teledyne Benthos**

- At the *Project Integration / Evaluation* step, the design sets, cost analysis, product space maps, resources and schedules were brought together to narrow down on final product specs. This step also involved making a mock prototype, choosing the components to use and setting the date for the product to be released to sales.
- Next, designs for long-lead parts were decided and released to production / procurement in *Beta-Build* stage, narrowing the design choices for parts with shorter lead times in later stage.
- To ensure that reuse and innovation go hand-in-hand, the *Limit / trade-off curves were used to redefine innovation.* Whenever customer interests were not met; it meant that trade-off curves (representing existing engineering knowledge) are not sufficient, triggering innovation (Panchak, 2007). Another advantage of accumulating all the knowledge about the existing family of products is the clarity with which product variation could be done now on.
- Finally, at the *Pilot Build stage,* engineering for the product was shut off and production took control. The engineering department hardly ever received any design change requests from production because of the several LAMDA loops built into the PD process. The final checklist

released to sales covered generic business needs such as brochures, manuals, sales literature, and data sheets.

Thus, the second step ensured that the Lean practices, thinking and tools fit together to form a coherent system, which is suitable for the company.

Within few months, the company’s design teams were able to build-on, and think further into advanced aspects of the way LPD should work. They were cautious not to overuse the trade-off curves, and A3 reports lest the knowledge capture system becomes weak. They also recognised that deployment should be steady and faith-based, as results would come about only slowly. Shortly, Teledyne Benthos were amazed with the results obtained due to implementation of Lean PD, some of which are described below (Kennedy *et al.*, 2008):

1. Tools helped to define the much-needed boundaries for the product performance for Product Development at the company,
2. The test-then-design paradigm worked for the company,
3. The product released after following the LPD system was 25% better in performance, 50% lesser in size and half the price of its existing version. In addition to these customer benefits, the company achieved higher profit margin from this product, with the help of its easy manufacturability feature.

According to Teledyne Benthos, the biggest challenge to overcome was the attitude change required from ‘doing first’ to ‘learning first’. The two focal points for every engineer within PD was (Kennedy *et al.*, 2008):

1. To know what customers want,
2. To know what the company can do.

In summary, the literature suggests that LPD has been successfully implemented at the North American Company Teledyne Benthos, with indications of good results.

**II. New Zealand based large company Fisher & Paykel Appliances Ltd:**

Fisher & Paykel (F&P) Appliances Ltd. is a leading manufacturer of inventive household equipment for over 70 years. They employ 4000 employees across the world (as per 2007 statistics), making it a large-scale manufacturing company. Their products reflect innovativeness, advanced industrial design, and world-class engineering technology. The Company used a ‘Stage Gate’ process as the Standard Operating Procedure (SOP) for Product Development and the designers used standard design packages such as CAD and Solid works to carry out detailed design work till 2006. But these were insufficient to meet their exponentially growing customer demands.

In their pursuit to improve PD, the company appointed an experienced, practical, tenacious, respected ‘full time champion’ to lead a team which compared the various improvement solutions. The contents of Kennedy’s book and a few telephonic conversations with Michael N. Kennedy were persuasive enough to make them believe that LPD might be just the thing they were looking for. Fisher & Paykel Appliances Ltd. felt that LPD would fix the fundamental flaws in their existing system, although it was an entirely different way of thinking. Fisher & Paykel Appliances Ltd. The agency involved in training and implementing LPD was the ‘Targeted Convergence Corporation (TCC)’ with experts Michael N. Kennedy (Founder and CEO), J. Kent Harmon (VP-Training Services) and Ed Minnock (VP-Business Development). Based in the United States, this consultancy provides training and industry solutions on ‘Learning-First Product Development’ (LFPD), another name given to ‘Lean Product Development’.

The highlights (events/ initiatives) of Company A’s journey into LPD are described below (Kennedy *et al.*, 2008):

- Kennedy was invited to New Zealand in August 2006 to give a presentation on LPD. Using the overwhelming response to his presentation as a springboard, the company took on LPD.
- In November 2006, all the engineering management members and key managers in operations, marketing, finance (approx. 20 members) were sent for training in LPD accelerated course. Further, this core team has been responsible for conducting knowledge sharing sessions and trainings to the remaining members in R&D to date.
- The next step was to look at the people structure and its compatibility with LPD. The decade-old organization structure (that supported a stage-gate system) was abolished and a ‘Chief Engineer (CE)’ system was put in place to support LPD. People for each new role / organization position were handpicked. Every range was designed with a CE who decided what the product should be like (specs); and the functional managers and team were responsible for meeting these specs (Figure 24). Mainly, re-defining the organization structure helped to balance market

driven development with technology driven development, and to improve prioritisation and resource allocation for development projects (Kennedy *et al.*, 2008).

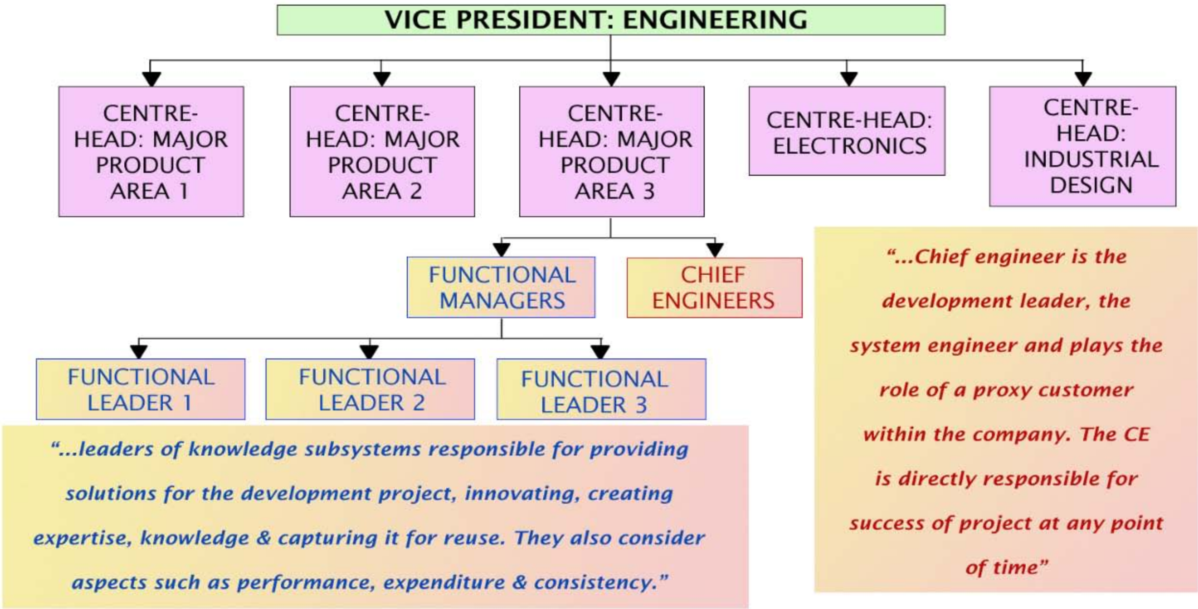



**Figure 24: Basis for organization structure at F&P as described in Kennedy et al., (2008).**

- In February 2007, additional training was conducted for all PD members on skills such as using LAMDA (Look-Ask-Model-Discuss-Act), writing Knowledge Briefs or A3 reports, drawing trade-off curves, etc. Leadership participation in the training helped boost the morale of employees and the teams moved quickly from merely understanding the concepts to applying them on long-standing problems. For six weeks, Company A's PD team continued to apply these foundational skills in the workplace.
- New appointees for roles of CE, functional managers, functional leaders and subject matter experts were sent for training on knowledge capture and Set-based knowledge maps. The participating members learned by applying it to projects, they were currently working on. Back in the company, the trained personnel identified critical knowledge gaps, and targeted those projects for implementing "Test-then-Design".
- In June 2007, a decision was made on redefining the process, and the new roles and responsibilities within the new organization structure using workshops.

- Two day LAMDA cycle workshops were used to modify the phase gate / stage gate process into a LPD system. This includes defining integrated events, timeframes and individual steps. The first workshop was used to draw the macro level picture of the process, which is very similar to the Toyota PD system.

Finally, large group sessions were used to pull together the complete business system using the participative change approach.

The key inferences from the implementation of LPD at F&P show that the benefits initially are mostly intangible. The employee morale, the involvement, and the engineering rigour improved at F&P that would reflect in the PD projects (Kennedy *et al.*, 2008). The case study provides no details of the "before and after" comparison of PD success metrics such as lead-time, cost, profitability, etc. that are required to quantify the gains. This suggests the need for further investigation at F&P on not only assessing the improvements but also on the affect LPD has on other PD aspects such as supplier integration, strategic matters, etc. Overall, the following areas can be listed for further investigation:

- Deployment of LPD in NZ operating environment,
- Supplier integration,
- Focus of the company now and the future in-order to understand the overall picture,
- The optimum duration for PD projects and related aspects,
- Similarities and dissimilarities between large companies and SMEs in NZ,
- Use of Value stream mapping tool,
- Practical examples of chief engineer system, and knowledge sub-systems,
- The exact PD process built on Lean PD model,
- Details of obstacles and challenges for LPD deployment,
- Selection of R&D projects and determining customer interests.

### 2.7.3 Most suitable Lean Product Development model for further investigation

In summary, Kennedy's approach to Lean Product Development or learning-first Product Development contains three implementation steps (Figure 25). Effectively, the prominence given to knowledge development is greater in this approach.

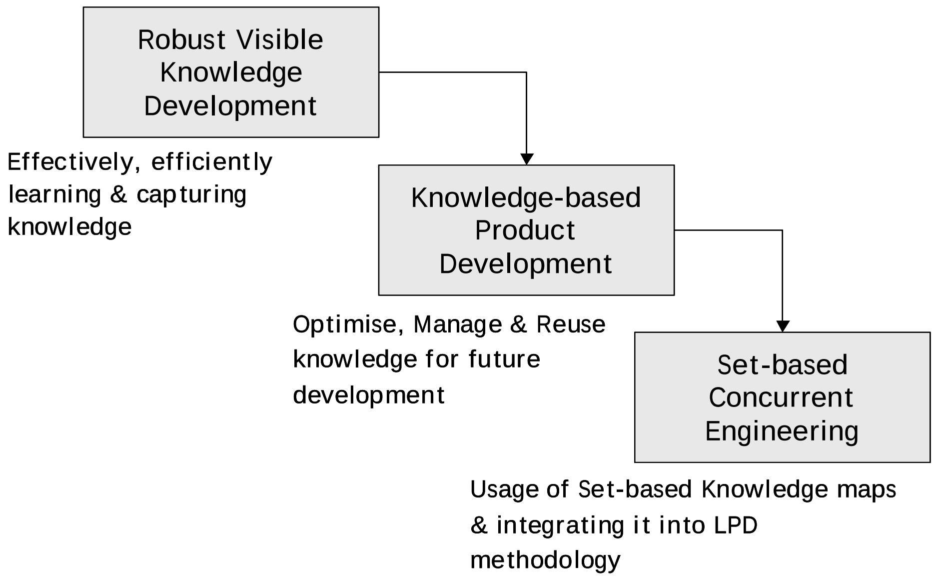



**Figure 25: Implementation plan for Lean Product Development (Kennedy *et al.*, 2008)**

The implementation steps have to be guided by certain critical factors for implementation, which are needed for actual transformation:

- Keeping it simple and practical,
- Training the workforce and encouraging a 'learning' culture,
- Functional sub-systems to ensure knowledge growth and quality,
- Chief Engineer system in place,
- Knowledge reusability and visibility, and
- Visionary leadership

All researchers and consultants of LPD suggest that the solutions have to be customised for every company based on its operating environment, which can be clearly observed in the approaches taken by Teledyne Benthos and Fisher and Paykel Appliances Ltd.. The three key differences that emerge on comparison include:

- LPD training provided to the entire organization within Teledyne, as against selected personal within Fisher & Paykel.
- Organisation structure was changed within Fisher & Paykel for establishing Chief Engineer system, but not at Teledyne Benthos.
- Although top management commitment was shown in both companies, the leadership style was more "hands-on" at Teledyne Benthos.

On analysing these differences, it emerges that Teledyne Benthos tailor-made some of the LPD practices to suit its size of business. However, the model suggested by Kennedy (2003) seems to be the most promising for further investigation for purpose of this research because:

- The application to a relatively small company has been carried out,
- The application in the NZ operating environment has been initiated successfully.

Again, the suggestion here is very clear that LPD solution, similar to other PD solutions needs customisation to work in Small and Medium companies.

## 2.8 Contribution this study makes to literature

The Product Development function is the key to survival in today's competitive world. PD in most companies practicing the traditional methods, face problems such as people management (work overload, multitasking, lack of co-ordination); process management (lack of visual performance controls, compliance to standard process); and integration problems such as supplier involvement, intra-organizational integration (Fiore, 2005). Section 2.7 explains how the holistic Lean approach is able to handle these modern day challenges and optimise the PD function. This has been proven possible in Toyota over decades and also in emerging case studies (section 2.7.2).

Thus beyond doubt; the Lean Product Development Systems provide clear and effective solutions to Product Development problems seen across the world with help of its multi-dimensional positives (Figure 26).


**Figure 26: Lean Product Development as a preferred innovation system**

Leading researchers across the world acknowledge the fact that the implementation of this system is in its embryonic state (Baines *et al.*, 2007). The publications and case studies point toward successful and emerging implementations of this system in large companies in automotive sector, medium large companies such as Fisher and Paykel Appliances Ltd. and Teledyne Benthos, and aerospace companies in the US and the UK, etc. The details of the change initiative and deployment methodology provided by industry consultants such as Kennedy (2003) were being 'experimented' in some companies, and in-fact, on implementation of the proposed methodologies in comparatively smaller companies such as Teledyne Benthos, the consultants have recognised the need for further exploration and customisation of LPD (Kennedy *et al.*, 2008).

SMEs form a considerable majority of the world's industry population, and require effective systems to carry out Product Innovation as their large counterparts also do. Literature reveals the several difficulties faced by small businesses, including resource scarcity, limited support for innovation, technological uncertainties, poor market requirement definition, planning and strategy (Kerr, 1994; Huang *et al.*, 2002; Owens, 2007). Based on the understanding derived from the literature on LPD, it is very likely that this system would work for SMEs as well as it does for large firms. However to make this transition, a 'Lean PD' framework is required for SMEs. To suggest a holistic solution such as Lean Product Development to these companies, a thorough investigation of their conditions and the characteristics has to be carried out. To date, there is minimal research on application of LPD to SMEs. Further, no documentation was found on LPD application in SME sector of countries such as NZ, where SMEs contribute largely to the economy. The question now is whether the holistic LPD approach as described by pioneers such as Ward (2007), Morgan and Liker (2006) can be applied in companies that employ between 50 and 250 staff. Research conducted on this will reveal to what extent Lean can improve PD performance in SMEs and how, what are the challenges faced by the SMEs in implementing these holistic solutions, and how these challenges can be overcome.

**CHAPTER 3**

# METHODOLOGY

# CHAPTER 3. METHODOLOGY

Based on the literature review it has emerged that a Lean Product Development System may encompass all vital elements for PD success in several large companies. The next logical question thus evolves as: “whether Lean methods can be applied to Product Development in SMEs”. In answer to the question, this research prepares to put forward a system based on Lean Product Development, which could offer itself as a ‘basket of best feasible options’ for Product innovation in SMEs.

## 3.1 Aim and objectives of research

The aim of this research work can be stated as follows:

**"To evolve a broad framework for Product Development that incorporates Lean principles for application in Small and Medium Enterprises."**

As discussed in earlier chapters, this study requires a live PD environment for collection of context-rich data, for in-depth understanding the SME PD environment, for testing of the LPD tools, and for obtaining feedback on the perceived positives and negatives of the LPD system. This is required, as doing multiple survey-styled case studies cannot capture PD environment in depth. Also, the most important enabler to such a research is the detailed understanding of implementation of LPD in other companies.

As a result, the objectives of the research were shaped as follows:

1. To understand the application of ‘Lean’ to Product Development and to comprehend the approach taken for its deployment within large companies.
2. To examine the current Product Development practices within Small and Medium Enterprises.
3. To propose a ‘Lean’ solution for Product Development in Small and Medium Enterprises that helps them to overcome obstacles in delivering high-quality innovative products.

## 3.2 Research methodology

A research study of this nature requiring in depth understanding of the topics (such as operating environment, processes, practices, people, leadership) needs live PD environment of a manufacturing company. As a result, 'case study approach' emerged as the most suitable research methodology.

As it is the core PD process that lacks structure in SMEs, and they face severe problems with respect to people management, knowledge management, planning and control, a survey would be of little use to achieve the research objectives. Further, to design a LPD system in SMEs, a longitudinal study to gain context rich data was a fundamental requirement. Hence, the *case study* methodology (Yin, 2003) was used to carry out this research using a SME based in NZ (the 'main case study') and it is characterised by a focus on contemporary proceedings in real-life context. The research strategy used was '*exploratory*' by nature, and it tries to elucidate the Lean Product Development System, dwelling on why they can be used in a SME, on how they can be implemented and with what consequence. The whole process is also termed as 'Action research' (Yin, 2003), where the author had to spend extended hours during the working hours of the company for a long span of time. The total period of investigation was 10 months. The research technique used was '*qualitative*' in nature, which helps gain better perceptive of research topic by allowing flexible interview structures (Gordon & Langmaid, 1988).

The literature suggests that the implementation of holistic LPD solutions is still in its embryonic stage, and the results are still nascent. This presents several gaps in literature that can be satisfied by an in-depth research in LPD implementing firms. Hence, a supporting case study from an organisation already implementing the Lean Product Development System, with similar operating environment (like NZ) would enable study of finer aspects of implementation and would guide the thought process. The supporting case study would facilitate building of the framework or design for SMEs by:

- Identification of PD areas for specific attention during Lean deployment, and
- Dwelling on the LPD solution or way for catering to these areas in SMEs as against the large firms.

In summary, an exploratory case study action research in a NZ SME, in addition to an additional case study research with one of the leading LPD implementing firms, was an ideal combination to achieve the research aim and objectives.

### 3.2.1 Case study questions:

The initial data collection questions as part of this research for the two case studies focused on understanding the PD environment of the two companies, both external and internal, which would aid in building individual aspects of the LPD system. One of the main objectives of this research study is "to examine the current Product Development practices within Small and Medium Enterprises." Literature survey led to a clear understanding that multiple subjects are involved in each case study: organisations, decisions, workforce and projects. These main areas were further drilled down into case study topics (as shown in Table 6) for investigation in the SME (namely Company B): The data collection questions, the fieldwork, data analysis, and design of LPD systems were shaped using these topics.

| CURRENT PD INVESTIGATION | ANALYSIS | CO-RELATION TO LEAN PD |
|---|---|---|
| Complexity of conducting PD in a SME in NZ | Understanding of basic lean principles, knowledge transfer | Lean principles |
| The PD value stream / process | Compatibility of PD flow with the PD steps | Identification of Value and waste within PD Process |
| Workload management, PD knowledge and Information exchange | Compatibility of overall system in SME environment | The Lean PD Process, people management, leadership and control systems |
| Supplier Involvement | Challenges for Supplier Partnership | Supplier Partnership |
| Customer Interaction | Challenges for Customer Focus | Customer / Value Focus |

**Table 6: Case study topics**

The questions (as listed in Appendix A) reflect the depth of enquiry on PD aspects for the SME, and the questions for the supporting case study (namely Company A) try to extract and build on the information published about LPD implementation. These questions were kept open-ended, such that the research would progress based on the first-hand findings at different points with each case study.

## 3.3 Selection of companies for case study

The firms to be chosen for the main and the supporting case studies were required to meet certain criteria in order to accomplish the research objectives and aim. The selection of the SME: Company B for main case study involved the following aspects:

I. <u>Commitment of the company to 'Lean' as identified with its journey into Lean Manufacturing:</u>

Several companies in NZ participated in the AICHI program of the NZ Trade and Enterprise (NZTE) department of the government that funded and supported large-scale implementation of Lean Manufacturing in chosen companies. Company B was one of the key participants in the AICHI 3 program, and showed admirable results on completion of this initiative.

The Lean philosophy of individual accountability, dedication to continuous improvement, easy clear visual systems etc. and the benefits of increased productivity were some of the key features that attracted Company B to implement Lean Manufacturing. Within a short period of time, tools such as 5S, one-piece flow and *kanban* were implemented with much success. One example of accomplishment due to implementation of one-piece flow methodology (within three days of training and familiarisation) was the unexpected 42% increase in production on one line (Cox, 2007). Further, *Kanbans* helped to create the pull from customers, leading to a huge decrease in finished goods stock. As part of production cycle reduction efforts, the company implemented the short cycle and small batch size delivery arrangement with suppliers. Over a period of time, the Lean philosophy was found to be deeply compatible with the company's values and had helped Company B to face challenges such as high-unexpected demands, among others (Cox, 2007).

II. <u>Firm that belongs to the highest process/ product innovation activity segment in NZ:</u>

Statistics NZ 2005 report (2007) summarises the various aspects of Product Development in NZ SMEs as follows:

1. 52% of the NZ businesses reported innovation activities, and the innovativeness increased proportionate to the size of the company. Further, manufacturing, finance and insurance sectors have the highest innovation percentage.
2. Amongst the various types of innovation activities, the highest percent is seen in process/ *product innovation* (42%). Within this category, *manufacturing* accounts for the highest

innovation activity (58%), with the highest percent of business innovation rate seen with the *specialised manufacturing segment*.

3. The highest percent of product innovation was seen in the businesses with *50-99 employee*s (medium scale enterprise in NZ context) and over 40% of these businesses reported the lack of management resources, costs, and lack of skilled personnel as the obstacles to enhance innovativeness.

Based on this, the main case study company would be preferably chosen from the specialised-manufacturing segment with 50-99 employees. Company B was found to be one of the firms that fulfilled this criterion, in addition to being a leading exporter. Since these firms require high innovation percentages, the need to optimise the PD function by eliminating the existing problems was essential. The scope of the project was limited to NZ SMEs due to the lack of resources in conducting an all-inclusive study, and the complexity it brings in with numerous factors. Also since the survey method was not being used, expanding the scope of this research to the worldwide scenario would be mismatched.

The selection of Company A (as supporting case study) in order to fulfil the objective of "comprehending the application of 'Lean' to Product Development within large companies" was done using the following criterion:

I. <u>Firm discussed in the literature as a holistic deployment case study in LPD:</u>

The company is one of the few companies across the world that has undertaken implementation of Lean PD in a holistic and systems approach. The company had completed 2 years of LPD deployment by 2008, and the positive results of this initiative was wide-ranging from increased morale, continuous improvement in PD processes; to employee involvement, effective use of knowledge capture tools, etc. (Kennedy *et al.*, 2008).

One of the key contenders for the supporting case study was the North American company: Teledyne Benthos. However use of this case could potentially bias the research on the approach taken by this small company, the methodology used, which would influence the LPD design for NZ SMEs.

II. <u>The Australasia business scenario:</u>

Although literature may suggest that the large and small companies in NZ vary in characteristics, there is a very prominent common feature: the Kiwi Ingenuity or Kiwi Innovativeness. Although large companies have structures to support PD, the firms in this part of the world are known for their free-style and relaxed work atmosphere compared to other Western countries. It became evident that the supporting case study for this project would be preferably chosen from the Australasia region. Company A satisfied this criterion and was found to be the only company actively involved in implementing LPD in NZ, which also proved to be easy access for the author, given the time-constraints.

Overall, the main and the supporting case studies were selected based on criteria and constraints associated with the aim and objectives of this research. Most importantly, the enthusiasm and involvement of Company B, in addition to the cooperation of Company A in sharing information was critical for the success of the project.

## 3.4 Methodology for the case study

Beyond the strategic selection of companies A and B, the task of forming a case study plan was carried out. The criteria involved were as follows:

- Aspects of PD to be studied,
- Commonly found issues in PD, and
- The research aim: Essential Lean PD system elements to be designed.

Although the methodology was pre-planned and carried out based on the case study questions discussed earlier, the company environment usually guides the exact course of 'action research'. Thus, the following three aspects were found to be the constraints that shaped the methodology:

- Time frame
- Accessibility to PD
- Confidentiality

### 3.4.1 Case study tools

Among the various case study data collection sources (refer Yin 2003, p.86) interviews, direct observations and insight into physical operations were used to collect facts about the companies. Since the data collection at Company B involved the need for an in-depth understanding of events as they occurred in a live project environment, additional methods such as condensed contextual inquiry and ethnographic interviewing were essential part of the methodology (Kantner *et al.*, 2003). Condensed contextual inquiry helped to collect data by engaging in interaction as PD personal conducted daily activities, while; ethnographic interviewing helped to gather data on Company B's feedback on LPD. In the case of data analysis, pattern matching and explanation or theory building have been used for interpretation of data collected (Yin, 2003). These case study research tools have greatly enhanced the research course of action by providing a framework to seek and process facts on PD in both companies.

### 3.4.2 Methodology for supporting case study: Company A

Timeframe: June to November 2008.

Contact points: One-to-one interactions with 2 prominent PD members at Company B. The members belonged to two different levels (managerial and engineering) of the functional system of the R&D unit of Company A.

Fieldwork: The main source used for collecting data was the 'interview' tool (Yin, 2003), which helps to obtain deep insight and helps to reveal specific information along with clear untailored inference. The discussions included a wide range of topics such as the company's understanding of the system, the approach taken toward deployment, the challenges faced before and during deployment, and the current areas of focus. The basic details of the company's LPD journey were pre-published. The case study to be carried out as part of this project had to be built on the available data. The other sources of evidence such as archival organization records, direct observations, participant observation and physical artefacts could not be used at the company due to confidentiality and sensitivity issues related to PD. Some examples and topics discussed during interviews were unavailable for publication in this thesis for the above-mentioned reasons.

### 3.4.3 Methodology for main case study: Company B

Timeframe: March to November 2008.

Contacts: The study-involved members of Company B's Research and development (R&D) i.e. the PD manager, engineers and designers; in addition to the Managing director of the company, the key managers of operations, finance, marketing, production, and sales. Other business partners of the company, such as suppliers were also included.

Fieldwork: As negligible documentation was found on PD systems within Company B, intense day-to-day fieldwork became a necessity. In order to trace out the project lead times and problems within the PD cycle, a decision was made to observe two PD projects that were scheduled in 2008 by the company. The phase review meetings, the step-wise tasks, the internal meetings, supplier discussions, and the process of prototyping and testing were observed during the timeframe. Project X was scheduled between Feb 2008 and October 2008, whereas Project Y was scheduled between November 2008 and April 2009. (Only the details of front-end of Project Y were captured for this research). The author has spent almost every day at the company to capture information on the above-mentioned details. This involved collecting documents, conducting workshops, formal and informal discussions, participant observation, etc.

In summary, the main tasks carried out at Company B included:

- First hand observation of two PD projects: A strategic breakthrough Project X (February-October 2008) and up gradation Project Y (November2008-April2009)
- Formal and informal discussions with PD personnel and key managers within the company,
- Workshops for communicating LPD system details, and
- Workshops for collecting feedback on LPD analysis and Design.

### 3.4.4 Plan and scope: Framework for action research

The above sections clearly stated the aim and objectives of the research based on the literature review carried out, the data collection questions; then explained the research methodology, the need for two case studies, the reasons for selection of the companies to be involved and the research tools. These elements put-together form the overall framework or the scope and plan for the research carried out (Figure 27).

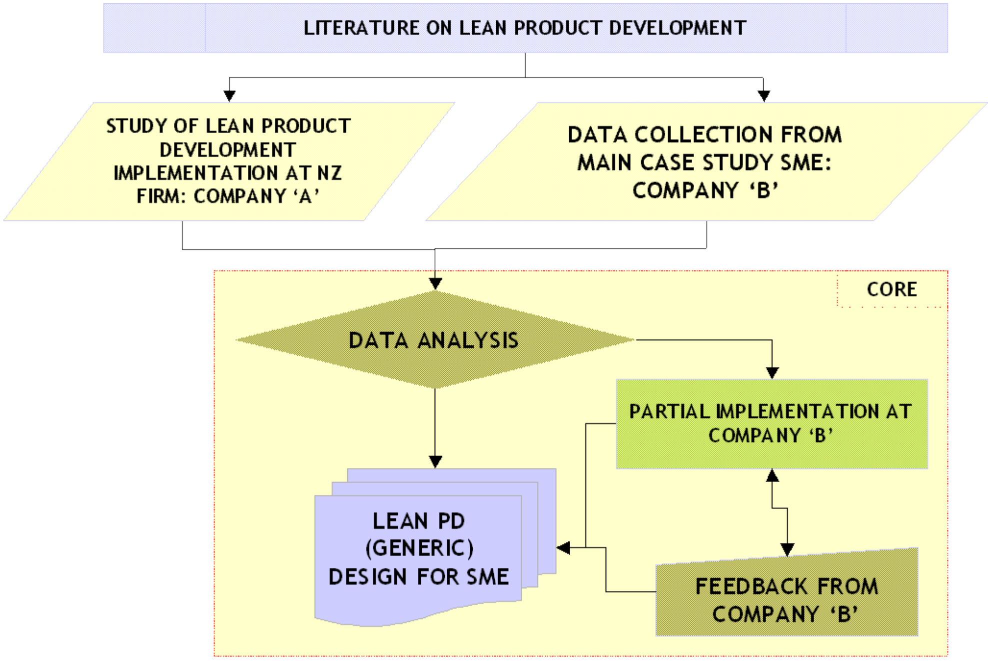



**Figure 27: Research Plan and scope**

Thus, the methodology involved the systematic flow of information collected in the two companies to analysis, which would further lead to formation of a Lean design for carrying out PD in SMEs. Since there has been no framework published for SMEs, the Lean PD model suggested for large organisations (as suggested by pioneers) was used to test its applicability in SMEs.

## 3.5 Summary

The research project aims to develop a framework for SMEs that is based on the Lean product Development model. In pursuit of this, the key phases included investigation of PD in a SME, supplementary data from a company already implementing LPD, and finally a discussion on proposed model for SMEs. In summary, the methodology chosen is the case study action research with extensive use of the 'interview' tool in fieldwork at both companies. The research result aims to guide the PD in SMEs based on the Lean principles that may enable firms with 50 to 250 employees to carry out efficient, Lean and flexible product innovation.

Ethics and confidentiality: All parts of the research were conducted in compliance with the Code of Ethical Conduct, set by the Massey University Human Ethics Committee. Both case study companies were provided with:

- The research proposal and questions,
- The expected outcomes and benefits,
- The tasks involved and time taken.

The anonymity and confidentiality of individuals within the company was well assured.

*“We don’t have the money, so we have to think”*

- *Nobel Laureate Ernest Rutherford (1871-1937) on NZ innovation*

**THE SUPPORTING CASE STUDY**

## CHAPTER 4

# STUDY OF LEAN PRODUCT DEVELOPMENT DEPLOYMENT AT COMPANY A

# CHAPTER 4. STUDY OF LEAN PRODUCT DEVELOPMENT DEPLOYMENT AT A LARGE NEW ZEALAND COMPANY A

## 4.1 Introduction

Company A is iconic for NZ economy, the LPD pioneer in this part of the world and the only published case study from NZ. The literature on an industry application of Lean Product Development throws light of the implementation of this holistic solution at Company A with much success (refer section 2.7.2). The initiatives included appointment of a full-time champion, extensive training of PD team and others in LPD by consultants, development of knowledge capture skills, reorganisation of people structure into the chief engineer system, and PD process modifications (Kennedy *et al.*, 2008). Although the company faced few challenges with respect to change in work culture, the success would slowly arrive. The current benefits ranged from increased morale, a continuous improvement culture, extensive use and reuse of knowledge, etc.; making the model suggested by Kennedy as one of the most promising ones.

There were however, several details missing in the published case study. The aspects related to NZ operating environment, optimum project lead times, PD similarities and dissimilarities with SMEs, examples on the chief engineer system, examples on the knowledge capturing tools, the exact LPD process, and the details of challenges faced were found to be prominent issues required to fulfil the aim of designing a LPD system for SMEs that would be based on the model proposed by pioneers. In addition, areas such as supplier integration, and the strategic decisions of project selection, customer interest generation were investigated as they were observed to be vital for success in SMEs during case studies at Company B (refer chapter 5). Thus, this supporting case study was conducted with the following main objective:

"To understand the application of 'Lean' to Product Development and to comprehend the approach taken for its deployment within large companies"

### 4.1.1 Methodology of the case study

As discussed in the literature review chapter, there is very little written on LPD implementation per se, hence it was deemed appropriate to approach one of the few written up case studies, which happen to be in NZ. Without ambiguity, it was chosen for this research in order to obtain first-hand understanding of LPD implementation in this NZ-based company.

The timeframe for this study was approximately six months, with access to two prominent members of PD at Company A. The members represented the managerial and the engineering levels of the R&D. The preparation phase of data collection included the study of literature on Lean Product Development, which assisted in formulating the data collection questions (refer appendix B). The interview tool for data collection helped to gain deep insight and helps to disclose specific information along with clear unmodified inference. Thus, the case study to be carried out as part of this project would have to build on the available data.

### 4.1.2 Limitations

As Yin (2003) explains, interviewing could weaken the case study if it is used with weakly constructed questions, insufficient data capture, analysis and conclusion extraction methods. Data collected through interviews also depends on the responses of the interviewee (which may be biased toward what the interviewer wants to hear). A similar limitation holds good with respect to the persons interviewed. Since, the entire case study at Company A has been conducted using the interview tool, the above-mentioned limitation has to be kept in mind. Further, the sources of evidence such as archival organization records, direct observations, participant observation and physical artefacts could not be used at the company due to confidentiality and sensitivity issues related to PD. Some examples and topics discussed during interviews were unavailable for publication in this thesis for the above-mentioned reasons.

It is important to note that the following revelations and discussions have occurred simultaneously with the publication of a case study on the company by the consultancy implementing LPD at Company A. Hence, most findings here are first–hand information collected as part of this research, and the exclusions, if any, have been clearly mentioned.

## 4.2 Case study questions

The main case study question was as follows:

"What are the details of the process, people structure, knowledge capture mechanisms, leadership, and planning and control aspects that shape the Lean PD at Company A, in order to understand the adaptation of the LPD model in NZ operating environment?"

The findings on conducting this case study and the purpose it serves to design LPD system for SMEs operating in NZ is vital for the research aim.

The data collection questions for investigation have been listed in appendix B. They were built upon the published findings in the literature, by investigating the gaps in the available data (refer section 2.7). The main areas include NZ operating environment, supplier integration, optimum project lead times, PD similarities and dissimilarities with SMEs, examples on the chief engineer system, examples on the knowledge capturing tools, the exact LPD process, the details of challenges faced and the strategic aspects. After preliminary discussions at Company A, some additional questions evolved on the details of 'LPD'. The areas of focus in probing further included:

- Answers to initial questions,
- Progressive reading of 'LPD' books, and
- PD problems observed at main case study Company B.

## 4.3 About Company A

Company A is a leading manufacturer of innovative domestic equipment for several decades in NZ. This successful large-scale manufacturing company has a global network of customers and suppliers. Their products reflect commitment to technology, design, user affability and environmental awareness. Company A defines its "DNA" as style, integrity, care and innovation. They design, manufacture and market a strong portfolio of products split into four ranges, each containing several models and variations. At Company A, the reasons for new products releases have been stated as:

- ❑ To lift the average selling price,
- ❑ To gain market share,
- ❑ Strengthen the brand,

- Attract state government rebate incentives,
- Extend the model range for market share gains,
- Tap the season’s favourite, and style desirability.

Most of the products contain complex mechanisms that provide consumers with multiple selection options for usage. The focus of new designs at Company A has been the ergonomics (ease of use), easy to maintain and efficient performance. The company believes in coming up with absolutely innovative, “first-of-its-kind” products that have superior industrial design, leading edge engineering and technology incorporated.

The PD department at Company A consists of approx 250-300 people; spread over two locations within NZ. The details of the PD processes and other aspects are discussed in sections below. The year-end release for 2007 showed a minimal increase in R&D expenses (0.11%) compared to 2006. The ratio of R&D expenses to sales expenses is 1:9 for the year ending 2007. Overall, R&D at Company A presents itself as a progressive and established team.

## 4.4 Major findings from Case study

Company A took up LPD deployment in 2006 for all the four major product ranges. A change agent or ‘sensei’ in form of LPD consultant was the key for deployment of this system, which started with ‘recommendations by committee’ approach. The company appointed a leader for augmenting this change initiative, although several of the PD personnel were already convinced that LPD would surely work (after reading books published by the pioneers in LPD). Thus, Company A has taken up the implementation of LPD using the four cornerstones approach as proposed by consultants based on LPD pioneering work by Ward (2007). The initiatives included appointment of a full-time champion, extensive training of PD team and others in LPD by consultants, development of knowledge capture skills, reorganisation of people structure into the chief engineer system, and PD process modifications. Although the company faced a few challenges such as change in work culture, success was obviously approaching. The current benefits ranged from increased morale, a continuous improvement culture, extensive use and reuse of knowledge, etc. The gaps in literature that prompted this case study have been investigated using the data collection questions (refer

Appendix B) have been discussed below. The feedback has been result of extensive structured interviews at Company A.

A. **Approach taken to implement, the present and future focus:** All the projects currently running were taken up for LPD deployment, which is a case of horizontal deployment. Mainly, the current focus at Company A was on knowledge capture. The functional manager of simultaneous engineering (SE) summarises: "*The focus is on knowledge capture and then applying it to all our product ranges. We are beginning to follow the Test-then-Design approach as outlined in the books...rather than designing then testing then redesigning………. We envisage that all new products (including product up gradations) will follow the Toyota LFPD (Learning first Product Development) process. Although, we do see potential challenges for Product Development in the near future, such as PD interface with manufacturing (due to the relocation of manufacturing to Asia).*"

**B. Suppliers associated and their integration in to Lean PD process:** At the current stage of LPD implementation, supplier integration is not been taken up at Company A. Since the manufacturing at Company A has been shifted to Asia in the recent past, proximity to suppliers and the pool of suppliers for components have considerably changed. According to Company A, initiatives for supplier integration will be taken up in the next level of LPD deployment.

**C. Influence of New Product Innovation (NPI) on average selling price, market share and affect of costs to margins:** This is an unexplored area at Company A. It is important to note that the deployment approach to Lean Product Development is different compared to most other improvement initiatives. In implementing LPD, measurable results generally come in the long term; short-term results are very subtle (Kennedy *et al.,* 2008). Company A seconds this statement. Twenty months into this initiative, Company A top management has observed how LPD boosted the morale of the PD team, made drastic improvements in project check sheets and arouse plenty of enthusiasm within PD to use knowledge capture tools.

D. **The Product Development practices used in the recent past (Phases, processes, technology and techniques)**: In the past, Company A used a ‘Stage Gate’ process as the Standard Operating Procedure (SOP) for Product Development (PD). In their experience, most other companies in NZ also have traditional practices similar to theirs. Likewise, designers in the company use standard design packages such as CAD and Solid works to carry out detailed design work. The transition to LPD has brought about several changes, such as:

- Changing the design-then-test phased process,
- Not just using the technology, but documenting it, and nurturing it,
- Use of the modelling packages as ‘supporting’ elements, the focus is always on in-depth research via test prototyping.

E. **Speed-to-market for a Product at Company A (and determining an optimum duration)**: Generally, PD projects at Company A take anywhere between 2-5 years, depending on the extent of new technology involved. The pilot LPD project was underway and its completion was expected in the following year. No optimum duration has been worked out for PD projects at Company A. They believe that clarity on duration will emerge only after the first project using LPD throughout gets completed.

F. **The transformation from implementation of 'Lean' in manufacturing to that in PD**: Process optimisation and improvement initiatives such as Lean have been a part of this organization’s manufacturing from the past two decades. The transformation from Lean Manufacturing to Lean Product Development was a natural step due to the company’s continuous improvement philosophy.

G. **Opinion on similarities and dissimilarities between New Zealand's large scale and Small Medium Enterprises**: Based on Company A’s experience with small companies, a discussion was carried out on the similarities and dissimilarities between SMEs and large companies. The findings are as follows:

- The similarities include the presence of leadership encouragement to continuous improvement and to "Lean" philosophy, efforts made to rationalise the manufacturing costs and eliminating waste in the factory. Most companies have PD problems such as expensive loop-backs, cost overruns and delays; that exist naturally in traditional Product Development process. In addition, problems in integrating the R&D function with other functions in the company, dependence on Low cost (Chinese) suppliers and NZ skill shortage has been leading to high costs and long lead times.
- The main dissimilarity observed is the absence of bureaucracy in SMEs, and an unstructured and informal operating environment. Company A believe more research needs to be done on the pros and cons of the 'informal style' of working in SMEs and on how it relates to product innovation.

H. **Use of Value Stream Mapping tool**: Value Stream Mapping (VSM) has emerged as a preferred initial methodology to implement Lean Thinking within the factory and in other functions of the organization (Womack, 2006). However, in Lean Product Development, the system emphasises building the four cornerstones followed by an integrating process to pull the 4 cornerstones of value stream together (Ward, 2007). As discussed earlier, Company A have drawn up a macro level map that is based on Toyota's PD systems; the VSM tool in specific has not been used. The detailed exercise of value stream analysis, design and identification of wastes (within the seven categories) may be carried out on completion of pilot project at Company A.

I. **The restructuring of people organisation:** The 'Chief Engineer' system has been established to sustain to other LPD cornerstones of Expert Engineering workforce and responsibility based planning and control. In conjunction with this, the following two aspects were investigated:

➢ **The need for this drastic step**: The people organisation had to be changed as a natural step, because the old organisation structure was incompatible with the LPD system. Without clearly defined roles for chief engineer and functional teams, the remaining LPD elements would not work.

- **The basis for the new organisation structure**: The basis for the new structure at Company A was the LPD way of balancing market driven development with technology driven development (Figure 24 in section 2.7.3). The various roles and responsibilities of functional team (managers, leaders and engineers) and the chief engineer were based on the logic explained by Kennedy *et al.*, (2008). An example of this new organisation structure is shown in Figure 28 below.

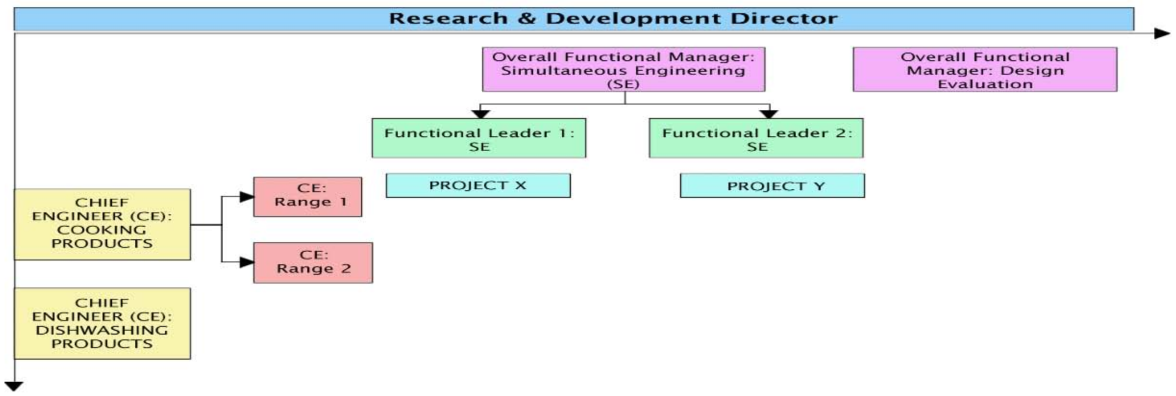



**Figure 28: Sample organization structure at Company A (based on discussions with PD Functional manager)**

Every project in the company has a chief engineer in charge. The CE sets the project deliverables based on customer requirements. The functional teams (who work across projects) work toward providing the technical solutions to these needs. Company A confirms that this structure has helped greatly to prioritise better on their R&D projects, and assign resources is an improved manner. In addition, the PD team has benefited by increased effective communication.

J. **The process of determining customer interests and selection of R&D projects:**

At Company A, the senior management does the task of selecting development projects with the help of subject experts, before handing it over to a chief engineer at the Research and development (R&D) department. The steps are shown in Figure 29.

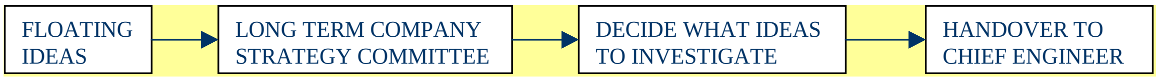



**Figure 29:Prioritising development projects (as discussed with the Functional manager at Company A)**

At Company A, the process of collecting customer needs is far more refined today due to LPD. There is constant interaction between customers and the R&D team, and they discuss needs with experienced people within the industry. Further, competitor products are stripped down and tested rigorously. Scientific market research tools such as questionnaires, service feedback forms, etc., along with discussions with market managers, interviews with technical representatives and customer care feedback, etc., are used to capture customer feedback and interests. An advanced '*Customer interest Database'* has been set up to store the data collected after consensus within the company. The database has been placed on a shared folder for easy access across departments.

K. **Details of the Lean PD process (the macro level picture) and its interrelation with knowledge subsystem**:

As discussed earlier, Company A had a well-established phase gate or stage gate system in place for over a decade. The main steps included preparation, concept development, system level design, element design, testing and fine-tuning, and manufacture ramp-up. One of the first steps taken in direction of redefining the PD process is to conduct a two-day LAMDA workshop to define the macro-level process based on 'Toyota PD system' (refer *appendix C* for detailed diagram). The salient features of the new 'Test then Design' process are listed below (shown in Figure 30):

- Fuzzy Front end: Knowledge sub-system and Set-based Concurrent Engineering
- Integrated Events (IE) and the 'Chief Engineer'
- Task based 'Stage-Gate' process beyond the IE

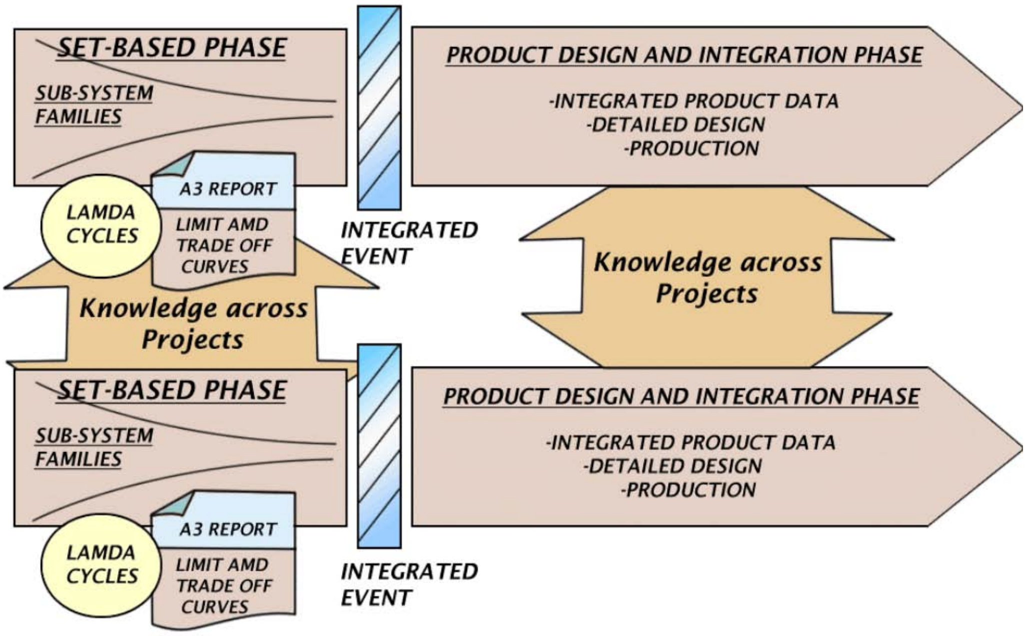



**Figure 30: The LPD process framework (adapted from Panchak, 2007)**

At any given point of time, the functional team is responsible for creating knowledge and expertise to understand all aspects of their product. This information is fed into the *knowledge sub-system*. Whenever a new Product Development project begins at the company, the functional team works with the chief engineer to understand the product specifications.

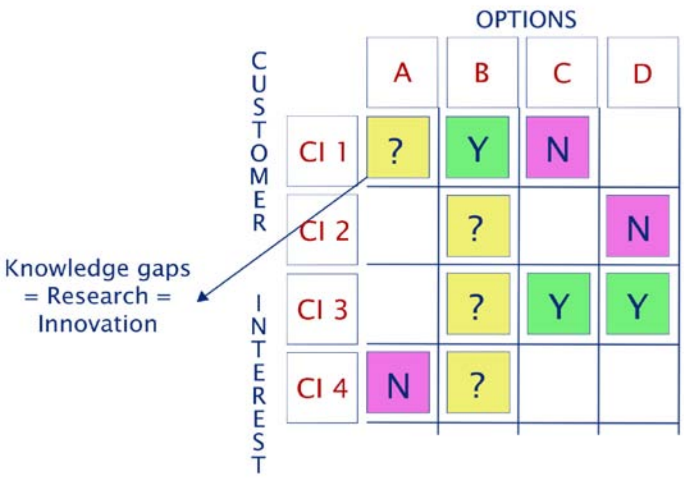



**Figure 31: Tool used to locate critical knowledge gaps for further investigation**

Further, the discussion is held on whether existing solutions can satisfy needs or not. This is done using the matrix tool described in Figure 31. The matrix tool is used to understand the various design options available for satisfying customer interest. Known behaviours/ previously understood concepts would either satisfy (Y) or not satisfy (N) the requirements. Further, the new solutions / 'the unknown' are explored by functional teams (to satisfy chief engineer / customer interest), this fills in the grey areas (?). Specific functional teams then get busy completing and bringing sets of solutions (*set-based concurrent engineering*) to a stage of maturity that will cater to the requirement.

Thus, the tool successfully locates critical knowledge gaps, arranges reuse of solutions and identifies specific quadrant for investigation in each subsystem. It eliminates risk of decisions based on 'gut feeling' and wishful thinking, thus avoiding expensive loop backs down the track.

During the set based engineering, the Chief Engineer watches over the sets available and chooses the most *feasible solution* from each subsystem (within purview of cost, time and other constraints). This event is described as the '*Integrated event (IE)*'. After the parts / sub-systems are chosen, *a normal task based design and development process* is ensued to complete the product / solution before handing it over to the production for manufacture. This 'stage gate' design process at F&P mainly consists the following steps: detailed product design and integration, parts and engineering trials, checking production capability and completion by handover to production. The launch dates are normally met.

L. **Details of the knowledge sub-system, the tools, and impact on PD projects**:

LPD gives high importance to 'knowledge' or 'learning' (hence also known as the 'Knowledge Based Development System' and 'Learning First Product Development'). According to LPD, only ample 'knowledge' about various features in a product can allow smooth 'development' of the product. Testing (learning) is used to generate knowledge, and then it is gathered, captured using Lean tools such as knowledge briefs (A3 reports), limit curves, trade-off curves, knowledge notebooks, etc. into the knowledge sub-system (Figure 32).

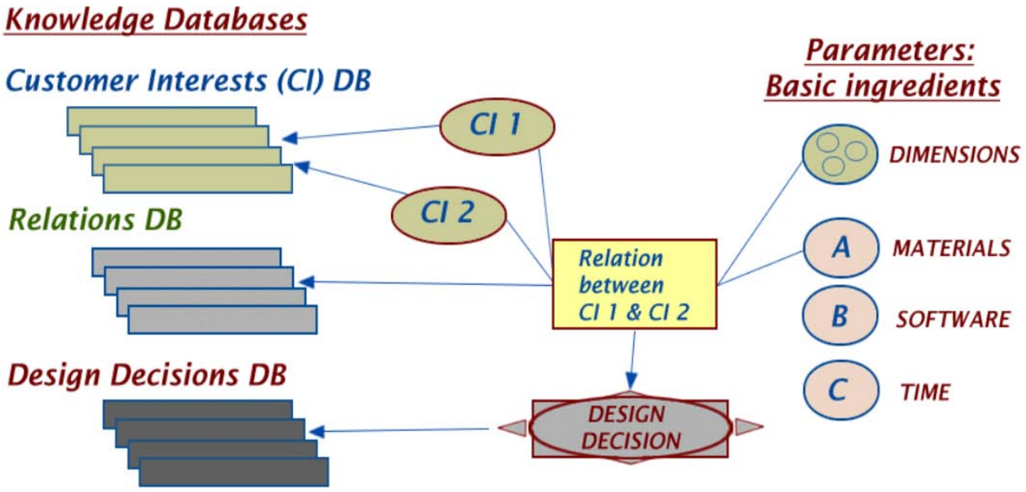



**Figure 32: Knowledge maps and the knowledge Databases (DB)**

As illustrated in Figure 32, a design decision is a product of interaction between multiple sub-system elements. The factors involved include customer interests, behaviour of individual sub-systems, relationship between sub-systems, etc. These aspects are captured into A3 reports, Limit curves, relationship curves, and trade-off curves. In turn, these forms of knowledge are stored in specific databases. Consequently, during an integrated event, the chief engineer demands to see the knowledge available on particular new product aspects from the knowledge sub-system, which will assist in making design decisions.

The knowledge stored is mostly generic in nature, it relates to the basics (for e.g.: physics, chemistry of material used for products), the relationships / interactions between functions of the product, etc. The logic behind this is to enable reuse of design knowledge across projects with a deep understanding on individual part functions. Figure 33 shows an example for the relationship curve. This example depicts the relationship between two customer interests and assists engineers to locate the ‘right quadrant‘ for investigation. Further, the additional two parameters that require investigation on this curve (speed, dimension) can be considered.

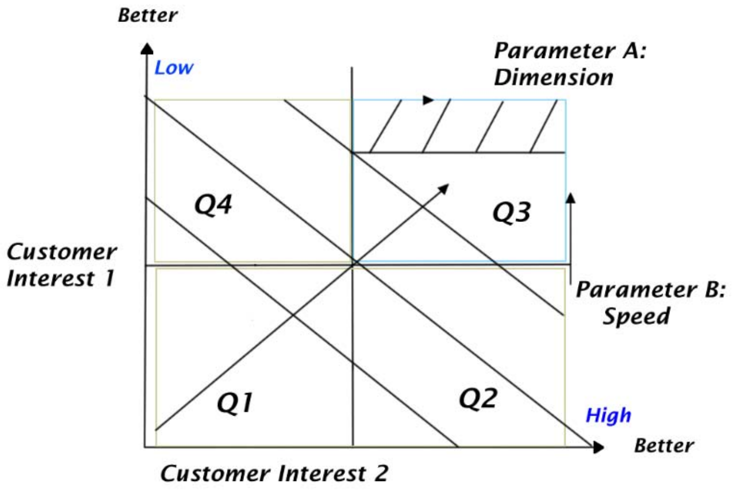



**Figure 33: Example of Limit / Relationship curve**

The **LAMDA** (Look-Ask-Model-Discuss-Act) cyclic investigation process is used to prepare Knowledge Briefs (KB). The LAMDA cycle is based on the PDCA (PLAN-DO-CHECK-ACT) cycle, the aim is to investigate, represent, discuss and implement solutions to problems (as discussed in chapter 2). Today KB or A3 reports have become a very popular tool at Company A, with almost a third of the members using them in their daily routine.

**M. Obstacles and challenges encountered in "Lean PD" deployment**:

The journey so far at Company A is satisfactory; the results have been emerging as time passes by. Some of the issues and reasonable doubts on the LPD system seen till date include:

- The fear that detailed analysis done using test-the-design and LAMDA would paralyse the PD process.
- Management's commitment for the new approach in rough times.
- The use of trade-off curves for determining technical performance meant 'limits on their creative ability' and deters innovation.
- Transparency demanded in the thinking and investigation by use of A3s, etc., meant 'no trust in capabilities'.

Most of these doubts cleared as the use of the tools and the training made their way through all levels of the organisation. Similarly overcoming the culture of jumping into ‘ACT’ stage even before the ‘LOOK’ step is completed was a major challenge at Company A. Information sharing and discussions were organised to stress the importance of ‘insist complete knowledge to avoid surprises’.

At Company A, there have also been cases where overuse of A3 reports had to be guarded against. The overuse of A3 would be harmful, as it accounts to excessive documentation i.e. “waste” in Lean terms.

## 4.5 Analysis of findings

The various concepts of LPD such as set-based concurrent engineering, expert engineering workforce, chief engineer system, responsibility based planning, knowledge capture, and LPD tools, have been explained adequately in the published literature (Ward, 2007), as explained in section 2.6 of this report. The details of specific tools for selection of R&D projects, the organisation structure transformation required, knowledge systems (refer glossary, p.219) and LPD process has not been explained in the past. These have been revealed for the first time during discussions with Company A personnel. Further, examples of relationship curves, knowledge systems, A3 reports and limit curves were extremely helpful in understanding the LPD concepts as such. Thus, the supporting case study for this research, i.e. Company A has resulted in achieving the following:

- Better understanding of LPD concepts in the context of a NZ enterprise,
- Hints on customising LPD design to SME,
- Understanding of potential problems for LPD implementation.

The major findings of the supporting case study can be analysed as follows:

- The Approach taken can be described as a framework containing elements of ‘Training- Building LPD skills- Implementing- Guidance from experts- Standardising- Continuously improvement’ (Figure 34).

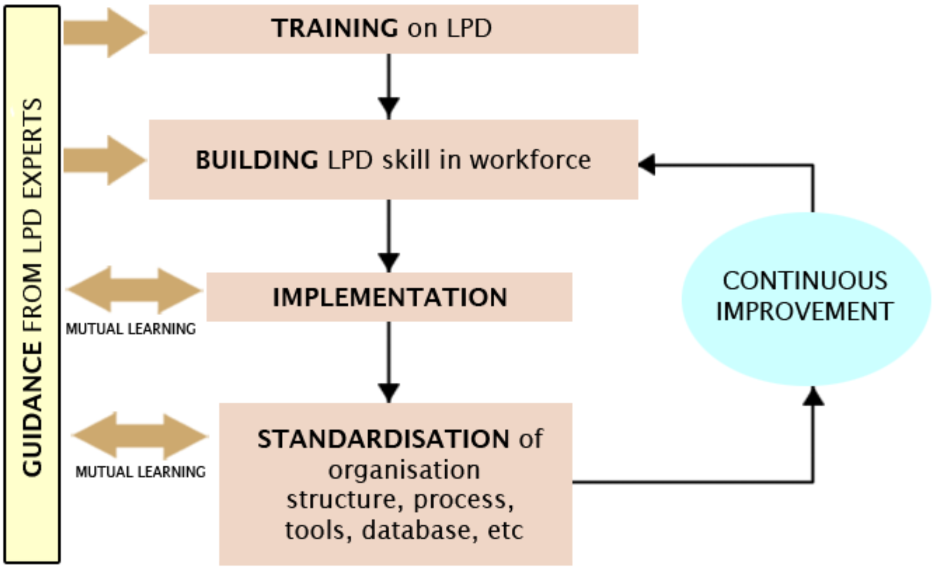



**Figure 34: Lean PD implementation framework**

- Thus, the study reveals that even though the LPD initiative began in a 'recommendations by committee' approach, the management at Company A ensured the entire organisation participated in, contributed to and applied LPD. Continuous improvement cycles have been included within each deployment cycle to sustain the change initiative. Examples of these improvement cycle initiatives are the workshops and re-trainings conducted to address doubts and concerns expressed by PD staff on the LPD system.
- The Lean PD process at Company A has incorporated the test-then-design approach (Figure 35), the set-based concurrent engineering for exploring alternatives, and the integrated events for selecting product solutions as described in LPD literature. The fact that the remainder of PD process can follow a stage-gate process has been exposed as a result of the case study at Company A. The use of simple 'matrix' tool in locating knowledge gaps is an important revelation of this case study.

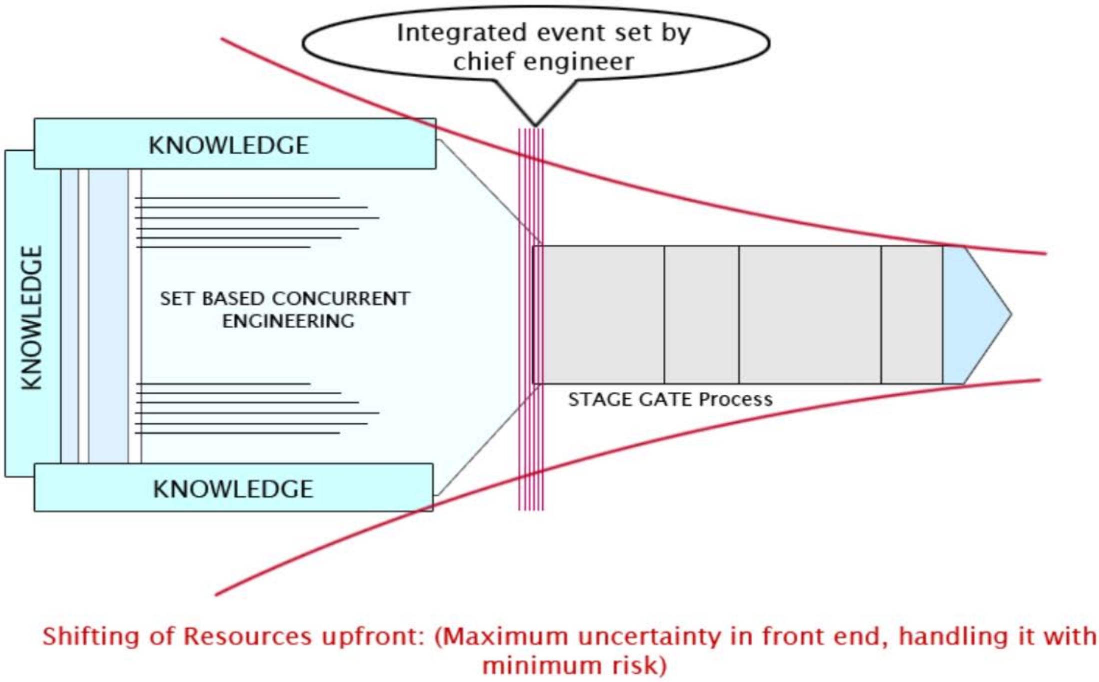



**Figure 35: The Lean PD representation based on understanding from literature and case study at Company A**

- The LPD literature clearly indicated a large distinction between Toyota's PD organisation structure and the traditional companies (with respect to the 'Chief Engineer' system). The Company A case study provided insight into the importance of reorganising the people structure very early into LPD deployment. It becomes clear that the people structure has to be moulded first in order to allow the other aspects of LPD to be implemented.
- Equally important in the PD system are external business partners in the form of suppliers, and contract designers. The case study conducted at Company A did not cover the supplier relationship aspect, nor use of contract designers at the company. Since this aspect was not taken up for LPD implementation, the investigation was not undertaken. However, the need to address these elements has emerged as more and more companies in NZ have offshore manufacturing, extensive outsourcing and taxing suppliers today.
- The process of selecting PD projects is an integral part of PD strategy. It emerges that large companies have this covered at the management level. The Company A case study provides

insight into their practices of prioritising and undertaking new projects, which has been discussed in least amount in the literature.

- Knowledge has been treated as the blood stream of PD within Company A. The knowledge is made to flow freely to nourish the PD process, and in turn, it is constantly revitalised using the LAMDA system. Examples of the knowledge subsystems at Company A (Figure 32), the relationship curves used (Figure 33), etc., have greatly helped the author to understand the LPD concepts in greater depth. Literature reveals that knowledge sub-system elements are crucial first steps of LPD deployment; making the depth of understanding this aspect appropriately.
- Although the model suggested by consultants at Company A stresses the need for a watching-out for 'loss of momentum' of this initiative, there is tremendous opportunity to include or develop a the sustainability aspect.

The studies at Company A have an important contribution to make to this research. The guidance it provides to anticipating and planning for potential implementation plans was abundant. The obstacles mentioned in section 4.4M are fairly logical and some of them may arise in SMEs and SME during LPD implementation. A first-hand experience in handling these problems can help to overcome similar problems at other companies.

## 4.6 Lean Product Development success at Company A

Overall, the approaching success of LPD implementation at Company A can be inferred based on the following statement provided by Company A on the system performance:

*"As far as I am aware we don't yet have any data to show the 'before' and 'after' effects of adopting the LPD approach to Product Design. The only things I can attest to are the following:*

- *We are capturing a large amount of generic and fundamental knowledge (which I know sounds like I am quoting from one of the textbooks!!!) and storing it. (To date we have well over a thousand A3's, which mostly would not have been written previously). It became apparent that we had a lot of knowledge in our heads (and to be fair, some in our systems) when we came to moving our manufacturing plant offshore. We have been 'forced' into changing this as we start to deal with vendors that are not just 'down the road', and people in our relocated factory that have close to zero experience with our product and manufacturing equipment. We have* *confidence that for new Product Developments we are in a much better position to implement them quicker, more successfully and with much less follow up after. For example we are fielding requests for info from our Asian plant each week and often daily. Although we are happy to help them and will continue to do so, it takes many hours of our time away from our future developments. Having our knowledge captured clearly and simply will help this in the future.*

- *In developing limit and trade off curves we are much more confident in our decisions we make with respect to the Design of our parts. We are also more confident that we are dealing with real Customer Interests, internal and external. We are also more confident that we have thought through what knowledge we have, and need to get, before we go ahead with a design."*

**- The Functional Manager for Simultaneous Engineering, *April 2009***

## 4.7 Results of case study at Company A

In conclusion, the study reveals that LPD can work successfully in a NZ based Company A. LPD application outside Toyota has been attempted for the first time in NZ like Company A. Every positive effect from this endeavour will re-confirm the generic nature of LPD system; whereas every unhelpful consequence will help in modifying the original LPD system for future industry implementation in various sectors.

The case study has ensured that the key objective of comprehending holistic LPD deployment in NZ has been fulfilled. It contributes a NZ industry application case study on LPD, reveals fine details of the methodology adopted by LPD consultants for implementation, and provides understanding on practical aspects of the LPD model proposed by pioneers from studies at Toyota. The key learning's from the literature and the supporting case study can be synthesized as follows:

A. The LPD model proposed by Ward (2007), is one of the most popular approaches adapted by companies that deploy this system, due to its generic and simplistic nature.

B. There is a need to adopt this system, its thinking and tools, to suit the concerned environment and size of business.

C. The perception and concerns of practitioners' in small and medium companies have to be obtained on the LPD solution.

D. There is need to obtain feedback on approach of large NZ companies from SMEs, which helps to define applicability of some of the steps undertaken as part of holistic LPD deployment.

The usability of inputs from this study toward LPD design for SME as explored has been described in following chapters. The focus will be on maximising usage of literature as well as the findings of the Company A case study for analysing data collected at the SME (namely Company B), in order to design a LPD system for SME.

One of the main drawbacks of the study has been the unavailability of concrete evidence on the exact scale of improvements at Company A. Although the parameters of lead time reduction, productivity improvement, etc. are required to spread the awareness and acceptability of this system in world-wide industry, the case study is able to suggest that further exploration and time is required.

## 4.8 Summary

The LPD model proposed by Ward (2007) is generic and simplistic nature, and has been used for deployment at NZ based Company A with positive results so far. However, until all aspects of the SME PD environment is investigated and analysed against the LPD system elements, the implementation of a standard model could lead to misleading results.

For example, the supporting case study suggests that the establishment of Chief Engineer system is one of the primary steps during deployment of this system. But since, literature reveals that SMEs have very small PD teams, it would be inappropriate to directly implement an organisation structure change without understanding the related constraints. However, use of knowledge capture tools such as A3 reports are fairly straightforward and can be directly tested at SMEs.

In summary, at this stage *there would be no initial LPD model that has been ready built to test at the SME*. Instead, a combination of activities would be a feasible plan for action research at Company B, like:

- Obtaining the perception and concerns of practitioners' in small and medium companies on the LPD solution, and on the deployment approach at large NZ companies,
- Observation of the people, project, process, leadership, business partnership, etc. of the PD system within SMEs, and
- Testing of knowledge capture tools such as A3 reports, etc.

The findings and results of the case study at Company B, in addition to, the conclusions drawn from literature review and supporting case study Company A, would ultimately guide in building the framework for SMEs.

# THE MAIN CASE STUDY

## CHAPTER 5

## DATA COLLECTION AND ANALYSIS

## FROM COMPANY B

# CHAPTER 5. DATA COLLECTION AND ANALYSIS FROM A NEW ZEALAND SME: COMPANY B

## 5.1 Introduction

The main case study of the research was conducted in Company B, and the duration of the study was March to November 2008. The company is a manufacturer of specialised equipment for the entertainment industry for the past few decades. The company consists of around 75-80 employees, and the entire Product Development plus manufacturing functions are located in NZ. As discussed in the chapter 3 of this thesis, the company was chosen because it belongs to the 'specialist-manufacturing' segment of NZ industry with a need for high innovation rate, and has shown commitment to the 'Lean' philosophy through its successful implementation of Lean Manufacturing. In addition, the enthusiasm and support shown by Company B from the very beginning was a huge advantage for this research.

Chapter 5 fulfils the second objective of this research, i.e. "To examine the current Product Development practices within Small and Medium Enterprises". Literature review and case studies reveal that the LPD model proposed by Ward (2007) is one of the most popular approaches that is adapted by companies for deployment, due to its holistic, generic and simplistic nature. In most cases, researchers and practitioners have found that its elements and tools need to be adapted based on the respective company's operating environment. Thus, the perception and concerns of practitioners' in small and medium companies have to be obtained, in addition to their feedback on approach of large NZ companies on the LPD solution.

Data has been collected from Company B using the 'case study' approach, and fieldwork was conducted using 'action-research'. An outline of tasks carried out at the company is as follows:

- Study of two Product Development projects at the company to observe the overall PD cycle, the PD process, and the detailed tasks within each phase.
- Participant observation in internal PD meetings, and stage-gate review meetings for project X in order to understand the criteria used for project screening, communication between key departments and PD, the discussions, etc.

- Observation of the user research stage in project Y,
- Observation of testing, prototyping stages for various products including project X and Y,
- Discussions with the members of the Product Development team to understand workload management, and problems faced in product innovation,
- Discussions with key suppliers to comprehend the integration issues with Company B,
- Extensive discussions with PD manager to understand PD project planning aspects, the knowledge database status within the company, the costing issues, the resource management, and the supplier, customer integration issues,
- Interview and visit with two companies within the Company B supplier network, and
- Observation of Lean Manufacturing at the Company B.

The data collected from Company B has been analysed in this chapter with respect to the Lean Product Development System elements such as the process, people, control system, leadership and flow. The supporting elements such as culture, the market environment, supplier collaboration and new product strategy have also been discussed.

### 5.1.1 About the company

The Company B manufactures specialized equipment for the entertainment industry since its inception four decades ago. The company decided to focus on the export market in 1985, and today it exports almost 95% of its products to countries such as Australia, South-East Asia, Europe and more recently North America. Although the design and manufacturing is based in NZ, the company has distribution and service centres in most parts of the world. It employs 75-80 employees and has an annual turnover of 20 million dollars (2008 statistics).

The company’s DNA is its ‘passion for the entertainment industry’. The Company’s Managing Director spends maximum time in meeting existing and potential customers, which ultimately helps the products to reflect the market needs. The PD (or R&D) department focuses on practicing a coherent design philosophy (documented on 31-01-2009), and building good knowledge and understanding of the underlying technologies. The design values include ensuring deep understanding of end users and their environment, making products that are unique, and making products environmental friendly. The R&D team's history of ‘out-of-the-box’ solutions to design problems is exceptional.

The company's products can be divided into two major categories 'The' and 'Arc', based on purpose it serves and user location. Within each category, the company has 8 types with several products and variations within each; the details are shown in Figure 36. Each product contains four basic technical sub-systems: Optical, Mechanical, Electrical and Aesthetics.

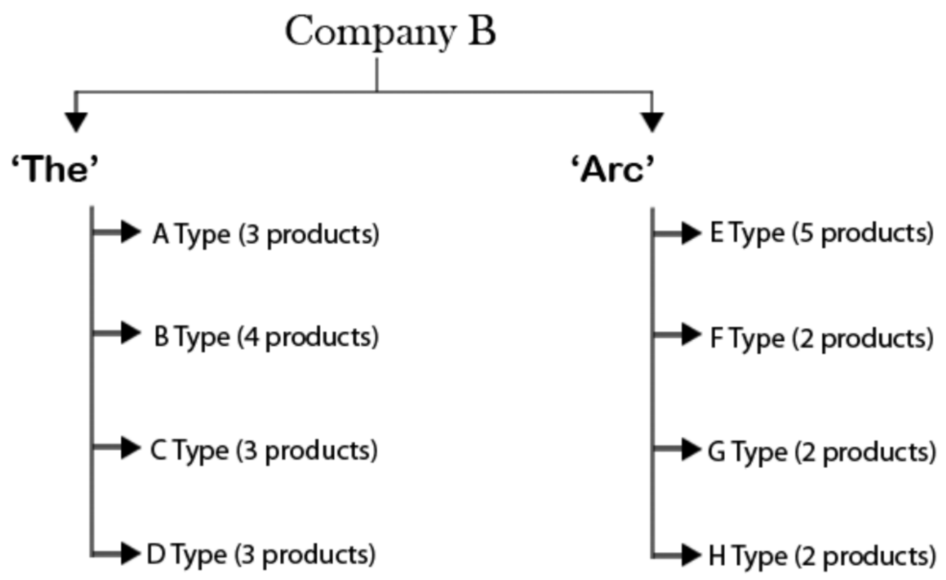



**Figure 36: Company B product range**

The data collected on the gross profit and turnover by product group shows that 'The' category accounts to almost 84% of the total profits and 88% of the total turnover, whereas the 'Arc' category accounts for 15% of the total profits and 11 % of the total turnover. Statistics on number of new products per year was unavailable, and no documentation of the duration of R&D projects was found. In 2008, the company came up with one new product introduction and two upgraded versions of products. The two projects observed for the purpose of this research belonged to the B type and the C type, in which Project X was a new product introduction (radical innovation) and Project Y is an up gradation of existing product (incremental innovation) respectively.

Some salient features of the company's product innovation activities observed are as follows:

1. Increasing awareness on government regulations in each region of the world,
2. Focus on ensuring that products do not mimic any other product in the world,

3. Maximum attention given to the performance of the product; aesthetics were in focus only recently,
4. Ensure feasible suggestions from external consultants, experts and assessments are incorporated to improve the company's innovation process,
5. According to an external assessment conducted in 2007, Strategic (competitive and organisational) capability was found to be one of the foremost strengths of the company, whereas, insight into product positioning, differentiation and rigour were found to be a major drawbacks.

### 5.1.2 Lean Manufacturing at Company B

The company's Managing Director is constantly ensuring that the organisation gets the best improvements. This drove the 10 step mentoring programme in mid June 2006 and the initial focus on introducing Lean principles to the entire organization to make sure the whole team gained an understanding of which direction the company was moving toward, with definite Vision, Goals and Values. Thus, the journey into Lean Manufacturing began. As part of this initiative, Value stream mapping, 5S (good housekeeping), *Kanban* and single piece flow elements were applied with much success.

The wastes in manufacturing were identified and eliminated with the help of Value Stream Mapping tool, the production became more flexible due to the single piece flow arrangements, process time improved and space optimisation was possible due to the Kanban flow systems, and 5S ensured excellent visibility of the processes which improved the product quality greatly.

One of the most encouraging aspects of Company B's Lean Manufacturing journey has been the commitment shown by top management. This has ensured that all employees understand the Lean principles and build a continuous improvement culture as required for the new system to work. The shop-floor team's involvement and participation was also a key enabler. As discussed earlier, the culture and top management commitment (leadership) have been listed as key foundation elements for deployment of any Lean system (Hines *et al.*, 2008).

Moving upstream i.e. applying Lean to PD was the next step for the company on its Lean journey. They were intrigued with the possible benefits. The already existing enthusiasm for Lean thinking would be used as a springboard for exploration of Lean PD.

## 5.2 Market environment and organizational aspects of SMEs in New Zealand

As the case study companies for this research have been chosen from NZ, it is important to understand the specific characteristics of the SME population, and the general industry environment (internal and external) in the country. As discussed in chapter 2 of this thesis, NZ firms are known for their product innovations and unique creative environment with an economic freedom score of 82 (2009 Index of Economic Freedom, 2009), and a large population of entrepreneurial firms and SMEs (firms < 100 employees constitute more than 99% of all businesses). Their contribution to the country's economy is vital (account for about 60% of employment in NZ and offer 40% of the total value added output), and several studies have been carried out to understand product innovation (Kerr, 1994; Gomes, 1998; Campbell, 1999; Ho, 2001), in SMEs.

The determinants of new product success for any company can be categorised into four factors: Market environment, strategy, organisation, and PD process execution (Haque & Moore, 2004), as shown in Figure 37.


**Figure 37: Determinants of New Product success (Haque & Moore, 2004)**

**I. Market environment:** The environment includes market potential and competitiveness. SMEs in NZ have a strong focus on customer and most of the inputs required to begin PD projects, emerge from gauging the potential, the competitiveness, etc. Past research by Souder *et al.*, (2003) and the NZ Statistics 2005 report (2007) have published similar findings. During the course of this research, it was found that the company gives a lot of importance on the marketing of their products, ensuring the market managers are always interlinked, and the awareness of competition is high. For example, the Company B export 95% of the products made and has hence built a network of market managers in every part of the world. These market managers are employed from respective local regions (i.e. Asia, Middle-east, Australia, UK and Europe, US), so that the company can capture customer needs better with the help of these local representatives. Another important finding was the role of the Managing Director (MD) in understanding market environment. The MD heads the marketing (in this case he is also the entrepreneur), and synthesises the feedback from market managers to identify opportunities in the market, the existing and potential competition, and the company/ product brand strength, in addition to consumer needs. The MD also spends much time travelling to meet customers, understand their needs and problems (as per discussions with the Company B Managing Director, Mr.JC).

**II. New Product Strategy:** The product lead, technological competence, company resources, and marketing synergy constitute the New Product Strategy. As discussed above, SMEs look toward the market and the customers to ideate, in most cases. The other factors include technological advancements in the world, inputs from external consultants and ideas from Product Development personnel. The company director engages in decision making on new product projects for the company; the first round of analysis is mostly by the individual. The MD considers the following aspects (listed as per level of importance) for understanding if a potential product has a market edge (as per discussion held in August 2008):

1. The intensity of customer need / reinforcement of an idea over time / trend or pattern of perceived need,
2. Competitor product features and prices,
3. Affect of new product on company Brand,
4. Trade-off between Cost and Features.

Further, Company B analyses its technological competence, its core competency and the resources available in the light of the perceived customer need, to decide on selecting projects for PD. The various elements that are probed on resources include finances, people, technology, and expertise. Company B has an average 5% expenditure every year for R&D purposes (material, labour, all inclusive) and these expenses form 5% of the company’s turnover. This is in line with past studies that reveal that on average most SMEs in NZ spend between 0 and 5% on PD (Massey, 2003). The MD along with the marketing team generally provides the first description of 'new product'.

All the above-mentioned elements are not structured for new product strategy, nor documented as a procedure within the company; but the Managing Director or the entrepreneur's rational decision-making process. This characteristic is also very typical to SMEs (Hull, 2003; Bruin, 2005).

**III. Organization aspects:** The internal relations in a company include employee practices, culture, whereas the external relations include co-operation with business partners such as suppliers, external design agencies, customers, government agencies, etc.

The labour market in NZ has distinctive characteristics. It is a small economy, with a large percentage of skilled migrants. However, past studies have shown that NZ employers have a 'conservative' attitude toward managing human resources (Boxall, 1993). Further, NZ statistics 2005 report states that most SMEs find the lack of personnel as a factor affecting product innovation; and an obstacle to increased innovation productivity. Although, Company B has a history of world-class innovative products for three decades now, the department of PD is facing problems on hiring and management of designers. It was observed that the ratio of projects to people was very high, and the management of part-time employees and contract designers (both on-site and off-site) was a tedious job for the manager. Other issues observed was the informal training and development given to new employees, the lack of consistent co-ordination between various sub-system designers, designers lacking experience within the company, and extensive multitasking.

The company's supplier relationship is crucial for product success. Most of the metal extrusion, die casting components, among others are bought from local markets. The company depends on Chinese toolmakers for most projects. Although the company successfully collaborates with suppliers and design agencies for PD work, long-term relationships have emerged only with some of them. Government agencies such as NZ Trade and Enterprise have been associated with the company's improvement endeavours for the past few years. For example, the company has participated in the AICHI program for implementation of Lean Manufacturing. The company also believes in knowledge sharing and conducting projects with educational institutions on process improvements.

**IV.** The PD function at Company B is one of the most important functions within the organisation, alongside manufacturing, sales and marketing and the business strategy. An adaptation of high level map explained by Kennedy (2003) has been included in Appendix H of the thesis. The finer details of the PD process have been elaborated in section 5.3. The high level map provides an overview of the PD departments internal inter-relationships, and this exercise shows that the high-level map depicted in Appendix H for SMEs is similar to large firms (i.e. generic).

## 5.3 Cornerstones of Product Development:

The following section details with the data collected in response to initial data collection questions (*refer appendix D*). The topics covered include current Product Development practices in SMEs (Phases, processes, technology and techniques), the PD people composition, and planning and control.

### 5.3.1 Current Product Development process:

The R&D department operated without a formalised Standard operating procedure or PD process until 2007. The company came up with innovative products for three decades now, with the help of a 'sequence of activities' that was ingrained in their way of work for all these years. Also, no documentation was found on this matter within the company. The importance of developing a standard PD process had become a priority only recently.

In 2007, the Managing Director Mr.JC requested the agency that helped Company B to implement Lean Manufacturing, to advise on how the R&D department can be transformed similarly. After a very brief period of study at the R&D department, the agency 'SL' came up with a possible 'standard operating procedure' that contained 5 linear phases. These phases drilled down into several steps with a time-tracking document for each step, but the deliverables were not defined anywhere (Figure 38). The R&D team were unable to relate their actual PD steps to the suggested process, and hence this process was not implemented. Upon analysis, it emerges that the lack of guidance (probably due to lack of expertise) from the consultancy services for implementing the new process was the main reason.

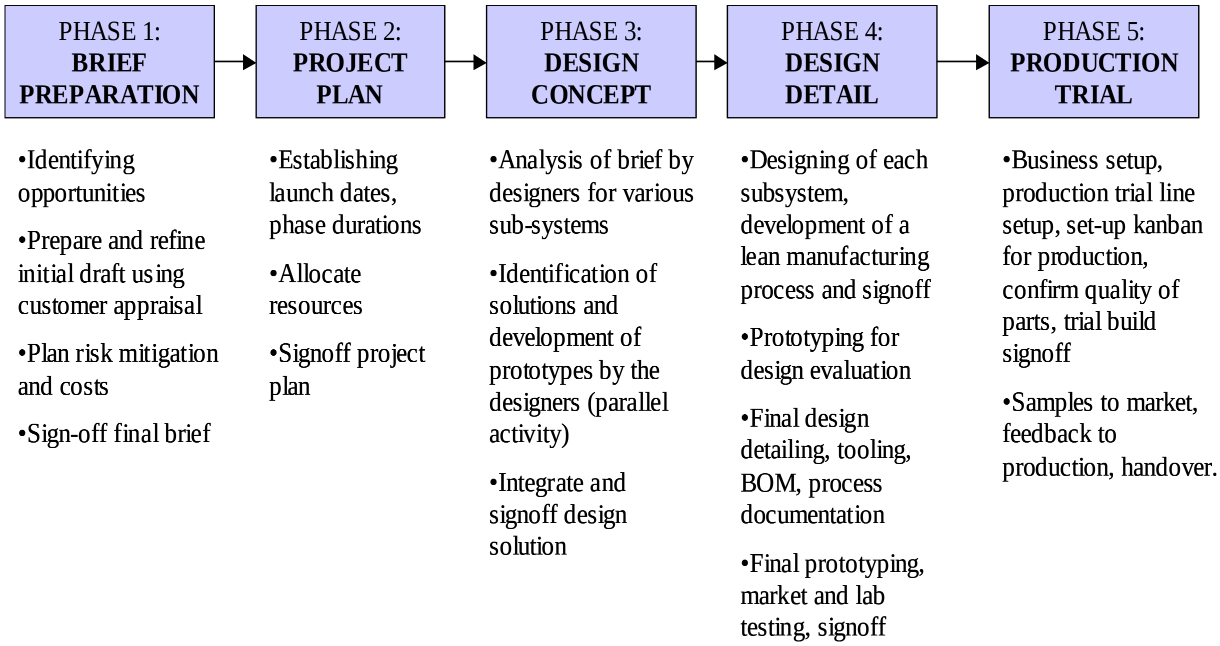



**Figure 38: Suggested process for PD in Company B, 2007 (Source: R&D dept., Company B)**

In 2008, the task of formalising a PD process for the department was taken up as part of this research study. With the help of a new leadership in the department, the first two workshops were conducted to understand the actual PD process at macro level and to understand concerns within the process. The PD process would contain 10 steps overall, (as shown in Figure 39) starting from the development of product brief and ending with handover of product design to production. The first step is the product brief prepared by the company director, then the Product Development team prepared concept drawing for each sub-system, followed by the detailed design stage, functional prototyping, tooling, and final prototyping.

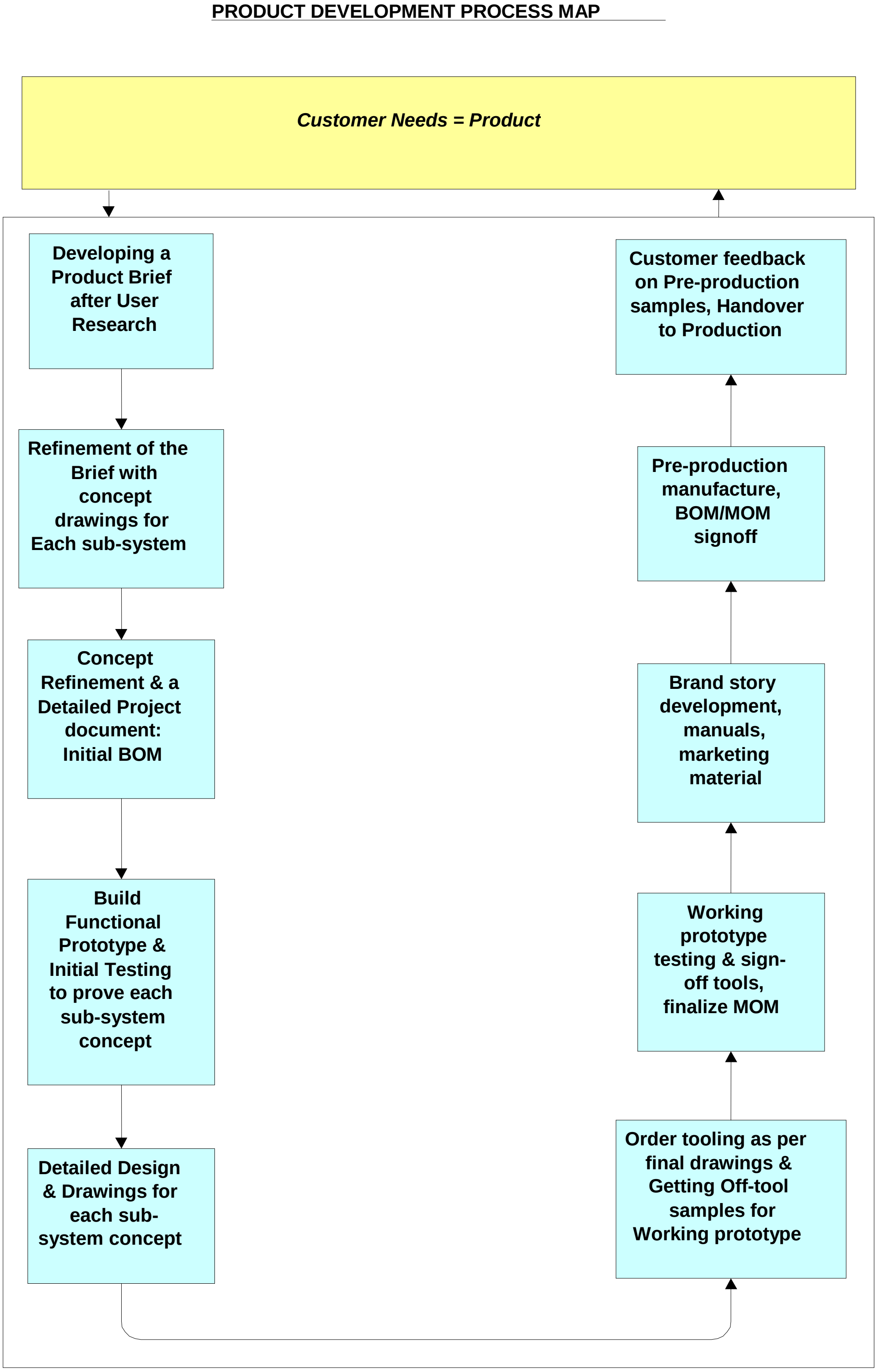



**Figure 39: Current Product Development process map (April 2008)**

**Analysis:**

As discussed in the literature review of this chapter, past researchers have found truncated, informal and unstructured PD processes within SMEs in NZ (Kerr, 1994). Studies found that only 61% of the total number of PD steps was used in the small companies. The need for a standard process was not perceived as important for most companies in this sector. Data collected from Company B also points in this direction.

The process suggested by the agency 'SL' was based on generic PD processes as described in section 2.1 of this thesis. Although it incorporated a great detail of tasks that have to be conducted, it was mostly theoretical in nature. The steps outlined were common for large and small companies, with no trace of customisation for small companies. In addition, the agency failed to guide the company on how to implement the process.

The actual process map (Figure 39) drawn shows the informal process followed by the Company B. It was a very simple but deficient process. The positive aspects of this process include:

1. Simple process with all the core PD activities covered,
2. Flexible process with no rigid task lists.

The drawbacks of this process include:

1. Linearity of the process, highly impractical for PD,
2. No mention of supplier / contract / off-site design work, and
3. Tools for internal and external communication, and database management aspects not covered.

This effort was the beginning for understanding the importance of PD process; it helped the R&D manager to 'write down' the process they followed unofficially till date. Further, details of the PD process including subtasks have to be studied in order to understand the exact deficiencies.

### 5.3.2 Product Development people and leadership

Two entrepreneurs, the Managing director Mr.JC and the R&D director, Mr.AN, have led the Company B since 1985. The company consists of a small Product Development team, with a R&D director (until January 2008) and the PD manager, heading a team of one full time engineer, and several on-site and off-site contract designers for various projects (Figure 40). Staffing at the PD department varies with project needs, for example: project X has three on-site and two off-site designers working on the Product Development. Each sub-system has a maximum of two engineers/ designers working on the system. Except for the full time engineer, none of the PD personnel have any engineering qualification. The Industrial designer and the designer in-charge for optics have previously been full time employees of the company, but are currently working on contract. The company chooses to have flexibility in employing other designers on project basis.

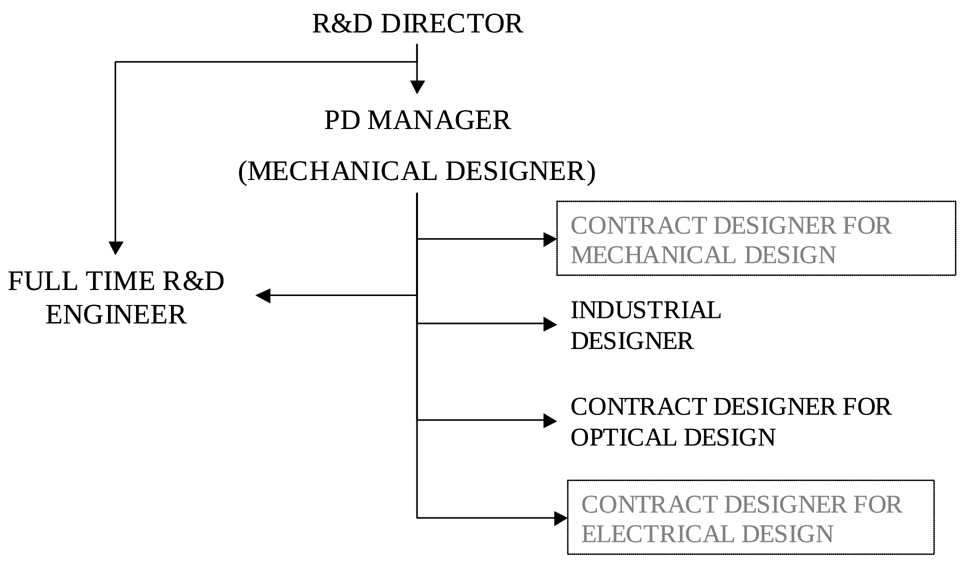



**Figure 40: In-house PD team at Company B (2008 structure)**

Currently the PD manager heads the PD department due to the loss of the R&D director in January 2008 due to unforeseen circumstances. The detailed profile of two prominent people in the organisation, the company's Managing Director Mr.JC (company leadership), and the PD manager Mr. BM (department leadership) has been provided below based on interviews:

*The company's Managing Director (MD):* As mentioned above, he is one of the entrepreneurs, and heads the marketing (and customer interaction) functions of Company B, while the co-entrepreneur headed the design / Product Development as the R&D director. Mr.JC has wide experience in the entertainment industry that helps him to understand customer needs very well and identify market opportunities for the company. As per discussions with the PD manager, the MD is responsible for new Product Development ideas in most cases. Mr.JC does the process of identifying market opportunity, selecting projects, and preparing the initial user research document after user research along with his team of market managers, before handing it over to the design team for Product Development.

*PD Manager:* The PD manager: Mr.BM is in-charge of the PD team since February 2008. He has excellent practical experience in Product Development gained by working at several manufacturing firms across the world. At Company B, he is in-charge of overall Product Development management, project planning and scheduling, co-ordination between designers, supplier selection and negotiation, supplier integration in development, conducting review meetings, mechanical design, and unplanned activities (production issues). The workload management of chart is shown in Figure 41.

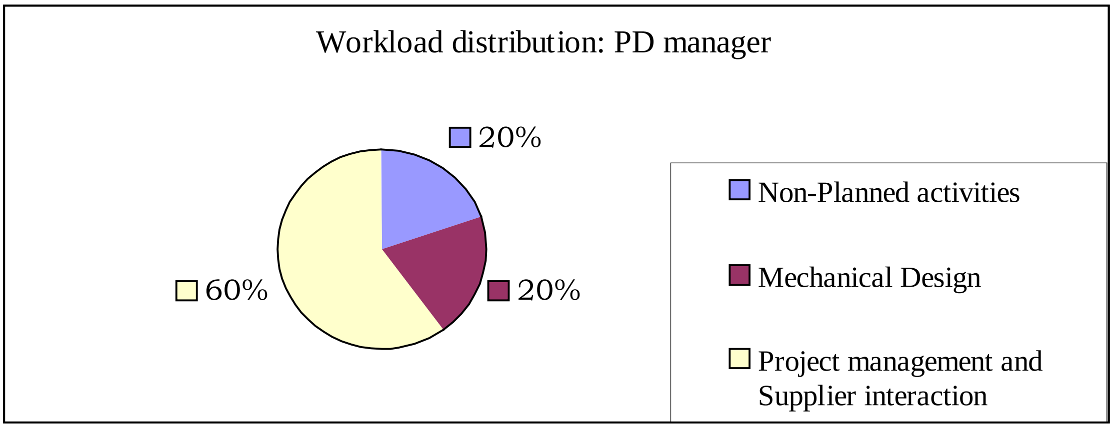



**Figure 41: PD manager Workload distribution**

Workload distribution charts of individuals working in Company B's PD department helps to understand the exact workload management arrangement present, expose the percentage of non-planned (or fire-fighting activities), and the distribution across projects. In-depth interviews were conducted with employees at the PD department and were mapped, as discussed below:

- Full time R&D engineer: The person is mainly responsible for CAD drafting and issues related to production engineering, supplier integration, and documentation (Figure 42).

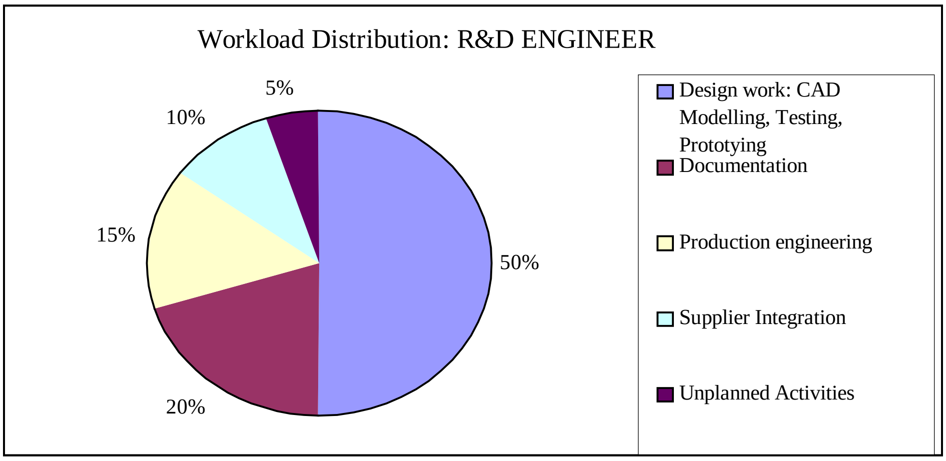



**Figure 42: Workload distribution: R&D engineer**

- On-site contract designer for mechanical systems: The designer is a new recruit and works on select projects for Company B, being responsible for prototype arrangements in addition to carrying out Mechanical design (Figure 43).

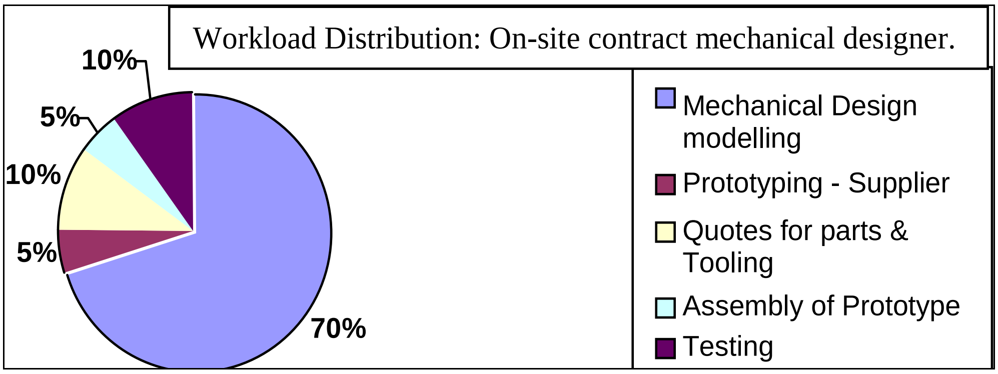



**Figure 43: Workload Distribution: On-site contract designer for mechanical systems**

- Contract industrial designer: The industrial designer has been a part of the company's full time staff until 2007. In 2008, the designer has been employed by Company B for looking into Aesthetics and 3D modelling of select projects on contract basis (Figure 44)

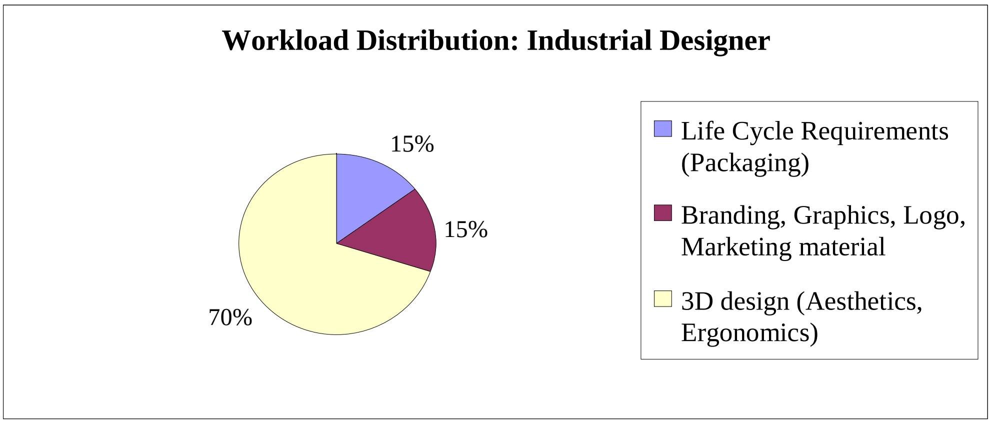



**Figure 44: Workload Distribution: Industrial Designer**

- Contract designer for Optical systems: The optical systems are the core of the company's products. The mechanical, electrical, and aesthetics are designed around the optic systems. Thus, the optical systems remained in-house for a really long time; the designer has been associated with the company for several years now. The designer works 100% on the optical systems (design and testing) for Product Development projects at Company B.
- Contract designer for Electrical systems: The designer has been associated with the company for several years now. The designer works 100% on the electrical systems for all Product Development projects at Company B.

Overall, the PD department has flexible staffing, a combination of full-time, on-site contract and off-site contract designers.

**Analysis:**

Overall, Company B expresses characteristics of a typical SME, with a very unstructured PD organisation. Some of the important points for discussion are as follows:

- The Company B employs up to 60% contract designers to carry out design work.
- One of the concerns of the company would be the fact that a designer employed *on contract* is handling the core system of their products. This leads to a sense of insecurity about core knowledge, and its retention for the future of the company.
- The use of several on-site and off-site designers for a single project can cause integration issues.

- The approach taken to generate new product ideas or choose R&D projects by the marketing (without involvement of designers) tends to make the product brief lacking technical details.
- The PD manager, and R&D engineer have reported a significant percent of time was spent on unplanned activities, which can be regarded as a 'waste' in resource management.
- The loss of R&D director has had a huge bearing on the company with almost three decades of expertise disassociated with the company now. During the course of the project the following impact was seen due to this:
  1. The 'science' behind the products has been lost, leading to 're-inventing of the wheel',
  2. Overloading of the PD work on remaining individuals,
  3. Higher risk of taking bad decisions and making mistakes,
  4. Loss of confidence for remaining employees, leading to higher attrition rate,
  5. Internal friction between PD and other functional departments on various issues due to increased number of 'Grey areas',
  6. Schedule slippages and PD process loop backs have increased, and
  7. Knowledge gaps make management of projects tougher than before.

Kennedy *et al.*, (2008) explains these similar situations are seen in most companies. The people or the 'knowledge' with people is one of the four important cornerstones of a Lean PD, and this aspect has to be carefully handled to ensure overall success.

### 5.3.3 Product Development project planning and control

A total of eight projects were planned for the year 2008 at Company B. Out of these eight projects, only two were 'new' Product Developments, the remaining were developments of some systems within the product, i.e. up gradation projects. In addition to the specific projects, the PD team is also responsible for production engineering at Company B. Table 6 shows the allocation of various people within the R&D team for projects in 2008.

| | PRODUCTION ENGINEERING | PROJECT W | PROJECT F | PROJECT U | PROJECT A | PROJECT X | PROJECT Y | PROJECT P | PROJECT V |
|---|---|---|---|---|---|---|---|---|---|
| R&D DIRECTOR | | | ✓ | ✓ | | | ✓ | | |
| PD MANAGER | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | | ✓ |
| R&D ENGINEER | ✓ | ✓ | ✓ | | | ✓ | | | ✓ |
| ON-SITE CONTRACT DESIGNER - MECHANICAL | | ✓ | | | | ✓ 100% | | ✓ | |
| OFF-SITE CONTRACT DESIGNER - MECHANICAL | | | | | | ✓ | ✓ | | |
| INDUSTRIAL DESIGNER | | | | | | ✓ 100% | | | |

**Table 7: Resource allocation for 2008 projects at Company B**

Most of the above mentioned projects faced delays due to waiting (overloaded staff), the supplier lead times and redesigning during 2008. For example, projects X has been delayed by six months compared to its original schedule. Further details are explained in the section 5.6.

**Analysis:**

The company has a single team that has to cater to all projects. At any point of time the team usually handles up to two projects with average 6 –9 months lead-time, although the number of projects scheduled is 8 per year. Only in the case of mechanical design, the company uses the option of employing additional designers from external design agencies. The other designers are mostly overloaded, and hence the capability to handle several projects per year decreases. The Table 7 shows the uneven workload management at Company B. As expressed by the company, the delays due to supplier lead times have several reasons, which have been discussed in the section 5.9. Further, clarity in the determining the amount of work involved in each project and planning resources accordingly has to be enhanced within PD.

## 5.4 Concerns in Product Development at Company B

One of the initial discussions held at the company was on listing the problems the PD department has with respect to PD. This was done using a process mapping exercise along with the PD manager in April 2008 and would enable to capture the practitioner's actual needs. As the process mapping activity was carried out, the issues related to people management, supplier collaboration, lack of knowledge, and planning and control emerged (refer Appendix F). The PD manager believes that the following have been the key weaknesses in the company's PD process:

1. Front-end: There has been no '*Idea Generation*' Technique used so far except for the Interview tool; hence the manager feels that a more comprehensive ideation system has to be evolved that can help capture all ideas at regular intervals of time.
2. Over-the-wall approach: The marketing and the Managing Director have been responsible for capturing ideas, investigating customer needs and writing the product brief for development. According to the PD manager, allowing the *design team to interact with end users* helps to avoid wrong conception of needs.
3. The PD manager believes that *supplier integration* must be explored early in the PD process, although he is not aware of when and how.
4. The idea of receiving *multiple viewpoints* from the various functional departments at Company B during the early stages of concept development or defining specifications has been an area of interest for the PD team.
5. In addition to the involvement of PD team for user research, the PD manager believes that going back to the customer during the concept development stage will allow *major assumptions to be verified with customer*.
6. Deciding on whether to Outsource or contract or keep the design element in house, has been a challenge for the company. A *criteria based decision-making* process is preferred, as compared

to the usual ‘trying-and-learning’ ways. In addition, methodologies to maintain control over external design teams have to be developed.

7. *Supplier Delays* in tooling stage have been a constant problem for the company.

Other concerns (non-process) were also listed, such as: lack of documentation on PD projects, ways to enhance expertise of designers (to aid workload management), no clarity in linking the long-term and the short-term strategy along with each project, want for identification and mentoring successors for the company directors, and the minimal understanding of user needs in the ‘Arc’ range.

**Analysis:**

The findings of the process-mapping exercise confirm the existence of several wastes within the system, which can be related to the Lean systems thinking (Table 8). The table below explains the reasons for the wastes, the causes and the effects.

| Concerns in PD | Analysis of Problem |
|---|---|
| 1. Front-end: Minimal ‘Idea Generation’ Techniques used: no comprehensive and systematic Ideation system. | Poor use of tools causes knowledge to scatter (Ward, 2007). Idea generation techniques tie in with the strategic aspects, and are required to constantly bring forth ideas for new Product Development. At Company B, the lack of any system for capturing ideas poses a high risk of missing-out market opportunities. |
| 2. Over-the-wall approach: Marketing and Managing director conducting customer needs investigation for new product brief without design team. | The preparation of product brief after user research (conducted by sales team and Managing Director) without involvement of design team can be categorised into the ‘Hand-off’ waste category (Ward, 2007). Team work to integrate knowledge, action, responsibility, and feedback is vital: i.e. the design team has required technical knowledge for product, the PD manager plans the project, the Managing Director has the responsibility for product success, and the sales obtain customer feedback (both positive and negative). |

| Concerns in PD | Analysis of Problem |
|---|---|
| 3. Supplier integration generally not explored early in the PD process. | According to Lean Product Development Systems, the suppliers have to be studied, evaluated (not just cost but also to include delivery, quality, reliability, service, etc.), and integrated with the PD process to derive mutual benefits in long term. The type of part determines the integration point for supplier. For example, suppliers for catalogued parts can be chosen later in the process, whereas the suppliers for design-in have to be integrated at the concept stage and the parallel development of the parts of the product have to take place (Morgan and Liker, 2006; Ward, 2007). |
| 4. Cross functional team review at concept development stage to be conducted more effectively | The valuable feedback on products and systems from other departments in the company is very essential to avoid problems due to creating 'useless information' and knowledge wastage due to 'discarded knowledge' (Ward, 2007). For example, knowledge created in the production in working around design problems is essential feedback for the design to improve upon, whereas some information collected by sales during user research may be useless for the design department. Need for an Integrated approach in concept development stage. |
| 5. Lack of customer feedback during the concept development stage poses risk of major assumptions designed into the new product. | The 'customer focus' ingredient of Lean systems has to be highlighted throughout the PD process. Need to see the Value in the eyes of the customer early in the PD Process enables successful Product design. Market dynamics can be monitored only if the company verifies the direction of development several times during the PD process, using tools such as LAMDA cycle (Kennedy, 2003). 'Wishful thinking' has been identified as a guaranteed result of not performing customer verifications. |

| Concerns in PD | Analysis of Problem |
|---|---|
| 6. Weak decision-making on whether to Outsource or contract or keep the design element in house, no proper methodology. | Although not much has been revealed on the Toyota's outsourcing systems; this aspect is very important for avoiding wastes such as waiting, unused knowledge, contact barriers, futile information, among others (Ward, 2007). One of the key criteria currently lacking and one that can enable this decision to be made successfully is Value Stream Mapping to identify Components and Sub-systems. (These Components and subsystems can then be evaluated on its merit for Outsource / Contract, Design in-house decision making.) |
| 7. Supplier Delays in tooling stage. | The supplier delays may appear as a problem in Company B, but it is actually an offshoot of basic supplier integration problems. Understanding supplier technical capabilities before selection, establishing long term relationships, working with suppliers to solve problems are required to avoid any problems such as delays, cost overruns (Morgan & Liker, 2006) (Refer to the analysis in Point 3 Above). |
| 8. Lack of documentation on products and PD projects | As discussed in section 2.7, an extensive knowledge capture systems are required for developing expertise within the company. Like most other companies, Company B does not recognise that Product Development has two value streams, the knowledge value stream and the product value stream (Kennedy *et al.*, 2008). |
| 9. Expertise of designers not developed / measured fully | Inadequate expertise is a consequence of wasted knowledge. Whenever a company uses external designers extensively, knowledge capture systems have to be improved to ensure the technical aspects of new product innovations are captured for use by future designers for the company. |

| Concerns in PD | Analysis of Problem |
|---|---|
| 10. Communication on long-term / short-term strategy with PD projects to design team | Strategic aspects of PD have to be communicated across the company as discussed in the leadership cornerstone of LPD (Kennedy, 2003). Leadership approach, Product and People Strategy, Systems for design and development play a vital role in PD Project selection, which are currently lacking. |
| 11. Identification and mentoring successors for the company directors | High reliance on some key people within an organisation (and not capturing their expertise) can lead to severe problems if these people disassociate with the company at any point of time. |
| 12. Minimal understanding of user needs in the 'Arc' range | Increasing the understanding of the design, marketing, and other key people within the company on this category of products is very essential for the company to make good products. |

**Table 8: Concerns at Company B about current Product Development practices**

Wastes such as those identified in the table above lead to damaging effects, if not eliminated from the system. The Figure 45 shows the logical connection between these wastes, and non-value adding activities with customer satisfaction.

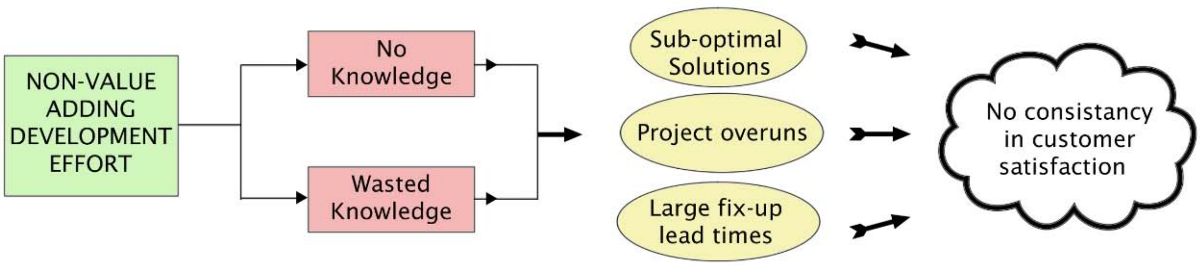



**Figure 45: How waste relates to customer satisfaction**

Any non-value adding effort (such as excessive or redundant communication) will result in either creating no knowledge or useless knowledge. This will lead to the problems 'seen' in Product

Development such as project overruns, costs, sub-optimal solutions, etc. Ultimately, customer satisfaction is found to fluctuate accordingly. The root cause of most PD problems is the lack of knowledge or wasted knowledge. This affects the overall innovation system.

## 5.5 Improvement of the Product Development function

The company has had long lead times for most of their projects, but an effort to capture the actual time per project or deriving an optimum duration for the PD projects has not been a priority in the company. Company B has not been able to reflect on this aspect of their R&D projects.

Project reviews are conducted and documented in most companies in order to reflect and introspect on shortcomings that may have occurred in projects; and to recognise any constructive practices. But, the Company B has not conducted projects reviews to date. Key individuals within the company (the Managing Director, and the PD manager) do most of the reflection and introspection within themselves, and they are discussed only to some extent.

Flexibility in staffing has been an advantage for the company from cost point of view. But it has not been adequately balanced with the other aspects such as placing a structure to operate, adequate mentoring programs, and procedure to retain knowledge.

**Analysis:**

One of the foremost steps in bringing about improvements is to understand the current status (assess, measure and define), and to build a ‘case for change’ (Kennedy, 2003). In most large-scale companies, several opportunities for improvement are ignored and lost due to the bureaucratic practices prevalent. In contrast, at Company B the reason for not conducting reviews were:

a) It recognises the opportunity, but are unaware on which systems to adopt for reflecting on projects (which technique, time required and resources to be committed).
b) Other ‘so-called’ important factors such as fire fighting in current PD projects, managing people, and other issues assume priority over understanding the past, or exploring improvement opportunities.

According to the Lean philosophy, the process of introspection or *Hansei* is very important for improving a process. Thus, due to the lack of any documentation on project reviews and previous projects within Company B, a decision was made by the author to choose two projects (X and Y) for live observation and conduct extensive interviews with PD manager on precedent and current projects.

## 5.6 Project X: An example of New Product Development

### 5.6.1 Introduction

Project X was a new Product Development project that began in 2006 after the Managing director recognised an opportunity for Company B to increase its market share by challenging a competitor's product. This product belonged to the 'The' category and was planned to use new technology in its core mechanisms, in addition to several "first-in-the-world" features.

This project was selected for investigation as a part of this research as it was one of the major in-house projects that had begun in 2008 and was planned to close by October 2008. It was an opportunity to observe the day-to-day happenings in the project and map the process flow (with sub-tasks) clearly.

### 5.6.2 History: Product Development for product X since 2006

The product X was targeted for development as early as May 2006. The Managing Director of the company, Mr.JC identified an opportunity to "capture 20% of the current world market" by incorporating new technological features and enhanced performance such as reduction in size, etc. The first 'idea document' mentioned two aspects of this new venture: the goal and the key product features in the form of bullet points. This document was used to investigate the related patents, and the new technology that was planned for this product, with the help of a contract designer and a supplier. In February 2007, a comparatively detailed brief stating the goals, details of product features, business objectives, key dates, the details of investigation conducted by the supplier and contract designer, costs, and a decision to hand over the project to external design contractors.

The external design agency that took up this project built a 21month schedule (starting May'07) that included the design and testing, until the post-commercialisation stage for project X. However, by December 2007, this design agency failed to keep up the schedules and costs as per the contract (refer Appendix E1). In addition, there were several areas that finally resulted in terminating the contract (As per discussion with PD manager and contract agreement document), such as:

- The original project duration planned was too long,
- Too many design concepts presented even after two stages of the design process,
- Delays in providing required drawings,
- Design agency's lack of transparency about the design work being carried out for Company B,
- Lack of information sharing from the design agency that would benefit of project X,
- Unsatisfactory results on basic product features such as simplicity, accuracy, size, uniqueness, etc.

### 5.6.3 Observations: April'08 to October'08

The Project X was taken in-house after it failing to progress with the external design agency. One of the first and foremost activities conducted was to rewrite the product brief. This new brief was rewritten in a new format suggested by the newly appointed PD manager, and this covered additional topics such as market and customer details, the servicing, packaging, and recycling aspects, the testing, manufacturing, and intellectual property issues. The project was now scheduled with three on-site and two off-site designers working on Product Development, and was planned for handover to production in October 2008. The fieldwork conducted as part of this research project observed several tasks and activities as a part of Project X design and development (refer Appendix E2). These include:

A. Observing discussions in PD department (Observing internal meetings),
B. Discussion with contract designer,
C. Observing the process of prototyping,
D. Emergence of Legacy issues and how it affected Project X, and observing an emergency meeting,
E. Conducting workshops to map the current PD process (overall, stages 1-4)
F. Discussion with PD manager on knowledge database,
G. Redesign of the Product X (major loop back),
H. Observation of Optics and discussion with optics designer

A. Observing discussions in PD department (Observing internal meetings):

The PD department at Company B has a very informal atmosphere. The department is consisted of an office area, a workshop area for prototyping, a testing room, and a mini storage space. The people at the department are provided with computer systems to carry out design work, and the workshop consists of spare parts and production samples that are used for effective prototyping and modelling. For the purpose of project X, several internal meetings took place, which were timed just before the stage-gate review. For example, the internal meeting before stage 3-gate was held four days before the due date. Most of the communication (intra and inter departmental) is verbal and at different points of time during the day as the situation/ project demands.

**Findings:** The internal meetings were generally carried out for reviewing the design work done by the individual designers at the PD manager level. The discussion goes through every minute detail of the design, and suggestions for redesign were discussed.

**Diagnosis:** Upon analysis of the observations at the meetings, the following emerged:

- During these meetings certain simple suggestions come up from members of the team and PD manager, that will result in the redesign of the parts,
- In some cases, the redesign is small scale and is completed within the timeframe; however there were certain changes that caused the design work to lag behind by several days.
- The individual designers have to wait for these internal discussions to sort out grey areas and clarifications from the PD manager, which can be avoided by using simple ‘Obeya’ room option of Lean PD (Ward, 2007).

B. Discussion with the on-site contract mechanical designer:

A discussion with the on-site contract mechanical designer was conducted to understand the major criteria considered for design, the constraints faced, and the enablers for design.

**Findings:** The set deliverables were worked on in bits and pieces during the stage, and were pulled together just before internal meetings. The main criterion for design was the trade-off between the specification set in the product brief, and the time available between gates.

The constraints for conducting design work according to the designer include lack of systematic integration with suppliers and the other departments, restriction on creative thinking (due to rigid specifications set in the brief), inadequate knowledge about the previous products (features, function, manufacture, operation, assembly complications), lack of direct interaction with end user to understand requirements, etc. Although, the contract designer discusses interface issues frequently with the Industrial designer (on-site), he is unable to meet the mechanical designer (off-site) working on the other half of product design. The other points mentioned by the designer as possible enablers include more frequent interactions with PD manager and other team members (will avoid rework), training on skills for better ideation, advanced training on software (such as Solid works), knowledge sharing among the team members, improvements in ergonomics of office layout, and establishment of a process system.

The enablers listed include the innovative environment and passion for products existing in the company, the accessibility to the shop floor to understand production requirement, interaction with on-site co-designers for inputs on ideas and for problem-solving, the flat organisation structure supporting easy discussions and general communication, and a good rapport with cross-functional department personnel.

**Diagnosis:** The discussion with mechanical designer was conducted during the concept refinement stage (stage 3) and the focus was on understanding the 'people' issues with respect to project X. The analysis of the discussion is as follows:

- Rigid specifications seem to restrict creativity at the PD department in Company B,
- According to Lean PD, specifications show the range for development and ideation and not specify exact measures (Ward, 2007). This provides a platform for the practice of Set Based Concurrent engineering,
- The designer feels that deliverables can improve with time, accuracy and experience matter, and will avoid rushing towards things by constricting ideation,
- Training and standardisation has been requested by the designer in order to improve the efficiency and learning.

- Most of the constraints explained above are a result of inadequate 'mentoring' from the Managing Director and PD manager due to time constraints. The knowledge existing within the company is stored primarily within individuals, which is a constraint for overall success of PD.
- As Ward (2007) explains, in a Lean enterprise the three behavioural requisites from PD personnel are: responsibility, teamwork, and expertise. The contract designer has been given the responsibility and the deliverables were mentioned. However, the enablers such as interaction with PD manager, teamwork, and mentoring were found to be inadequate. In many cases, the designer waited for the PD manager for clarifications at certain points before proceeding further on design, which is '*muda*'.
- Another important factor for effective Product Development is the tool used for communication. At Company B, we can observe that the main means of communication has been oral, and through e-mails. But in a Lean enterprise tools such as A3 reports, visual information (graphs), and conducting effective meetings are preliminary (Ward, 2007) for knowledge to grow.

<u>C. Observing the process of prototyping:</u>

The process of prototyping was conducted during the stage 4 (in May 08) of project X. The PD manager was in-charge of building two rapid prototypes for testing of optics component developed by supplier in Europe. In total three models were being built, the third one kept in-house for testing by on-site designers. The process was observed in a small workshop that is present within the R&D area, where different parts (spare) and tools are stored for the purpose of prototyping and modelling.

The highlights of this process include use of previous product's parts (that had similar dimensions), the planned number of hours much lesser than the actual time it takes, and the trial-and-error method employed. The PD manager plans the prototyping activity for one day, but it takes four working days and two non-working days, while the supplier waits. Initially the first prototype fails due to use of wrong parts (assumption busted). The manager takes almost two days to come-up with another idea to build the prototype, but the PD manager is unable to spend time to try it for another two days due to other priorities. Thus, on day-five the new idea built into first prototype is tested and verified. This time, the prototype works, and then the manager build the other two. When the prototypes were sent to the supplier, there was no confirmation on the duration required by the supplier for completing testing in their company.

**Diagnosis:** The process of prototyping is one of ‘trial-and-error’, but within reasonable limits. The process of prototyping described above shows the clear lack of brainstorming sessions, teamwork, and systematic problem-solving skills. In small companies such as Company B, individuals take several decisions, and the scope for teamwork or extensive discussions is very minimal due to resource constraints. The following are the comments after analysing the prototyping process with respect to Lean Product Development practices:

- The lack of documentation on the process of prototyping and problem-solving,
- Lack of discussions with other designers (especially the on-site contract mechanical designer),
- The prototypes waiting for PD manager,
- The process is completed and there is documentation done after it to capture the details of what worked and what did not during the process of prototyping.

D. Emergence of Legacy issues and how it affected Project X:

During the months of June, July and August 2008, the PD manager received repeated requests to sort out the problems related to previous years projects and other supplier issues. Some of these ‘legacy issues’ have been described in section 5.9. The result of the issues was an impact on the PD resources available for carrying out project X. Hence the project X was declared delayed by three weeks in July 2008.

**Diagnosis:** The nature of PD is variation and the result of designing without adequate knowledge will result in loop backs and rework (Kennedy, 2003). This is applicable to both project X as well as the previous year’s projects.

E. Conducting workshops to map the current PD process (overall, stages 1-4)

One of the primary reasons for choosing project X was to conduct process mapping of tasks related to each phase of the PD cycle at Company B. During the months of July and August, three workshops were conducted with PD team members to map out the various activities, the related documents, the people involved, the criteria; and then it was diagnosed by discussions on possible improvements. The Appendix E2 shows the maps for stage 1 till 10, with details provided only for stage 1 to 4. Project X did not continue its journey beyond Stage 4 as per schedule due to the major loop-back; hence the blank formats for stage 5-10 have been attached as-it-is for these.

The activity of process mapping and diagnosis was undertaken for the design team to reflect on the process followed, and the possible improvements at each point. Ultimately, it was useful in convincing the PD team at Company B that the various improvements targeted at individual shortcomings were only temporary solutions and the problems were interrelated. Thus, an altogether new way of thinking such as Lean Product Development was required to optimise the process.

F. Discussion with PD manager on knowledge database:

Company B does not carry documentation on PD. The knowledge and expertise has been imbibed within the design, and is stored within individuals. A discussion was held in August 2008 with the PD manager to understand the systems existing for knowledge capture and the importance given to this aspect.

The existing forms of knowledge stored (software or paper) include CAD drawings, testing results, standards, communication with certification agencies, etc.; and all have been organised product-wise. The company recognises the importance of having a knowledge database.

**Diagnosis:** Like most traditional companies, Company B does not recognise the existence of the 'knowledge value stream' (Ward, 2007).

G. Redesign of the Product X (major loop back):

As discussed earlier, the project X was running late as a result of unavailable resources. During August and September, the PD department faced several issues related to Project X that resulted in a major loop back. Some of these issues are described below:

- The prototyping budget for the electrical components has been spent, and the final design is still not completed. The root cause was the fact that the concerned engineer has so far designed and redesigned the electrical component at least four times, every time asking

Company B to go ahead with ordering the samples. Effectively having spent thousands of dollars on the prototypes (all scrap now) and not obtaining constructive results.

- As discussed in earlier section, Company B entered a discussion with a supplier of key components for project X as early as 2006. In spite of 2 years of co-development, the supplier has been able to meet the product requirement only partially. The supplier has been able to develop the right component, but at a very high price. This affects the overall cost of the product and hence the Managing Director of Company B decides to abandon the idea of using the specialised part developed by the supplier. Instead, the PD team goes through another round of redesign for other parts (the mechanical design), to accommodate a standard part in its place.
- A visit by PD manager to the largest potential market for product X resulted in an important, but appalling discovery for the Project. The product X was being developed for the purpose of increasing market share. However, the largest customer suggested that the features developed thus far make product / project X a niche market product, and hence cannot be purchased.
- The Product Development until September suggests an increase of 40% on the final product price. Thus, this led to a basic question of product positioning and potential customers.

Overall, the PD Manager summarised as follows: "*Project X will not be able to meet the October deadline…. nor the launch date. The delay has exponentially grown (along with the existing 3 weeks delay); because of the rework of Mechanical design, the testing results for prototyping, tooling delays, the growing complexity of product, and the time diverted to settle urgent legacy projects and engineering changes. In fact, my time spent on project X has decreased by 10 times due to legacy issues…*".

**Diagnosis:** Loop backs are normal in a PD process; the only difference is that traditional process set-ups do not plan for it. The design-then-test sequence would lead to loop backs in most cases. In addition to this, if other issues (such as the legacy issues described in the next section) snatch prime resources, it could not be any worse. Buffer staff is an option for many companies to looking into unplanned activities, but not for SMEs.

H. Observation of Optics and discussion with optics designer

As a part of the discussion with the various designers, a discussion was held with the contract designer working on the core systems of optics. The following is an account of observations in October in the testing room:

The designer was conducting tests on one of the three important aspects of design in optics. The objective was to check if the changes made in ‘a’ would increase life of ‘b’ component.

**Observations:** The component representing ‘a’ being used for testing is different from the actual component that will be used in the final product. Although all competitors are using the actual component, Company B has no experience on using them yet. In theory, the actual component should perform better than the testing component. And the entire optics system will be designed around this new component. Although the designer faces challenges (such as parts breakage several times) because of using representative components instead of the actual components for testing, the relationship between the performances of the product to the test results were coming along “in theory”.

**Diagnosis:** The following can be inferred from the observations and the discussions held with the optics designer:

- The knowledge of new technology being developed for a particular project for the first time.
- R&D component (research) not carried out independent of project and the knowledge was not being captured,
- Companies making the components being pushed to explore new technology in a short time period,
- Exploration of cost – effective and quality supplier not done systematically and in advance,
- Assumptions by using representative components lead to failure,
- Need to eliminate rework (re-testing due to breakages),
- Standard A3 reports should replace the ‘Test results” sheet via mails as circulated by designer. These A3 reports will be documented for the future purposes in a simple and effective way.

### 5.6.4 Analysis of findings

The observation of project X shows that the problems emerge out of root causes that have been recognised under the Lean PD approach. Almost every project in the past has had these problems, according to the PD manager. These issues are usually blamed on two main unchangeable aspects within the company:

- The small size of the company,
- The resource scarcity in the PD department.

The very next argument to this is 'whether nothing can be done about it?' As a learning organisation, Company B is confident that there has to be a solution to their recurring problems. The key learning from the observation of project X were as follows:

- The lack of communication between in-house and external design engineer can be sorted by use of simple '*Obeya*' room meeting practice, and the exchange of A3 reports of status as part of Lean PD,
- Specifications to show the 'range' for development and ideation (technical and commercial of new products) can be done using Set Based Concurrent engineering,
- The flexibility and in-build improvement cycles of LPD approach will address the problems seen in project X of unplanned loop-backs.
- Short-term approach to fixing internal problems with standard PD solutions would only be temporary, since the problems observed were interrelated.
- Like most traditional companies, Company B does not recognise the existence of the 'knowledge value stream'.
- Delay in Project X became inevitable, this affects the launch date, and hence the customer commitments.
- R&D collaboration with suppliers and production needs to be improved.

Overall, observation of Project X has surfaced several problems related to the PD internal and external areas. In addition, Company B decided to use the SOP drawn as part of this project (Stage 1-10 as per Appendix E2) until the new LPD process or framework is developed.

## 5.7 Project Y: An example of upgrading project

Project Y was an upgrading project planned for 2008 by the company, in-order to come out with an improved version of their existing product. The Product Development team was planned to work on it from November 2008 till April 2009. The user research stage of the project was observed as part of this research study.

### 5.7.1 User research for the product:

The front-end of a Product Development project is one of the most crucial phases. This determined most of the criteria that would enable a successful product launch. As part of the user research stage, Company B had planned to visit customers in local markets and capture the specific needs in each region. In the past the company's Managing Director had completed an initial survey during the opportunity identification stage.

The design team was given the task of conducting a detailed user research with the assistance of the market managers. This was one of the few occasions when the design team was encouraged to meet the end customers. The criteria to be researched with the customer included:

1. Issues faced by end users with the existing model,
2. The issues faced by rental companies, which cater the products to the entertainment industry,
3. Discussion on improvements perceived by the company.

### 5.7.2 Discussion:

The customer interests have to be captured accurately for the PD project to progress and the product to succeed. The Lean PD system encouraged the involvement of technical experts in collecting customer needs with the establishment of the chief engineer system. In addition, the LPD system encourages the use of customer interest A3 reports to systematically collect the information required, to communicate well and to store the knowledge for the future.

During this stage of the research work, it was observed that the company had begun to be more receptive about the LPD approach. It emerged that the user research for this project can integrate some of the simple Lean thinking techniques.

## 5.8 Legacy issues

As discussed in section 5.3 on the PD workforce, unplanned work has a huge impact on the actual design work that can be carried out. Unplanned work arises mostly in the form of problems from previous projects, production and customer issues; which ultimately consume the time devoted for current projects. Here are some examples of ‘Legacy’ issues that were observed during the fieldwork duration at Company B:

I. <u>Tool breakage at Contract supplier’s manufacturing facility:</u>

*Problem:* The contract supplier who does the stainless steel brackets for company B’s products generates lots of scrap pieces (almost 15,000 to 20,000) every time. Company B receives the scrap along with the brackets, and it has to pay for the total material and labour.

*Temporary solution:* PD company can just sell the scrap and claim the money for the steel, but it’s a waste of time and effort for the Company B.

*Root cause analysis by the PD manager (May 2008):* The reason for so many scrap pieces is the tool breakage at the supplier’s machine shop. The tool used by the contract supplier is a standard tool made of hard steel (in China). So, the reason for tool breakage is not the quality of tool itself, but the machine used by contract supplier. The machine is manual and outdated, and this causes the life of the tool to drastically reduce.

*Suggestion to Contract supplier from PD manager:* The machine to be replaced to avoid tool breakage, and will work in the supplier’s favour for future orders. But the contract supplier is unable to commit to this suggestion.

**What Company B decides to do:** Make an order for the brackets to the Chinese tool manufacturer. This will allow the tool and bracket to be manufactured in the same facility and the integration will be simpler.

II. ‘The’ category: B type product fails tests conducted by an Independent standards authority.

*Problem:* The rejection from the international standards authority as the product temperature exceeds the lamp rating used in it.

*Root cause analysis by the PD manager (July 2008):* The lamp manufacturer has mentioned the lamp rating as 250°C, but the product heats up to 300°C. Tests conducted within the company (using methods similar to the international standards authority) showed that the product heats up to 250°C only, and hence the product was passed on to obtain a certification from the standards authority.

*Solution:* Company B has to either use a lamp that is officially rated for 300-350°C or the PD department has to reduce the product temperature to less than 250°C.

**What Company B decides to do:** At this early stage, the company decides to pursue both options, to see which one will work out easily for them.

III. Electrical circuit/ fitting breakage during production

*Problem:* One of the products designed in previous years had begun production in 2008. The electrical circuit breaks during assembly and testing of the product. Hence the production of these units has been suspended for the past two months, and the customer is waiting.

*Root cause analysis by the PD manager (July 2008):* The fault lies in the switch board/ electrical unit, and this has to be replaced with ones from a different supplier.

*Solution:* Since these units are standard one, the search for new suppliers may not take a long time.

**What Company B decides to do:** The PD manager treats this as a pressing need and a serious problem, and decides to spend time to choose correct supplier rather than work on Project X.

IV. Project WW: Product has wrong lamp base

*Problem:* The lamp base used in the Product WW (designed 2 years back) is not rated to mount a discharge lamp.

*Root cause analysis by the PD manager (July 2008):* Unknown details of the design that was conducted two years back, and no documentation found, so the current PD team decides to understand the design done on this product and then suggest a replaceable lamp holder quality and order so that production is not affected.

*Solution:* Investigation has to be conducted.

**Analysis:** Such legacy issues have been occurring every year even in the past (as per discussions with PD team). These problems are accounted as the 'unplanned' work, and the PD team does not document the event after successfully solving the problem. Since, every time the problem is different and in most cases the constitution of the PD team would have changed; it leads to the 'discarded knowledge' waste (Ward, 2007).

The first (I) issue explained above on the tool breakage is a result of the supplier's slack problem solving skills, that allows it to pass on the cost of the problem to its customers. Supplier relationship management is a key function that helps the company to select suppliers carefully based on technical capabilities, negotiate the terms and conditions that help both parties, maintain long term relationships by helping each other in times of crises, etc. In spite of the shortage of people within the Company B, the PD manager has spent time to identify the root cause and suggest a solution. Although Company B has made this effort; the supplier has not been proactive in discussing it.

The issue discussed in II is related to 'communication barriers' and use of 'poor tools'. At Company B, the importance given to international standards and testing has increased in the recent past, but, the level of understanding on the details of testing procedures have to be looked into further. Since customers are increasingly demanding for 'certified' products across the world, the compatibility between the testing procedures in the two organisations has to become a priority for Company B.

The issues discussed in III and IV occurred as a result of not capturing knowledge during previous Product Development.

## 5.9 Supplier involvement in Product Development

As it appears from initial studies at Company B, the supplier collaboration is a vital factor for their PD success. In view of this, a brief study was conducted on two suppliers of Company B, i.e. ABC engineering (interview conducted in August 2008) and XYZ technologies (visit to the facility in October 2008).

### 5.9.1 Interview with supplier: ABC Engineering

ABC Engineering is a NZ based manufacturing company that specialises in the design and manufacture of industrial enclosures and fabrication of custom subcomponents. Company B purchases a small percentage of the sheet metal components from ABC engineering. According to Company B, ABC engineering carry out very good design work, with good quality, are "*extremely enterprising and proactive to customer needs*". ABC Engineering has always been willing to discuss Company B's ideas and specific requirements. They were chosen for this study based on this feedback from Company B. The objectives of the interview with ABC engineering were:

A. To understand the operating environment (external and internal factors) of ABC Engineering
B. To discuss a Supplier's Viewpoint on Company B's R&D systems.
C. Comments on 'Lean Product Development'

The interview questionnaire consisted of queries on basic PD elements in small companies, its understanding of supplier-customer relations, its relationship with Company B (positives and negatives) and comments on 'Application of Lean PD' in SMEs (Refer Appendix G).

This interview with one of the chief technology officers revealed the following:

A1. Small enterprises operate in a 'make-to-order' environment where, they are dependent on the customer for the design of the part ordered. The company's PD team only uploads the design on the CAD/CAM system to generate the instructions to the production. The Small enterprises are seldom involved in the design of parts for their customer's products. Significantly unique about the small scale enterprises in that most percentage of their business lies on fulfilling customer orders and only a small percentage (25%) of the business involve design of new products.

A2. Most of the small enterprises have one or two persons working on Product Development. These are skilled engineers, but often end up doing multitasking due to the size of the organization and resource constraints.

A3. Some of the concerns expressed at the discussion are:

1. It could be a win-win situation, if the company's designers are involved in designing the parts they make for the customer.
2. The labour and material costs are always increasing, leading to cost pressures. They are forced to pass this on to their customers most of the times.
3. Fragile Supplier ~ Customer relationship is affecting long-term success of both organizations.
4. Inadequate sharing of knowledge between the supplier and customer, resulting in redundant development, high costs for both entities.
5. Lack of clear understanding on production issues, causing design complexities.

A4. There are no 'new products' that are designed at ABC engineering, nor is any kind of formal PD process required for small-scale developments.

A5. Most of the design work done at ABC Engineering is documented and organized in a systematic way. Traditionally, most of them are stored in the file system, but in the recent past, a software database is being developed. However, the 'Practical Personal Experience or PPK' is lost most of the time along with employee (like most other SMEs). As long as the, people are present, there is high interaction between departments, sharing of knowledge and communication. In-addition to this, kaizen is actively encouraged in ABC Engg.

B1. ABC Engineering strongly believes that in order to face current day and future challenges for SMEs, its very important for the companies to join hands with more trust and communication. The present system of simply "customer gives drawings – we just make it" will become inadequate and will impact growth of NZ Industry. Even if a collaborative effort is being made, only one of the several suppliers (short listed and asked for quote) is selected, leaving the others with loss in cost, effort. Product Development that goes hand-in-hand for design optimization is never seen. Thus, according to ABC engineering: loyalty, true partnership, involvement of suppliers in design stage of products is very important. The benefits from this include, optimizing of time, effort and cost in the PD system.

B2. ABC Engineering feel that Company B should focus their attention on developing long-term relationship with suppliers like themselves, who are willing to participate actively for establishing Lean systems.

As ABC contribute only a small percentage of Company B's business (and probably other reasons), ABC hardly ever gets an opportunity to understand Company B's products. In spite of this, Company ABC recognises that Company B products a high brand power, excellent technology and performance. Again, Company ABC personnel have observed that Company B is one of the very few companies that actively engage with customers to listen and care.

B3. Currently, Company B only specifies the part it requires from ABC and the design is completely decided by R&D at Company B. Company ABC work toward fulfilling that requirement in the best possible way that they can (although sometimes they do not understand part interfaces and function of part in final product).

B4. ABC engineering recognises the following strengths of collaboration with Company B:

- Very responsive to customers, excellent products at Company B,
- Superior design capabilities at Company B,
- Long term relationship to benefit ABC engineering significantly, and
- Commitment shown by leadership to improvement initiatives such as Lean Manufacturing.

The weaknesses were listed as follows:

- Inadequate insight for suppliers into the various products and functionalities of Company B,
- Company B does not learn a lot from suppliers,
- Company B has great potential to expand its business, they must recognise it.

B5. ABC engineering believes that "Trust" is the only criterion that can ensure a long-term relationship between suppliers and customers.

B6. ABC engineering feel that by integrating suppliers in the PD process, Company B can ensure optimization of design and manufacturing. It will also bring about openness in relationship and enhance problem-solving skills within both companies.

C. ABC engineering believes that Lean Product Development will work in SMEs and the following maybe some challenges and enablers: Small companies struggle on allocating resources for Lean PD.

A 100% involvement is easily achievable in SMEs and this should be the way to deploying such an important change.

"*Advantage with SMEs in deploying Lean PD is the 'Leadership' aspect. Especially with Company B, JC is committed and there could be nothing better than such a visionary and hand-on leader like him...*"

### 5.9.2 Visit to supplier's facility XYZ Technologies

XYZ Technologies is one of the largest privately owned injection moulding companies in NZ. XYZ Technologies were seen as one of Company B's strongest contenders for making the complete plastic body for product X.

The Managing Director of the company visited Company B to hold preliminary discussions about Project X in October 2008; which was followed by a visit by Company B design team the following week to the facility of XYZ technologies.

The following is a summary of the two discussions held:

- Mostly technical aspects were discussed: with the help of rapid prototypes and CAD drawings, design interfaces were explored. Aspects were categorised as 'doable' or 'unfriendly' by the supplier.
- The supplier suggests design changes such as size of screw holes, widening cress cross beams, angles, flanges, etc.
- Discussions were held on the type of material that can be used and the properties of these (the supplier is an expert on plastic moulding), it becomes apparent that Company B does not understand moulding problems. Eg: Designers at Company B make certain designs treating metal and plastics as the same, the supplier explains that the use of screws in metal is ok, but in plastic it tends to focus the heat.
- Discussions occurred on some macro aspects of future product possibilities at Company B, and how XYZ technologies can contribute.
- Designers at Company B observe firsthand the moulding of plastics, and look at the moulding problems faced by the supplier during their visit to XYZ manufacturing plant. The designers

then gained a clearer picture of the various design changes suggested by the supplier, and how it would benefit both companies.

### 5.9.3 Struggling supplier: Company AX

Company AX has three major divisions: the die-casting, the engineering and the plastics component manufacturing. It has been a supplier to Company B for several years now. Due to the recent transfers in manufacturing operations of large NZ companies to Asia, Company AX has lost several major customers, and the company relies on smaller companies such as Company B for orders today.

However, management control, planning and scheduling have become slack and problematic at the Company AX today due to apparently unknown reasons. A current order from Company B has had a three-month delay from Company AX. The R&D at Company B has made an effort to help Company AX's production group initially by providing a scheduling document for better planning, but has been of little use. Company B then took the issue up to the top management level of two companies, checking for underlying reasons to discover that Company AX had problems related to unbalanced workload in the shop floor leading to machine waiting times. Company B has hence been unable to bear the consequences of such large delays from a supplier, and has decided to award future orders to other companies.

**Analysis of supplier relationship at Company B:**

The interview with ABC engineering and the visit to XYZ technologies have shown that most of the NZ based suppliers are technically competent, capable and confident companies. Discussions with *ABC engineering* reveals that there exists a moderate level of awareness on NZ SME sector within industry, on aspects such as design environment, the supplier-customer relationships, the workload management in PD, and the major concerns. ABC engineering also provided an unbiased opinion on the strengths and weaknesses of its existing collaboration with Company B such as the innovativeness and design expertise at Company B, the need for knowledge sharing, the need for long-term relationship, etc. It was encouraging to hear that the chief technical officer at ABC engineering was aware of the 'Lean Product Development Systems' (due to his previous experience at Company A which deploys LPD), and the viewpoint provided on its applicability to SMEs was based on practical experience.

*XYZ technologies* have developed high technical standards in a short period of time. Its contemporary facility is a motivating force for knowledge in both process and design in the plastics industry. The understanding gained by designers at Company B on some important aspects to be kept in mind while designing plastics has proved helpful for the product design. However, since the discussions and the visits have taken place after the detailed design of product X has been completed, the Company B designers are having to engage in “redesign”, which is a ‘waste’ of time and resource. As Morgan and Liker (2006) explains, Toyota chooses suppliers early on in the PD project, assures the order, and includes them as part of the extended PD team. Thus, Company B would have gained if selection of main suppliers (such as XYZ technologies) had been done before completing detailed design of the body of product X.

As explained in section 5.9.3, long-term supplier Company AX has been facing problems that have affected Company B in recent past. According to the Lean Product Development approach, Company B has to “work with new / struggling suppliers to get up to speed”, and the suppliers should not be punished if inconsistencies are found (Morgan & Liker, 2006). We can observe that Company B has tried to emulate these characteristics of Toyota-supplier relationship by helping AX out initially. But Company B itself being a small company with several resource constraints, it has been unable to devote the extra time required to solve problems at Company AX, and has ended up ‘punishing’ Company AX for the delays by deciding to disassociate with them.

This brings up a very basic question: Does Company B have the resources (time, people, technology) that Toyota has to “develop” suppliers by conducting step-by-step approach (testing several suppliers using sample orders, etc.)?

Or, even better Company B should ‘get their own house in order first, then go out and find the most qualified companies to partner with, working with them to develop compatible systems and procedures’ (Liker and Morgan, 2006).

## 5.10 Summary

In the traditional companies, the marketing and customer service departments collect customer needs (Liker and Morgan, 2006; Ward, 2007). However, as per observations at Company B and discussions with company ABC, the MD at SMEs actively engages in identifying opportunities, customer needs and potential markets most of the time. This is one of the several other instances that reveal that there are distinctions between the large traditional companies and SMEs. NZ based suppliers are technically competent, capable and confident companies, but lack resources and discipline when it comes to delivering on time. The study on the legacy issues has revealed that knowledge is not captured during or after projects and hence creates problems to the forthcoming projects as reuse and problem solving suffer.

In summary, the PD function at Company B needs to retain the aspects of simple communication, the lack of bureaucracy, the continuous improvement culture, the involvement of design engineers with production, and the effort given in incorporating suppliers. These are very important for effective innovation. However, these efforts at the company are mostly not influential enough. They lack the rigour, are sporadic, and hence need to be streamlined. As observed in the literature review most of the standard solutions influence individual PD elements, which would not suit Company B in the given circumstances. Over several decades large companies have used the standard solutions to cater to their improvements, but this has also resulted in "wastes" and heavy structure. The innovativeness at Company B has to be enhanced without adding too much structure. This fine balance of PD discipline and creativity has to be achieved in SMEs.

## CHAPTER 6

# DESIGN OF A LEAN APPROACH TO COMPANY B’s PRODUCT DEVELOPMENT PROCESS

# CHAPTER **6.** DESIGN OF A LEAN APPROACH TO COMPANY B's PRODUCT DEVELOPMENT PROCESS

## 6.1 Introduction

The research on applicability of 'Lean Product Development' to SMEs has reached its purpose in chapter 6. Here, the main research question on how the LPD system would work for firms with employee count between 50 and 250 has been answered. The specific details of the PD process, the people management, the knowledge capture mechanisms and the PD tools have been extrapolated to finally arrive at a framework based on Lean principles (refer to the 'Core' of the Figure 46)

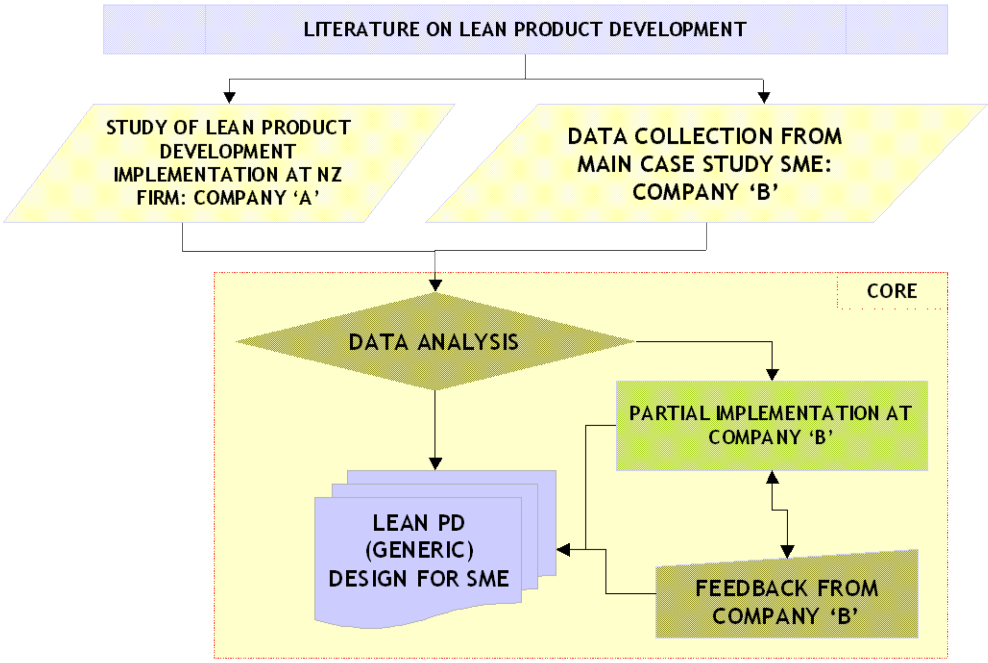



**Figure 46: Research plan and scope**

As discussed in chapter 2, the literature review reveals that there has been no research conducted on applicability of LPD to firms with less than 250 employees, which was a decisive gap prompting this research. Further, this research has particularly adapted the Lean approach to Product Development as explained by Michael N. Kennedy (2003) and Allen C. Ward (2007), due to the following two main reasons:

a) They are the only literature that covers fine details of the Toyota's Product Development system and evolves beyond principles and into a framework, and
b) It provides an implementation plan for traditional companies to make a transition, and an approach has been explained in detail.

Another important basis for this research work has been the book by Kennedy *et al.*, (2008), which describes how two companies across the world have begun the implementation of LPD with seemingly positive results, and the book also explains details of the 'lessons learnt'. Since the research on applicability of LPD to SMEs requires generation of a framework and a discussion on relevance of latest published approaches, the above-mentioned literature have been central references.

A survey would be of little use in this scenario, as there was a clear need for in-depth context rich data from SME environment. Thus, a case study approach was adopted. As an added bonus, one of the foremost companies implementing LPD in the world is situated in NZ, leading to the supporting case study for supplementing the LPD literature.

The data collected from the main case study Company B revealed some of the typical characteristics of SMEs (both positive and negative aspects) and the various types of problems faced by them in conducting PD. The PD problems in SMEs can be summarised into the following points:

- Informal truncated Product Development process,
- Resource constraints and a small team of designers / engineers,
- Ad-hoc sharing of knowledge across projects and lack of documentation,
- Unplanned loop backs and fire fighting are common in the PD cycles,
- Supplier / business partner integration problems,

Similarly, the positive characteristics can be listed as follows:

- Bureaucratic practices and un-important paperwork absent,
- Arrangement of PD personal in a flat organisation structure that allows good communication across the department,
- Quick learning attitude/ culture (from internal and external sources) across the company,
- A visionary and hands-on leadership.

The overall picture of data collected from Company B show that although SMEs have fairly different kind of problems (as discussed in chapter 2), they also have several characteristics and practices that support LPD systems (as discussed in chapter 5).

The important results of investigating supporting case study Company B have been the detailed understanding of the LPD process, the understanding of LPD tools, the matrix tool, the configuration of the knowledge database and the project selection process. Some of these details were requested by Company B, some were a result of the concerns observed at Company B by the author, and the remaining were provided by the Company B as examples on LPD system tools. Thus, the data from Company B supplements the literature and helps to design the LPD solution for SMEs.

The Lean approach for PD (based on the literature and supporting case study) was communicated and partially implemented in Company B, in order to understand whether the standard tools and process would work, and to recognise the weaknesses of Toyota's PD model (in the company B's viewpoint). An interview was conducted with the Chief Technology Officer at Company C (with 200-300 employees), to obtain concurrence with company B' viewpoint. Both these feedbacks were used to design a 'Lean design framework' for SMEs that may be used in firms between 50 and 250 employees. This framework also provides hints for possible solutions to the weak links.

## 6.2 Design and validation plan

As the nature of SMEs (with hands-on leadership and skills of PD team) plays an important role, the initial analysis and selection of right tools was an important and difficult process, but a necessary one. Thus, even-though the logic and approach designed for conducting the overall research was linear (as shown in Figure 46), the fieldwork actually evolved into a complex inter-related network of events that suited the study environment, as shown in Figure 47.

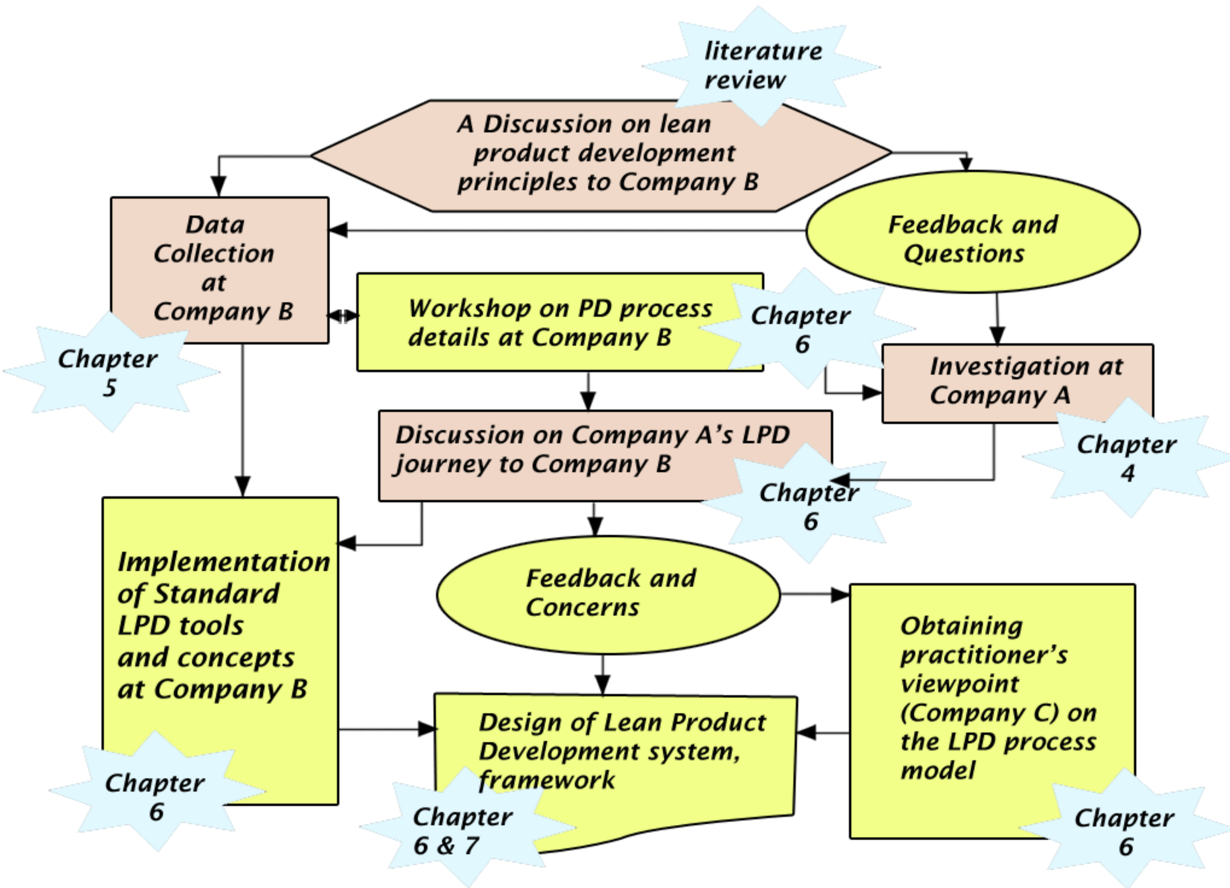



**Figure 47: Inter-relation between data collection, analysis, design and validation for LPD systems using the two case studies**

The initial presentation to the team at Company B resulted in a positive feedback and also a set of advanced questions that could be called "practitioner's queries". These were used as investigation points for conducting advanced studies at Company B. Data collection at Company A and Company B was conducted in parallel, and the findings were used to prompt the next round of investigation in most cases. Midway through a workshop was conducted at Company B on the PD process as understood from the literature and the investigation at Company B. This was the beginning of the actual "buy-in" on LPD at Company B. The workshop proved that the LPD details could be uncovered and made perfect sense to be followed. Some of the standard tools used for LPD such as A3 reporting, were implemented at Company B in-order to validate its usage in SMEs. Other simple, easily implement-able ideas/ concepts of LPD and other good practices were also adopted at the company, such as:

- Involvement of PD designers in user research,
- Documentation on CAD drawings, design concepts, testing results, and supplier details,
- Involvement of design team in production etc.

The use of these concepts has shown positive results. Although the tools used were in standard formats, the need for customising these to SMEs also emerged.

The design of LPD systems was done between October 2008 and January 2009, although the inputs accumulated during important junctions of the fieldwork and ideas evolved during discussions with various practitioners. In January 2009, an interview with the Chief Technology Officer at Company C (employs 200-300 people) was conducted to obtain a feedback on the LPD model that would help in fine-tuning it.

## 6.3 Knowledge sharing and validation on LPD at a SME

### 6.3.1 Workshop of Lean PD system at Company B

In May 2008, a brief overview on the LPD principles was presented to the key personnel at Company B. The intention of presenting literature on LPD was to furnish facts on the LPD systems, to communicate the methodology adopted for this research and to obtain a response from the company about the LPD system. The two main outcomes of this event were:

1. The understanding of LPD system, and
2. The reassurance of support to the research and its results.

Some examples of the feedback mentioned above are listed below:

- The Managing director, Mr.JC actively participated in the discussion during the presentation by providing some examples of wastes in the Product Development systems within Company B, and by sharing his knowledge about the LPD systems.
- The key managers of finance, operations, manufacturing, marketing, etc. posed questions that related to their understanding of Lean thinking, and tools such as Value stream mapping.

Some of the queries that pointed direction for further investigation were as follows:

- Information on the experts in this field and the popular models,
- How the supplier integration with PD occurs at Toyota, and

- How the actual transition occurs from traditional system to Toyota's PD systems.

### 6.3.2 Interactive discussion on Company A's Lean PD deployment details:

The presentation on Company A's journey into LPD covered aspects such as PD process, the people management, the knowledge capture tools, the approach taken and help received from the LPD experts, and the challenges faced. These details were presented in order to share information and findings of the investigation conducted at Company A. As discussed in the earlier section some of the investigation at Company A were a result of queries posed by Company B. Thus, this presentation was a knowledge sharing session in addition to an interactive discussion on its applicability at Company B.

The following feedback was received on the presentation:

- Key members of Company B pointed out that the 'approach' taken to the LPD system was suitable for large-scale companies. For example, Company B feels that it would be impractical to allow all engineers to attend training on LPD for several days, as it would affect their overall business.
- The supplier integration aspect is a very essential aspect for SME business, hence information on details of Company B's supplier / business partner collaboration would be extremely helpful,
- The organisation structure (i.e. the chief engineer system) cannot be applied as-it-is in SMEs due to the small team of designers, and
- The impact of resource constraints (of SMEs) on building a knowledge sub-system is considered huge.

Another important concern raised by Company B was the affect of "reuse" on innovation. They believe that the level of innovativeness for a small company is fairly high compared to large companies such as Toyota, and that the reuse of concepts may cause the company to fall behind in competitiveness.

### 6.3.3 Testing of Lean PD tools and concepts at Company B

One of the simplest and most powerful ways of confirming if a system will work in a particular business scenario is the implementation of some of the new system tools. In case of Company B, the A3 reports were understood by most of the R&D personal and were used in two separate cases to observe its acceptability and applicability.

The testing of standard LPD tools and techniques, and the Lean PD thinking as described by Ward (2007), Kennedy (2003) were tested at Company B to obtain feedback on whether they require modifications. The acceptability of these at Company B (and other practical constraints such as time, opportunity, etc.) guided the implementation process. The inputs obtained from studies at Company A were also used to guide the testing. The process of validation of LPD tools at Company B was logical:

a) Use simple tools such as A3 reports,
b) Make engineers to participate in the user research process, and
c) Allow collaborative research.

Similar methodology has been described in Kennedy *et al*., (2008, pg 124). [The third simple step of 'removing knowledge gaps before design' described in the book was beyond the scope of this project timeline]. The aim of the research is to build a framework and a PD system for Company B that is based on the standard LPD solution, with the help of inputs from Company A. Hence, the testing was done at a macro level, with no initial framework, tools, processes used for testing.

a) Use simple tools such as A3 reports,

Figure 48 shows the A3 report generated by the R&D engineer and moderated by the author. The A3 report deliberated on the problem of 'mirror cracking' in Product F. A standard A3 format with fields such as theme, background, current condition, cause analysis, target condition, implementation plan and follow-up was used. As discussed earlier, the A3 is written with the help of the LAMDA process, which enables the engineer to encompass all elements of the problem, ensure deep thinking, and in a systematic manner.

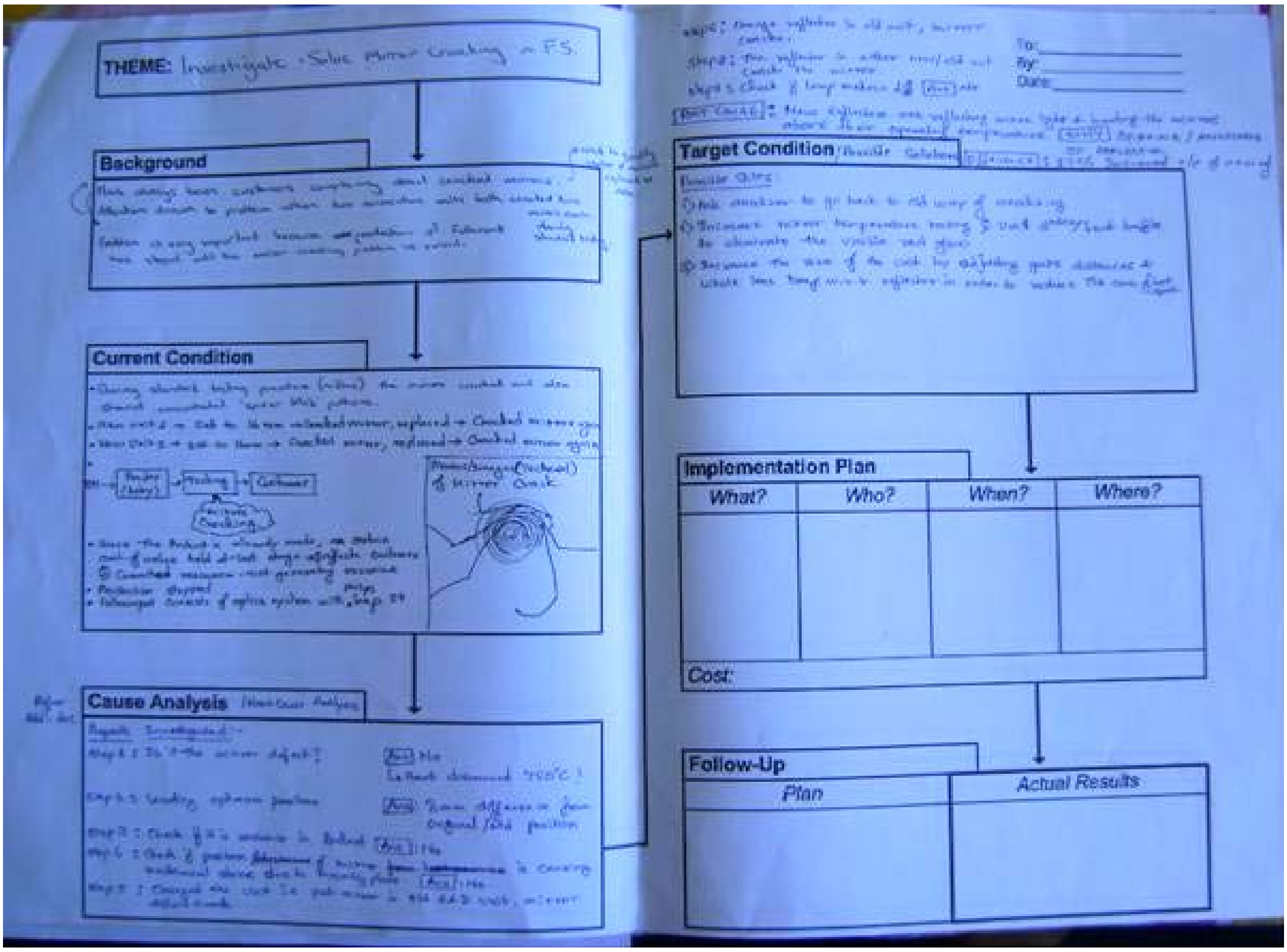



**Figure 48: A3 report for problem solving (also refer Appendix E)**

The writing of the A3 report progressed till the target condition (or possible solution) stage with the help of the engineer conducting most of the tests. However, it was later revealed that the R&D manager was taking certain parallel problem solving steps and that the A3 report being written was missing in several vital details. This also showed that parallel investigations occur for problems and the communication between members needs to be improved. However, this also suggests that multitasking at Company B has resulted in shared responsibility. The A3 report will allow capture of all the details in one location for present and future reference.

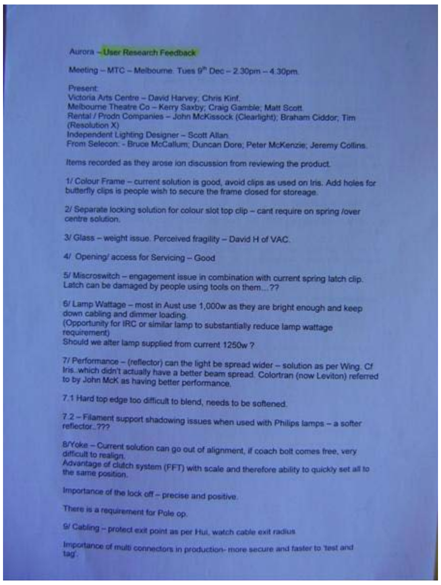
The process of writing an A3 for the first time turned out to be time-consuming, but rewarding in the end. As a result of this exercise, the engineer handling the problem was able to clarify his process of thinking, able to document and communicate better to the PD manager and concerned personnel on the topic, and was able to explore all solution options without fearing about losing the way. The R&D manager was able to later incorporate details. Overall, the A3 report worked well when used in a SME and would work better when practiced in a methodical way.

Other simple, easily implement-able ideas/ concepts of LPD and other good practices were also adopted at the company, such as:

b) Make engineers to participate in the user research process:

For the project Y, the user research document and the user research process was designed and conducted by the PD manager alongside the Managing Director for the first time in the history of Company B. The user research A3 document was prepared during a workshop conducted by the author with the PD manager. Figure 49 shows the initial user interview document that covered only the existing customers, and list of technical problems for the up gradation of product Y. Figure 50 shows the 'Overall customer interest A3' that contained details of customer category, list of major customers, competition, market volumes, investigation plan, questions for the customer etc., which were designed based on the LAMDA cycle.

This step helped Company B by allowing the technical specifications to be understood better and more quickly compared to previous projects.



Aurora – User Research Feedback

Meeting – MTC – Melbourne. Tues 9th Dec – 2.30pm – 4.30pm.

Present:
Victoria Arts Centre – David Harvey; Chris Kinf.
Melbourne Theatre Co – Kerry Saxby; Craig Gamble; Matt Scott.
Rental / Prodn Companies – John McKissock (Clearlight); Braham Ciddor; Tim (Resolution X)
Independent Lighting Designer – Scott Allan.
From Selecon: - Bruce McCallum; Duncan Dore; Peter McKenzie; Jeremy Collins.

Items recorded as they arose ion discussion from reviewing the product.

1/ Colour Frame – current solution is good, avoid clips as used on Iris. Add holes for butterfly clips is people wish to secure the frame closed for storeage.

2/ Separate locking solution for colour slot top clip – cant require on spring /over centre solution.

3/ Glass – weight issue. Perceived fragility – David H of VAC.

4/ Opening/ access for Servicing – Good

5/ Miscroswitch – engagement issue in combination with current spring latch clip. Latch can be damaged by people using tools on them….??

6/ Lamp Wattage – most in Aust use 1,000w as they are bright enough and keep down cabling and dimmer loading.
(Opportunity for IRC or similar lamp to substantially reduce lamp wattage requirement)
Should we alter lamp supplied from current 1250w ?

7/ Performance – (reflector) can the light be spread wider – solution as per Wing. Cf Iris..which didn't actually have a better beam spread. Colortran (now Leviton) referred to by John McK as having better performance.

7.1 Hard top edge too difficult to blend, needs to be softened.

7.2 – Filament support shadowing issues when used with Philips lamps – a softer reflector..???

8/Yoke – Current solution can go out of alignment, if coach bolt comes free, very difficult to realign.
Advantage of clutch system (FFT) with scale and therefore ability to quickly set all to the same position.

Importance of the lock off – precise and positive.

There is a requirement for Pole op.

9/ Cabling – protect exit point as per Hui, watch cable exit radius

Importance of multi connectors in production- more secure and faster to 'test and tag'.

**Figure 49: Company B's 'initial user interview' document for project Y (also refer Appendix E)**

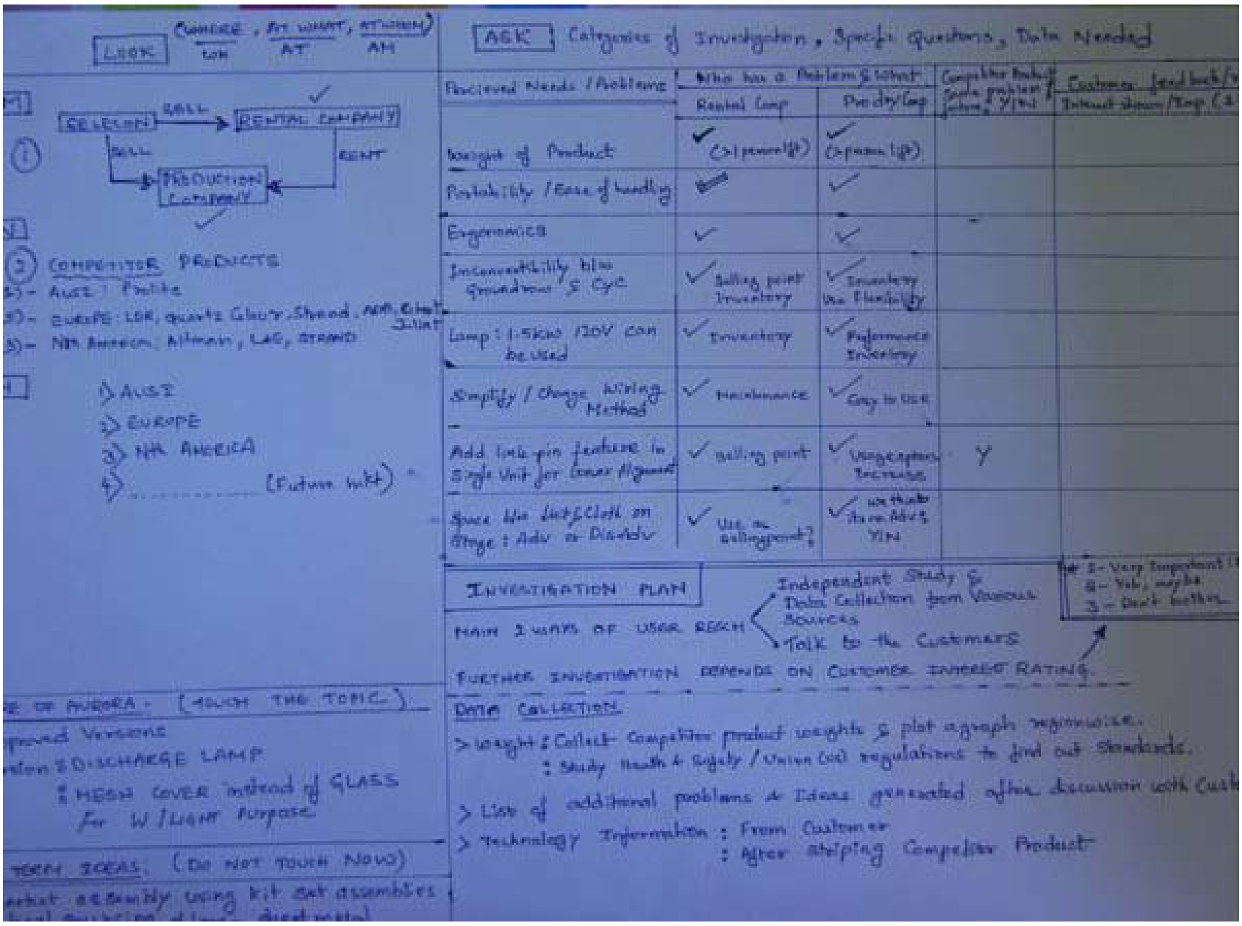



**Figure 50: Overall user research document or the customer interest A3 developed during workshop (also refer Appendix E).**

Further two variations of the brief were made, one for mailing across to the customers (refer Appendix I, pg2) and another overall document for the PD personnel (refer Appendix I, pg1). These A3 reports were used successfully and were effective in understanding the exact user requirements versus the assumption made in the 'initial user interview' document.

**Documentation on CAD drawings, design concepts, testing results, and supplier details:**

The PD personnel realised the importance of making meaningful documentation an important activity for designers. Since the author stressed the importance of not rushing into too much information storage, the PD manager was quick to select four main categories as important databases. Knowledge captures on CAD drawings, design concepts, test results, and supplier details were inevitable and basic requirement of any PD system, and hence chosen for knowledge capture at Company B. Although not much attention was given to the formats used for capturing this information, most of the data was stored in simple documents within a shared folder in the company server.

c) Allow collaborative research: Involvement of production in design process

The production personnel were included in the Product Development process of product X as early as the initial BOM design. This allowed the designers to obtain feedback from the production personnel (including line workers) on the possible improvements. It also ensured that production is well informed of the forthcoming product. This step helped the company to avoid several engineering change notices from the production.

Overall, the use of A3 reporting and other concepts has shown positive results and hence it can be concluded that they are effective in SMEs. The two situations tested i.e. 'customer interest' and 'problem solving' has shown that the reports can be customised to ensure minimum time is spent in writing them. Company B reframed its design values to include building long-term relationships with suppliers. The next logical step would be to expose the company to the other types of A3 reporting such as project proposal A3, etc.

In addition, a customised knowledge database for Company B was recommended as one of the foremost LPD deployment steps. Further details of recommendations are mentioned in section 6.4.3. The effective integration of production can be recommended after a detailed study (example: Value stream mapping) in the 'interface' areas between the two departments. In conclusion, this exercise of validation proved as indicators for the applicability of some of the LPD system tools.

### 6.3.4 Practitioner's viewpoint on the Lean PD model: Discussion with Company C

As the LPD design for SMEs is targeted to the group of companies with as less as 50 members till a 250 member organisation, there emerged a need to concur the proposed solution with another company that was significantly different from Company B. Therefore, a company with approximately 250 members based in NZ was chosen for fulfilling this purpose. Company C is one of the world's leading suppliers of energy saving electronically commutated motors and fans. They consist of a 30-member R&D team located in NZ, with a support infrastructure of 30 marketing personal, and a manufacturing office located in Singapore. The entire manufacturing of Company C has been outsourced to China.

The interview was conducted with the Chief Technology Officer (CTO) of Company C and the following are the findings of the discussions held:

**A: The operating environment (external and internal factors)**

I. About the PD department (Sub-groups, Dept. Size, Roles, Project timeline, Process)

<u>People organisation structure</u>: The overall PD department is divided into main sub-groups based on the product subsystems. In addition there is a specialised customer project unit. Within each sub-group / unit, there are 3-4 project teams consisting of an operational engineer (operations), a Chief Technology Officer (research and technology, strategy), and a project manager (multitasking, planning and control). As a growing global company, the Company C has adapted the recruitment model similar to that used in large firms. The company recruits the top cream of university graduates, in order to enhance the productivity of the overall organisation. Specific to the R&D, the CTO stressed the need that engineers have 'passion' for innovation. In his words "*Unless and until the prospective candidate for role of design engineer does not spend his/ her leisure time with some creative and innovative builds in his / her garage, I cannot see how that person can be an effective addition to our company*."

<u>Project Timeline</u>: The new Product Development projects at Company C takes a little over a year to complete, whereas an up gradation project takes less than a year.

<u>PD process</u>: Company C uses the stage-gate model partially for conducting the PD process. The CTO suggests that rigid stage-gate reviews are of little use to small companies. Hence, the stage-gate model has been understood and adapted with flexibility at Company C. The main stages of PD are:

1. Feasibility study,
2. Concept testing,
3. Development,
4. Tooling and pre-production,
5. Production ratification.

II. Problems faced in the PD cycle (Process, People, Leadership, Planning and control)

Some of the problems faced by Company C are similar to the ones found in Company B, but in a larger scale. These include:

a) Minimal usage of 'Idea Generation' Techniques,

b) Supplier integration generally not explored early in the PD process,

c) Lack of customer feedback during the concept development stage,

d) Supplier Delays, and

e) Lack of documentation on products and PD projects.

The additional problems faced by the company are related to the integration of manufacturing and R&D. Since the manufacturing at Company C has been outsourced (China), and the office located offshore (Singapore), the problems about effective communication, planning, control, MOM/ BOM generation are a challenge. In company C's viewpoint, the main cause for most of the problems in SMEs are due to resource constraints.

Some of the other issues lie submerged due to lack of reviews using quantified parameters. Neither lead-times nor cost comparisons are calculated before and after each project. Suggestions such as calculating the cost difference for slippage in PD schedules (Reinertsen and Smith, 1991) would be a good way to ensure the importance of optimum lead-time is publicised, and would eventually drive an improvement initiative.

III. Knowledge management

As mentioned earlier, the Company C believes that lack of documentation is one of the problems at SMEs. Although, they understand that SMEs will have less documentation compared to large firms; there definitely exists a need to capture knowledge and important information in every business. Like Company B, Company C also has not paid much attention to the categorisation of necessary and unnecessary documentation, and on how to take the knowledge management systems forward.

IV. Significant differences between SMEs and large firms on carrying out PD:

According to the CTO of Company C, small businesses have advantages and disadvantages compared to large organisations with respect to PD. The communication is simpler and faster in small companies, the people constantly learn from internal and external sources and they adopt to change easily. However, the supplier relationship and the resource constraints are the major differentiating points. The impact of these two factors on small companies lead to truncated processes, deficient documentation, etc. For example, fire fighting on one project significantly affects work on the other projects, due to resource diversion.

**B. Viewpoint on the applicability of the 'Lean Product Development' model**

According to the CTO of Company C, the four main areas that are weak for handling PD in SMEs are as follows:

*1.* Supplier Integration: Since small companies, unlike Toyota are unable to exercise control over their suppliers, the supplier integration aspects of Toyota system are irrelevant to SMEs. According to the CTO, the logic and thinking behind the systems may be the best in the world, but in case of SMEs, it is very difficult to practice them. For example, suppliers to SMEs are either unable or will not be responsive to short lead-time / emergency requirements in most cases. Again, the co-development of suppliers with the help of a company's expertise is not feasible due to the resource constraints of SMEs.

*2.* The chief engineer system: According to the CTO, since the size of the PD departments in SMEs range between 3 and 30, the chief engineer system may not be practical in extremely small companies. The 'know-all' role of the chief engineer is difficult to practice in the given situation. A typical design team may consist of one person representing each of the sub-systems, and a PD manager in most cases. The characteristic of a CE, according to the CTO of Company C, are seen split between the Managing Director and the PD manager, although not completely.

*3.* Resource constraints: In spite of setting-up a LPD process based on a test-then-design approach, Company C believes that the cause for most other problems such as long lead times, and cost overruns are a result of resource limitations in SMEs. Toyota has built a buffer capacity for people, such that any unforeseen event will not throw the other projects into problems. Since small companies cannot afford the buffer capacity, the result of problems such as supplier delays, legacy project issues, etc. will impact current and future projects.

4. Reuse of concepts: The CTO concurs with Company B on the issue of reuse. Since most small companies rely on innovation to build a special place for themselves in the market, the

Toyota system of reusing sub-systems from old models is unlikely to work for SMEs.

Since most of the above-mentioned concerns reflect the concerns expressed by Company B, it became obvious that the LPD solution is deficient for application in SMEs and that there was a need for complementary solutions that could address the above mentioned four concerns. They are discussed further in chapter 7.

## CHAPTER 7

# DISCUSSION

# CHAPTER 7. DISCUSSION:

During the period of study at Company B, bureaucratic practices (as discussed by Kennedy, 2003) such as rigid control paradigms, multi-layered administration, complex structures and processes were clearly invisible. Being a SME, this is one of its typical characteristics such companies have a system of direct observation of all the parts of the process by hands-on managers, deep involvement of company directors in R & D and visionary leadership. However SMEs are in the process of growing into larger companies, they are quick learners; they encourage improvement initiatives and best practices. In the process, it becomes more important for these companies to avoid adding those structures with improvements, which can cause problems similar to what large organizations have accumulated.

A discussion with the R & D managers in this regard reinforced the above stated view. (Formal reviews already exist at Company B, but are used to monitor of a particular project. In spite of these reviews, development stoppages occur, and unplanned loop backs, fire fighting was observed).

The most encouraging factor for this research is company B's belief in Toyota's Lean thinking. They are intrigued with the possibilities Lean Product Development can bring. The various reasons for this are:

1. The constant problems faced at the company's R & D department (refer chapter 5) and the visionary leadership of Mr. JC, ("Every change must be accompanied by a valid case for action and an engaged leader" – Michael N. Kennedy).
2. The 'Kaizen' attitude prevalent within the company, and
3. Motivation derived from the benefits of implementing Lean Manufacturing.

The whole discussion above more-or-less answers the most important question of this research: Will Lean Product Development Systems work in Small and Medium Enterprises?

*If any SME has visionary leadership to drive the change initiative, has employees willing to continuously improve, has a fair understanding that "Lean Philosophy" is rewarding, and they see a solution in TPDS to their R & D problems, then; Lean development stands a chance! This is one of the first conclusions of the study on applicability of LPD in SMEs.*

## 7.1 Assessing the current state

One of the foremost steps in understanding the transition required toward Lean Product Development is to assess the current state of affairs at the SME (example: Company B) versus that of Toyota. Using the organisational capability scale (adapted from Kennedy, 2003), the same has been discussed below (Figure 51). The assessment was done after the author spent several months at Company B conducting action research. Although the rating was provided subjectively, it emerged from deep insight into the observations, findings and interactions of the research.

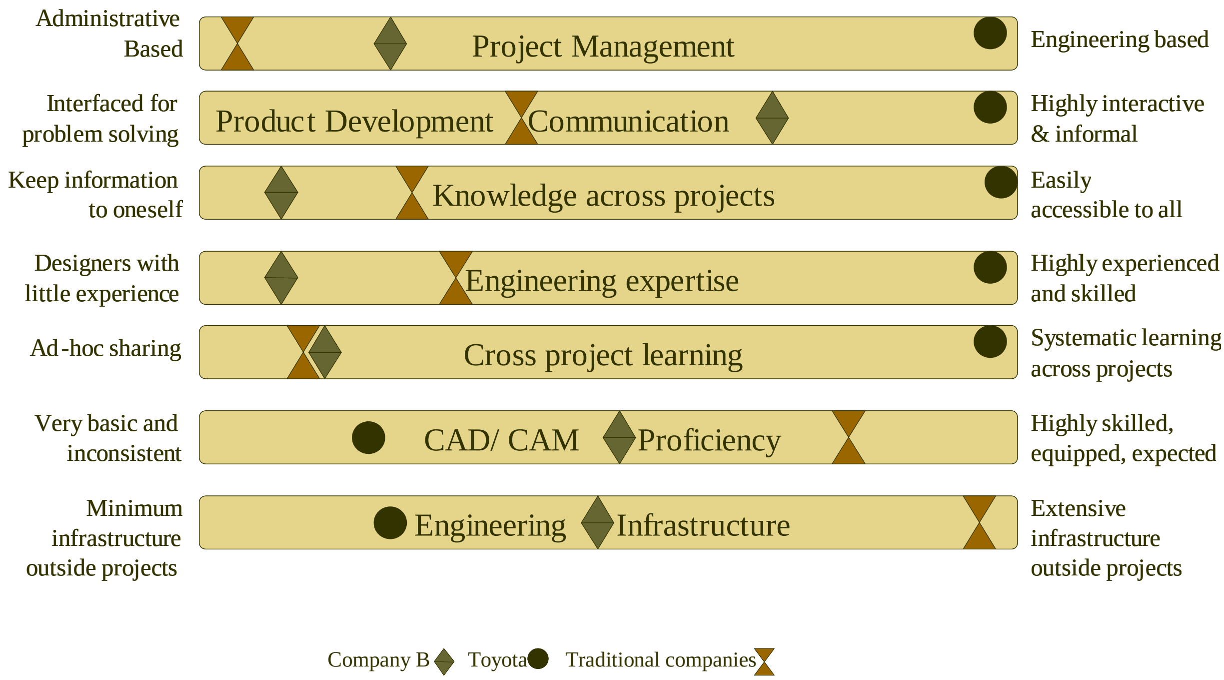



**Figure 51: Assessment of current state (adapted from Kennedy, 2003)**

As discussed in Kennedy (2003), there exists a 'sharp contrast' between Product Development characteristics in traditional companies and Toyota. The traditional companies (referring mostly to large companies) have highly administrative project management system, unsystematic knowledge sharing across projects, schedule slippages, severe production-design problems, and high project success variability. Observations at Company B have resulted in the acknowledgement that indeed SMEs have different characteristics compared to large organisations. The only difference is that they have not had the time to reflect systematically on the way of working (both positive and negative aspects). This also does not indicate that the SMEs do not engage in improvement initiatives, because it has been observed that the company's visionary leadership is at all times busy in introspecting on the company status within himself / herself.

Some of the key areas that SMEs were found to be closer to Toyota are discussed below:

- Better communication in Company B compared to large traditional organisations:

  The people at Company B were seen to have more face-to-face communication compared to papers and emails. Although informal, it eliminated the waste of "waiting". Based on the data collected at Company B (also supported by literature) we can conclude that *a flat organisation structure found in SMEs allows the design team to be flexible, interactive, responsive and efficient, in line with LPD.*

- CAD/CAM proficiency:

  In most companies, excessive attention is given to sophisticated software for modelling (Ward, 2007). But at Toyota, the belief is that software should complement the overall Lean processes and the value stream and not vice-versa. At Company B, designers may have suggested that the CAD capability should be improvised, but the question is whether this would jeopardise the consistency of design work. *Thus, it can be stated that the CAD/ CAM proficiency at SMEs may be closer to the Toyota environment, allowing easy deployment of Lean systems*.

- Flexible engineering Infrastructure:

  At Company B, most of the infrastructure has co-developed with projects. A glimpse of the Toyota environment, where project-focused infrastructure takes precedence over general infrastructure was observed at Company B. *This suggests that SMEs have flexible engineering infrastructure that allow LPD deployment as against the excessive infrastructure built in other traditional large companies.*

## 7.2 Lean Product Development system can address concerns at Company B

Based on the understanding of literature and the observations at Company B, it is clearly visible that PD problems in SMEs such as those found in Company B can be addressed through the LPD systems. A discussion of the various problems, the current fire-fighting actions, resulting chaos, and the recommended “Lean” way of handling the problems are explained in Table 9.

Overall, the main point here is that SMEs such as Company B has to give equal importance to long-term success along with short-term goals. Capturing knowledge may seem least important before other activities at any given point of time, but this aspect has the potential to regress the growth of the company. One example for this from Company B: is the loss of 25 years of precious product knowledge and experience along due to the disassociation of R&D director, Mr.AN. The PD team is now left with just a few hand-written diary notes from the director. This can be addressed by LPD by systematically capturing knowledge not just for effective communication at present, but also in the future.

LPD presents solutions to all the various problems at the company such as scheduling, fir-fighting, supplier integration, etc. The Table 9 explains how the short-term PD measures (second column) will result in further chaos (third column). In the fourth column of Table 9, the practical day-to-day issues have been provided with a long-term, consistent remedy based on LPD systems thinking.

| SITUATION | WHAT DO YOU ALWAYS DO | THEN WHAT HAPPENS | NOW ON DO THIS |
|---|---|---|---|
| ***Project behind schedule*** | Fire fighting | More fire, delay inevitable | ➢ Employ additional resource and distribute workload within PD,<br>➢ Identify buffer resources across the company, develop them,<br>➢ Use external consultants as buffer. |
| ***Expensive loop backs*** | Ø Revise cost targets, revisit brief (change technical specs)<br>Ø Change the contract design agency | Ø Compromise on either technical or market requirements<br>Ø Buffer lost, overloading of internal resources | ➢ Don't choose another concept, go to the lab & customer first<br>➢ Allow project to complete, mentor them |
| ***Supplier Lead Times*** | Penalize and Change supplier. | Problem solved temporarily, but time lost to searching for a new one, new supplier selected without prolonged investigation | Build long term supplier relationships (follow Toyota method of selecting partners), Trust and openness, Solve the suppliers problems |
| ***Over Loaded*** | Nothing | Projects delay (problems in one project affects the other)<br>Time and Costs rise with delays (waiting / queue) | ➢ Don't add new projects (use R&D project selection methods to prioritise)<br>➢ Form simultaneous engineering unit (common between Engineering and PD) |
| ***No Documentation*** | Allow knowledge to be stored in people's minds | Knowledge lost due to attrition, etc. / forgotten over period of time<br>(It is a root cause – leads to 'Things go bad', 'over-load', 'expensive loop backs' situations, etc). | ➢ Understand what knowledge is worth capturing (direct value to product value Stream)<br>➢ Capture the Knowledge<br>➢ Create a simple, customised Knowledge Database |
| ***Things are going bad*** | Re-organize / stall project | Things go bad after sometime again... | ➢ Find root cause (LAMDA), Fix.<br>➢ Write A3 report on it (Problem Solving): So, anywhere, anybody can fix it quickly in the future. |
| ***No Standard operating procedure / PD process*** | Make one & publicise, Looks good | Non-compliance, add unnecessary structure & tasks for compliance- no use | ➢ Follow LPD process: fix Testing (IE) due dates separately, later make a schedule for Design.<br>➢ Use the VSM tool to identify wastes, discuss & address them. |

**Table 9: Discussion on the required change in actions within PD department**

## 7.3 Building systems for effective 'knowledge capture'

The literature on Lean Product Development has revealed the importance of capturing the core knowledge of a business. The knowledge value stream has been portrayed as a vital element of PD of a Lean enterprise (Kennedy, 2003; Ward, 2007; Kennedy *et al.*, 2008). Thus, the knowledge systems can be described as a comprehensive, effective and consistent with the following prominent features:

- Basic storage forms such as A3 reports, trade-off curves, relationship curves and limit curves,
- Knowledge evolve into 'checklists' when applied to the PD value stream at various stages and phases,
- Tools used to generate knowledge are beta testing, LAMDA cyclic investigation, etc.

Further, Kennedy *et al.*, (2008) proposed a LPD implementation roadmap with a suggestion that knowledge development would be the first step to take (Figure 52).

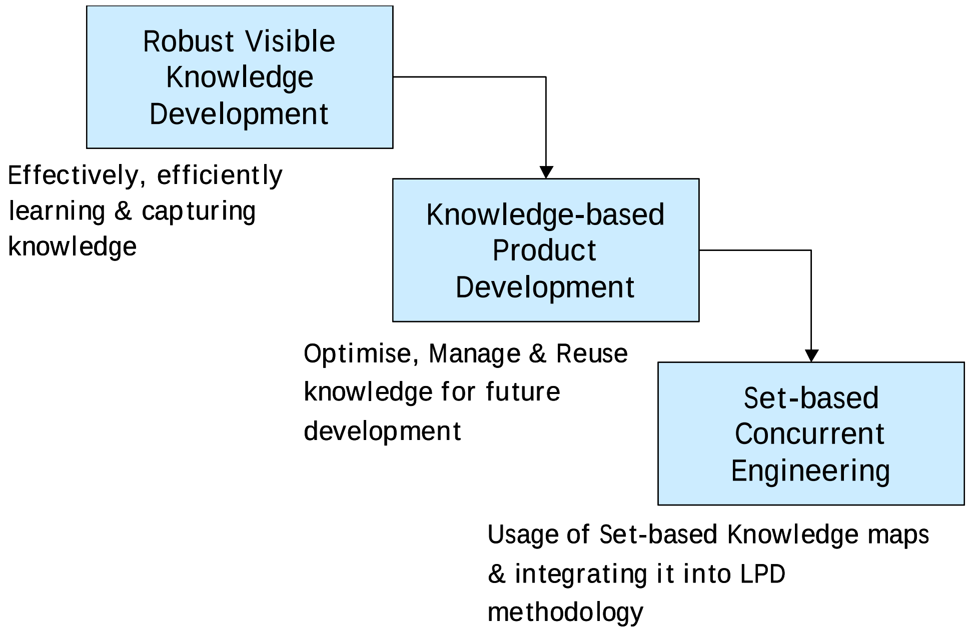



**Figure 52: Implementation plan for building and reusing knowledge systems (Source: Kennedy et al., 2008)**

It can be clearly seen from the section 6.3, that the author has taken a almost similar approach to validate the LPD systems at Company B. The acceptance of knowledge capture tools such as A3s is a logical and crucial step to understand the implications of the entire LPD system in SMEs. Based on the observations and findings at Company B, the following recommendations can be made for the knowledge systems at SMEs:

1. The implementation roadmap shown in Figure 52 is applicable to SMEs because it is based on principles of LPD. The core of LPD is knowledge, and this would be the first step to take, immaterial of the size of a business.
2. Some of the steps recommended for building knowledge in SMEs are listed below:
   a) To train all PD members on the use of LPD forms (Eg: A3, Curves) and the tools used to generate them (Eg: LAMDA),
   b) A commitment from top management on building knowledge i.e. making use of tools and formats compulsory for all PD team members in daily work, and leading by example.
   c) Further, simple steps such as use of A3 forms instead of PowerPoint presentations during review meetings and as status reports help to build the 'Lean' culture. Also, ensure these are used for mentoring within the department.
   d) In the meanwhile, workshops can be conducted to plan a 'Knowledge Management System' (KMS) by analysing the options available. The standard formats have to be customised in order to ensure it is effective for the kind and size of the SME business. Easy retrieval options also have to be incorporated.

From the findings of supporting case study Company B, the following points emerged as excellent suggestions for a company using LPD knowledge tools:

- A3 reports have to be written from the time the investigation is started, and not in the end.
- Always debate and discuss, arrive at a consensus on the reported findings before feeding it into the database.
- It is equally important to avoid overuse of the formats and knowledge storage documents, as it is to use them.

- The owner of a certain problem solving A3 would be allocated based on the root cause found. For example, if a certain problem arose due to design defects, the A3 would be stored with the design department.
- *Obeya* rooms are of great help to work on A3s.

Overall, the current culture in SMEs of discarding valuable knowledge and experience has to be reversed into the LPD ways. This will allow the company to generate world-class innovative products by removing most of the obstacles faced by these companies today.

In January 2009, the following discussion between the author and one of the Lean experts (presenter of Webinar series III: 'A3 reports and Visual knowledge', 24-01-09 for: Lean Product and Process Development Exchange, Inc. (LPPDE)) reinforced the approach taken by the author.

**Author**: *"In a small-scale business of approximately 75 people, we can see a very informal PD system in place. Looking at improvements, does using knowledge building tools such as A3 reporting take priority over establishing a Standard operating procedure?"*

**Tricia Sutton:** *"Using A3 reporting and LAMDA will help to develop a good, sound problem solving, visible knowledge process. This will be a good foundation for establishing a Standard operating procedure."*

The two main reasons for asking this question was to understand the correctness of the approach taken by the author for validating LPD at Company B, and secondly to confirm the stand taken by the author on avoiding establishment of a standard operating procedure (SOP) (as the first step) when requested by the PD manager. It is important to realise that setting a SOP or defining a process for PD at an early stage (when there is no understanding of the vital components and knowledge value stream) will only make the company to focus in the wrong areas.

## 7.4 Process for Product Development

As discussed in Kennedy *et al.,* (2008, pg61), the Value Stream Mapping exercise or process mapping can be applied at the overall PD process level and for sub processes within PD such as the engineering change note (ECN) process. It is beneficial to split a process into sub-processes and address each of them, as it ensures all details are covered in the mapping activity. Based on the observation at Company B, the following three processes can be targeted for the VSM activity:

a) Overall PD process,

b) The ECN process, and

c) The supplier collaboration process.

Within the scope of this project, only the macro-level PD process has been included for the process mapping activity. The exact lead times have not been measured here, as there was no system for collecting the exact time designers spent in completing each stage at Company B. It can be mapped in terms of months with the help of the workload distribution charts. In addition, the time period required for each type of project varies with the complexity of parts and level of reuse. These factors are usually explored in the 'test' phase of LPD process.

Based on the literature on LPD, the fieldwork at Company A and at Company B, a Product Development process for SMEs has been designed. This model is based upon 'Lean' principles and incorporates a variety of tools and techniques described as best practices from Toyota (Figure 53).

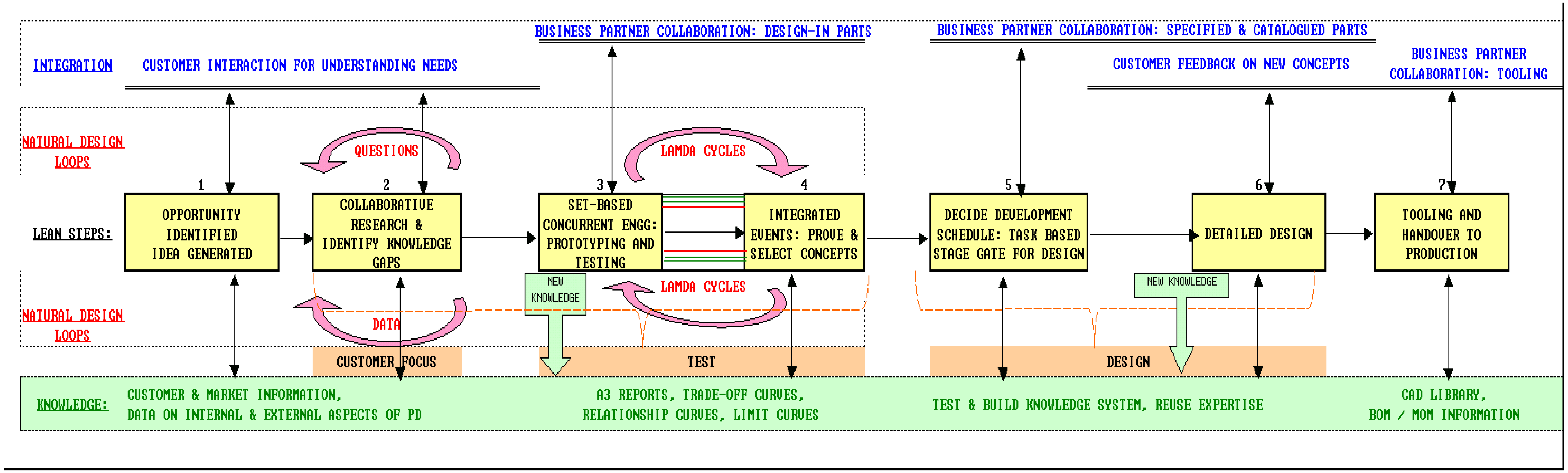



**Figure 53: The proposed Lean Product Development process for Company B (adapted from Ward, 2007; Kennedy *et al.*, 2008)**

The process was developed based on the following elements:

- The required steps according to Company B for developing their products,
- The Lean process thinking based on literature, especially by Ward (2007),
- The inputs from study carried out at Company A on the LPD process.

The salient features of this process are as follows:

- The entire process is based on the ‘test-then-design’ approach; wherein “proven” concepts are designed leaving no room for late failures / unplanned loop backs,
- The exact concept / part definition is locked-down only later in the process to allow a successful set-based engineering in the front end, with the help of the LAMDA cycles,
- Loop backs are made an integral part of the process, in order to absorb the natural variations in PD process, and to allow solutions to emerge from thorough testing,
- The organisation set-up would ensure that products reflect deep understanding of customer needs (role of ‘Chief Engineer’) with quality innovative features (role of functional teams),
- The ‘expert workforce’ or the design engineers are responsible for meeting the dates (with careful planning and control) for ‘integrated events’ with feasible solutions for the new product,
- The Customer interaction maintained whenever required during the process, especially after prototyping some feasible solutions to customer needs,
- The User research activity involves design engineers, wherein the knowledge and experience of R&D team is part of the discussion with the customers,
- Involvement of the production personal early in the design process, to ensure a ‘collaborative’ research and development,
- The suppliers and business partners are integrated early in the process for ‘design-in’ parts, and knowledge is shared across companies that would lead to a long-term win-win relationship, and
- The ‘knowledge database’ supports and grows with the product value stream by systematic capture, simple storage and easy retrieval features.

## 7.5 The details of proposed Lean PD solution for SMEs:

Using the four-implementation pillars of LPD (Process, people and planning, leadership, knowledge) and the vital elements of knowledge, customer focus and supplier integration, the various steps of the proposed LPD solution for SMEs has been explained below.

### 7.5.1 Front-end

<u>Step1:</u> Opportunity Identification and Idea Generation:

The first phase ideally involves ‘a systematic search’ of market opportunities for company’s products, by recognising needs of existing and potential customers. Since SMEs differ significantly from large companies (as discovered in chapter 5), the solution suggested has certain special features proposed to suit SMEs. The changes recommended for the step 1 of the PD process are:

- Customer focus: For an exporting SME (such as Company B), a network has to be established between the market managers across the globe and the base (R&D office) that allows smooth information exchanges on customer preferences. In addition to Lean thinking such as allowing engineer interaction with customers, other simple PD practices such as maintaining customer portfolios at regional level can be used. This particularly rewarding for companies that caters to niche markets.
- Process: The sources for idea generation are mainly of two types: Customer requirement or Expert / Internal creative thinking. The various PD techniques such as focus groups, brainstorming, employee’s suggestions, manager’s ideas, observations, and customer requests can be used systematically to capture these ideas at regular intervals. The advantage that SMEs have is the extensive interface of top management with customers (as observed in Company B). This allows better understanding of customer needs at the leadership level. Further, scientific methods such as scoring methods (using criteria and weights), and group evaluation techniques can be used as ‘funnel’ for choosing feasible ideas; instead of current practices in SMEs of doing this process individually (for example the MD of Company B, Mr.JC uses his rationale to complete first round of filtering ideas).

- People and planning: The Lean techniques such as use of teamwork to identify opportunities (market managers and design engineers) are applicable in SMEs. However, some simple techniques such as motivating people with incentives if their ideas are accepted as a new Product Development project can benefit the company by increasing the overall creative ability of workforce. (Such techniques are used successfully in large companies across the world as a part of 'continuous improvement' for Lean production systems).
- Knowledge: In most companies, the marketing department maintains a database on company's customers across the world, their product and features preferences, the market segmentation, etc. Within SMEs, events such as 'idea generation summits' can be held at regular intervals wherein regional market managers, design engineers and key managers across the company meet to ideate and hence update the existing databases. Such practices have also been observed at Company B during the fieldwork.
- Supplier: In case of SMEs, Lean helps to establish long-term supplier relationships, and these partnering companies contribute to the idea generation process with their knowledge and experiences.

Step2: Collaborative research to build a product brief

The second step in the PD process involves a feasibility check on the captured ideas / market opportunities. It allows all the stakeholders (R&D team, production, marketing, finance, external experts, suppliers, and top management) to arrive at a consensus on what and how projects should be taken up for Product Development at any given point of time. A process of extensive user research for the chosen projects follows this, in form of a cyclic investigation process.

- Process: As mentioned above one of the key features of a Lean process, is "collaborative research". Understanding customer needs, discussing internally with all stakeholders and going back to the customer to know more are part of this cyclic investigation process. It is during this process that the company appoints a 'Chief Engineer' (CE) for a selected project. The chief engineer usually conducts detailed analysis of knowledge gaps and conducts advanced user research to address these gaps. SMEs suffer from lack of proper techniques during this phase (refer chapter 2) and hence it is recommended that techniques such as attribute analysis, gap analysis, lateral thinking, focus groups, brainstorming, six thinking hats, etc., are used in this step. The two major categories of data analysed include:

a) Commercial reality: Information from competitors, market shares, market size, customers, product positioning,

b) Technical facts: Government regulations information, patents information, capability analysis, and engineer's assessment.

- Customer focus: In Lean thinking, the customer requirements take utmost priority. This is matched with the technological capability of the company to understand the feasibility of carrying the new Product Development. The 'chief engineer' feature of Lean Product Development puts the customer-focus on the forefront for development. This ensures that the data is collected in depth, as the CE spends considerable amount of time with prospective customers, matched with his / her technical expertise. Customers are also asked to compare existing products with that of competitors in order to understand the complete scenario.

- People and planning: Although, it is believed that the CE is responsible for understanding customer requirements, all the functional aspects, profitability, the risks involved, and the system design, the situation in SMEs are slightly different. The know-all role of a CE can be replaced with teamwork. For example, if the role of CE is given to the PD manager, then some selected designers (representing various sub-systems) and the MD may be included in discussions with customers and overall it may be termed as a "CE team". Kennedy *et al* (2008, pg 176) has suggested that small company tend to have the Managing director for the role of chief engineer.

- Knowledge: The entire user research process is conducted with the help of past experience of individuals in SMEs, in contrast to large companies where most of the information is stored in databases. This aspect is highly recommended for SMEs because unless tacit-knowledge is captured using LPD formats such as A3 reports (like 'customer interest A3'), the other aspects of LPD cannot be practiced such as reuse by other members of the team, effective communication across the company, and knowledge capture for future projects. It also poses risk of loss under various circumstances. For example, checklists can be developed on the criteria for selecting projects in the first / second step of the process, based on the tacit knowledge of the Managing Director.

- Tools: Use of simple tools such as the matrix tool (refer chapter 4) is recommended for SME for identifying knowledge gaps. The knowledge gaps help to diagnose the amount of new concepts to be generated and the amount of information already available due to past research.

### 7.5.2 Testing Phase

<u>Step3 and 4:</u> Integrated Events to choose feasible sets that evolved from Set-based Concurrent engineering:

The analysis of critical knowledge gaps suggests the amount of new research or 'testing' involved. For example, the company had never understood a particular solution expected by customer before (i.e. its new technology). Later, the company invested extra-time in the lab to completely understand the sub-system before starting design. This was observed in Company B for the project X (refer chapter 5). Further, the CE determines a timeframe that may be spent to explore the options before conducting 'integrated events' to choose the sets of solutions that will merge into a system design.

- Process: The LAMDA cyclic investigation is the core of this step. It helps to solve problems, test concepts, assumptions, and improve. Some specific techniques such as physical construction tests, field tests, technical tests, expert evaluations, customer evaluations, and study of competitor products are recommendations for SMEs to conduct this step. The number of concepts to be explored can be defined for each type of project, as SMEs may not be able to explore too many concepts due to resource constraints.
- People and planning: As discussed in chapter 2, the functional teams are responsible for conducting the detailed analysis of concepts during the set-based phase. In SMEs, the functional teams consist of single persons, leaving a void in teamwork and internal discussion aspects. This may be countered by using the creativity and innovation technique such as six hat of thinking, wherein the engineer can evaluate at the sub-system from different perspectives. The CE has an important role of selecting the sets of solutions during integrated events, based on the CE's understanding of customer interests. The chief engineer's role can be played by either the

PD manager, or the MD, or can be allocated to individual designers on rotation basis. The matrix in Table 10 shows the characteristics of Chief Engineer versus the potential candidates for the role:

| | CHIEF ENGINEER CANDIDATES IN SMEs: | | |
|---|---|---|---|
| **Chief Engineer Characteristics (Ward, 2007):** | PD Manager | Managing Director | Engineers: (Rotation Basis) |
| Representing the customer | | y | |
| Guiding consensus and trade-offs | y | | y |
| Provide and communicate a Vision | | y | |
| Designs the value steam | y | | |
| Able to link engineering decisions with business needs | y | y | |
| Have Ideas, passionate about innovation | y | y | y |
| See beyond their part of the project (system design) | y | | |
| Explain clearly what they are doing and why | y | y | y |
| Conscious of the cost and profitability aspects | y | y | |
| Provide technical leadership | y | | y |

**Table 10: Characteristics of Chief Engineer role and potential candidates (based on study at Company B)**

The table above shows the characteristics of individual people as observed at the case study company. It is interesting to note that although the PD manager appears to be the most suitable candidate, only the MD has the most important characteristic required: ability to represent the customer. SMEs can choose the CE based on a matrix evaluation of the characteristics and the effort required to inculcate the remaining characteristics in the individuals. For example, using the third option of rotating engineers in this role has long-term benefits for the company, as it can lead to knowledge sharing and development of the individuals in systems thinking.

- Supplier: The exploration of design-in parts / sub-systems may be delegated to suppliers/ business partners at step 4 so that parallel development can occur. The most important point for SMEs here is that, suppliers have to be preferably selected early such that they understand the nature of the company’s products and are prepared to receive the part manufacturing / tooling work in the near future. The parts delegated must be based on the following ‘Lean thinking’ criteria:

a) Supplier is an expert / fast learning in that area,

b) Supplier’s track record is proven (quality, delivery, cost),

c) Supplier believes in trust and openness,

d) Supplier has adequate resources.

- Knowledge: The testing phase is the research phase for Product Development. Here, multiple concepts are explored using the SBCE method, and vigorous functional prototyping and testing is done to understand each concept at the basic science level. As per the Lean system, trade-off curves, limit curves are used to store test information on this, which helps to decide on the feasible and infeasible regions for design of the current project as well as stores information for forthcoming projects. During integrated events, this knowledge (captured in standard formats) is presented as proof on whether certain functional systems work. Concepts not chosen for the particular project can be put away into the database for the next project.

### 7.5.3 Design Phase

Step 5, 6 and 7: Conducting a task based detailed design process leading to tooling and handover to production:

The design phase of the Toyota model is slightly different from the normal design phase seen in traditional models. The detailed design phase in traditional process is based on untested assumptions, and unreal boundaries. This phase in LPD includes a firstly setting a schedule with tasks outlined, a detailed design phase, and finally a tooling phase.

Process: The task based design phase of the LPD model can be classified into three broad steps based on observations at Company B. The SMEs can set a schedule (as earlier) outlining the tasks to be completed for the detailed design before tooling and handover to production. The detailed design step in specific shall contain tasks to define measurements, and dimensions to the already tested concept. Here, the boundaries for design are real, i.e. the limits are known beforehand due to testing and there is no room for any assumptions.

People and planning: The functional teams work on the design parts for which they have already conducted tests. The people are provided with software tools to conduct efficient modelling, with accuracy in dimensions.

Supplier: This phase will involve supplier / partner collaboration on specified and catalogued parts. The suppliers for design-in parts would work on the tooling of the parts, whereas contracts with other suppliers are completed for the simple specified/ catalogued parts. This option helps SMEs by allowing the flexibility to choose suppliers in two rounds instead of one.

Knowledge: Data on CAD drawings can be reused in most cases, with minor changes. The reuse and adding of knowledge during this phase is important, but depends on the complexity of the products. Another important area of knowledge reuse is the BOM/ MOM (refer glossary p.218) information, in order to understand what works well with the existing manufacturing capabilities of the company.

## 7.6 Summary

The sections 7.4 and 7.5 provide an in-depth analysis, design and discussion of a proposed LPD model applicable to SMEs. This was generated from the assimilation of published literature, on-going research, and findings of case studies conducted in 2008. It encompasses all elements of PD and provides a comprehensive system that allows SMEs to work with flexibility to achieve targeted growth. In summary, the overall framework of the proposed model can be illustrated as shown in Figure 54.

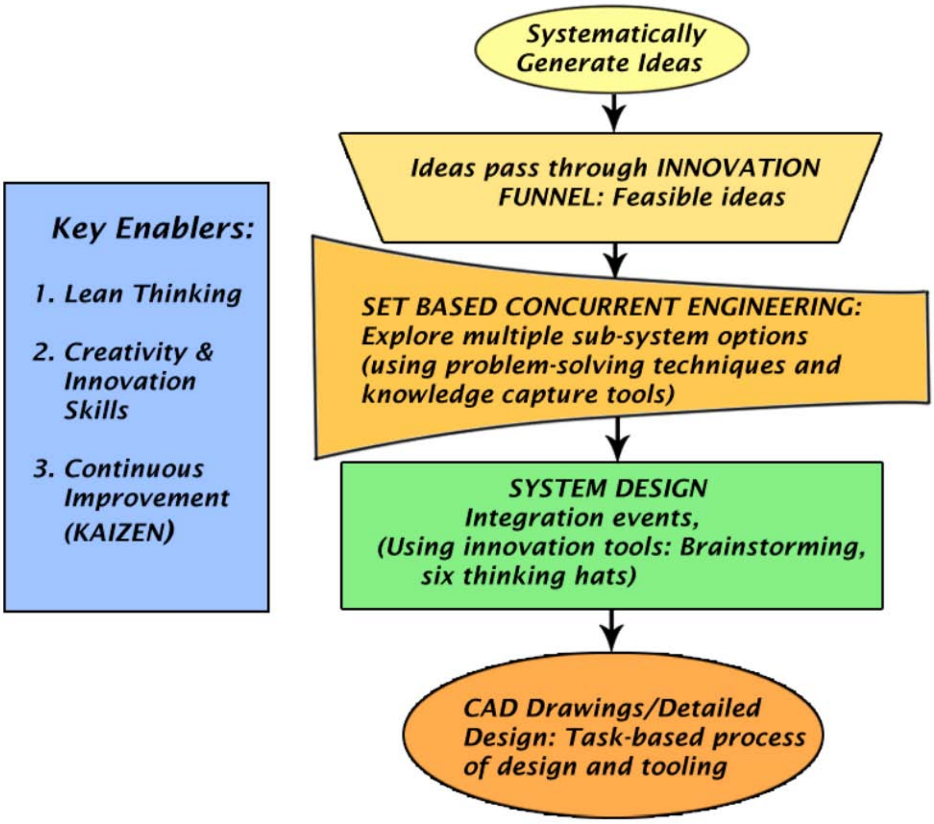



**Figure 54: A high level framework for the proposed solution**

The key highlights for discussion in the framework include:

- The systematic and continuous idea generation front-end,
- The balanced and collaborative decision making step on feasible ideas,
- The 'research' phase of PD, with intense testing and knowledge generation,
- The merger of innovative concepts into a product, with the help of advanced tools, and
- The 'development' phase consisting of modelling and tooling of the new product.

The key enablers for the LPD model to work in SMEs are the establishment of 'Lean' thinking or 'Lean' culture, the use of innovation and creativity skills, and practice of continuous improvement philosophy.

As discussed in the earlier sections, one of the major problems in SMEs is the shortage of personnel. The above-mentioned model works to eliminate this constraint by suggesting the use of innovation and creativity tools such as Lateral thinking, brainstorming, six hats of thinking, etc.

These tools may help SMEs to enhance the creative and innovative potential of its small design and development team, without affecting other aspects.

It can also help to increase the value of intellectual property, strengthen patent applications, and get around competitive patents (Hipple and Reeves, 2001).

### 7.6.1 Impact of Lean PD on supplier partnership

The literature on SMEs and the observations at Company B reveal that supplier collaboration is a very important aspect in SMEs. The magnitude of any delays or problems is probably double compared to that of large companies, because in this scenario, it is one 'SME' depending on another (supplier) in most cases. As discussed in chapter 5, SMEs such as Company B face several problems such as delays, cost overruns, wrong parts, among others. Although the company is trying hard to adopt some of the good practices such as helping suppliers in times of crisis, and integrating suppliers of core technology early in the PD stage, the efforts lack rigour. The Lean Product Development System provides a holistic solution that will allow seamless integration of suppliers leading to a long-term win-win situation.

Out of the various literatures published on LPD, the book by Ward (2007) provides accurate details of Toyota's supplier integration within PD. The details of the basis of long-term relationship, types of suppliers, types of supplier decisions, and criteria for choosing suppliers are covered in detail. Thus, the most important aspects for SMEs are the 'basis' for a long-term relationship, as discussed below:

- Work as a team and for system design: It simply implies a transparent, open, and workable relationship between SMEs and partnering companies during PD collaboration, which includes knowledge sharing, and problem solving as a unit.
- Keeping the focus on customer needs: Usually the main company takes up complete responsibility for satisfying customer needs, but in Lean PD, the supplier shares this responsibility. This will avoid suppliers coming up with wrong parts (i.e. no sub-optimal solutions and no assumptions). SMEs and suppliers can work together to overcome individual limitations that may affect the journey to the goal.

- Trying to achieve maximum with minimum: The focus of PD should be to design excellent systems with the help of minimal resources. This can be achieved when PD and manufacturing work together to cut down on costs, and set joint targets. This feature is applicable to SMEs.
- Agree on mutually profitable terms: In SMEs this feature has already been partially practiced. However, the ingredient missing here is lack of transparency on price break-up details at both sides

### 7.6.2 The transformation model: Roadmap for Lean PD deployment

Any change initiative has to have a clear transition plan, or a roadmap that would bring about a steady yet powerful transformation. Kennedy (2003, pg 221-235) describes the change plan that can be used for large companies (>250 staff in PD), but this is not applicable for small companies due to its complexity.

As discussed in chapter 6, SMEs like to have it "simple". In the same lines, a simple bridging plan / transformation model has been proposed that will allow SMEs to complete the transition in an effective way (Figure 55). In 2008, Kennedy *et al.,* stated the following on making a transition:

*"-Get all the key Toyota principles on the table, understood, and then customise, in a participative way, all the new roles and responsibilities of each organisation."*

This statement was the basis for proposing the model here, and its salient features are:

- The following three aspects relate to the strategy and alignment aspects of 'Lean' deployment:
  1. The Assess-Measure-Define is the initial methodology that helps to understand the current situation pragmatically,
  2. Interaction with LPD experts, and training help to develop a coherent vision of the future,
  3. Workshops with the help of a "Lean" moderator / change "sensei" may be used to decide on the transition required,
- The implementation plan ensures that the four cornerstones (process, people, leadership, and responsible planning control) are used,

- Continuous improvement or *Kaizen* can be achieved by conducting periodic reviews, internal and external assessments to monitor the implementation, and
- The Lean thinking foundation stones of Leadership, behaviour and engagement form the driving forces for this change to occur.

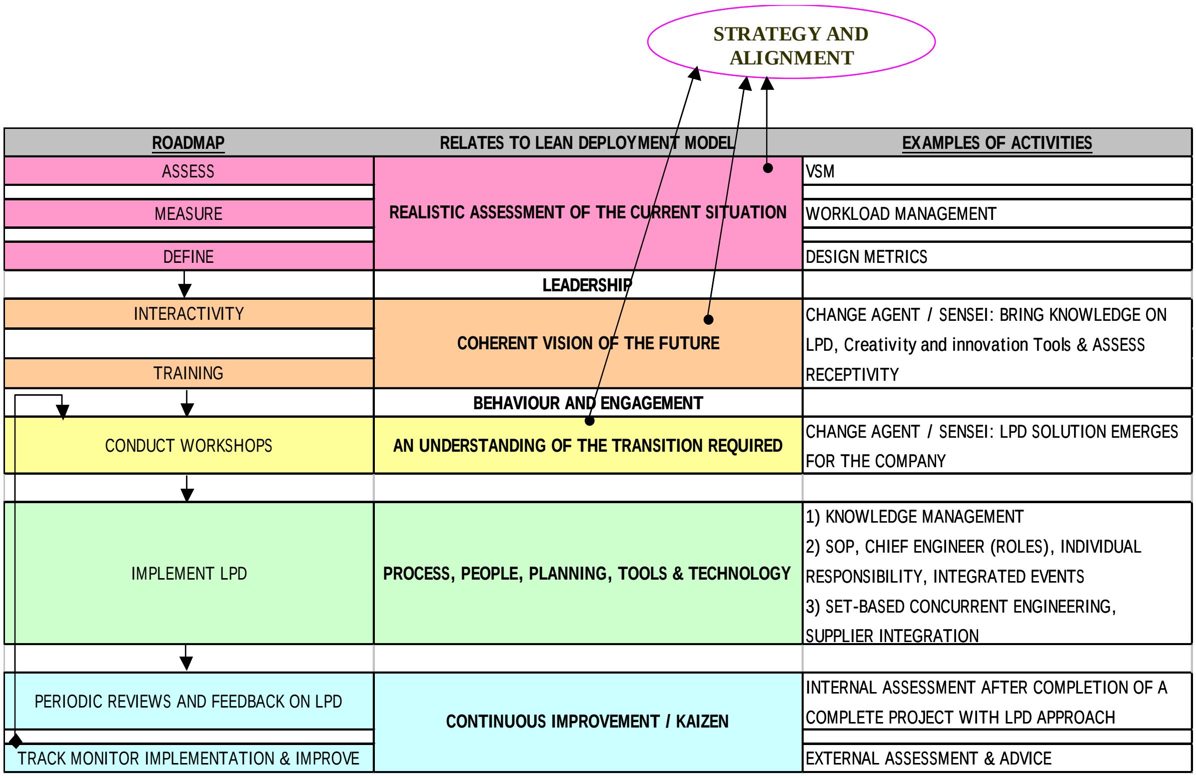



**Figure 55: Roadmap toward the Lean Product Development framework**

The transition plan proposed is one of the first in the world to show a simple and effective way for SMEs to move from the current chaotic PD environment to that of a superior PD environment, and the plan is related to the ‘Lean’ thinking all along. This plan ensures that SMEs retain their positive aspects during and after the transition, which is vital for this initiative to succeed.

## 7.7 The overall picture

A Lean Approach to PD for SMEs has been discussed in the above sections. Figure 53 deliberates the various aspects of a Lean PD process, including the associated people, knowledge, supplier, customer and management elements. Figure 54 summarises the highlights of the LPD process in the form of a framework. This framework presents the LPD process as a simple five-step system that is enabled by Lean thinking, *Kaizen*, and creativity tools. Finally, Figure 55 comes one step closer to actual LPD deployment by suggesting a possible transition roadmap. The roadmap puts forth a step-wise plan to ensure all elements of the proposed LPD system is implemented at the SME.

Overall, chapter 6 and 7 are able to provide a framework for applying Lean Product Development in Small and Medium Enterprises in a holistic way and discusses a variety of aspects in detail. The few drawbacks have also been listed and complementary solutions such as innovation and creativity tools have been proposed.

## CHAPTER 8

# CONCLUSION

# CHAPTER 8. CONCLUSIONS

*"Innovation is everywhere, the difficulty is learning from it"*

***- John Seeley Brown***

Creative ability is vital for survival of an organisation. But for an organisation to become a market leader, they have to *constantly learn and grow,* just like a 'living organism' or a 'minding organisation' (Rubinstein & Firstenberg, 1999). Lean Product Development ensures the learning process in innovation is easier, is practiced more systematically and is in-harmony with the rest of the PD elements.

## 8.1 Concluding comments on Lean framework for Product Development

In conclusion, this research uncovers the need for implementing Lean thinking for Product Development in Small and Medium Enterprises within countries such as NZ. One of the key answers to why Lean Product Development can be used in SMEs is its ideal balance of systems-based, process-oriented, interactive, people-managed approach with a clear customer / value focus. Cost advantage, partner collaboration, best practices, tools and methods are inbuilt into the LPD way of doing things. This offers a competitive advantage and better survival prospects for SME's without which they often will find it hard to stay in business. However, it is implied that leadership commitment, acceptance by design team is vital for success of LPD in SME's.

Some of the practices that LPD framework offers and are best suited for SMEs include:

1. Increased use of idea generation techniques (a systematic approach to ideation, and innovation using Lean principles with a process to identify and eliminate waste),
2. Use of customer feedback to see value in eyes of the customer early during the concept development phase as opposed to customer complaints,
3. Use 'Lean thinking' approach in feasibility study phase to systematically eliminate redundancy and duplication of design efforts,
4. Use of A3 reporting techniques in internal design and partner collaboration along with LAMDA for efficient and effective design validation. Additional reporting tools like trade-off

curves, relationship curves and limit curves also enhance data analysis and easy decision making,

5. Involvement of production in design process and vice versa to minimize post-design problems (i.e. production-related and market/ customer-related),
6. Supplier and partner collaboration with a focus and based on long-term relationship for mutual benefits as opposed to fire fighting and supply side problems,
7. Use of Set-based Concurrent Engineering (SBCE) to analyse, explore, evaluate alternate design options and systemically arrive at the right design which is transparent to all key stakeholders in the supply chain and to the leadership,
8. Using a 'systems design' approach, which uses brainstorming, 6 thinking hats, integrated events, innovation tools etc. as a multi-dimensional way to manage innovation. This approach also augurs and enhances the capability of the SME's to practice continuous improvement (*Kaizen*) in shorter time duration, and
9. LPD approach is not limited by technological factors but will enable the use of technology for efficient master data management, design change management, knowledge management and task based process management of design and tooling aspects.

Based on the discussion chapter, it emerges that there are characteristics within SMEs that favour the success of LPD in SMEs. In-fact, SMEs have a clearer value stream, as there is no scope for unnecessary work, given the resource constraints. Thus, targeted and customised Lean PD solution will ensure that required benefits are obtained.

8.2 A comparison between traditional PD processes in SMEs and the proposed Lean PD process

The Figure 56 illustrates the difference between the current state of PD systems in SMEs and the proposed future state.

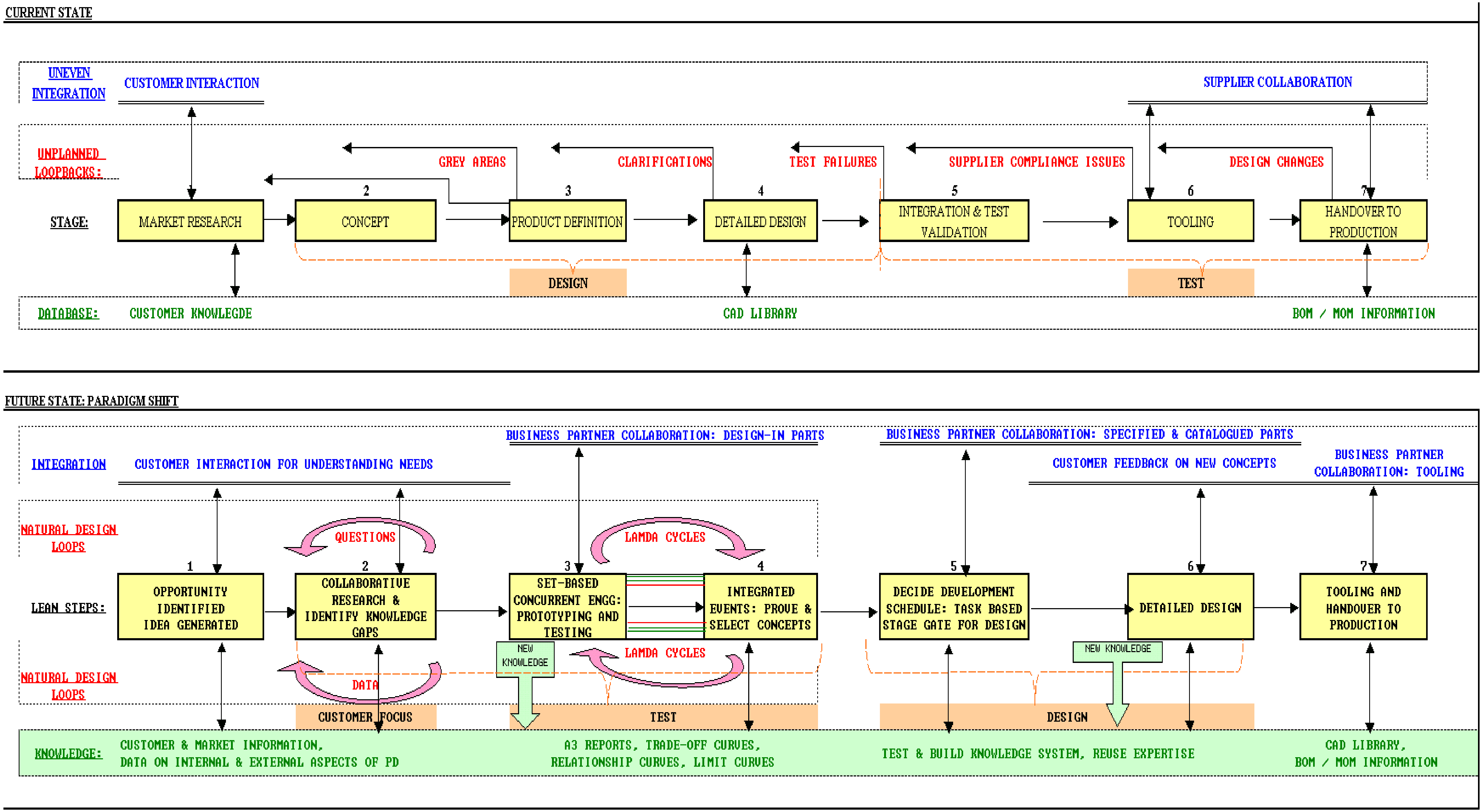



Figure 56: Current versus future state of PD process in SMEs

The main differences between the two models shown in Figure 56 is explained in Table 11 below

| | TRADITIONAL SET-UP | LEAN ENTERPRISE |
|---|---|---|
| 1 | Customer Interaction only initial - no feedbacks and verifications during the rest of the process. User Research involves the marketing engineers only, needs of customers collected on a fresh sheet of paper. | Customer interaction maintained whenever required, especially after prototyping some feasible solutions. User research involve design engineers, options from past experience is part of the discussion with customers. |
| 2 | Supplier contacted very late in the process | Supplier integrated early in the process and knowledge is shared, leading to a win-win situation. |
| 3 | Expensive unplanned loop backs are common | 'Planned' loop backs are a part of the process, because basic nature of New Product Innovation process is variation. |
| 4 | Concept and product definition locked quite early in the process. | Concept and product definition lock-down delayed in order to check feasibility of more than one concept- new learning using 'LAMDA cycles. |
| 5 | 'Over the wall' approach, needs 'tight controlled' management to ensure accountability. | 'Chief Engineer' in charge of the project, whereas the functional manager responsible for delivering the targets. Responsibility-based planning and control practiced. |
| 6 | 'Design-then-test approach' - redesign comes as a surprise / disappointment. | Test-then-design approach - proven concepts are designed and hence no surprises |
| 7 | Knowledge not captured, existing information in isolated islands, inconsistent reuse. | Knowledge captured systematically, stored with inter-relation between various aspects and a consistent reuse is ensured. |
| 8 | Production personal integrated only in the last stage of the design process. | Production personal integrated early in the design process. |

**Table 11: A high-level comparison of features of the current versus the LPD system**

## 8.3 Impact of the study

The Lean philosophy has proven time and again as a holistic system to enhance efficiency of the entire supply chain by optimising all internal processes, in addition to bringing about responsiveness to external environment. This research is an important study carried out to explore application of Lean principle in SMEs (with staff of 50 to 250 employees). With the help of a sound 'exploratory case study' methodology, and extensive 'action research', this work is able to draw some significant conclusions. It discusses the people, process, leadership and planning aspects of the new system; and presents the various challenges LPD may face to work successfully in a SME. It also goes one step further to provide a high-level framework for the LPD model. Several positive signals from the representative SME augment the conclusions drawn, instil confidence in the new system, and opens avenues for further research.

In conclusion, the three research objectives have been systematically covered using the literature review, the supporting case study, the main case study and the PD system designed for SMEs (Figure 53, Figure 56); leading to the fulfilment of the aim **"To evolve a broad framework for Product Development that incorporates Lean principles for application in Small and Medium Enterprises."**

Lean practices find significant importance in times of positive and negative economic growth across the world. It helps to achieve faster time-to-market when companies are experiencing upward growth, even as, it helps to reduce cost and increase benefits in hard times. In-fact, the latest survey by Lean Enterprise Institute (2009), shows that even in times of the recession, up to 76% of the companies implementing 'Lean' world-wide are ploughing in more resources and efforts in their Lean transformation. Thus, it is persistent and continuous effort that will construct a 'Lean' firm.

## 8.4 Scope for future research

In terms of future research, the foremost recommendation would be to implement the proposed Lean Product Development model for SMEs in order to gain an understanding of exact implications of the solution. It can be easily spotted that the contributions to LPD application is sprouting across the world, which are also experimental by nature, similar to the work presented in this thesis. Thus, advancing learning (and research) by deploying in 'live' industry environment i.e. SMEs is the chief recommendation for future work.

One of the main drawbacks of the study at supporting case study Company A has been the unavailability of concrete evidence on the exact scale of improvements at the company. Although the parameters of lead time reduction, productivity improvement, etc. are required to spread the awareness and acceptability of this system in world-wide industry, the case study is able to suggest that further exploration and time is required to understand the effects in NZ-based large Company A. Some of the areas identified for further research during the course of the supporting case study carried out there are:

a) Study on the influence of New Product Innovation (NPI) on average selling price, market share and affect of costs to margins, and a comparison between the pre and post LPD implementation figures,
b) Value Stream Mapping and design study, and identification of wastes,
c) Effectiveness of capture tools used for knowledge captures, and
d) Comparison between approaches taken at large companies versus that in SMEs.

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# GLOSSARY OF TERMS

**ACRONYMS:**

BOM: Bill of Materials

CAD: Computer-aided Design

CAM: Computer-aided Manufacturing

DOTWIMP: **D**efect **O**verproduction **T**ransportation **W**aiting **I**nventory **M**otion **P**rocessing

EC: Employee Count

FMEA: Failure Mode and Effect Analysis

IPD: Integrated Product Development

LPD (S): Lean Product Development System

MOM: Manufacturing operations management

NCMS: National Centre for Manufacturing Sciences

NPD-New Product Development

NPI: New Product Innovation

NZ: New Zealand

PDCA: Plan-Do-Check-Act

PDMA: Product Development and Management Association

PERT-CPM: Project Evaluation and Review Technique-Critical Path Method

QFD: Quality Function Deployment

R&D: Research and Development

SBCE: Set based Concurrent engineering

SME: Small and Medium Enterprises

TPDS: Toyota Product Development System

TPS: Toyota Production system (also called Lean Manufacturing)

TRIZ: Theory of Inventive Problem Solving

**TERMS:**

PD-Product Development: Overall process of strategy, organization, concept generation, product and marketing plan creation and evaluation, and commercialization of a new product.

Four cornerstones' model of Lean Product Development: Consists of *Process*- Set based Concurrent engineering, *People*- Expert engineering workforce, *Leaders*- System designer entrepreneurial leadership, and *Control system*- Responsibility based planning and control.

*Gemba*: "Actual place" or the place where real action occurs, that is where products or services are performed. In a manufacturing environment, the gemba often refers to the shop floor, because it is there that product is being transformed.

Knowledge System: A database of knowledge stored in form of knowledge briefs (A3 reports), limit curves, trade-off curves, and knowledge notebooks.

Trade-off curves: It stores relationship information or design decisions between two parameters within a subsystem, indicating the feasible and infeasible regions for design.

ESD-Enterprise system designer / CE-Chief Engineer: The product champion with ultimate authority and responsibility of the entire process for a particular Product Development project.

IE-Integrated event: Decision points within the Lean Product Development process where right set of alternatives from each sub-system developed by the functional teams using Set Based Concurrent Engineering is chosen.

A3 report / Knowledge Brief (K-Brief): A3 sized format that contains information on a topic's background, current situations, analysis, future plan; used for the purpose of customer interest, problem-solving, etc.

LAMDA (Look-Ask-Model-Discuss-Act): Process of thinking used for problem solving and for writing A3 reports.

*Kaizen*: Continuous improvement

5S: Group of five Japanese terms derived from Toyota practices that ensure visual control in production.

*Obeya*-Big: Refers to the meeting room for daily discussions, consisting of required information and facilities.

*Hansei*: Introspection.

Cadence / TAKT: Rhythm that helps to reduce variation, stabilise workload and aid continuous improvement.

*Muda*- Waste
Wastes in Lean Manufacturing: Over-production, defects, unnecessary inventory, inappropriate processing, excessive transportation and waiting, unnecessary motion.

*Mura*: Unevenness or variability in process or demand.
*Muri*: Overburden or excessive workload

VS (M/A/D): Value Stream (Mapping / Analysis / Design)

*Kanban*: 'Signal card' used to bring about pull system in Lean Manufacturing.

# APPENDICES

## APPENDIX A: Initial data collection questions

Company A: Large manufacturing company implementing LPD

1. What are the current Lean Product Development practices in Company A - Phases, processes, technology and techniques? How does that compare with their past PD system?
2. What are all the initiatives taken at Company A on 'Lean Product Development'?
3. What is the composition of the PD department at Company A?
4. Approximately how long is the speed-to-market for a Product at Company A? Is it the optimum duration and how was this arrived at?
5. How did the transformation take place at Company A on implementation of 'Lean' in manufacturing to that in PD?

Company B: New Zealand manufacturing SME:

6. What are the current new Product Development practices at Company B - Phases, processes, technology and techniques?
7. What is the composition of the PD department at Company B?
8. What are the major concerns and at which stages in the PD cycle at Company B?
9. Approximately how long is the speed-to-market for a Product at Company B? Do they see the need to optimize the duration?
10. What are the various aspects of the operating environment (internal and external) that influence the Product Development?
11. Is there any initiative already at Company B on 'Lean Product Development'? If so, what is the progress till date?
12. Does Company B conduct 'Project reviews'? What is the feedback provided to top management on this? How often is this conducted and have any recurring problems been identified so far?

**Investigation and analysis questions:**

13. What are the similarities and dissimilarities between PD transformation required in large firms versus that in SMEs?

14. What outlook do these companies have about 'Lean Product Development'?
15. How will 'Lean PD' be successful in SMEs? What results should we expect?
16. How do we customize 'Lean PD' stages for PD process of a SME?
17. Can a flowchart be drawn up on the LPD design implementation proposal for the SME or should an open framework be suggested?
18. What are the challenges recognised for LPD implementation in SMEs and hence the modifications required to customize the 'Lean PD' for Company B?
19. Will the LPD framework built based on Company B be applicable in other SMEs?

## APPENDIX B: Investigation questions for Company A

**Case Study Question:**

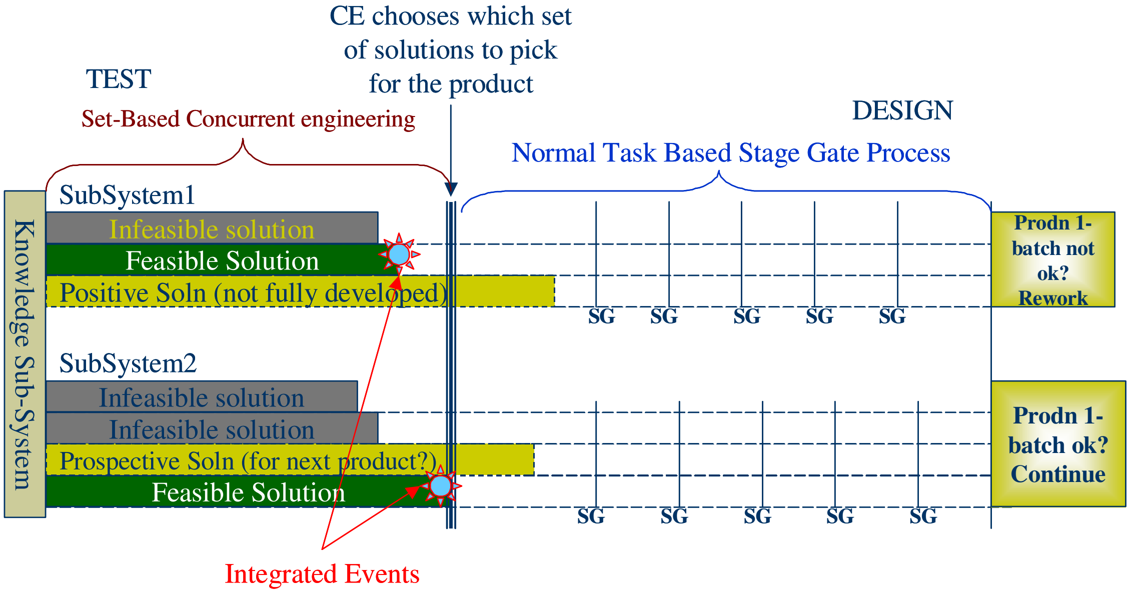
- What are the details of the process, people structure, knowledge capture mechanisms, leadership, and planning and control aspects that shape the Lean PD at Company A, that influences the adaptation of the LPD model in NZ operating environment?

**Data collection questions:**

1. What approach was taken to implement Lean PD, and what are the present and future focus areas?
2. How are suppliers associated and integrated into the Lean PD process?
3. What influence does Lean in Product Innovation have on average selling price, market share and affect of costs to margins?
4. What are the current new Product Development practices in a large company of New Zealand- phases, processes, technology and techniques? Is it based on 'Lean PD'?
5. Approximately how long is the speed-to-market for a product at Company B? Is it the optimum duration? How was this arrived at?
6. How did the transformation take place at Company B on implementation of 'Lean' in manufacturing to that in PD?
7. What are the similarities and dissimilarities between New Zealand's large scale and SM Es?
8. Was Value Stream Mapping and design tool of Lean used?
9. Comments on information published in literature on the restructuring of people organisation (Kennedy *et al,* 2008):
   - Reorganising the structure and redefining roles in PD: What made Company B to believe that something so drastic is required, it is a very big step?
   - What was the basis for this new organisation structure?
10. What is the process of determining customer interests and making design decisions?
11. Discuss further details of the LPD process (the macro level picture), and how it links to the knowledge subsystem.

12. Since the focus is on ‘knowledge capture’ today, what are the tools used, how and to what extent? Knowledge capture is a big task. Has this slowed down projects, how do you manage the whole situation?
13. What are the obstacles and challenges encountered in “Lean” deployment? How to tackle them?

**APPENDIX C: Macro-level process map at Company A based on Toyota's Lean PD process**




**Source: Macro-level process map at Company A (CONFIDENTIAL)**

## APPENDIX D: Investigation questions for Company B

**Case Study Question:**

- What are the details of the process, people structure, knowledge capture mechanisms, leadership, and planning and control aspects that shape the Lean PD at Company B, and how do they relate to the Lean PD approach?

**Cornerstones of Product Innovation:**

1. What are the current new Product Development practices in SMEs - Phases, processes, technology and techniques?
2. What is the composition of the PD department at Company B?
3. What is the Leadership style within the company and the department?
4. What is the management: planning and control structure in the PD department?

**Concerns and Improvements needed for the PD function:**

5. What are the major concerns and at which stages in the PD cycle at Company B?
6. Approximately how long is the speed-to-market for a Product at Company B? Do they see the need to optimize the duration?
7. Does Company B conduct 'Project reviews'? What is the feedback provided to top management on this? How often is this conducted and have any recurring problems been identified so far?

# APPENDIX E: Figure 48, Figure 49 and Figure 50

**THEME:** Investigate · Solve Mirror Cracking in F.S.

## Background

Has always been customers complaining about cracked mirrors. (Need to quantify number of mirrors replaced to date.)

Attention drawn to problem when two consecutive units both cracked two mirrors each during standard testing.

Problem is very important because ~~xx~~ production of Followspots has stopped until the mirror cracking problem is solved.

## Current Condition

- During standard testing procedure (~2hrs) the mirrors cracked and also showed concentrated 'spider Web' patterns.
- New unit 1 → Set to 16 mm → Cracked mirror, replaced → Cracked mirror again
- New Unit 2 → Set to 16mm → Cracked mirror, replaced → Cracked mirror again
-

RM → Prodn (Assy) → Testing → Customer

(Mirror Cracking. → Testing)

- Since the Product is already made, an certain amt. of value held at last stage → ① affects customer ② Committed resource – not generating revenue
- Production stopped
- Followspot consists of optics system with Philips lamp. D7

Photos/Images (Technical) of Mirror Crack.

## Cause Analysis /Root Cause Analysis

Refer Addl. doc

Aspects Investigated:-

Step 1 : Is it the mirror defect? [Ans] No
→ Heat discovered 750°C!

Step 2 : Locating optimum position [Ans]: 3mm difference from Original/std position

Step 3 : Check if it is variance in Ballast [Ans]: No

Step 4 : Check if position ~~/distance~~ of mirror ~~from heatsource~~ is causing mechanical stress due to mounting plate. [Ans]: No.

Step 5 : Changed the Unit i.e put mirror in old R&D unit, mirror didn't crack

Step 6 : change reflector in old unit, mirror cracks.

Step 7 : The reflector in either new/old unit cracks the mirror.

Step 8 : Check if Lamp makes a diff [Ans] No

[ROOT CAUSE] : New Reflectors are reflecting more light & heating the mirrors above their operating temperature. [WHY] SPINNING / ANODIZING OF REFLECTOR

[Difference] : 17% Increased o/p of new refl

To: ____________

By: ____________

Date: ____________

## Target Condition /Possible Solutions

Possible Solns:

1) Ask anodizer to go back to old way of anodizing
2) Increase mirror temperature rating & Use 2ndary heat baffle to eliminate the visible red glow
3) Increase the size of the unit by adjusting gate distances & whole lens tray w.r.t. reflector in order to reduce the core of hot spot.

## Implementation Plan

| What? | Who? | When? | Where? |
|---|---|---|---|
| | | | |

Cost:

## Follow-Up

| Plan | Actual Results |
|---|---|
| | |

Aurora – User Research Feedback

Meeting – MTC – Melbourne. Tues 9th Dec – 2.30pm – 4.30pm.

Present:

1/ Colour Frame – current solution is good, avoid clips as used on Iris. Add holes for butterfly clips is people wish to secure the frame closed for storeage.

2/ Separate locking solution for colour slot top clip – cant require on spring /over centre solution.

3/ Glass – weight issue. Perceived fragility – David H of VAC.

4/ Opening/ access for Servicing – Good

5/ Miscroswitch – engagement issue in combination with current spring latch clip. Latch can be damaged by people using tools on them…??

6/ Lamp Wattage – most in Aust use 1,000w as they are bright enough and keep down cabling and dimmer loading.
(Opportunity for IRC or similar lamp to substantially reduce lamp wattage requirement)
Should we alter lamp supplied from current 1250w ?

7/ Performance – (reflector) can the light be spread wider – solution as per Wing. Cf Iris..which didn't actually have a better beam spread. Colortran (now Leviton) referred to by John McK as having better performance.

7.1 Hard top edge too difficult to blend, needs to be softened.

7.2 – Filament support shadowing issues when used with Philips lamps – a softer reflector..???

8/Yoke – Current solution can go out of alignment, if coach bolt comes free, very difficult to realign.
Advantage of clutch system (FFT) with scale and therefore ability to quickly set all to the same position.

Importance of the lock off – precise and positive.

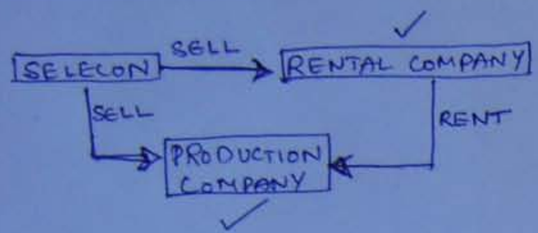
There is a requirement for Pole op.

9/ Cabling – protect exit point as per Hui, watch cable exit radius

Importance of multi connectors in production- more secure and faster to 'test and tag'.

LOOK (WHERE, AT WHAT, AT WHOM)
WH AT AM

M




N

(2) COMPETITOR PRODUCTS
1) - AUST : Prolite
5) - EUROPE : LDR, quartz Glour, Strand, ADB, Robert Juliat
3) - Nth America : Altman, LAE, STRAND

H

1) AUST
2) EUROPE
3) Nth AMERICA
4) ............ (Future mkt)

RE OF AURORA : (TOUCH THE TOPIC)
proved Versions
sion & DISCHARGE LAMP
: MESH COVER instead of GLASS
For W/LIGHT Purpose

TERM IDEAS : (DO NOT TOUCH NOW)
arket assembly using kit set assemblies
local sourcing of large sheet metal

ASK : Categories of Investigation, Specific Questions, Data Needed

| Percieved Needs / Problems | Who has a Problem & What: Rental Comp | Who has a Problem & What: Prodn Comp | Competitor Product Same problem / feature? Y/N | Customer feed back / Interest shown / Imp (1 |
| --- | --- | --- | --- | --- |
| Weight of Product | ✓ (>1 person lift) | ✓ (>person lift) | | |
| Portability / Ease of handling | ✓✓ | ✓ | | |
| Ergonomics | ✓ | ✓ | | |
| Inconvertibility b/w Groundrow & Cyc | ✓ Selling point Inventory | ✓ Inventory Use Flexibility | | |
| Lamp : 1.5kW 120V can be used | ✓ Inventory | ✓ Performance Inventory | | |
| Simplify / Change Wiring Method | ✓ Maintanance | ✓ Easy to use | | |
| Add link-pin feature in Single Unit for Convex Alignment | ✓ selling point | ✓ Usage options Increase | Y | |
| Space b/w Unit & Cloth on Stage : Adv or DisAdv | ✓ Use as selling point? | ✓ we think its an Adv? Y/N | | |

* 1 - Very Important
2 - Yeh, maybe
3 - Don't bother

INVESTIGATION PLAN

MAIN 2 WAYS OF USER RESCH
- Independent Study & Data Collection from Various Sources
- Talk to the Customers

FURTHER INVESTIGATION DEPENDS ON CUSTOMER INTEREST RATING.

DATA COLLECTION

> Weight : Collect Competitor product weights & plot a graph regionwise.
: Study Health & Safety / Union (US) regulations to find out standards.

> List of additional problems & Ideas generated after discussion with Cust

> Technology Information : From Customer
: After striping Competitor Product

## Appendix E1: 2008 SCHEDULE FOR PROJECT X

| TIMEFRAME | 2007 | April-08 | May-08 | | June-08 | July-09 | August-08 | September-08 | | | October-08 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PLANNED COMPLETION OF STAGE (2008) | 2007 | 9-Apr | 9-May | 22-May | 27-Jun | | 22-Aug | EARLY SEPTEMBER | END SEPTEMBER | END SEPTEMBER | END OCTOBER |
| ACTUAL COMPLETION OF STAGE | 2007 | 3-Apr | 12-May | END MAY | 26-Jun | | - | - | - | - | April-09 |
| | **1** | **2** | **3** | **4** | **5** | **6** | | **7** | **8** | **9** | **10** |
| STAGE | Developing a Product Brief after User Research | Refinement of the Brief with concept drawings for Each sub-system | Concept Refinement & a Detailed Project document | Build Functional Prototype & Initial Testing to prove each sub-system concept | Detailed Design & Drawings for each sub-system concept | Order tooling as per final drawings & Getting Off-tool samples for Working prototype | | Working prototype testing & sign-off tools, finalize MOM | Brand story development, Prodn manuals, marketing material | Pre-production manufacture, BOM/MOM signoff | Customer feedback on Pre-production samples, Handover to Production |
| ACTIVITIES CONDUCTED AS PART OF THIS RESEARCH | | | Observing discussions in PD department, Discussion with contract designer and R&D engineer, Observing the process of prototyping | | Observing the internal meeting, Emergence of Legacy issues & how it affected Project X | Observing the emergency meet, Conducting workshops to map the current PD process (overall, Stage1) | Conducting workshops to map the current PD process (Stage 2, 3, 4), Discussion with the managing director Mr.JC, Discussion with PD manager on knowledge database | Redesign of the Product X (major loopback) | | | Observation of Optics & discussion with optics designer |

## APPENDIX E2: Standard Operating Procedure for PD at Company B

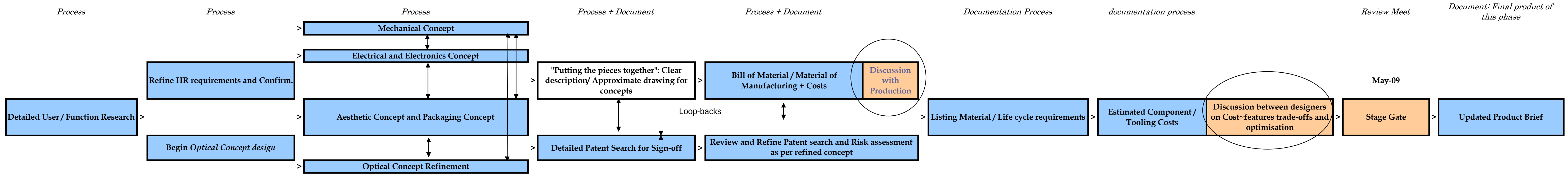
**(Stage 1 to 10)**

**STAGE 1*: Idea Generation and product brief**

| | *Process + Document* | *Process* | *Review meet* | *Decision / review meet* | | *Process* | | *Document* | *Review meet* |
|---|---|---|---|---|---|---|---|---|---|
| | IDEA GENERATION AND WRITING UP OF SHORT BRIEF | > TECHNICAL FEASIBILITY<br>> GENERIC PATENT FEASIBILITY: SEARCH IN-HOUSE | > STAGE GATE | > APPOINT A PD TEAM: RESOURCES | > | DEFINING DETAILED PRODUCT SPECIFICATIONS | | > FINAL BRIEF | Apr-09<br>> STAGE GATE |
| | | | | | THE' RANGE | | ARC' RANGE | | |
| PEOPLE | Managing director / Sales Team | Technical Feasibility : External Technical Expert Contractor (Optical / Electrical / Aesthetics / Mechanical)<br>PATENT SEARCH: In-house and Brief | Managing director, PD Manager, Design team, Sales team, External Technical Expert engineer | Managing director, Operations Director, PD Manager | | Managing director, Operations Director, PD Manager, Design team | | Managing director, Operations Director, PD Manager, Design team | Department heads |
| METHODOLOGY / DETAILS | Research on Market, competition, customers, future technology | Intense research by person responsible(Techanical Expert) and then a meeting on outcome | Meeting for signoff | Identify people to lead, engineers, contractors, suppliers, production in charge, etc | 4 major families | End User Research and come up with a detail brief | 3 major families | Discussion by Design team, production team, service team, sales team to chalk out every aspect of the new product and generate a document | Meeting for signoff |
| OUTPUT DOCUMENT | | | | | | | | Brief consists of:<br>> Objective<br>> Product Market<br>> Product Attributes and Specifications: Purpose, performance, features, design range, reliability/warranty, servicing, aesthetics, packaging, perceived quality, production scale, cost, CAD output<br>> Testing<br>> Recycling | |
| PEOPLE | Managing Director / Sales Team, R&D team | Technical: External Technical Expert Contractor (Optical / Electrical / Aesthetics / Mechanical)<br>Pat: Attorney | Managing director, sales team, external Technical expert contractor | Managing Director, Operations Director, PD Manager | | Managing Director, Operations Director, PD Manager, Design Contractors | | Managing Director, Operations Director, PD Manager | |
| METHODOLOGY / DETAILS | Due to extensive travelling and hence contact with key customers, overall view of market, competitors; Managing Director is able to ideate. Sales team may also collect some ideas due to their constant interaction with end Users. | Intense research by person responsible (technical expert/attorney) and then a meeting on outcome | Meeting for signoff | Identify people to lead, engineers, contractors, suppliers, production in charge, etc | 2 major families | End user research | 4 major families | Discussion by Design team, production team, service team, sales team to chalk out every aspect of the new product and generate a document | Meeting for signoff |
| Critical areas | Business Justification: To gain market share, fill-up the gap in their product range | Product possible? | | Cost | | Specific to product family | | | |
| COMMENTS | By chance / badly needed by customer | Technical aspect specific to project is probed.<br>Approximate patents that may affect are listed and debated. | Technical ok?<br>Patent ok?<br>Market, Resources, Exchange Rates Ok? | Optical and Electronics is handled since many years by 2 well known external experts (problems do exist). Mechanical design (handled by 2 separate designers, working at different locations) and Aesthetics aspects are contracted to design engineers. | | All aspects of mechanical, Aesthetics, Electronics, Optical are collected | | Overall Project document | Decision on 'What is required next to get the project going?', based on the final brief |
| DIAGNOSIS | > Lack of a Systematic method to collect ideas at different points of time.<br>> PD team not involved and Brief is an interpretation of sales team: high possibility of being filtered info/ distorted translation of customer needs. | Involvement of PD team in the process essential to avoid any deviations/ shortcomings (Eg:depth of research) whenever external people are involved. This will avoid any repeatation/ redundancy in work carried out. | If data depth is inadequate to take the decision, person responsible takes more time to complete requirement and a stage gate meet is held again. | PD team includes only 3 full-time employees. Outsourcing design work has several strengths as well as weaknesses. Issues encountered include: Disorganized Working style of contractor, no / minimum control on their delivery dates, quality of work, costs incurred | | Sales team is in the forefront; and PD team has limited/indirect access to needs. Scientific 'Needs Determination' tools not employed. Detailed Project management document should also be prepared parallely. | | Its more of a Project management document consisting of timelines, costs, serviceability, recycling, Intellectual Property; in addition to Product specifications. Committing Resources this early??? | If certain aspects need to be probed, this becomes a repeated activity: team goes back, does what is required and a stage gate meet again. |

*Flowchart indicates the steps involved and the documents generated after each step.

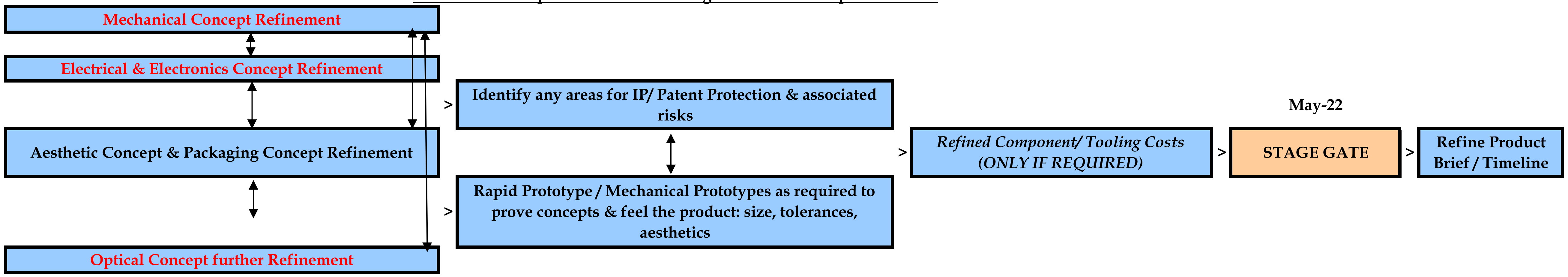
STAGE 2*: Refinement of product brief




| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| WHAT EXACTLY DO YOU DO? | Further drill in, focus areas, grey areas that have been identified during the stage gate. | Look into new findings in previous step | Intense research by person responsible and then a meeting with PD manager | Putting the pieces together | Discussion with the Production personal on assembly aspects, observing the production, trying out on the line. | Discussion with experts on Aspects Probed:<br>1) Manufacturability and Assembly of Luminary,<br>2) Energy conservation,<br>3) Environmental impact and Recycling, etc… | Build Supplier Data Base of Cost | Plan A and Plan B are looked into to arrive on compromises to be made. | Meeting for Signoff: Rework on the schedules/ revised cost targets/ Specifications | Implications on others aspects mentioned in the brief: Changes as a result of stage gate |
| OUTPUT DOCUMENT | Clear, functional End user requirements: Updated Brief | | | Clear description/ Approximate drawings | | Refining the Material / Life cycle requirements in the brief | Refining the Tooling / component cost figures in the brief | | | |
| PEOPLE | Sales and Marketing, Managing Director, PD manager | External Technical Expert Contractor (Optical / Electrical / Aesthetics / Mechanical)<br>Optical: External Contractor | External Technical Expert Contractor (Optical / Electrical / Aesthetics / Mechanical)<br>Mechanical: 1 In-house Contractor + 1 External contractor<br>Optical: External Contractor<br>Electrical: External Contractor<br>Aesthetic: In-house Contractor<br>Patent: External Attorney<br>Packaging: In-house manager | PD manager and all Design engineers | PD manager and all Design engineers | PD manager and Industrial Engineer | Individual Designers and PD manager | | Managing Director, Operations Director, Production manager, Sales manager, PD manager and all Design engineers | |
| WHAT EXACTLY DO YOU DO? | Meet customers, Managing Director attends conferences, meets all major customers on a regular basis: keeps up to date. Invite Customers to visit the company. | Intense research by person responsible and then a meeting with PD manager | Intense research by person responsible and then a meeting with PD manager | Putting the pieces together | Discussion with the production personal on assembly aspects, observing the production, trying out on the line. | Aspects Probed:<br>1) Manufacturability and assembly of Luminary,<br>2) Energy conservation,<br>3) Environmental impact and Recycling, etc… | | | Meeting for Signoff | |
| CRITICAL AREAS | Discuss the positive and negative aspects of company's existing products, how they use the products, generate ideas / concepts, additional features needed. Product Attributes and Specifications: Purpose, performance, features, design range, reliability/warranty, servicing, Aesthetics | Technology / Price target and Managing Director, Supplier Involvement | Technology / Price target and Managing Director, Supplier Involvement | Design Interfaces | Deep understanding of Patents identified and related risks | > PLC<br>> Proactive measures, based on future norms / standards | | | | |
| COMMENTS | Availability of sample products is a constraint and having Clear benchmark product is an enabler. | Supplier involvement would help.<br>Optical redesign leads to mechanical design rework.<br>Technology/Price Target is a matter of concern. | Supplier involvement would help.<br>Optical redesign leads to mechanical design rework.<br>Technology/Price Target is a matter of concern. | | Discussion with the production personal helps to integrate manufacturing issues in the Bill of material / Material of Manufacturing development: Addressing production. Concerns + avoids rework after handover to production. | Trigger for looking at these aspects: European Customs | Supplier involvement would help. | | | |
| DIAGNOSIS | Scientific 'Needs Determination' tools not employed.<br>PD team needs direct interaction with customers and several of them please. | Delays due to poor information exchange, reworks. Interface between various concepts and associated designers needs improvement. | Delays due to poor information exchange, reworks. Interface between various concepts and associated designers needs improvement. | Very important step to ensure the weak areas are identified. Since the designers involved are on and off the site, it becomes a 'must-have' step. So far, such meetings are not done frequently. | Production being involved for the first time into PD, Patent search can be done hand-in-hand / In-house?<br>Insist greater understanding on technical aspects of products. Discussion with the production personal TOO EARLY? | This step has never been done for previous projects. The first of its kind being done by the Aesthetics/Industrial Designer In-house: needs improvement and standardization. | | Step missing: Required to eliminate risk of concentrating on single alternative | Another Stage gate required earlier in this stage? | |

*Flowchart indicates the steps involved and the documents generated after each step.

## STAGE 3*:Concept refinement including initial estimated product costs




| | | | | | |
|---|---|---|---|---|---|
| OUTPUT DOCUMENT / PRODUCT | Final Concept Drawings | Risk Assessment and Prototype / Model | Bill of Material / Material of Manufacturing sheet updated | Approval to Proceed & Updated Product Brief | Updated Product Brief incl. list of risks, agenda for next stage |
| PEOPLE INVOLVED | | | The actual prices from suppliers from quotes are updated. | | |
| PROCESS DETAILS | | | | | |
| PD MANAGER COMMENTS | Undefined Areas in concept are a constraint. Also, rework has to be minimized, as it affects the other aspects of the design. Currently, Contract Electrical Engineer, On-site Mechanical designer and Contract Industrial Designer are well connected. Contract Optical Engineer and Off-site Mechanical designer are well connected. | Clear/Resolved Concept is very essential for this step. Rapid prototypes can be used to gather customer, supplier, production feedback. | Supplier Involvement will help, Supplier Lead Times may cause issues with respect to timelines | | |
| DIAGNOSIS | There should be a team meeting between all the designers (moderated by the PD manager) immediately after the above mentioned series of parallel activities, in order to clearly understand the interfaces, Opportunity for Improvements, help in generating more ideas, etc. | | | | |

*Flowchart indicates the steps involved and the documents generated after each step.

## STAGE 4*: Functional Prototype/ Initial Testing Phase

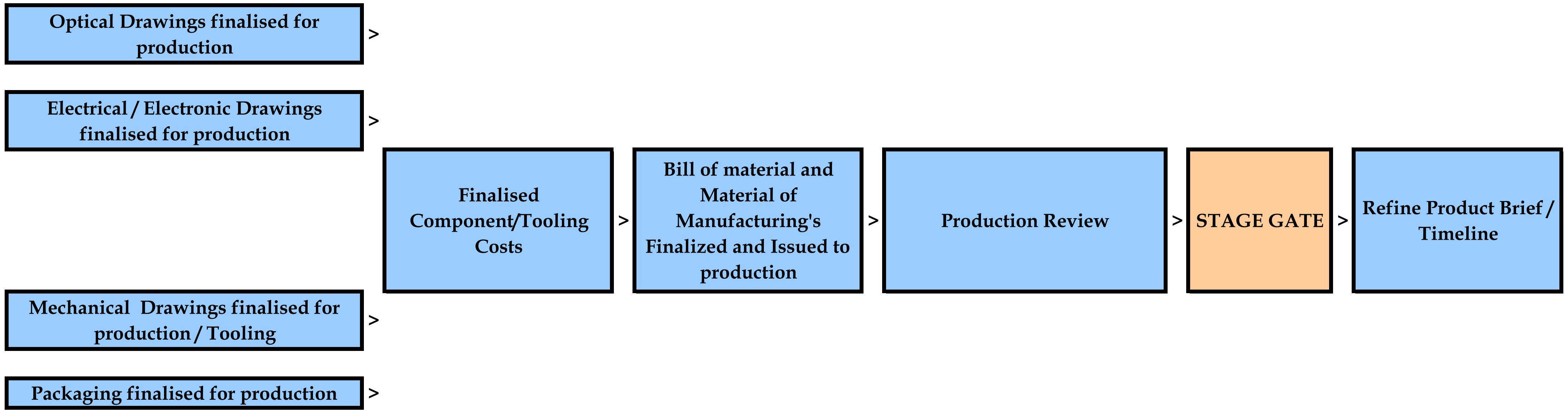
- Aesthetic Prototyping
- Optical Prototyping
- Electrical/Electronic Prototyping
- Mechanical Prototyping

> Revised Product/ Tooling Costs > Initial Testing as required to prove concepts: - Optical - Electrical - Mechanical-Partial > Identify Overall Risks > STAGE GATE (Jun-26) > Refine Product Brief / Timeline

| | | | | | | |
|---|---|---|---|---|---|---|
| OUTPUT DOCUMENT / PRODUCT | 1) Overall Final Concept,<br>2) Functional Prototypes and<br>3) 1:1 Study model for Aesthetic concept | Updated Bill of Material / Material of Manufacturing | Tests results and Analysis sheet of 'how the prototype meets the brief requirements in every aspect' in order to prove the concept | Risk Assessment sheet updated | Approval to Proceed | Updated Product Brief |
| PEOPLE INVOLVED | | | | | | |
| PROCESS DETAILS | Process of mechanical Prototyping conducted in-house, also includes aesthetics. Electrical prototypes ordered based on contract designers drawing(Who works off-site) | | | | | |
| PD MANAGER COMMENTS | Supplier Lead Times can cause issues. | Inputs from Suppliers will be an enabler to this step | Accuracy of Prototype is very critical, or, the testing & subsequent analysis will be based on several assumptions | | | |
| DIAGNOSIS | Issues in Mechanical and Electrical prototyping causing delays and budget over runs. | | | | | |

*Flowchart indicates the steps involved and the documents generated after each step.

## Stage 5*: Detailed Design & Drawings




| | | | | | | |
|---|---|---|---|---|---|---|
| **OUTPUT DOCUMENT / PRODUCT** | Full Supplier Requirements | Costing documents | Bill of material and Material of Manufacturing | Review reports and appropriate changes | | Updated brief |
| **PEOPLE INVOLVED** | | | | | | |
| **PROCESS DETAILS** | Tested/Verified Prototype serves as the input | | | | | |
| **PD MANAGER COMMENTS** | | | | | | |
| **DIAGNOSIS** | | | | | | |

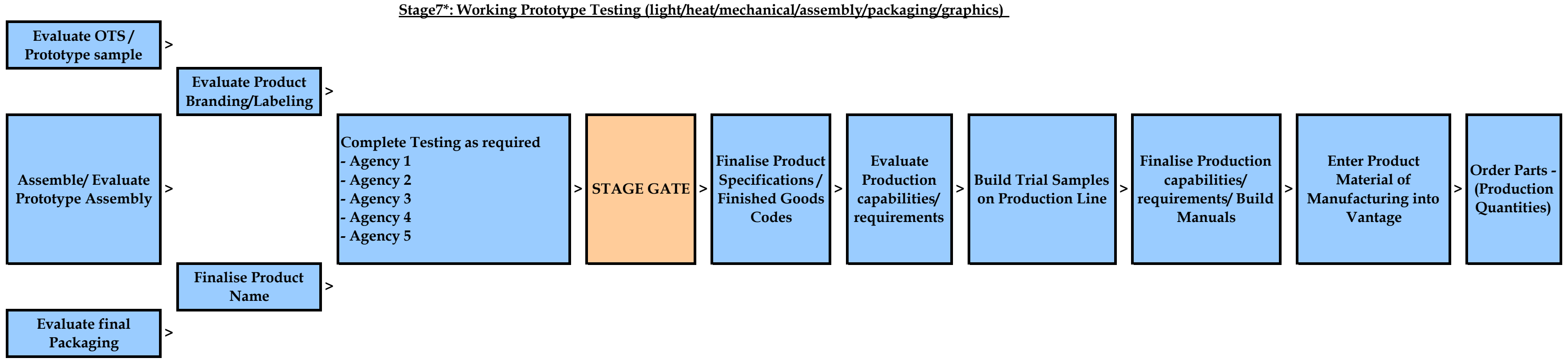
*Flowchart indicates the steps involved and the documents generated after each step.

Stage 6*: Off Tool (Prototype) Samples

| | Order Tooling & receive Off Tool Samples (OTS) | > Order Non-Tooled Prototype Samples | > STAGE GATE | > Updated brief |
|---|---|---|---|---|
| OUTPUT DOCUMENT / PRODUCT | Off Tool Samples | Samples | | |
| PEOPLE INVOLVED | | | | |
| PROCESS DETAILS | Final Design & supplier identification leads to this step | | | |
| PD MANAGER COMMENTS | Supply chain optimization is a major challenge. | Supply chain optimization is a major challenge. | | |
| DIAGNOSIS | | | | |

*Flowchart indicates the steps involved and the documents generated after each step.

**Stage7*: Working Prototype Testing (light/heat/mechanical/assembly/packaging/graphics)**




| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **OUTPUT DOCUMENT / PRODUCT** | Approval of Parts<br>Approval of Assembly Process<br>Approval of Packaging | Approval of Design<br>Product Name | Certification as required | Approval to Proceed | Finalise Product Specifications / Finished Goods Codes | Jigs/Tool/Line setup requirements | | Refinement of Jigs etc | Material of manufacturing within Vantage | | |
| **PEOPLE INVOLVED** | | | | | | | | | | | |
| **PROCESS DETAILS** | Samples are the essential inputs among others | | | | | | | | | | |
| **PD MANAGER COMMENTS** | | | | | | | | | | | |
| **DIAGNOSIS** | | | | | | | | | | | |

*Flowchart indicates the steps involved and the documents generated after each step.

Stage 8*: Development of Brand Story / Product name/ Marketing material

| | Develop Brand Story > | Develop Product Specification Sheets, Manuals, Exploded Drawings, Web Data etc |
|---|---|---|
| OUTPUT DOCUMENT / PRODUCT | Brand Story | Product Specification Sheets, Manuals, Exploded Drawings, Web Data etc |
| PEOPLE INVOLVED | | |
| PROCESS DETAILS | Input: Product Design | Input: Product Design |
| PD MANAGER COMMENTS | | |
| DIAGNOSIS | | |

*Flowchart indicates the steps involved and the documents generated after each step.

**Stage 9*: Pre-production Manufacture, Bill of material / Material of Manufacturing completion**

**Pre-Production Run => Make Customer samples** > **Review Production requirements/ Build Manuals / Build Times** > **Completed MOM & Product Costs** > **Review Customer Feedback on Samples** > **FINAL STAGE GATE**

| | | | | | |
|---|---|---|---|---|---|
| **OUTPUT DOCUMENT / PRODUCT** | Customer Samples | Refined Process | | Total Approval? | |
| **PEOPLE INVOLVED** | | | | | |
| **PROCESS DETAILS** | | | | Customer Feedback on samples are considered in order to make any late Engineering Changes / give an approval for handover design to production. | |
| **PD MANAGER COMMENTS** | | | | | |
| **DIAGNOSIS** | | | | | |

*Flowchart indicates the steps involved and the documents generated after each step.

**Stage 10*: Handover to production**

Full Handover to Production > Start Production of Commercial Quantities

Full Handover to Production > Product Development: Review of Project

| | | |
|---|---|---|
| OUTPUT DOCUMENT / PRODUCT | Production Signoff | |
| PEOPLE INVOLVED | | |
| PROCESS DETAILS | Total Approved Design as per the previous stage | |
| PD MANAGER COMMENTS | | |
| DIAGNOSIS | | |

*Flowchart indicates the steps involved and the documents generated after each step.

**Appendix E3**

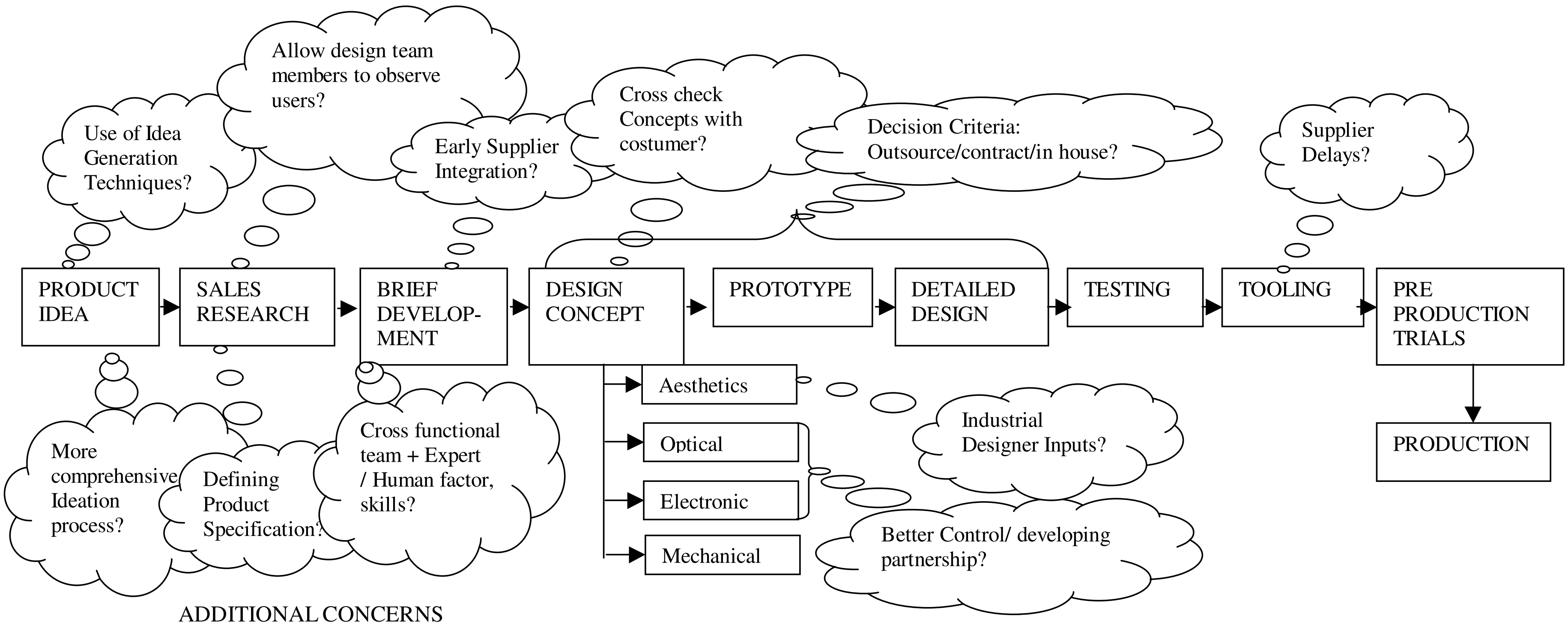
**FIRST SCHEDULE FOR PROJECT X**

| TIMEFRAME | 2006 | | 2007 | | | | | | | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|
| PLANNED COMPLETION DATES | May-06 | February-07 | Feb to Aug 07 | | | | | Aug-07 to Mar-08 | | |
| ACTUAL COMPLETION DATES | May-06 | February-07 | REVISED INTO SCHEDULE BY CONTRACT AGENCY AS SHOWN ABOVE | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| STAGE | Developing a Product Brief after User Research | Refinement of the Brief with concept drawings for Each sub-system | Concept Refinement & a Detailed Project document | Build Functional Prototype & Initial Testing to prove each sub-system concept | Detailed Design & Drawings for each sub-system concept | Order tooling as per final drawings & Getting Off-tool samples for Working prototype | Working prototype testing & sign-off tools, finalize MOM | Brand story development, Prodn manuals, marketing material | Pre-production manufacture, BOM/MOM signoff | Customer feedback on Pre-production samples, Handover to Production |

**SCHEDULE DRAWN BY DESIGN CONTRACTOR FOR PROJECT X**

| TIMEFRAME | 2007 | | | | | | | | | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PLANNED COMPLETION DATES | May & Jun 07 | | July & Aug 07 | | | Sep07 to Jan08 | | Feb08 to March 09 | | | |
| ACTUAL COMPLETION DATES | May & Jun 07 | | July to Dec 07 | | | Contract discontinued due to unsatisfactory work from design agency | - | - | - | - | - |
| | 1 | 2 | 3 | 4 | 5 | 6 | | 7 | 8 | 9 | 10 |
| STAGE | Developing a Product Brief after User Research | Refinement of the Brief with concept drawings for Each sub-system | Concept Refinement & a Detailed Project document | Build Functional Prototype & Initial Testing to prove each sub-system concept | Detailed Design & Drawings for each sub-system concept | Order tooling as per final drawings & Getting Off-tool samples for Working prototype | | Pre-production manufacture, Testing, product manufacturing and monitoring | | Brand story development, Prodn manuals, marketing material | Customer feedback on Pre-production samples |
| | | | | Working prototype testing | | | | | | | |

**APPENDIX F: PD process mapping to identify major concerns** (April 2008)




ADDITIONAL CONCERNS

- **Documentation** / design library
- Understanding & experience should be enhanced within the department alongside **work load** management
- **R&D strategy** overall – Short term goal
- Long term goal – know how's – future technologies - etc
- High dependency on R&D director & MD / no clear successor
- **Technical:** Applying design approach for 'The' range to 'Arc' range– not enough user understanding for 'Arc' range exists

## APPENDIX G: Study on Company B's suppliers

Three-fold approach to study supplier:

A. To understand the operating environment (external and internal factors) of *ABC Engineering*

B. To discuss a Supplier's viewpoint on Company A's R&D systems.

C. Comments on 'Lean Product Development'

**Interview Questions:**

<u>**A:** The operating environment (external and internal factors):</u>

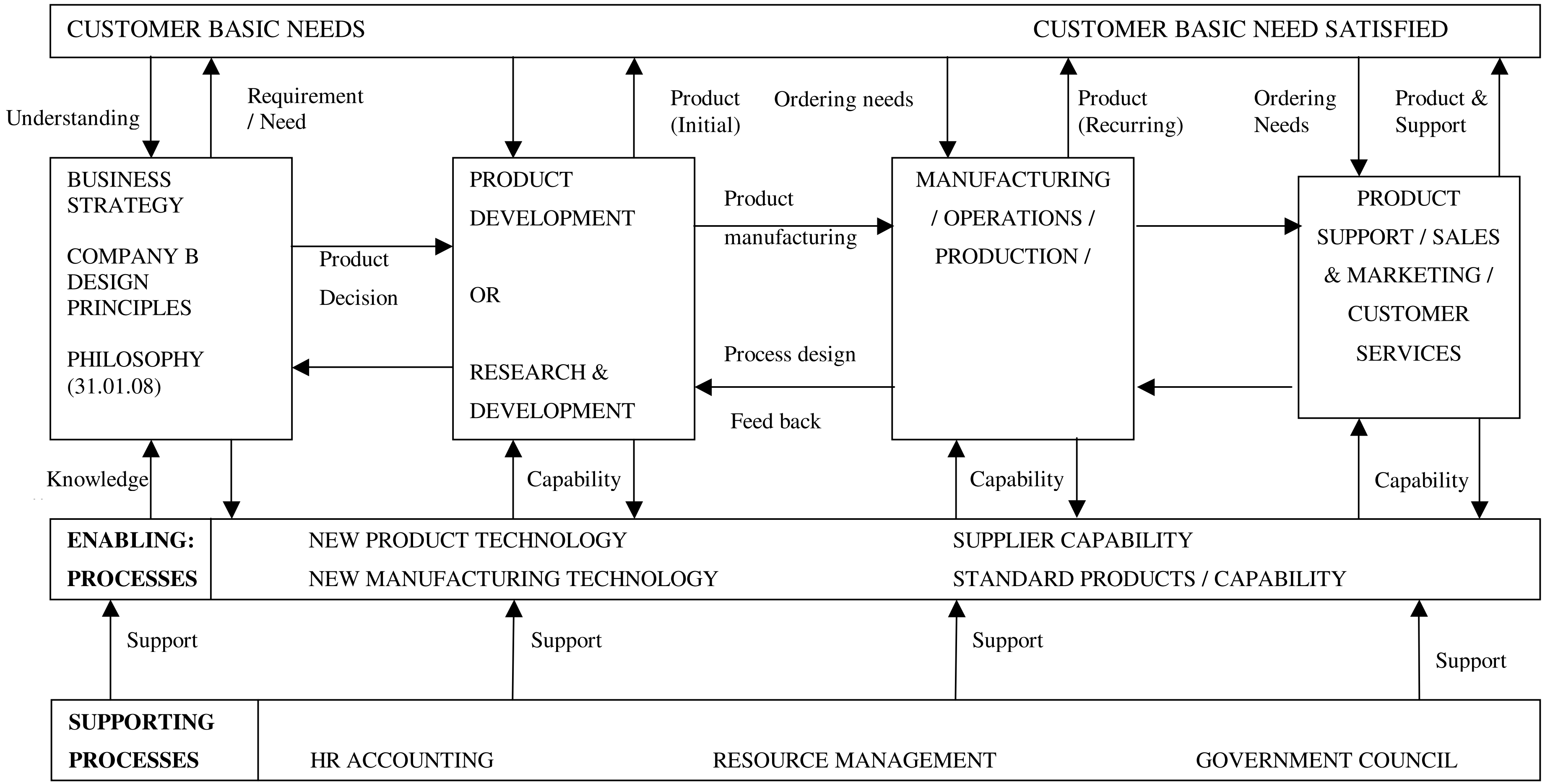
- What are the significant factors influencing their products in NZ: Market Environment, New Product Strategy, Development Process Execution, and Organization?
- What is significantly different about Small enterprises and how do they currently do PD?
- What is the composition of the PD department?
- What are the major concerns; and at which stages of the PD cycle?
- Approximately how long is the speed-to-market for any product? Do they see the need to optimize the duration?
- Do they conduct 'Project reviews'? What is the importance given to documentation and knowledge capture?

<u>**B:** Supplier's Viewpoint on Company A's R&D systems:</u>

1. Comments on the supplier-customer relationship in NZ.
2. How do they view Company B's products in terms of quality, cost and performance?
3. How do they collect customer (i.e. Company B) needs for new supplies?
4. What are the strengths and weaknesses of their existing collaboration with Company B: Design and Manufacture?
5. What does long-term supplier relationship mean to them? What should be a basis for it to be a success?
6. How do they think they can contribute to the PD process at Company B? What actions do they think, will significantly improve supplier integration?

***C. Additional Discussion Question:*** Comments on 'Lean Product Development'. In their view, will it be successful in SMEs?

## APPENDIX H: HIGH LEVEL ORGANISATION MAP

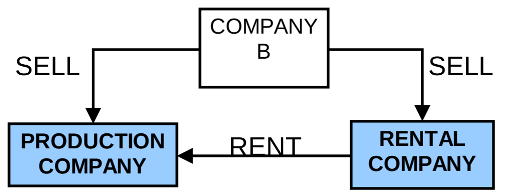



*Source:* ***Adapted from Kennedy (2003), p.67***

## USER RESEARCH DOCUMENT (NOV-2008): REDESIGN OF 'Y'

### LOOK

**A] WHO ARE THE CUSTOMERS?**



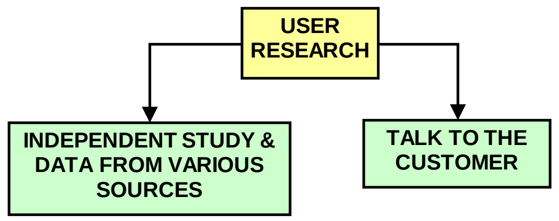

**C] WHO ARE THE COMPETITORS AND IN WHICH REGION?**

> AUSTRALIAN MARKET: COMPANY **P**

> EUROPEAN MARKET: COMPANY **LDR, COMPANY Q, COMPANY S, COMPANY ADB, COMPANY RJ**

> NORTH AMERICAN MARKET: COMPANY **L&E, COMPANY T**

**E] INVESTIGATION PLAN**




FURTHER INVESTIGATION DEPENDS ON CUSTOMER INTEREST RATING (COLUMN Z]) AND OTHER DATA COLLECTED (COLUMN G]).

### FUTURE OF PRODUCT Y

| B] VERSIONS | REACTION FROM CUSTOMER |
|---|---|
| MENTION THE FOLLOWING TO GET THE REACTION:<br>1. PRODUCT Y WITH A DISCHARGE LAMP?<br>2. USE OF MESH COVER AS AGAINST THE EXISTING GLASS FOR W/LIGHT PURPOSE | 1.<br>2. |

| D] LONG TERM IDEAS (STRATEGIC DECISIONS) | REACTION FROM AREA MANAGERS |
|---|---|
| IN-MARKET ASSEMBLY (BY DEALERS) USING KIT SET ASSEMBLIES WITH LOCAL SOURCING OF LARGE SHEET METAL COMPONENTS (ESPECIALLY IN EUROPE) | |

| F] INDEPENDENT STUDY & DATA FROM VARIOUS SOURCES: DATA COLLECTION | G] DATA COLLECTED FROM INDEPENDENT STUDY |
|---|---|
| **1. WEIGHT OF PRODUCT:**<br>> COLLECT COMPETITOR PRODUCT WEIGHTS AND PLOT A GRAPH REGION-WISE<br>> STUDY HEALTH & SAFETY REGULATIONS, UNION & OTHER STANDARDS REGION-WISE<br>**2. TECHNOLOGY UPDATES: STUDY/ ANALYZE CUSTOMER PRODUCTS**<br>**3.**<br>**4.**<br>**5.** | |

### TALK TO THE CUSTOMER: ASK

| W] PERCIEVED PROBLEMS / NEEDS | X] WHO HAS A PROBLEM & WHAT | | | | Y] COMPETITOR PRODUCT HAS SAME FEATURE? | | Z] IMPORTANCE OF PROBLEM TO CUSTOMER<br>RATING SCALE:<br>1-Problem must be solved; 2-YEH MAYBE; 3-Ignore Problem |
|---|---|---|---|---|---|---|---|
| | RENTAL COMPANY | | PRODUCTION COMPANY | | Y/N | COMPETITOR NAME/ NAME OF THAT PRODUCT | |
| 1. WEIGHT OF THE PRODUCT >20KGS | 4 | >1 PERSON LIFT | 4 | > 1 PERSON LIFT | | | |
| 2. PORTABILITY /EASE OF HANDLING | 4 4 | | 4 | | | | |
| 3. ERGONOMICS | 4 | | 4 | | | | |
| 4. INCONVERTIBILITY BETWEEN GROUNDROW & CYC FUNCTIONS | 4 | SELLING POINT, INVENTORY | 4 | INVENTORY, USAGE FLEXIBILITY | | | |
| 5. CAN 1.5KW-120V LAMP BE USED? | 4 | INVENTORY | 4 | PERFORMANCE, INVENTORY | | | |
| 6. WIRING DONE DIFFERENTLY IN EACH REGION IS NOT GOOD? | 4 | MAINTANANCE | 4 | USAGE EASE | | | |
| 7. LINK-PIN NOT AVAILABLE IN SINGLE UNITS (OF PRODUCT Y 'GROUNDROW') TO ALLOW CONVEX ALLIGNMENT | 4 | SELLING POINT | 4 | INCREASE USAGE OPTIONS | Y | ORION | |
| 8. POSITIONING OF 1.5m FROM BACKSTAGE CLOTH IS AN ADVANTAGE OR NOT (IN PRODUCT Y 'GROUNDROW') | 4 | EVER USED AS SELLING POINT? | 4 | UNKNOWN ADVANTAGE | | | |

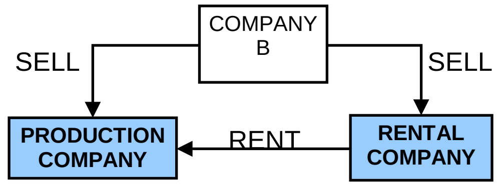
| **ADDITIONAL INFORMATION:**<br>I) LIST OF OTHER PROBLEMS<br>II) LINK TO ANY OTHER IMPORTANT INFORMATION ON TECHNOLOGY/ COMETITORS | | **COMPANY B TEAM** |
|---|---|---|
| 9 | **CUSTOMER** | *Managing Director* |
| 10 | *NAME:* | *PD Manager* |
| 11 | *CONTACT DETAILS:* | *Market Managers* |
| 12 | | |
| 13 | | |

**APPENDIX I: CUSTOMER INTEREST A3 FOR PROJECT Y** PAGE 2: TO OBTAIN FEEDBACK FROM CUSTOMER

| **USER RESEARCH DOCUMENT (NOV-2008): REDESIGN OF 'Y'** | ***REGION: PACIFIC (AUSTRALIA & NZ)*** |
|---|---|

**LOOK**

**A] WHO ARE THE CUSTOMERS?**




| **CUSTOMERS INVOLVED** | **COMPANY B TEAM** |
|---|---|
| *NAME:* | *MD, PD Manager* |
| *CONTACT DETAILS:* | *Market managers* |

**TALK TO THE CUSTOMER: ASK**

| **W] PERCIEVED PROBLEMS / NEEDS** | **X] WHO HAS A PROBLEM & WHAT** | | | | **Y] COMPETITOR PRODUCT HAS SAME FEATURE?** | | **Z] IMPORTANCE OF PROBLEM TO CUSTOMER** RATING SCALE: 1-Problem must be solved; 2-YEH MAYBE; 3-Ignore Problem |
|---|---|---|---|---|---|---|---|
| | **RENTAL COMPANY** | | **PRODUCTION COMPANY** | | **Y/N** | **COMPETITOR NAME/ NAME OF THAT PRODUCT** | |
| 1. WEIGHT OF THE PRODUCT >20KGS | 4 | >1 PERSON LIFT | 4 | > 1 PERSON LIFT | | | |
| 2. PORTABILITY /EASE OF HANDLING | 4 4 | | 4 | | | | |
| 3. ERGONOMICS | 4 | | 4 | | | | |
| 4. INCONVERTIBILITY BETWEEN GROUNDROW & CYC FUNCTIONS | 4 | SELLING POINT, INVENTORY | 4 | INVENTORY, USAGE FLEXIBILITY | | | |
| 5. CAN 1.5KW-120V LAMP BE USED? | 4 | INVENTORY | 4 | PERFORMANCE, INVENTORY | | | |
| 6. WIRING DONE DIFFERENTLY IN EACH REGION IS NOT GOOD? | 4 | MAINTANANCE | 4 | USAGE EASE | | | |
| 7. LINK-PIN NOT AVAILABLE IN SINGLE UNITS (OF PRODUCT Y 'GROUNDROW') TO ALLOW CONVEX ALLIGNMENT | 4 | SELLING POINT | 4 | TO INCREASE USAGE OPTIONS | Y | ORION | |
| 8. POSITIONING OF 1.5m FROM BACKSTAGE CLOTH IS AN ADVANTAGE OR NOT (IN PRODUCT Y 'GROUNDROW') | 4 | EVER USED AS SELLING POINT? | 4 | UNKNOWN ADVANTAGE | | | |

**ADDITIONAL INFORMATION:**
I) LIST OF OTHER PROBLEMS
II) LINK TO ANY OTHER IMPORTANT INFORMATION ON TECHNOLOGY/ COMETITORS

| | | |
|---|---|---|
| 9 | | |
| 10 | | |
| 11 | | |
| 12 | | |
| 13 | | |
| 14 | | |
| 15 | | |
| 16 | | |

**FUTURE OF PRODUCT Y**

| **B] VERSIONS** | **CUSTOMER FEEDBACK** |
|---|---|
| **FUTURE POSSIBILITIES: Please Comment** | |
| 1. PRODUCT Y WITH A DISCHARGE LAMP | 1. |
| 2. USE OF MESH COVER AS AGAINST THE EXISTING GLASS FOR W/LIGHT PURPOSE | 2. |