A NEW PRODUCT IMPLEMENTATION MODEL FOR THE PNEUMATIC TYRE MANUFACTURING PROCESS

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DECLARATION

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Abstract

Pneumatic tyre manufactures face the problems related to the life cycle of products at product launching stage. In an effort to improve timeliness and effectiveness, pneumatic tyre industry is experimenting with different best practices in their new product implementation processes.

This research aims to develop a model for new product implementation for pneumatic tyre industry using a framework based on quality function deployment (QFD). It supports the development of customer focused, agile products and to meet customer expectations in terms of innovation and customisation, quality and competitive price.

During this research, new product implementation models were studied. Some issues of existing new product introduction processes were discussed and new product implementation model was proposed based on the literature, and case studies were used to support the development of the model. A QFD structure was introduced to identify relationships between product design factors and issues of each sub process. These relations were described as weak, moderate and strong. Then the proposed model was validated using case studies.

When the proposed model is applied to the new tyre development, communication path of all relevant parties strengthened by four times, new product implementation time reduced by 20 percent and cost of implementation reduced by 30 percent. In this new model issues can be identified at the product design stage.

This model can be modified to use for new product implementations of any other product. This system can also be modified using computerized system with artificial intelligence to make it more attractive to the users.

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LIST OF ABBREVIATIONS

CE - Concurrent Engineering

FMEA - Failure Mode Effect Analysis

FFE - Fuzzy Front End

QFD - Quality Function Deployment

HOQ - House of Quality

SPC - Statistical Process Control

VA/VE -Value Analysis or Value Engineering

JIT -Just-In-Time

LLT -Less Liner Thickness

QC - Quality Checkers

SM SW - Short Mould on Sidewall

OD – Outer Diameter

CHAPTER 1 INTRODUCTION

1.1 Research Rationale

A new product introduction and implementation process is one of the cornerstones towards a competitive advantage in tyre marketplace today. A fully optimized new product implementation process in combination with other lean and agile manufacturing techniques and systems is guaranteed to reduce lead-time and save on cost.

Developing a highly successful new product is possible through the integration of the abilities of both upstream (e.g., Design engineers) and downstream knowledge workers (e.g., Manufacturing engineers). In business and engineering, new product development is the term used to describe the complete process of bringing a new product or service to market. Companies typically see new product development as the first stage in generating and commercialising new products within the overall strategic process of product life cycle management used to maintain or grow their market share. The manufacturing industry seeks new product introduction to gain competitive advantage, lower cost and reduce time-to-market.

When considering the launching of new products, the problems faced by most manufacturing companies lies not only in accelerating and maintaining sales after the launch but in reducing the costly development time before the launch.

In an effort to improve timelines and effectiveness, a number of firms within the automotive industry are experimenting with different best practices in their new product implementation processes.

Product development is a broad field of endeavour dealing with the design, creation, and marketing of new products. Referred to as new product introduction and development, the discipline is focused on developing systematic methods for guiding all the processes involved in getting a new product to market.

In the Sri Lankan context, there is no standard method to introduce new product in the tyre industry. When considering new products implementing in the Sri Lankan tyre industry, it has no defined method or proper system. So it creates more time to implement, high scrap rate of new implemented products. Because manufacturing of this new product is not aligned with the current existing manufacturing system. So it creates a lot of issues and when handling these issues, it creates high cost and more times. Before launching to the market sometimes it will fail in implementing stage.

1.2. Aim:

The aim of this study therefore is to develop a new product development model in a pneumatic tyre manufacturing environment using case studies and quality function deployment (QFD) tools. This will support the development of customer focused, agile products as well as meet customer expectations in terms of innovation and customisation, quality, competitive price and steps to ensure a sustainable and environmentally friendly product.

1.3. Objectives:

- Study the contemporary models for global new product introduction and development and analysing current industry convention and synthesis of the best practices.

- To identify the barriers of new product implementation in pneumatic tyre section by analysing the historical data
- To explore the areas of concerns in the process of new product implementing by benchmarking the barriers of existing products
- To propose a model by using QFD and case studies
- To validate the model

1.4. Methodology

In order to address the previously mentioned objectives the following methodology would be adopted.

A new product introduction and development process is researched through literature and available internal documents. Best practice in new product implementation tools and techniques, new product implementation models which are currently practicing in worldwide is studied.

New product implementation failures, barriers of new product introduction in the pneumatic tyre industry are explored. Reasons for failure of new products, case studies of implementing products in pneumatic tyre sections are considered.

A model is proposed, that will be suitable to address all the challenging issues identified by using historical data, literature review and case studies within the pneumatic tyre section. The proposed model is developed by using based on QFD techniques and barriers of each sub process. Barriers of each sub processes are identified by proper survey in each sub process of pneumatic tyre manufacturing process and major barriers are identified by analysing the collected data. Then proposed model is validated by using case studies of new implementing products.

In Chapter 2 discusses about literature related to new product development models and tools. Chapter 3 is related to review the current existing model and its issue with some case studies. Chapter 4 explains about the proposed new model of new product implementation. Chapter 5 discusses about validation of the proposed new model using case studies. Chapter 6 is related to the conclusion and recommendation of the proposed new model. Future work of this proposed model is also discussed in this last chapter.

CHAPTER 2 LITERATURE REVIEW

2.1. Introduction

This section will explicate and appraise the literature that is applicable to this research. This literature survey will provide a more detailed evaluation of existing new product implementation systems. During this survey, existing new product development models, new product implementation tools and new product implementation failures are going to study.

2.2. Existing New Product Implementation Models

Recently, ever-changing customer demands, technological innovations, and intense global competition challenge companies to succeed in satisfying dynamic market requirements through new product launch. Companies have realized that successful new product launch to deliver true customer value is a competitive weapon to defeat rivals and to dominate the market. A successful new product facilitates firms to achieve commercial success, such as through yielding long-term return on investment and satisfying the needs of both potential and current customers.

New product process models can be categorized as descriptive versus normative, and further by industrial product versus consumer product. Descriptive process models have evolved from empirical studies of the new product case histories. Booz, Allen, and Hamilton [1], Myers and Marquis [2], Utterback [3], Rothwell [4], and Little [5] all propose flow charts that identify the steps of the new product process. The Myers and Marquis' model is typical: a five-stage descriptive model, whose stages include recognition, idea, search, solution, and implementation. Such models, however, were never intended as normative guides for managers: while conceptually correct, they lack the detail and precision necessary for use as a normative model.

Moreover, since descriptive models are based on actual practice. There is no guarantee that such practice itself is ideal and could stand as a guide to others.

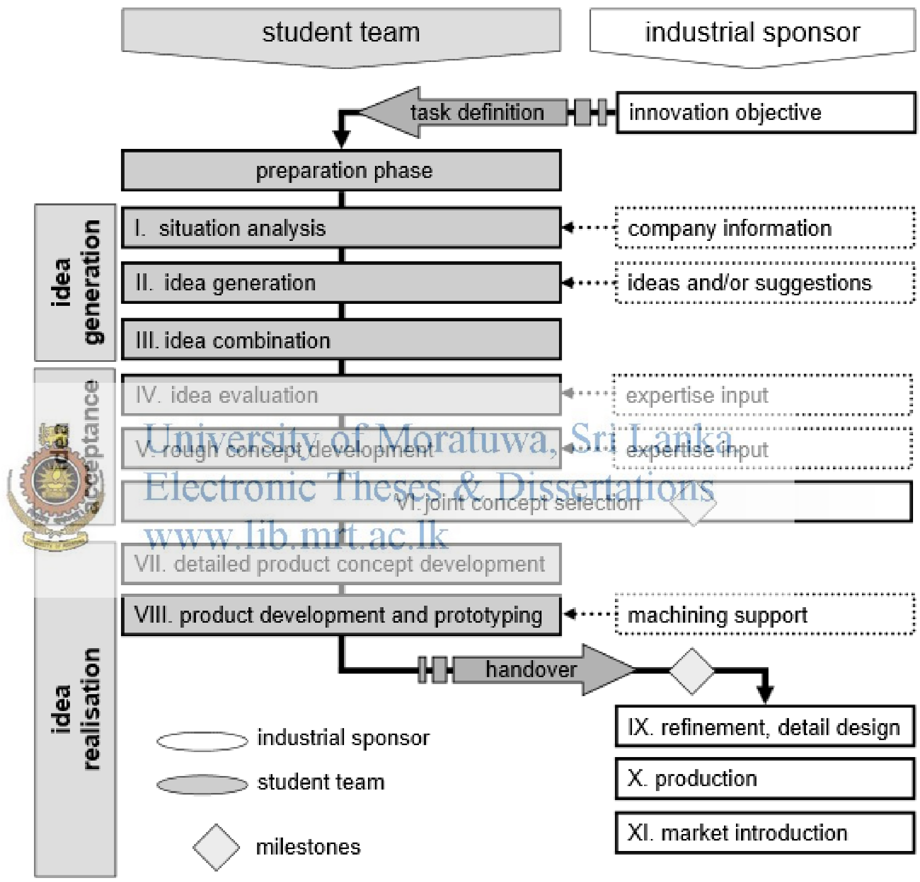


Figure 2.1 Myers and Marquis' model

Source: [30]

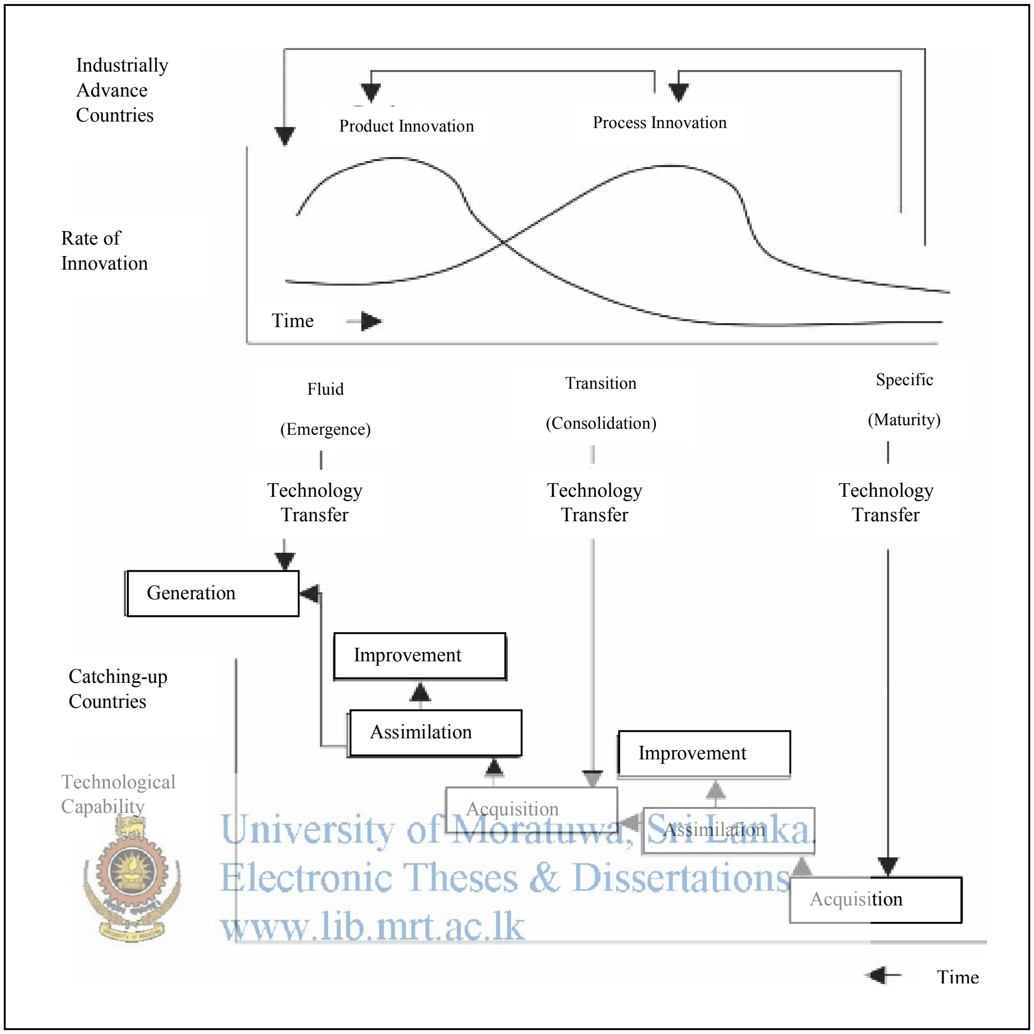


Figure 2.2 JM Utterback' model

Source: [3]

2.2.1. Concurrent engineering model

Concurrent Engineering (CE) is a product development methodology, which enhances productivity and can lead to better overall designs; it still relies heavily on the quality of information, interpretation, execution and implementation. Terwiesch and Loch discussed that in the development of a product, there are many aspects to be considered. These include final cost, manufacturability, safety, packaging and recyclability. These aspects represent different phases in the product's life cycle. In traditional design methodologies, the product is evaluated after each phase is completed [6].

Rosenthal, however points out, “the downstream aspects are affected by decisions made during the design phase”. Consequently, these aspects should be taken into account during the design phase, considerably difficult in globally dispersed teams [7]. Figure 2.3 shows a diagram representing the Concurrent Engineering (CE) Model as defined by Terwiesch.

Activities in the model are progressed concurrently and completed simultaneously and the phases within the project are completed simultaneously thereby reducing project lead-time and cost. Within the model the individual strategy can be broken down into new product implementation activities that are crucial to that period of the new product implementation process. For instance the completion of the design Failure Mode Effect Analysis (FMEA) is imperative before commencing product design verification in order to reduce cost, lead-time and process complications.

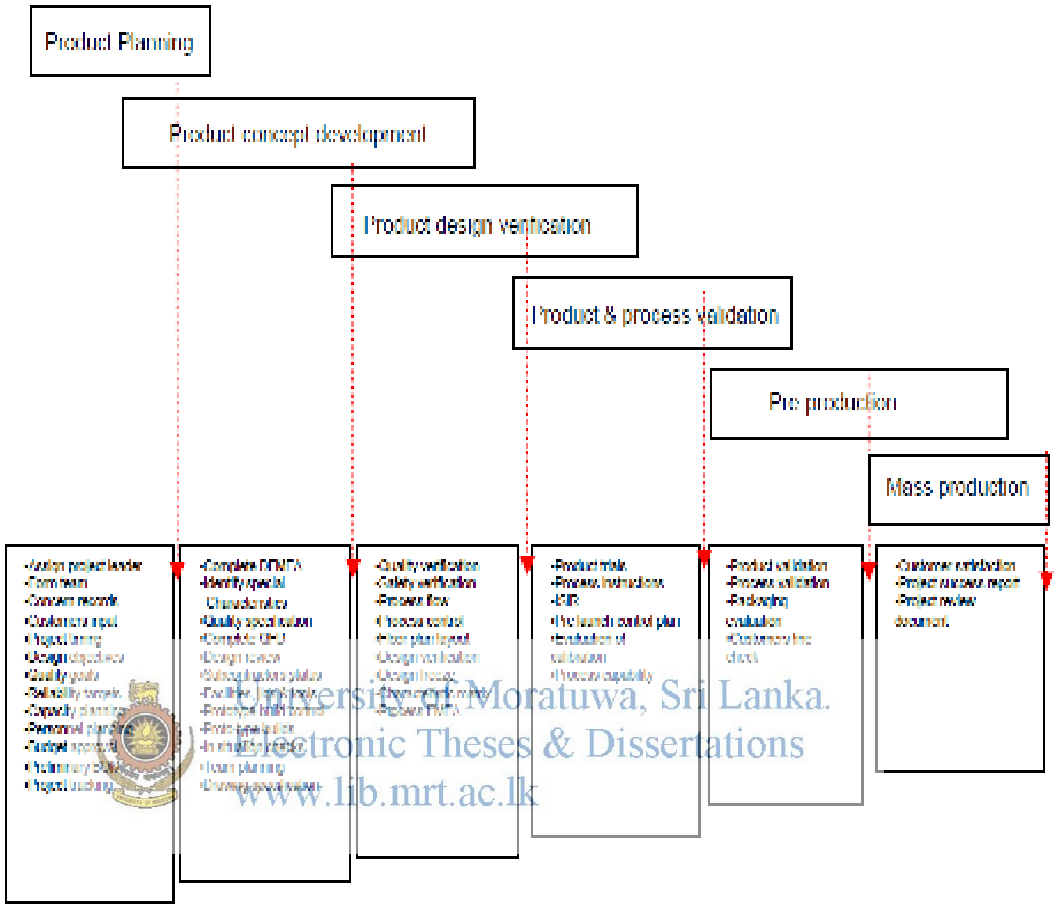


Figure 2.3 New product implementation based concurrent model

Source: [19]

These Concurrent Engineering (CE) issues from a global perspective are;

- Cross-functional and extended project team management – team management is particular by strenuous in new product introduction and can lead to numerous project managers in diverse locations all pulling in different directions [8].
- Overlapping activities - dependence and confidence in dispersed team members [9].
- Direct communication through teamwork – distance and time difference make this almost impossible, strong information technology (IT) support is also required [9].
- Rich partial information transfer, which allows the merging of upstream and downstream activities – difficult to generate at a distance, and will necessitate a strong and expensive technical support [9].
- Directions and decisions, which take downstream activities into account, Particular suppositions such as manufacturing made at the start of the project have a direct bearing on downstream departments [9].
- Front loading of information – information pertinent to the initial team may not be as crucial to a downstream department like manufacturing and the reverse is equally true [9].
- Problem solving, review and response between the product and process phases – an activity that will be completely disregarded in most new product development projects [9].
- Integrated supply based management by early involvement – a globally dispersed supplier base has the added complications of communications, currency fluctuations, which are not perceived in local new product development projects [9].
- Development tool integration with customers and suppliers – new product implementation can often lack the suppliers or customers' integration and are therefore reliant on the extended team for this activity [9].

2.2.2. Phase and stage gate model

The Phase and Stage Gate Model constructed by Cooper (illustrated in Figure 2.4). The phases are separated by gateways to complete the phase before starting the next phase. Utilizing this model, managers can review the progress of a project at the various stages of development and verify that all the objectives have been achieved prior to progressing to the next stage.

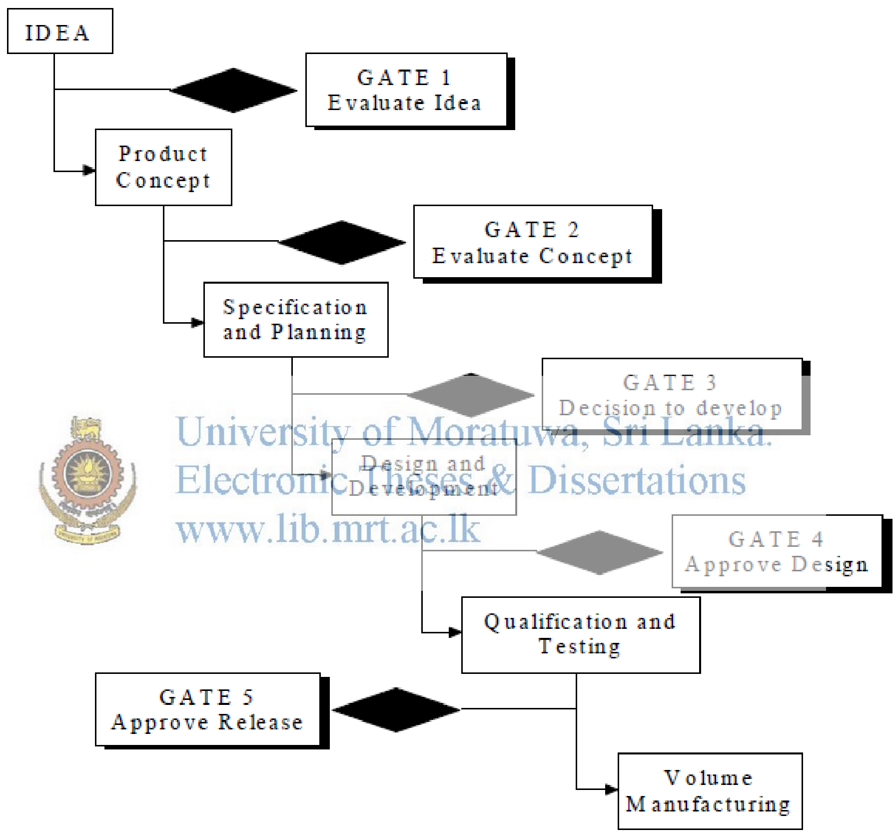


Figure 2.4 The Phase and Stage Gate Model

Source: [31]

The key points noted are: [10]

• It is less expensive to screen products in the early stages

• Each stage control improves the product and increases the success rate.

2.2.3. Booz, Allen and Hamilton's new product development process

Although risk is inherent in new product development, it can be lessened by adopting a systematic framework for managing new product activities. One such framework for managing new product activities was developed by management consulting firm of Booz, Allen and Hamilton as shown in Figure 2.5. They divided new product development into seven sequential stages: new product strategy development, idea generation, screening and evaluation, business analysis, development, testing, commercialization.

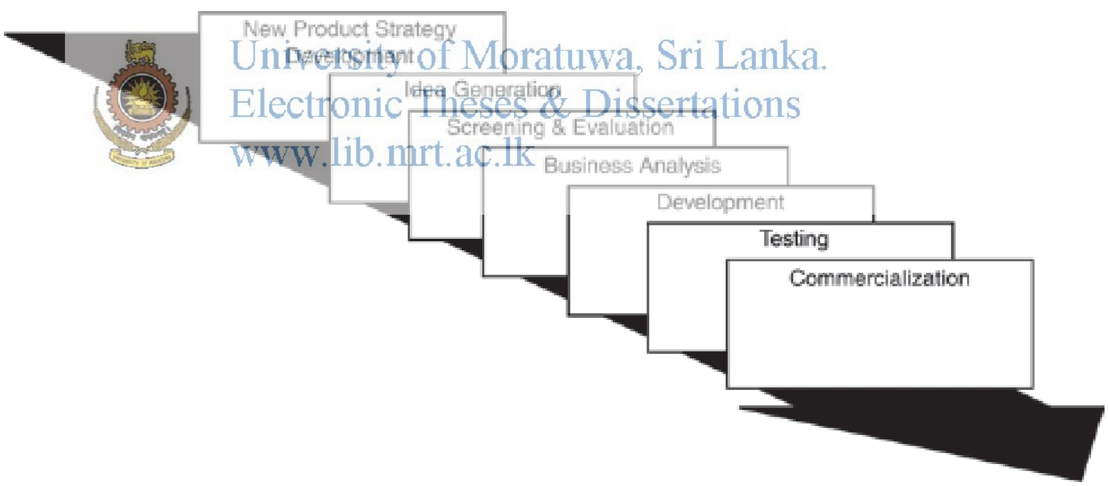


Figure 2.5 Booz, Allen and Hamilton's new product development process
Source [1]

New product difficulties must engage in the new product process if they wish to endure and prosper.

Causes of new product failures were identified from previous researched [11].

Market/marketing failure

- Small size of the potential market
- No clear product differentiation
- Poor positioning
- Misunderstanding of customer needs
- Lack of channel support
- Competitive response

Financial failure

- Low return on investment

Timing failure

- Late in the market
- Too early –market not yet developed

Technical failure

- The product did not work
- Bad design

Organizational failure

- Poor fit with the organizational culture
- Lack of organizational support

Environmental failure

- Government regulations
- Macroeconomic factors

The Phase and Stage Gate Model process (Figure 2.6) is a conceptual and operational road map for moving a new product from idea to launch. The approach is a widely employed product development process that divides the effort into distinct time-sequenced stages separated by management decision gates. Multifunctional teams must successfully complete a prescribed set of related cross-functional tasks in each stage prior to obtaining management approval to proceed to the next stage of product development [12].

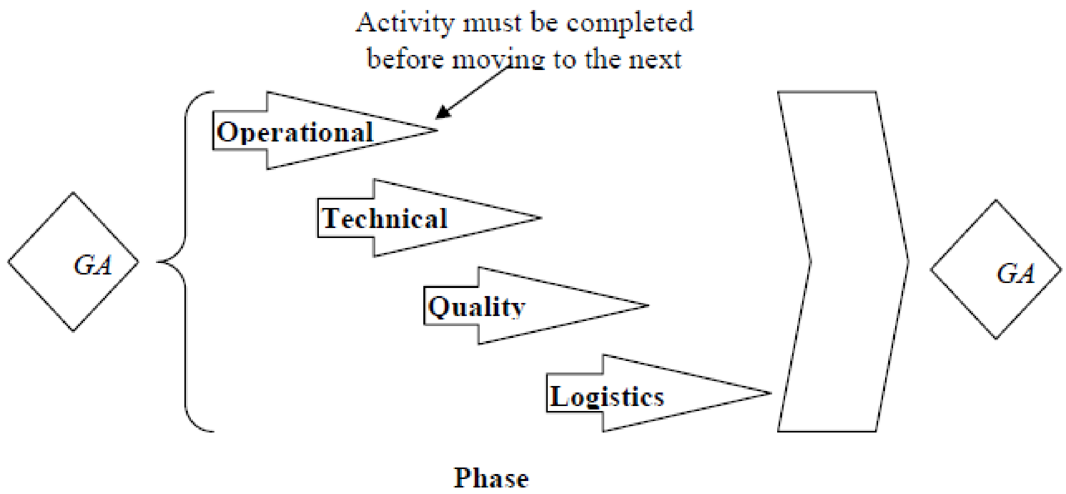


Figure 2.6 The gates of the Phase and Stage Gate Model

Source: [12]

McGrath describes a five phase development model consisting of concept evaluation, planning and specification, development, test and evaluation, and product release with decision gates at the conclusion of each phase [13]. Within Phase 1 of this model, called 'Planning and Specification', the development team is expected to plan the project while at the same time defining the product specifications. Others suggest that the product specifications must be set prior to detailed planning. If the product specifications are not set prior to detailed planning, the product being planned is also being scoped, which causes increased uncertainty and fuzziness during the planning that likely continues into development. In addition, the organization members who set product specifications are sometimes different from the team that will develop the product. So, it is conceivable that a formal sharing of information is needed from the venture team to the development team. By having a separate phase, this review would be built into the process.

A Five Phase Model

Phase 1: Concept Evaluation

Phase 2: Planning and Specification

Phase 3: Development

Phase 4: Test and Evaluation

Phase 5: Product Release

Clausing takes a total quality view of the development process with a four phase model of concept, design, preparation, and production [14]. Within the framework, he defines specific tools that can be used within each of the phases. This model mostly focuses on the technical attributes of the product and does not claim to cover the entire new product development process. For example, the planning is largely skewed toward planning the product and not the project. For this model to be more complete, it would require details for portfolio review, and an additional focus on a project versus product planning and execution.

A Four Phase Model

Phase 1: Concept

Phase 2: Design

Phase 3: Prepare

Phase 4: Produce

Ideas enter the front end funnel segment, pass through a number of development segments, and are ultimately released to market. The front end is depicted here as a cloud due to the fuzziness and the challenge of making sense of the uncertainty in this segment. This early part of the process, from when the product idea is initiated up to the point just prior to the formal developmental phases, has been termed “The Fuzzy Front End” (FFE).

Smith and Reinertsen specify a three-stage front end model to help with the front end planning and decision making [15]. In the first stage a project proposal is presented, the second stage prepares a business plan for financial and market justification, and the third stage is for detailed project planning prior to detailed design activity. This is a high level model and it is not known if it has been validated. In addition, the Smith and Reinertsen model gives very little treatment to the initial idea generation process.

Three stage Front End Model.

Stage 1: Project Proposal

Stage 2: Business Plan

Stage 3: Detail Project Plans & Product Specifications

Paul studied business to business product development and stressed the importance of having an idea screen process within the front end segment [16]. He proposed a general three-step approach consisting of the internal idea screen, concept development and testing, and business analysis. However, again very little is discussed on capturing the idea generation process. Additionally, it is questionable whether or not one should perform concept testing before a business analysis. That is something that is very likely dependent on an industry and type of product.

Three Steps Front End Model

Step 1: Idea screen

Step 2: Concept Development and Testing

Step 3: Business analysis

Khurana and Rosenthal, using interviews, analysed problems reported in the front end of twelve companies in the U.S., Japan, and Europe [17]. From this study, they summarized that organizations either used a formal process approach or a culture-driven approach to their front end. The majority of the companies in their sample tended not to have any formal front end process, a situation the authors called a shortcoming in need of remedy. Another key point the authors argue is that the front end process should be adapted to the innovation level of the product, the target market, and the organizational context. Their front end model has a pre-phase zero, a phase zero and a phase one. In the pre-phase zero phase, they suggest a preliminary opportunity identification and a market and technical assessment, in parallel with the product and portfolio strategy evaluation. During phase zero the product concept is defined. Phase one is used for product feasibility and project planning. Within this model, a significant amount of work is expected in the pre-phase zero and phase 1 phases. This includes both product feasibility studies and project planning. Separating out the activities of these phases into a more structured process could improve on the decision making. This is especially needed if information is transferred amongst organizational units or teams doing this work.

A Three Phase Front End Model

Pre-phase Zero: Preliminary Opportunity Identification and Market and Technical Assessment; in Parallel with the Product and Portfolio Strategy Evaluation

Phase 0: Product concept is defined

Phase 1: Product feasibility and project planning

2.3. New Product Implementation Tools

There are several tools to implement new products in an effective way.

2.3.1. Quality function deployment (QFD)

QFD is a way of listening to customers to learn exactly what they want, and then using a logical system to determine how best to fulfil those needs with available resources [18]. It is a product-development tool that translates customer requirements into design and production requirements. QFD ensures that everyone works together to give customers what they want and it gives everyone in the organisation a road map showing how every step, from design through delivery, interacts to fulfil customer requirements.

Introduced in Japan by Yoji Akao in 1966, QFD is a technique that aims to capture what the customer needs, and work towards how it might be achieved. In 1990 Akao described QFD as 'a method for developing a design quality aimed at satisfying the consumer and then translating the consumer demand into design targets and major quality assurance points to be used throughout the production phase'.

The QFD system consists of the four phases that are summarized as follows [18].

Phase 1, Product Planning: Building the House of Quality. Led by the marketing department, Phase 1, or product planning, is also called The House of Quality. Many organizations only get through this phase of a QFD process. Phase 1 documents customer requirements, warranty data, competitive opportunities, product measurements, competing product measures, and the technical ability of the organization to meet each customer requirement. Getting good data from the customer in Phase 1 is critical to the success of the entire QFD process.

Phase 2, Product Design: This phase 2 is led by the engineering department. Product design requires creativity and innovative team ideas. Product concepts are created during this phase and part specifications are documented. Parts that are determined to be most important to meeting customer needs are then deployed into process planning, or Phase 3.

Phase 3, Process Planning: Process planning comes next and is led by manufacturing engineering. During process planning, manufacturing processes are mapped (flowchart) and process parameters (or target values) are documented.

Phase 4, Process Control: And finally, in production planning, performance indicators are created to monitor the production process, maintenance schedules, and skills training for operators. Also, in this phase decisions are made as to which process poses the most risk and controls are put in place to prevent failures. The quality assurance department in concert with manufacturing leads Phase 4.

Projects are traditionally defined by three factors: cost, time, and quality. Improving one factor often requires a tradeoff in another [29]. During the design process, many decisions are made regarding materials to be used, construction techniques, etc. In making these decisions, approximately 80% of the project overall costs are locked in, before any construction have been started. When changes are required early in the planning process, they can easily be integrated into the plan with minimal effects; problems found later in the process have a greater impact to fix them. (Figure 2.7)

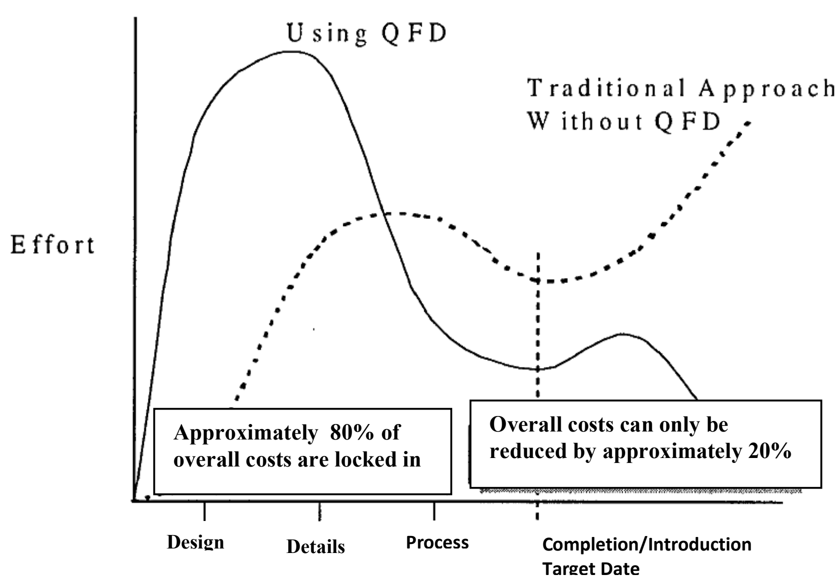


Figure 2.7 Comparison between QFD and traditional method

Source: [32]

House of quality

The first phase in the implementation of the Quality Function Deployment process involves putting together a "House of Quality" (Hauser and Clausing, 1988) which involves the first of these matrices [19]. This matrix has the most general structure and is often called the 'house of quality' (HOQ). Typically applications of QFD are limited to the HOQ; however QFD can play a greater role as a linking mechanism throughout product development through the use of subsequent matrices.

2.3.2. Taguchi method

The Taguchi method was developed by Dr. Genichi Taguchi of Japan who maintained that variation [20]. Taguchi developed a method for designing experiments to investigate how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning.

Taguchi's response to quality differs rather greatly from the goalpost philosophy of the European and American countries. The Japanese implementation of Taguchi's concept sees them working on the principle that when designing a product, it should be designed with minimum loss, with the relative product been designed as close to the optimum value as is feasibly possible.

In general, there are four quality concepts devised by Taguchi:

- Quality should be designed into the product from the start, not by inspection and screening.
- Quality is best achieved by minimizing the deviation from the target, not a failure to conform to specifications.
- Quality should not be based on the performance, features or characteristics of the product.
- The cost of quality should be measured as a function of product performance variation and the losses measured system-wide.

Taguchi's main objectives are to improve process and product design through the identification of controllable factors and their settings, which minimize the variation of a product around a target response. By setting factors to their optimal levels, a product can be manufactured more robust to changes in operation and environmental conditions. Taguchi removes the bad effect of the cause rather than the cause of a bad effect, thus obtaining a higher quality product.

2.3.3. Statistical process control (SPC)

Arguably the most successful SPC tool is the control chart, originally developed by Walter Shewhart in the early 1920s. A control chart helps you record data and lets you see when an unusual event, e.g., a very high or low observation compared with "typical" process performance, occurs.

Control charts attempt to distinguish between two types of process variation: [21]

- Common cause variation, which is intrinsic to the process and will always be present.
- Special cause variation, which stems from external sources and indicates that the process is out of statistical control.

There are changes in production output from one unit to the next (which may be small) and this continuous variation has two basic causes: [22]

1. Common Causes are variations due to operating environment (temperature, humidity and atmospheric pressure), small equipment vibrations, and small variations in the materials used and so on. When a process varies in such a way, over time these variations become predictable. In general, as long as the outputs of a process lie within the expected amount of variation (from common causes) then the process is said to be in control.
2. Special Causes are abnormal and cannot be predicted. In manufacturing process special causes are excessive machine or tool wear and drifting from calibration, an inferior batch of raw materials, a poorly trained operator or an

incorrect work method. Any of these cause variations in the process output and unless rectified could harm the output quality of the process. Whenever a process is judged to have been influenced by a special cause, it is said to be out of control.

Control charts are an essential tool of continuous quality control. Control charts monitor processes to show how the process is performing and how the process and capabilities are affected by changes in the process. This information is then used to make quality improvements.

2.3.4. Value analysis or Value engineering (VA/VE)

VA/VE is an approach to productivity improvement that attempts to increase the value obtained by a customer of a product by offering the same level of functionality at a lower cost. Value engineering is sometimes used to apply to this process of cost reduction prior to manufacture, while value analysis applies the process to products currently being manufactured. The terms are interchangeable; both attempt to eliminate costs that do not contribute to the value and performance of the product.

Value engineering programs are best delivered by multi-skilled teams consisting of designers, purchasing specialists, operations personnel, and financial analysts. Pareto analysis is often used to prioritise those parts of the total design that are most worthy of attention. These are then subject to rigorous scrutiny. The team analyses the function and cost of those elements and tries to find some similar components that could do the same job at lower cost.

Common results are a reduction in the number of components, the use of cheaper materials, or a simplification of the process.

Several characteristics differentiate the Value Method from other techniques. These help ensure that the customer obtains the kind of product they need and want.

Typical benefits of a VA/VE project [23]

- Reduce piece cost and total cost — up to 26% across the board savings
- Improve operational performance 40-50%
- Improve product quality between 30-50%
- Reduce the manufacturing costs up to 30%
- Improved customer-supplier relations
- Cost avoidance on future programs
- Reduction in product variations

2.3.5. Failure modes and effects analysis (FMEA)

Product failures through design or manufacturing faults are costly both in monetary terms and in the customer's perception of the product and manufacturer [24]. Therefore a multifunctional approach to product system analysis, done in a timely manner, provides a valuable guard against the introduction of poor products. FMEA is a structured approach to the identification and evaluation through a 'risk priority number' (RPN) of possible modes of failure in a product or process design. The RPN delivers a list of prioritised failure modes to be considered during design. Failure is taken in its broadest sense, not as a catastrophic breakdown, but as a consequence of not meeting a customer's requirements. The aim is to anticipate and design out all possible failures before they occur, removing the cost to manufacture, warranties, and customer satisfaction. It can be used from design through to production.

It was developed by reliability engineers in the 1950s to study problems that might arise from malfunctions of military systems. An FMEA is often the first step of a system reliability study. It involves reviewing as many components, assemblies, and subsystems as possible to identify failure modes, and their causes and effects. For each component, the failure modes and their resulting effects on the rest of the system are recorded in a specific FMEA worksheet.

The purpose of FMEA is to: [25]

- Help identify risks
- Establish the relative priorities of the risks
- Focus on an action plan to reduce the risks
- Track the progress of the action plan

Design FMEA: uncovers potential failures associated with a product that could cause product malfunction, shortened life or potential safety hazards.

Production FMEA: uncovers potential failures that can impact on product quality, reduce process reliability, create safety hazards and ultimately cause customer dissatisfaction.

Advantages of FMEA

- Improve the quality, reliability and safety of a product/process
- Improve company image and competitiveness
- Increase user satisfaction
- Reduce system development time and cost
- Collect information to reduce future failures, capture engineering knowledge
- Reduce the potential for warranty concerns
- Early identification and elimination of potential failure modes
- Emphasize problem prevention
- Minimize late changes and associated cost
- Catalyst for teamwork and idea exchange between functions
- Reduce the possibility of the same kind of failure in the future
- Reduce impact on company profit margin
- Improve production yield

2.3.6. Lean manufacturing

Lean Manufacturing is a comprehensive business strategy that seeks to eliminate waste in order to reduce the time between a customer order and shipment, and often improves profitability, customer satisfaction and employee morale [26]. Lean manufacturing is an umbrella term for a variety of tools. The following are the most frequent tools employed.

1. Just-in-Time (JIT) – 'pull' system – parts are brought to the production work site only when needed.
2. Kanban – 'pull' system – Japanese method that uses carts, or kanbans, that hold the minimum amount of inventory needed on the plant floor.
3. Continuous Flow Work Cells (a.k.a. Cellular Manufacturing) – collocate machines, equipment, tools and people necessary to complete a product in one work setting.
4. Set-up Time and Maintenance Reduction – reducing machine downtime by training each worker who uses a machine how to set-up, maintain and clean the machines; keeping all parts required for set-up near the machine.

Lean Manufacturing views the cause of poor performance is wasteful activity. Lean is a time-based strategy and uses a narrow definition of waste (non-value-adding work) as any task or activity that does not produce value from the perspective of the end customer. Increased competitive advantage comes from assuring every task is focused on the rapid transformation of raw materials into finished product [26].

The Toyota production system introduced the original seven wastes are: [26]

- Transport (moving products that are not actually required to perform the processing)
- Inventory (all components, work in process and finished product not being processed)
- Motion (people or equipment moving or walking more than is required to perform the processing)

- Waiting (waiting for the next production step, interruptions of production during shift change)
- Overproduction (production ahead of demand)
- Over Processing (resulting from poor tool or product design creating activity)
- Defects (the effort involved in inspecting for and fixing defects)

Later eight wastes were defined by Womack et al. and it was described as manufacturing goods or services that do not meet customer demand or specifications. Many others have added the "waste of unused human talent" to the original seven wastes [26].

2.4. New Products Failures

Table 2.1 New product success rates

Development Stage	Probability of Success	
	Consumer	Industrial
Design	50%	60%
Market test	45%	65%
Introduction	70%	75%

Source: [27]

These high failure rates can typically be traced to a few recurring reasons: [27]

- Technology, rather than customer-oriented marketing, drives the new product process resulting in "better mousetraps that nobody wants" or "products in search of markets"
- Unambitious "me too" products (incremental changes) lack distinguishing advantage versus entrenched competitive products, or competitors quickly follow with "one up" products that cannibalize the innovation.

- Products miss performance specifications (that may be changed excessively during the project), or are over-engineered, missing cost targets (resulting in unsatisfactory margins, or unacceptably high "recovery" prices).
- Projects are under planned, underfunded, understaffed (too few people, too much "churning" of the project team), or unrealistic with respect to timing or technical feasibility.

In summary, an effective new product development process is characterized by:

- Top management commitment: willingness to assume prudent risk and drive the organization to demanding NPD objectives.
- Disciplined process, fast pace: sensitive to both the need for thoroughness (all critical steps taken) and the need for speed (shortened development and life cycles)
- Practical creativity, rigorous analysis: stretch to find the "white spaces" but cull out inherently bad initiatives.
- Proven or predictable technology: avoiding the need for high cost, high risk "invention on demand".
- Explicit multifunctional coordination: recognizing the product is unique among the Ps in that it touches most organization functions.
- Real time schedules and budgets: drive for heroic performance, but don't stretch to breaking point.
- Predetermined milestones & decision criteria: avoid setting "go / no go" criteria in the heat of battle when the natural bias is to continue on course
- Sufficient & scalable launch resources: providing the critical mass of initial support, and having the wherewithal to ramp-up if successful
- Team continuity before & after launch: avoiding the temptation to shift the key players and their accumulated knowledge prematurely
- Relentless attention to detail: ultimately, the difference between success and failure lies in execution, which is inherently detailed-oriented.

2.4.1. Examples for new product implementation failures

Mosquito magnet

In 2000 working with American Biophysics on the launch of its Mosquito Magnet, this uses carbon dioxide to lure mosquitoes into a trap [28]. The timing was perfect: The West Nile virus scare had elevated mosquitoes from irritating nuisances to life-threatening disease carriers.

Mosquito Magnet quickly became one of the top-selling products in the Frontgate catalogue and at Home Depot. But American Biophysics proved more adept at killing mosquitoes than at running a fast-growing consumer products company. When it expanded manufacturing from its low-volume Rhode Island facility to a mass-production plant in China, quality dropped. Consumers became angry, and a product that was saving lives almost went off the market. American Biophysics, which had once had $70 million in annual revenue, were sold to Woodstream for the bargain-basement price of $6 million. Mosquito Magnet is making money for Woodstream today, but the shareholders who originally funded the device have little to show for its belated success.

Computer software

In 2007, when one of the largest computer software company launched new software, the media and the public had high expectations. So did the company, which allotted $500 million for marketing and predicted that 50% of users would run the premium edition within two years [28]. But the software had so many compatibility and performance problems that even company's most loyal customers revolted. That software flopped, and another software company lampooned it in an ad campaign ("I'm a Mac"), causing many consumers to believe that introduced new software had even more problems than it did.

If that new software were launched today, the outcome might be even worse, owing to the rising popularity of Twitter and YouTube and the prevalence of Facebook "hate" pages. As social media and user-generated reviews proliferate, the power of negative feedback will only increase—making it even more imperative that product is ready before they hit the market.

Cola drink

For its biggest launch since drink A, these cola drink identified a new market: 20- to 40-year-old men who liked the taste of this cola drinks (but not its calories and carbs) and liked the no-calorie aspect of drink A (but not its taste or feminine image) [28]. Drink B, which had half the calories and carbs and all the taste of original this type of cola drink, was introduced in 2004 with a $50 million advertising campaign.

However, the budget couldn't overcome the fact that cola drink B's benefits weren't distinctive enough. Men rejected the hybrid drink; they wanted full flavor with no calories or carbs, not half the calories and carbs. And the low-carb trend turned out to be short-lived.

It had problem that why these issues didn't come up before the launch. Sometimes market research is skewed by asking the wrong questions or rendered useless by failing to look objectively at the results. New products can take on a life of their own within an organization, becoming so hyped that there's no turning back. This cola drink's management ultimately deemed drink B a failure. Worldwide case volume for all three drinks grew by only 2% in 2004 (and growth in North America was flat), suggesting that drink B's few sales came mostly at the expense of cola drink and drink A. The company learned from its mistake, though: A year later it launched this cola drink Zero, a no-calorie, full-flavor product that can be found on shelves—and in men's hands—today.

Music player

In 2004 a scent "player" was launched, that looked like a CD player and emitted scents (contained on $5.99 discs with names like "Relaxing in the Hammock") every 30 minutes [28]. The company hired the singer Shania Twain for its launch commercials. This confused consumers, many of whom thought the device involved both music and scents, and the ambiguity caused this music player to fail.

When a product is truly revolutionary, celebrity spokespeople may do more harm than good. A strong educational campaign may be a better way to go. The product's features provide the messages to build brand voice, aided by research and development teams, outside experts, and consumers who've tested and love the product.

2.4.2. Failure factors

Considering the above examples, reasons of new product implementation failures and suggestions can be summarised as follows.

- There should be planning to ramp up quickly if products take off. In the example of launching the mosquito magnet, company cannot give support fast growth of the product.
- New product launching has to be delayed until the product is really ready. An example of Microsoft windows vista, the product falls short of claims and gets bashed.
- Test the product to make sure its differences will sway buyers. Considering the example of Cola drink B, the new item exists in product limbo.
- If consumers can't quickly grasp how to use the product, it's toast. According to example of one of the music player, the product defines a new category and requires substantial consumer education—but doesn't get it.

Some of these problems are more fixable than others. Example 1 and 2 are largely matters of timing: If the launches of Mosquito Magnet and computer software had been postponed, the manufacturing and quality problems might have been resolved. Even though companies may be wedded to a long-established or seasonal launch dates, they would do well to delay if waiting might increase the odds of success. Examples 3 and 4 are trickier, because they relate more directly to the product itself. Managers must learn to engage the brand team and marketing, sales, advertising, public relations, and web professionals early on, thus gaining valuable feedback that can help steer a launch or, if necessary, abort it. Hearing opposing opinions can be painful—but not as painful as launching a product that's not right for the market or has no market at all.

2.5. Summary

There are several models were developed in order to facilitate smooth process. One of the first developed models that today companies still use in the NPD process is the Booz, Allen and Hamilton Model. This model represents the foundation of all the other models that have been developed afterwards. Other models are Myers and Marquis, Utterback, Rothwell and Little. Concurrent engineering should begin at the earliest stages of preliminary design and continue through the life cycle of the product

- Decisions made during design typically drive 70%, and sometimes more, of the product cost. Input from the forging source and material supplier, beginning at the earliest stages of product design, are essential in controlling the end cost of the product.
- The cost of design revisions increases approximately ten-fold through each stage of product development. For example, a change made during detailed design may cost ten times as much as it would have cost during preliminary design. A change made during prototyping and testing may cost 100 times as much.

Another, often overlooked advantage of concurrent engineering is the opportunity to identify opportunities for cost and weight reductions that can only be detected with the interchange that occurs when all stakeholders are present. The major perceived disadvantage of concurrent engineering is that it increases the time spent in preliminary design, when the design staff is anxious to finalize details and release drawings. However, experience has shown that additional up-front time sharply reduces changes in subsequent stages of product development, where changes incur substantially more cost and time.

Taguchi method is a scientifically disciplined mechanism for evaluating and implementing improvements in products, processes, materials, equipment, and facilities. These improvements are aimed at improving the desired characteristics and simultaneously reducing the number of defects by studying the key variables controlling the process and optimizing the procedures or design to yield the best results.

The Taguchi method is a combination of an engineering approach and a statistical method to achieve improvements in product/process's cost and quality, accomplished through design optimization.
The Taguchi method has been proposed to help benchmark in the house of quality. QFD identifies the direction of improvement for certain design parameters, cannot give the exact amount improvements or the exact target values. The Taguchi method will help determine precise target values for the manufacturing process.

The purpose of statistical quality control is to ensure, in a cost efficient manner, that the product shipped to customers meets their specifications. Inspecting every product is costly and inefficient, but the consequences of shipping non-conforming product can be significant in terms of customer dissatisfaction. Statistical Quality Control is the process of inspecting enough product from giving lots to probabilistically ensure a specified quality level.

Failure modes and effects analysis also document current knowledge and actions about the risks of failures, for use in continuous improvement. FMEA is used during design to prevent failures. Later, it’s used for control, before and during ongoing operation of the process. Ideally, FMEA begins during the earliest conceptual stages of design and continues throughout the life of the product or service.

Quality function deployment (QFD) is a critical aspect of the quality control policy of an organization. It is a process for translating customer requirements into manufacturing standards. QFD is used for new product development. It is very powerful as it incorporates customer needs into the design parameters so the final product will be better designed to meet customer expectations.

There are many benefits to be realized by using Quality Function Deployment (QFD), including the following:

Customer driven: The focus is on the customer's wants, not what the company thinks the customer wants. The "Voice of the Customer" drives the development process.

Competitive analysis: Other products in the marketplace are examined, and the company product is rated against the competition.

Reduced development time:

The likelihood of design changes is reduced as the QFD process is focused on improvements to be made to satisfy key customer requirements. Careful attention to customer requirements reduces the risk that changes will be required later in the project life cycle. Time is not spent developing insignificant functions and features.

Reduced development costs: The identification of required changes occurs early in the project life cycle. Minimizing changes following production, reduce warranty costs and product support costs.

Documentation: A knowledge base is built as the QFD process is implemented. A historical record of the decision-making process is developed.

Considering the QFD tool with other new product implementation tools, QFD tool can translate customer requirement into design factors. For development of this new model, it has requirement to translate barriers of new product implementation into design factors. So QFD is the best tool to achieve this requirement.

CHAPTER 3 BOTTLENECK IDENTIFICATION

3.1. Introduction

During this chapter, each stages of existing model (illustrated in figure 3.2) of new product implementation is reviewed. Then two case studies were done for implementing new products in existing models. Issues of existing model are highlighted at the end.

3.2. Pneumatic Tyre Manufacturing Process

The pneumatic tyre manufacturing process is a very complicated process which contains various sub processes. Figure 3.1 shows the manufacturing process of the pneumatic tyre. Each sub process is divided into cells and each cell has team leader. Operators in each sub process are responsible to give a good quality semi product for next operation. Quality checkers (QC) randomly check the quality of product and process. Figure 3.2 shows existing model for new product implementation.

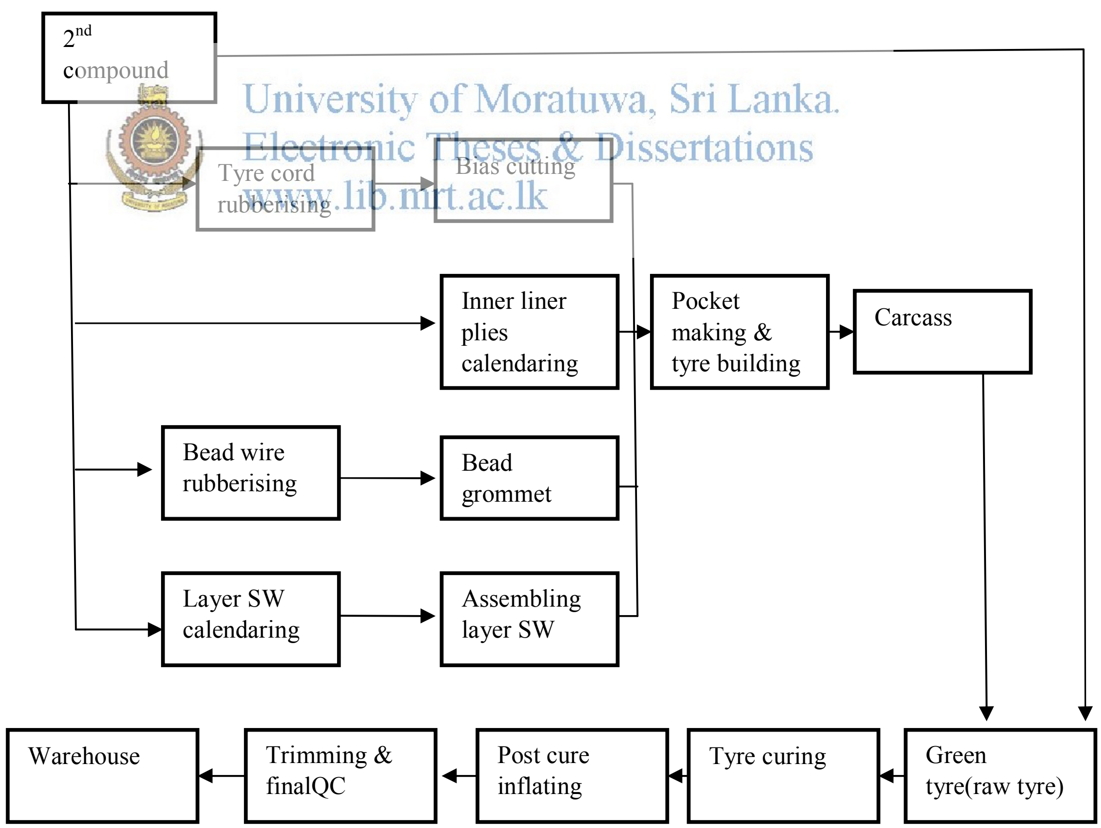


Figure 3.1 Pneumatic tyre manufacturing process

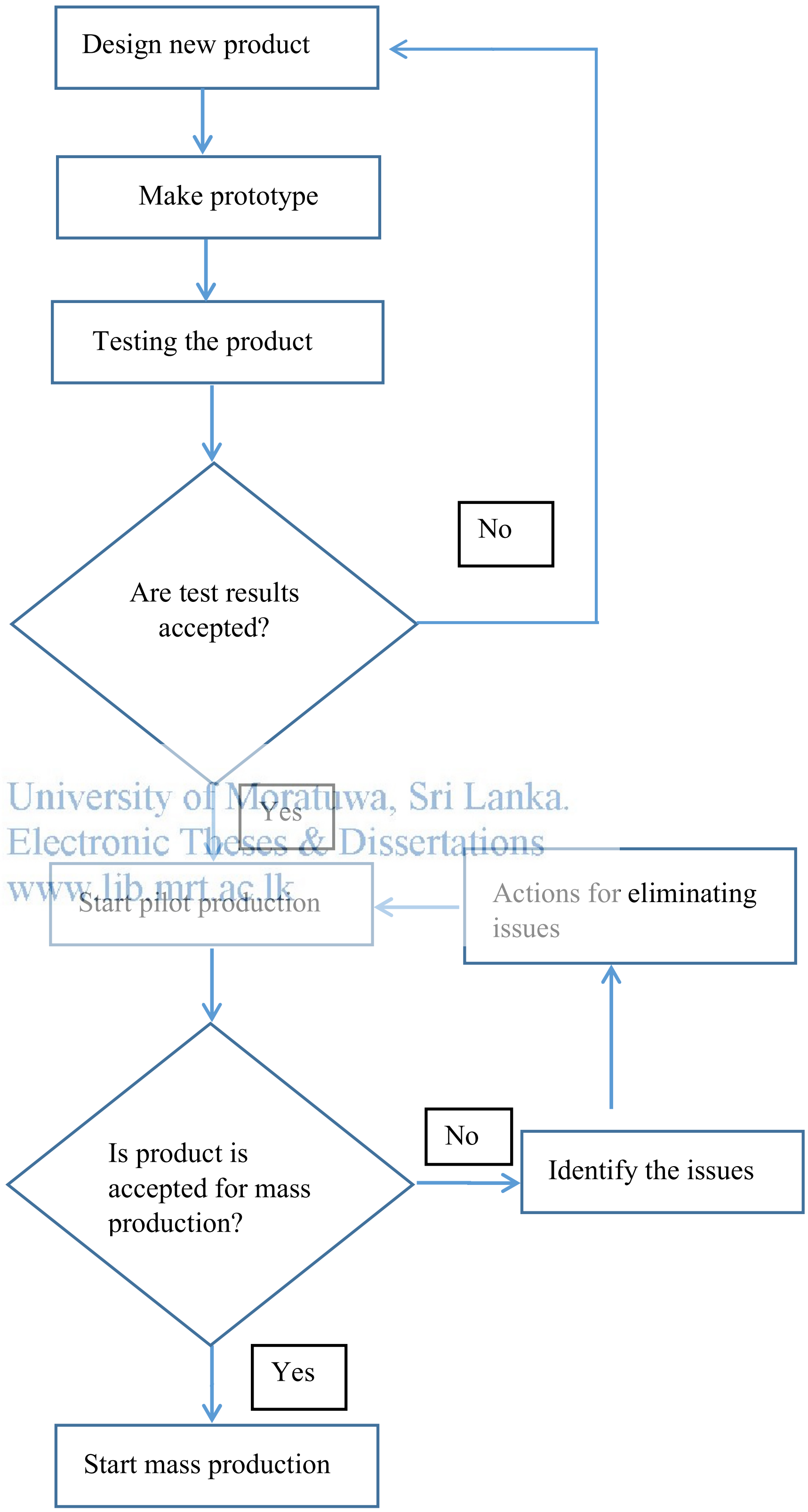


Figure 3.2 Existing new product implementation model

3.3. Product Design

Product design is the process of creating a new product to be sold by a business to its customers. A very broad concept, it is essentially the efficient and effective generation and development of ideas through a process that leads to new products.

In a systematic approach, product designers conceptualize and evaluate ideas, turning them into tangible inventions and products. The product designer's role is to combine art, science, and technology to create new products that other people can use.

There are various product design processes and they focus on different aspects. This process is usually completed by a group of people. It focuses on figuring out what is required, brainstorming possible ideas, creating mock prototypes, and then generating the product.

Tires are highly engineered structural composites whose performance can be designed to meet the vehicle manufactures' ride, handling, and traction criteria, plus the quality and performance expectations of the customer. Figure 3.3 shows cross section of pneumatic tyre.

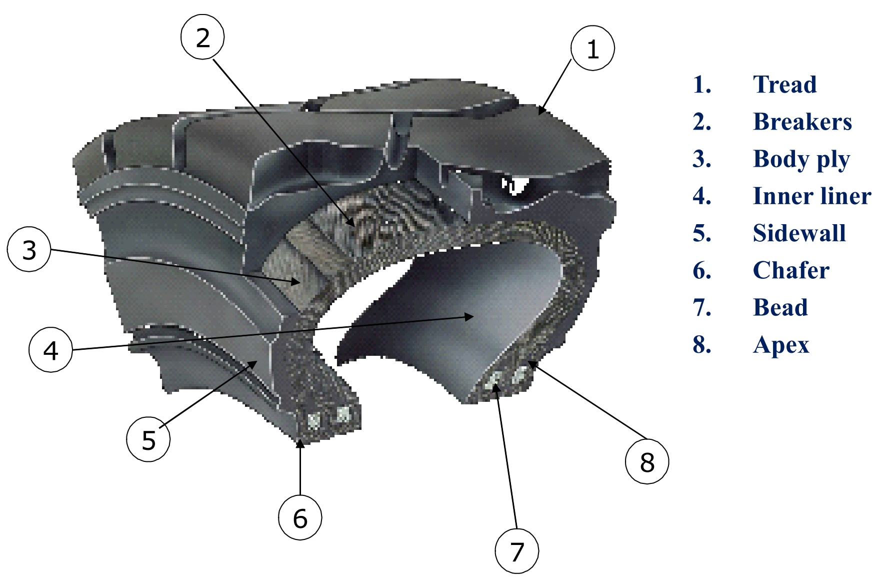


Figure 3.3 Cross section of pneumatic tyre

3.3.1 Tire components

Rubber compound

Purpose

Beyond the visible tread and sidewall compounds, there is more than a dozen specially formulated compounds that are used in the interior of the tire.

Basic ingredients

Polymers are the backbone of rubber compounds. They consist of natural or synthetic rubber.

Fillers reinforce rubber compounds. The most common filler is carbon black, although other materials, such as silica, are used to give the compound unique properties

Softeners: Petroleum oil, pine tar, resins and waxes are all softeners that are used in compound principally as processing aids and to improve tack or stickiness of unvulcanised compounds.

Antidegradents: waxes, antioxidants, and antiozonants are added to rubber compounds to help protect tires against deterioration by ozone, oxygen and heat.

Curatives: during vulcanization or curing, the polymer chains become linked, transforming the viscous compound into strong, elastic materials. Sulfur along with accelerators and activators help achieve the desired properties.

Reinforcement materials

Purpose

A tire's reinforcing materials- tire cord and bead wire- are the predominant load carrying members of the cord-rubber composite. They provide strength and stability to the sidewall and tread as well as contain the air pressure

Type and usage

Nylon type 6 and 6,6 tire cords are synthetic long chain polymers produced by continuous polymerization/spinning or melt spinning.

Advantage: good heat resistance and strength; less sensitive to moisture

Disadvantage: Heat set occurs during cooling (flats potting); long term service growth

Inner liner

The inner liner is a thin, specially formulated compound placed on the inner surface of tubeless tires to improve air retention by lowering permeation outwards through the tire.

Body plies

Body plies of cord and rubber skim wrap around the bead wire bundle, pass radially across the tire and wrap around the bead bundle on the opposite side. They provide the strength to contain the air pressure and provide for sidewall impact resistance.

Bead bundle

Individual bronze plated bead wires are rubber coated and then wound into a bundle of specified diameter and configuration prior to tire assembly. The bead bundles serve to anchor the inflated tire to the wheel rim.

Abrasion gum strip (chafer)

It provides a layer of rubber between the body plies and the wheel rim for resistance against chafing. The airtight seal between the tire and rim must be maintained under all operating conditions.

Bead filler (apex)

It is applied on top of the bead bundles to fill the void between the inner body plies and turned up body ply ends on the outside. Varying the apex height and hardness affects tire ride and handling characteristics.

Sidewall

Tire sidewall rubber serves to protect the body plies from abrasion, impact flex fatigue. The rubber compound is formulated to resist cracking due to environmental hazard such as ozone, oxygen, UV radiation and heat.

Under tread

The under tread is a thin layer of rubber placed under the tread to boost adhesion of the tread to stabilizer plies during tire assembly and to cover the end of the cut belts.

Tread

It must be provided the necessary grip or traction for driving, braking and cornering, and the tread compound is specially formulated to provide a balance between wear, traction, handling and rolling resistance. A pattern is moulded into the tread during vulcanization or curing. It is designed to provide uniform wear, to channel water out of the footprint, and to minimize pattern noise on a variety of road surfaces.

3.4. Prototype Making

Prototyping is the design verification phase of Product Development. It used to demonstrate or prove aspects of a design. Prototyping is simply taking the design from the virtual, imaginary realm into the physical world. Typical prototyping methods include mock-ups, fabrication, and rapid prototyping. Mock-ups are typically done very early in the design for visualization, feel, and to allow adjustments or fiddling with shape and size. Fabricated prototypes are typically functional versions that may or may not look like the final product, but given the opportunity to test function or prove something works.

The term "Rapid Prototyping" encompasses a large group of technologies that create 3D physical parts directly from the computer. This is becoming very popular because of the speed and accuracy available. These can be made in almost any shape and can be finished to look exactly like a production part though usually much more fragile. A whole host of service bureaus has sprung up to meet this need, so for more information, a quick web search will usually yield an overload of information.

Prototypes provide following advantages.

- It enables to test and refine the functionality of the design.
  When designing the product, idea is perfectly done in theoretically. But it needs to check the functionality of the idea. So prototype enables to know the design issues and challenges, when taking the idea from theory to reality.
- It makes it possible to test the performance of various materials.
  At prototype stage will help to determine the best material that performs better at a lower cost in a particular application.
- It'll help to describe the product more effectively
  It can be explained clearly to the team, including marketing experts, engineers and potential business partners.

Product design engineer designs the product as requested target parameters. A design engineer does not have much knowledge on some critical parameters on the manufacturing floor. He gives his main concern to make prototype somehow on managing available resources and get approval for prototype. After the prototype is approved to launch, then management decides to implement that product as soon as possible.

After getting designing the product specification for making prototypes, required material preparation and allocation of required machines have to be discussed with the relevant parties. Because prototype making has to be done on the manufacturing floor and it should be arranged to do with minimum disturbance for other manufacturing products.

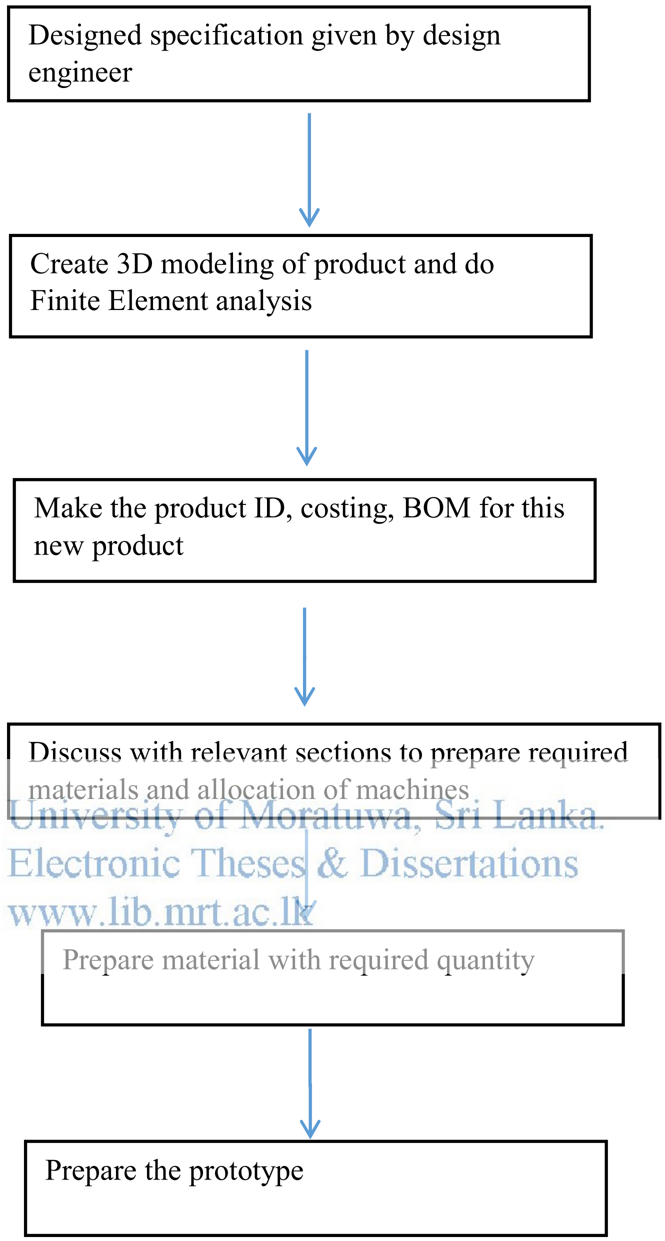


Figure 3.4 Prototype making process

In making prototypes, following sections are involved and need to do discussion about them. Table 3.1 shows the responsible sections for prototype making.

Table 3.1 involving sections for prototype making process

Action	Relevant parties	Remarks
Make the product ID, costing, BOM for this new product	Financial department, quality assurance department, Research and Development dept.	
Prepare required materials	Product scheduling department, up- stream production department	Discuss required quantity, because prepare excess material has to be rejected
Fixing the mould	Mould department, Product scheduling department	Discuss the ,mould fixing date, location
Carcass building, applying tread profile	Relevant production line, Product scheduling department	Discuss carcass building date
Curing	Relevant production line, Product scheduling department	Discuss curing date, discuss arrangement of curing bladders

In prototype process, only three or four products are made in different versions. So in prototype stage, it is difficult to get an idea about production capability of that product. Sometime machines are adjusted temporary as requirement of prototype product.

3.5. Product Testing

Prototype testing is one of the most rewarding phases of new product development. Developing a prototype of the product allows bringing products to life for the first time and testing it. To achieve the final product prototype, it is very important that the product is tested at all stages during its design for technical compliance, acceptability to the consumer, and compliance with cost constraints. Technical testing varies a great deal depending on the type of product, the testing facilities available, safety needs, processing needs and legal regulations.

Testing of pneumatic tire is done externally and internally. As external testing, field test is done. According to field test, Developed new product is fixed to the vehicle and it is driven in varied types of roads. Then the condition is checked in the newly developed tyre. Parameters, visual appearance, lug depth, hardness, etc.…, are checked in field tests.

In internal testing, the product is tested in testing machines. During this test, tyre measurements, slip torque, fatigue, bursting, air leakage, etc.… are done.

Slip torque test:

When doing the indoor testing, testing of products has to be prioritized. Because there is a queue to do testing due limited testing machines and equipment. There is tyre testing engineer and testing team who is responsible to do testing accurately and to do as priority schedule. Figure 3.5 shows flow chart of product testing.

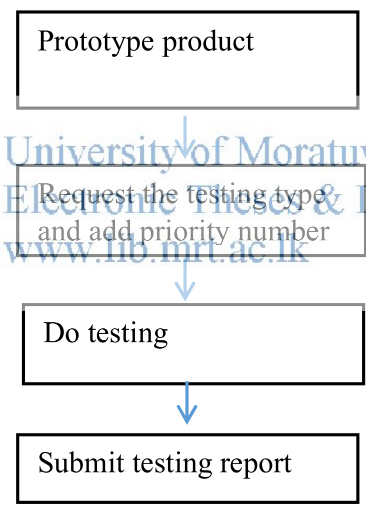


Figure 3.5 Product testing process

3.6. Pilot Production

Before starting mass production, pilot production is conducted. At this stage following points are considered.

- Communication of new product approval for the project team, confirming the goals and objectives to be achieved

- It is produced verifying and documenting the conformance to the original specifications.
- Pilot production is helpful to audited validating the production process.
- If pilot production completed and assessed, ordering of required equipment can be commenced. Because of in pilot production stage, further required equipment can be identified.
- Ensure that the technology specification and concepts can also be finalized at this time.
- Pilot production trials should be used to verify production and the process. Pilot production should confirm process controls and subsequent builds, to confirm capacity and capability.
- Utilization of Manufacture techniques, product and process concepts should be identified to reduce costs, production and processing time as well as improve Quality.

Before starting pilot production, meeting is arranged between the following persons to give the message about the new product.

- Design engineer
- Process engineer
- Quality control and assurance engineer
- Production manager
- Member from scheduling department
- Shift in charge

During this meeting, Design engineer explains following special points during the meeting

- What are the special features of this product have?
- When manufacturing, what areas to more concerns
- What are the objectives for implementing this product?
- What are the process differences when comparing existing manufacturing process?

A sample size of pilot production can be varied from product type to product type. In smaller products, select big sample size. It may be 250 -300 products. Complex and bigger products, select small sample size. It may be 50-70 products. These sample size is decided after discussion by the design engineer, process engineer and quality assurance engineer.

During the pilot run period, process engineer is responsible to collect quality issues, process issues and communicate it to the relevant parties. If there is major defect comes in new products, manufacturing floor has authority to stop the production process of new implemented product temporary and inform relevant parties. In pilot production stage, specification of product can be changed several times to continue the production. So it is more time and cost consuming process.

3.7. Mass Production

The concluding stage of the new product development process is mass production.

During this phase, activity must include:

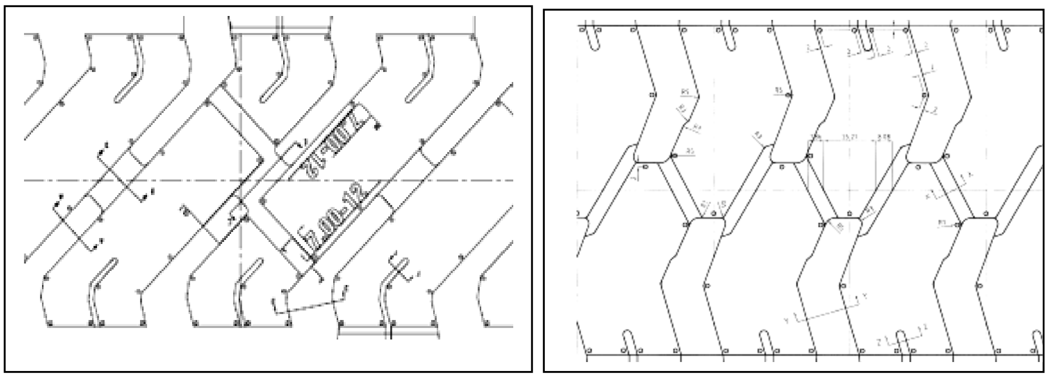
- To ensure productivity (profitability) and quality satisfaction and continuous improvement are all essential manufacturing requirements.
- Achieve production of a final transition report to ensure knowledge is retained within the company.
- When transforming production from pilot stage to mass production stage, documents are signed by the relevant parties to confirm as it is ready for mass production

A further check three months into mass production should be completed to ensure the product and process are behaving as planned and countermeasure to problems can be undertaken. This three month period could also have some very late design changes due to problems found in the final customer's mass production process.

3.8. Case Study 1: Product Name AB-X SD ED PLUS

Details of two case studies are studied considering one of the major pneumatic tyre industry in Sri Lanka.

Description: This is a new type of tread pattern for this size. Tread pattern of "HA LT", "SD ED" is available for this AB-X size. This pattern was introduced as more attraction of the customer and replacing tread pattern for ED pattern. Tread pattern differences is shown in Figure 3.6.



AB-X SD ED PLUS pattern　　　　AB-X SD ED pattern

Figure 3.6 Tread pattern differences in AB-X

Implementing the product of AB-X SD ED PLUS

The manufacturing process of this is similar to AB-X sizes which are currently producing. Mainly difference of this product is tread profile and tread pattern. So currently using machines and equipment for producing AB-X sizes, this can be used for making this product. The capacity of available machines and equipment has to be considered. In pilot production stage capacity issue of the machine has not been highlighted.

During Pilot production period following quality issues were highlighted.

Less liner thickness (LLT) defect

This defect can be identified by visualizing the nylon tyre cord from the inner liner area. This product uses inflated the inner tube (tube type pneumatic tyre). If tyre cord comes outside of the inner liner area, the inner tube can be damaged during the running of tyre. So this is a critical defect and these types of tyres have to be scrapped. Defect behaviour is shown in Figure 3.7 and Figure 3.8 as graphs.

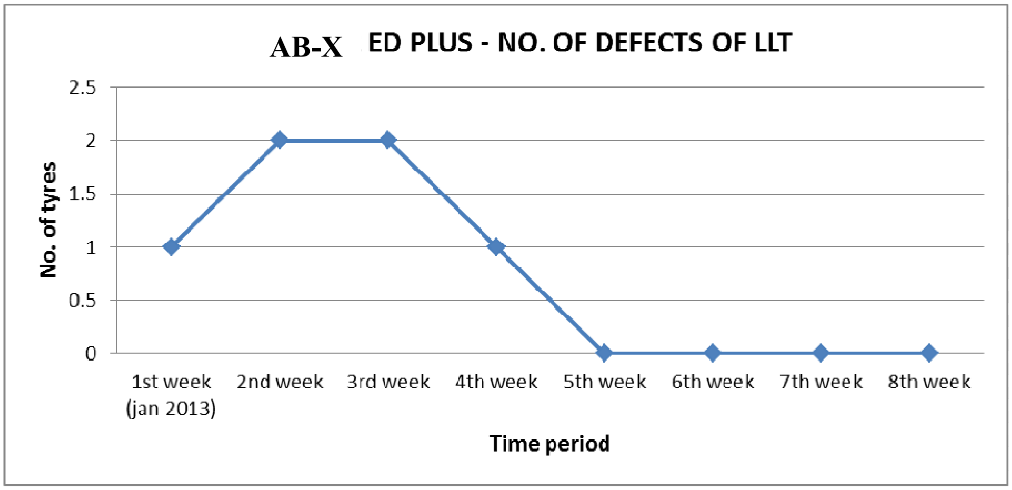


Figure 3.7 Number of LLT defect tyres in AB-X SD ED PLUS

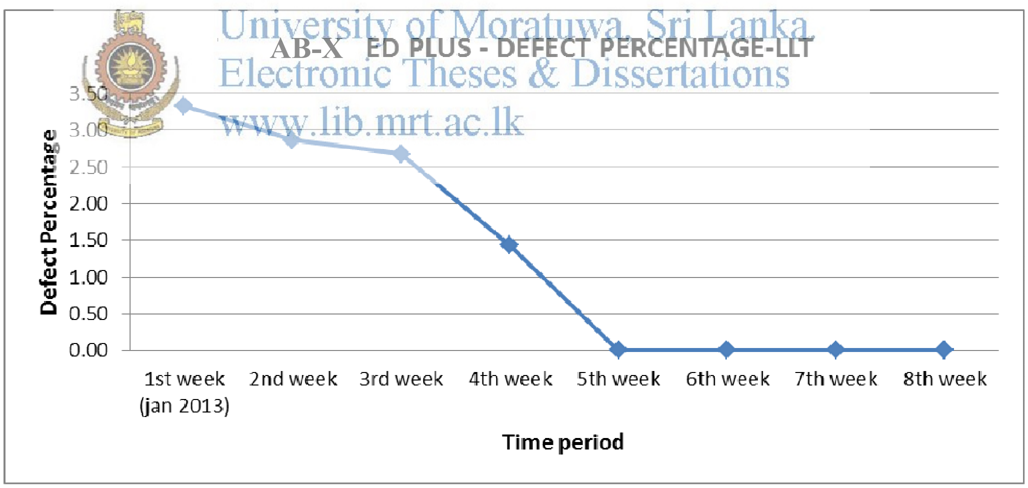


Figure 3.8 Defect percentages of LLT defect tyres in AB-X SD ED PLUS

As a solution for this defect, inner liner thickness was increased from 1.2mm to 2 mm. after increasing the thickness of inner liner, this defect can be solved. (From 5th

week to 8th week). Due to increase the material of inner liner; cost of the product has increased by Rs 140. Production is continuing is on and off due to this defect.

Short mould on sidewall (SM SW) defect

When curing stage, the tyre is forming at inside the mould. At this time letters on sidewall does not form properly. This affects the visual appearance of the tyre. If this appeared as badly, these tyres have to be rejected. The behaviour of defect percentage during each period is shown in Figure 3.9

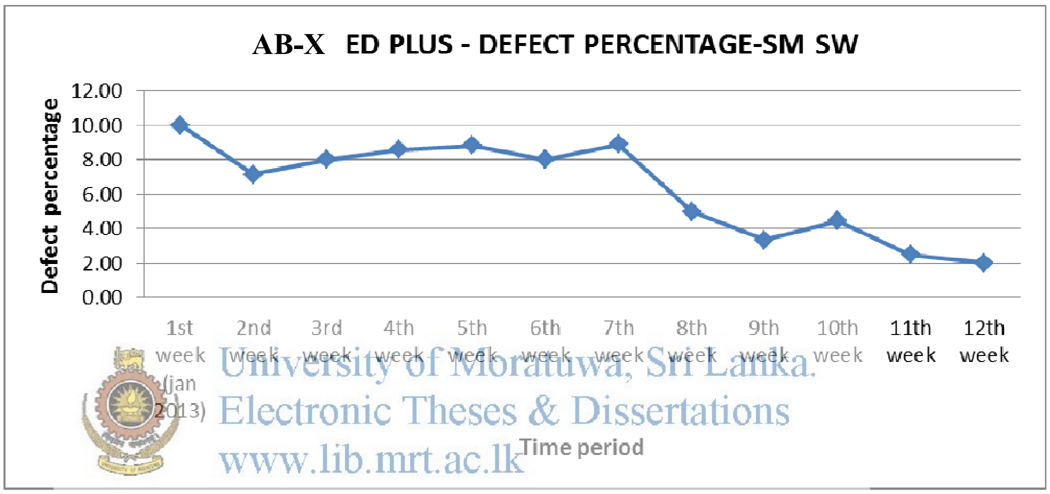


Figure 3.9 Percentage of SM SW defect tyres in AB-X SD ED PLUS

This defect comes due to entrap the air between mould surface and uncured tyre surface. As a solution for this defect, venting holes has been added to letters to remove entrap air. So the defect level is reduced (from the 9th week to 12th week).

3.8.1. Timeline for implementation

Table 3.2 shows the consumption of time during each sub process.

Table 3.2 Timeline for implementation of AB-X SD PLUS

PROCESS	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Design new product								
Make prototype								
Product testing								
Pilot production								

3.9. Case Study 2: Product Name CD-Y 28PR HA LT

Product Description: This is a new treading pattern and new ply rating for CD-Y size. When considering the size of CD-Y, 10PR,12PR,14PR and pattern of SD L2, SD L3 are available. This product uses 14 numbers of nylon plies and two four numbers of beads. Its weight is nearly 160kg. So it weights twice as normal CD-Y size.

Implementing the product of CD-Y 28PR HA LT

Required machines and equipment are available, because the current size of CD-Y is producing. But this product is more complex due to high ply rating. So carcass building time is very high and curing time is very high. For building one carcass, 45 minutes were taken and four hours were taken for curing process. Normal existing CD-Y takes for carcass making 20 minutes and 100minutes as curing process time. It has safety issues for lifting the tyre and ergonomic issues in handling due to the higher weight of this tyre Other than capacity issues, quality issues were highlighted during the pilot production stage.

Thin bead defect

After curing, bead of this tyre comes as thin as comparing required bead width. This defect is visually appearance and it affects for tyre performances also. The tyre is difficult to mount on the rim and air leakage is happening through the bead area due to this defect. So these types of defects tyres have to be rejected. The behaviour of defect in each period is shown in Figure 3.10.

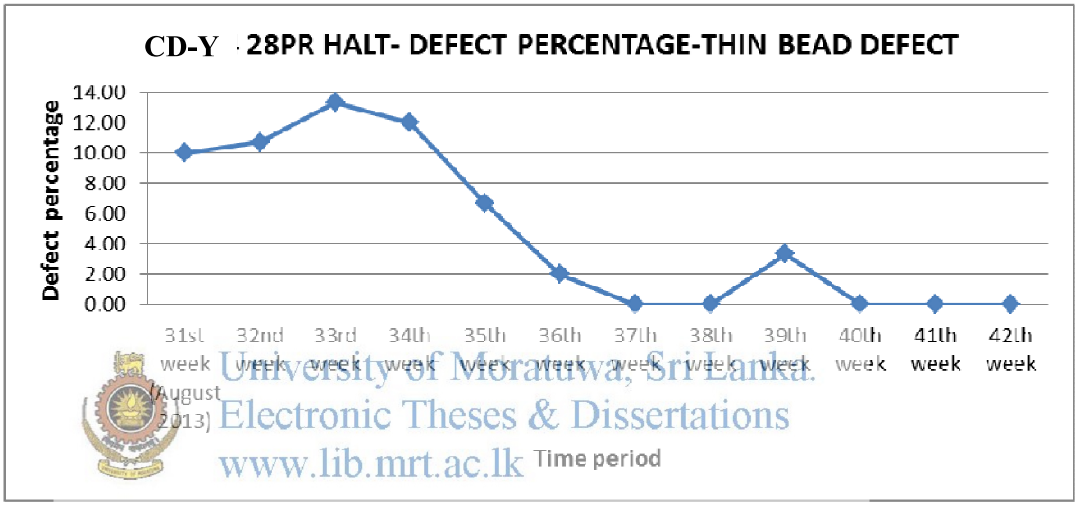


Figure 3.10 Percentage of thin bead defect tyres in CD-Y HA LT

This defect was solved by reducing the angle of plies. Change was done on 36th week. It means reducing the tension of carcass. So when analysing the root cause of this defect, it was found that bead is pulled upward during the curing process due to high tension of carcass.

Short mould on side wall (SMSW) defect

The root cause of this defect is same as earlier. So vent holes were added on letters to solve this defect. This change was done on 36th week. As defect behaviour shown in Figure 3.11, defect level has been reduced after 36th week. For adding vent holes, the mould was kept away from the production line and vent holes were added. This process took some considerable time. After adding vent holes, the mould was fixed again on the production line.

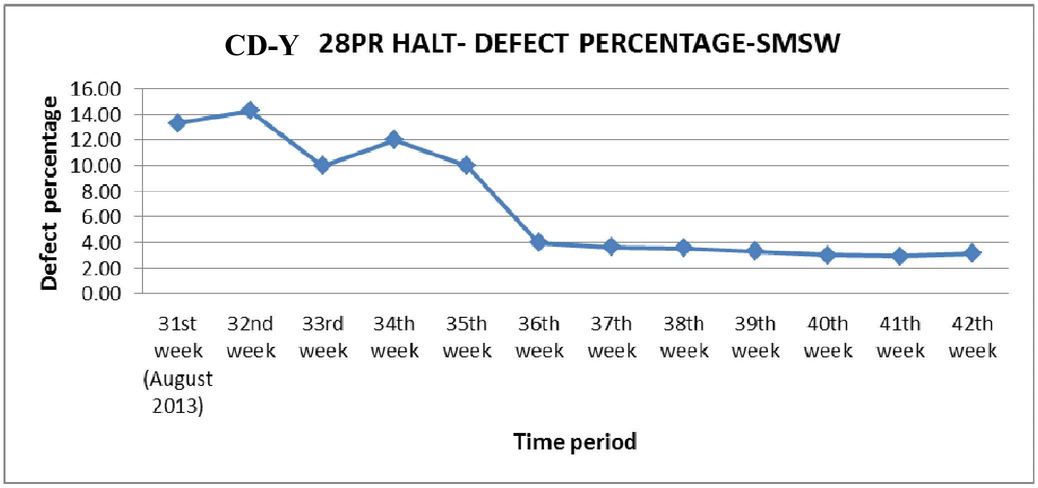


Figure 3.11 Percentage of thin bead defect tyres in CD-Y HA LT

3.9.1. Timeline for implementation

Table 3.3 shows the time line for implementation product of CD-Y HALT

Table 3.3 Time line for implementation of CD-Y HA LT

PROCESS	week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8
Design new product								
Make prototype								
Product testing								
Pilot production								

3.10 Summery of New Product Implementation in History

Table 3.4 describes the issues of product implementation in history

Table 3.4(A) Issues of implemented new products in history

New Product Name	Issues Of Implementation	Root Cause	Action Taken
1A	Quality issue (defect of LLT), No tread rolling bladder	For bladder curing, inner liner thickness is not enough, Carcass height is higher than bladder height	Increase inner liner thickness, Designed new tead rolling bladder
2B	Quality issue (defect of LLT), Defect of SM on sidewall	The inner liner thickness is not enough, Air trap on sidewall area	Increase inner liner thickness from 1.2 mm to 2 mm, Add vent holes on letters
3C	Defect of LLT, No building machine capacity	The inner liner thickness is not enough, The product is more complex and productive making time is high	Increase inner liner thickness, Manufacturing of some part of the product is transported from another plant
4D	Safety issue for treads rolling process, Capacity of tread rolling machine material flow is uneven, Quality issue (defect of SM SW)	Size of tyre is too high to do tread rolling process, Taken more time to tread rolling, Air trap on sidewall area	Introduce orbit tread process, Change the module, Add venting holes on engraved letters
5E	Quality issue (defect of LLT & LUTT), No building machine	Under tread thickness and inner liner thickness is not enough, Existing machine cannot produce this	Increase treads weight and IL thickness, Carcasses are transferred from another plant

Table 3.4(B) Issues of implemented new products in history

New Product Name	Issues Of Implementation	Root Cause	Action Taken
6F	Quality issue (defect of SM SW), Building machine capacity	Air trap on sidewall area, More products are produced on this building machine	Add venting holes on engraved letters
7G	Building machine capacity, Quality issue (defect of SM SW), Press is not capable due to high weight	More products are produced on this building machine, Air trap on sidewall area Product is too weight to lift the tyre	Add venting holes on engraved letters Change the press
8H	Building machine capacity, Quality issue (defect of SM SW), Press is not capable due to high weight	More products are produced on this building machine, Air trap on sidewall area, Product is too weight to lift the tyre,	Add venting holes on engraved letters, Change the press

3.11. Issues of Existing Model

- The volume of information that is exchanged has significantly increased. More issues were highlighted in pilot production stage. More information was exchanged between relevant parties to solve these issues. So there is more work load to do during a pilot production stage. Sometime it is difficult to solve issues completely during the pilot production stage and it takes more time to solve. In pilot production stage, some bulk production is scheduled to do.
- Some concurrency of activities needs to be addressed to prevent the extension of deadlines.

- From producing new product, the manufacturing process may be different from existing processes. So the production procedure has to be changed. Sometime production members resist changing. During the only pilot production stage, adjusting the manufacturing process and handling members issue are difficult to do. So it requires another stage to handle some amount of issues, before the pilot run period.
- In this model, it has no path to give information to design engineer about ergonomic factors, safety concern factors. When implementing this product, product has to be redesigned again. As an example, introducing product of 445/50D-710, it was originally designed for applying tread profile at module 5 machine. But when implementing, it is difficult to handle in that machine of module 5 due to higher size. It has a safety risk to damage the member when handling such big size. Then the design engineer changed his designed to suitable another module and tread profile was changed.
- Implementing products according to this model is not aligned with lean principles. So after implementing, the productivity of this product is dropped unexpectedly.
- In this model, it has no stage to check the technical feasibility of new product. So some product is designed for unavailable machines. As example, the product of 265/50-20 was designed for manual building machine which was rejected machine. So until receiving automated machine, some production orders were made using this manual machine.
- When solving the issues during Pilot production stage, it takes costlier. Because of handling issues of some amount of bulk production, amount of rejected products cannot be controlled. During the month of October in 2013, this cost takes over three million rupees, it is shown in table 3.3.

Table 3.5 shows cost of scraps, when implementing new products during month of October 2013

Table 3.5 Cost of scrap and 2nd choice products during new product implementing on October

Tyre size	2nd	Scrap	Total	STD Cost	2nd Choice (LKR)	Scrap (LKR)	Total Cost (LKR)
1A-X /24 OUT OTRBOTROUT		6	6	45,786.93	-	274,722	274,722
2B-Y/18 OUT OTRBOTROUT		43	43	33,049.05	-	1,421,109	1,421,109
1AB-Z 16PR OUT OTR		1	1	28,476.14	-	28,476	28,476
2CD-Y /12 BHZ SDSD		3	3	16,876.61	-	50,630	50,630
3AB-Y/10 SKS HF-3 SDSDGR	3		3	9,826.08	29,478	-	29,478
4GH-Y/16 ED+ SDSDEDP		3	3	6,513.34	-	19,540	19,540
7JH-K/16 ED+ SDSDEDP		3	3	9,137.73	-	27,413	27,413
UI-O/10 F3 SDSD	35		35	10,965.98	383,809	-	383,809
9LK-I/16 ED+ SDSDEDPS		1	1	12,250.02	-	12,250	12,250
RT-O/18 ED+ SDSDEDP		1	1	16,156.64	-	16,157	16,157
9PK-L/12 PR L2/G2/E2		1	1	33,806.80	-	33,807	33,807
YU-K/28 LT HAHA		2	2	64,109.50	-	128,219	128,219
NH-F 18PR HASKS		5	5	23,824.59	-	119,123	119,123
8UY-R-28/14 LB OTRBLIT		1	1	32,552.13	-	32,552	32,552
QW-V/32 LT HAHA		1	1	89,061.67	-	89,062	89,062
6MN-H/12 BHZ SDSD		4	4	41,782.41	-	167,130	167,130
CB-T/12 BHZ SDSD		8	8	27,234.89	-	217,879	217,879
NU-R/18 OUT OTRBOTROUT		1	1	33,049.05	-	33,049	33,049
Total	**38**	**84**	**122**		**413,288**	**2,671,117**	**3,084,404**

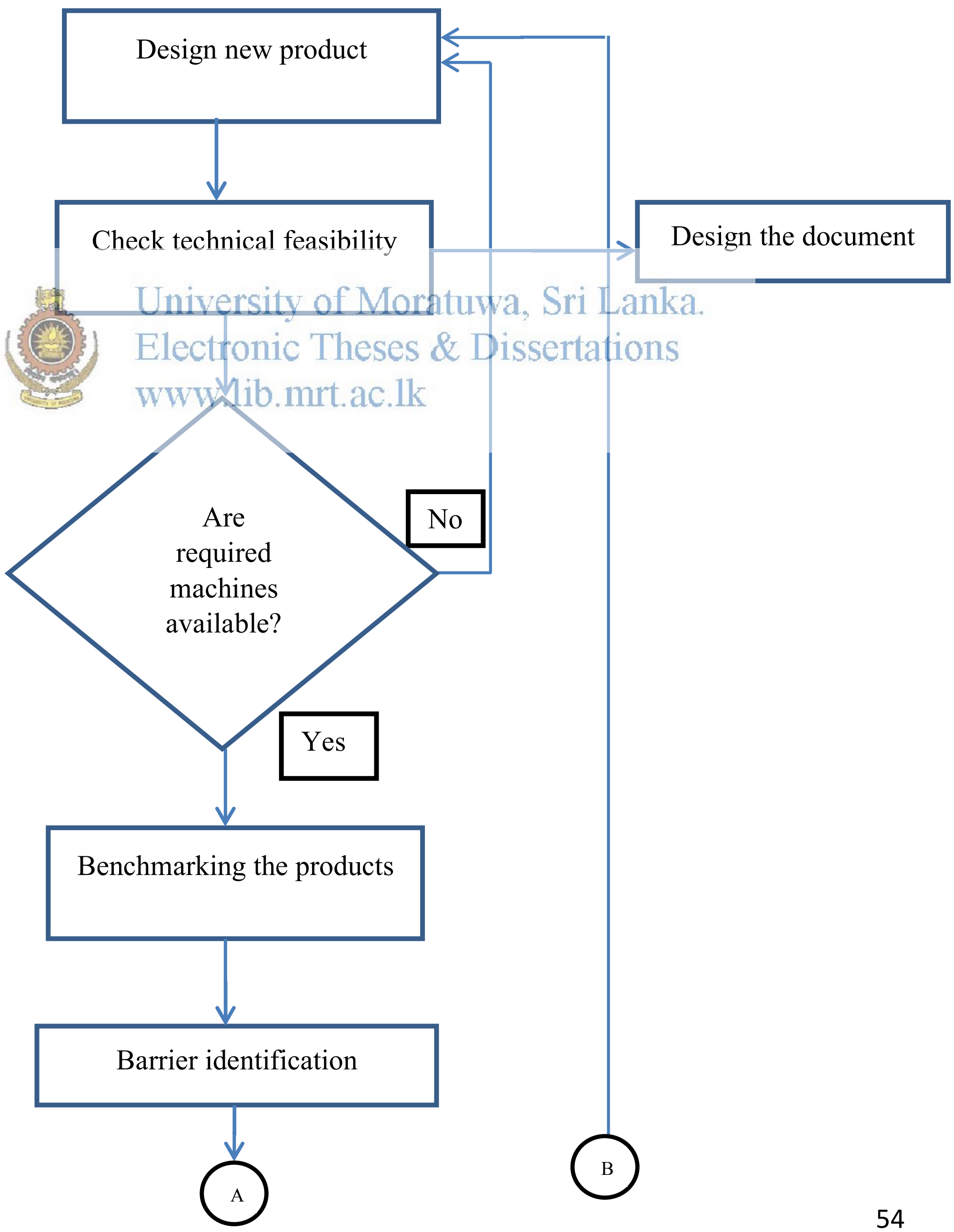
CHAPTER4 MODEL FOR NEW PRODUCT IMPLEMENTATION

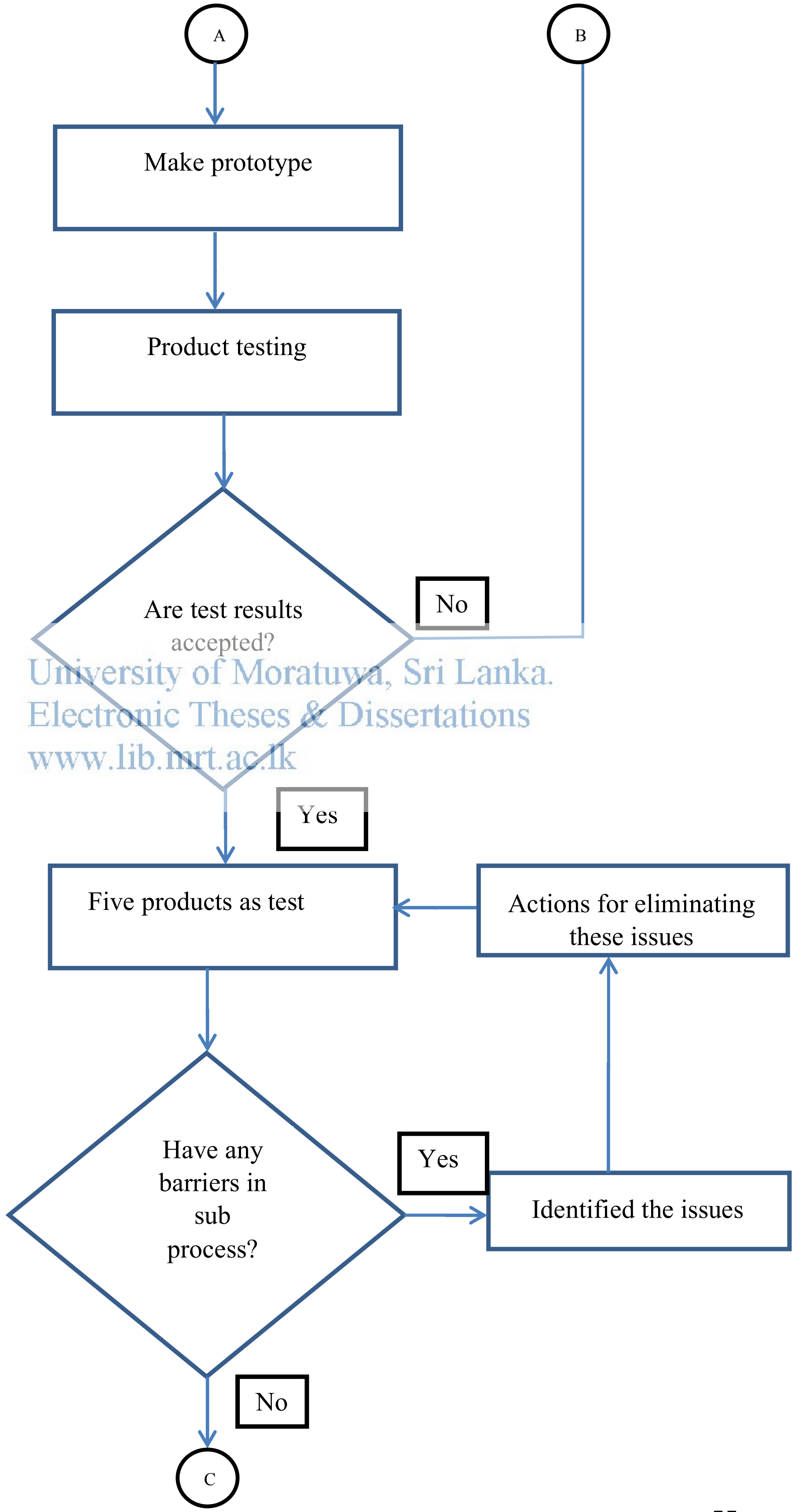
4.1 Introduction

During this chapter, new model for new product implementation was proposed and each step of model was described. The new model was proposed based on historical data and case studies of implementing new products.

4.2 Proposed Model

This model was named as QFT model. Because it was based on **Q**uality function deployment, **F**ive product test and **T**en product test. This model was shown in Figure 4.1.




A
B
Make prototype
Product testing
Are test results accepted?
No
Yes
Five products as test
Actions for eliminating these issues
Have any barriers in sub process?
Yes
Identified the issues
No
C

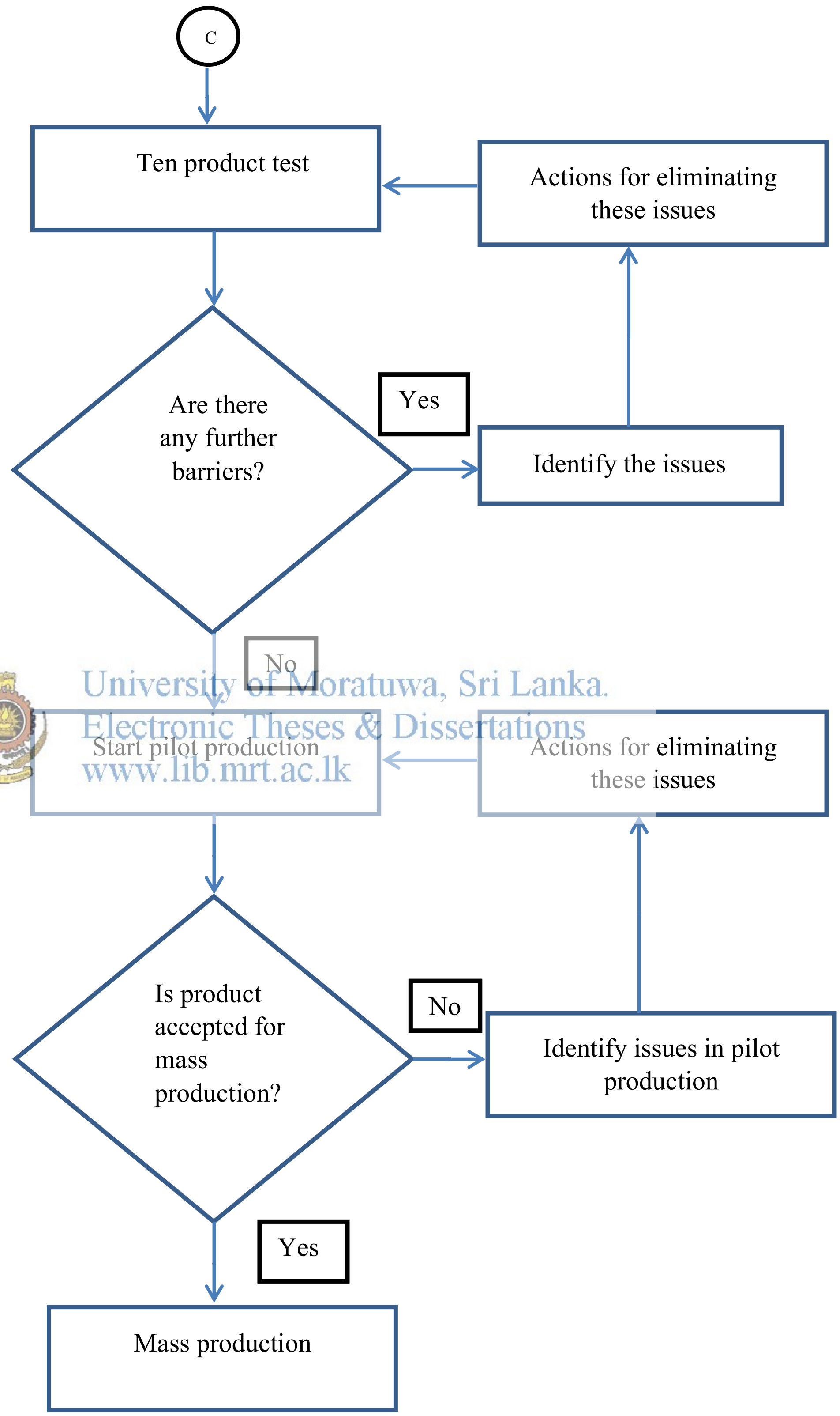


Figure 4.1 QFT model for new product implementation

4.3. Technical Feasibility

The technical feasibility assessment is focused on gaining an understanding of the present technical resources of the organization and their applicability to the expected needs of the proposed system.

A large part of determining resources has to do with assessing technical feasibility. It considers the technical requirements of the proposed project of new product implement. The technical requirements are then compared to the technical capability of the organization. The systems project is considered technically feasible if the internal technical capability is sufficient to support the project requirements.

The analyst must find out whether current technical resources can be upgraded or added to in a manner that fulfils the request under consideration. This is where the expertise of system analysts is beneficial, since using their own experience and their contact with vendors they will be able to answer the question of technical feasibility.

For analysing the technical feasibility in pneumatic tyre section, questions were designed by considering the required machines and its capacity. This was analysed by dividing into sub sections.

4.3.1. Carcass building operation

Table 4.1 Technical feasibility study for carcass building operation

Selected Parameters	Remark
Proposed buildings drum diameter / (mm)	
Proposed buildings drum width / (mm)	
Proposed building machine	
Current capacity of building machine (carcasses per day)	
Excess capacity of building machine (carcasses per day)	
Number of carcass requirement per day	
Shortage of carcass per day	
% of new carcass building capacity	

4.3.2. Bead preparation process

Table 4.2 Technical feasibility study for bead preparation process

Selected Parameters	Remark
Is available required bead drum?	
Can required bead wires be loaded	
Current capacity of bead making machine (Number of beads per day)	
Excess capacity of bead making machine (Number of beads per day)	
Number of beads requirement per day	
% of new bead machine capacity per day	

4.3.3. Layer, inner liner and side wall preparation process

Table 4.3 Technical feasibility study for calendar machine process

Selected Parameters	Remark
Can required width and thickness be getting?	
Current capacity of calendar machine (Number of layer meters per day)	
Excess capacity of calendar machine (Number of layer meters per day)	
Number of quantity requirement per day	
% of new calendar machine capacity per day	

4.3.4. Tread rolling process

Table 4.4 Technical feasibility study for tread rolling process

Selected Parameters	Remark
Proposed tread rolling cell or module	
Current capacity of tread rolling unit (Green Tyres per day)	
Excess capacity of tread rolling unit (Green tyres per day)	
Number of green tyre requirement per day	
% of new green tyre tread rolling capacity per day	

4.3.5. Tyre curing operation

Table 4.5 Technical feasibility study for tyre curing operation

Selected Parameters	Remark
Proposed curing press size	
Proposed Module	
Current capacity (number of curing slots)	
Running/planned capacity (number of curing slots)	
Excess curing capacity (number of curing slots)	
Number of curing slots needed for the project	
Shortage of curing slots	

4.3.4. Financial analysis

Table 4.6 Technical feasibility study for financial

Selected Parameters	Remark
Unit price of product/ (LKR/Kg)	
Proposed Weight of product/ (Kg)	
Current material and OH cost / (LKR/Kg)	
Annual demand	
Target output per day	
Number of mould required	

From these analysing, design engineers can get idea about proposed machines, their capacities for a proposed new product. For details of this analysis, If required machines are not available, the decision can get as ordering new machines are worth or not.

4.4. Benchmarking

Introducing new products of pneumatic tyre section can be divided into following sections.

- New Ply Rating implement
- The new tread pattern
- New construction due to cost reduction
- Construction change due to quality defects
- New tire size
- Change the product raw material

So introducing new product can be categorized into one section which is described in above. Considering the pneumatic tyre products, there are 298 products available with having different ply ratings, different tread patterns, different sizes.

As benchmarking, existing product was selected from available 298 products considering the similar behaviour with the proposed new product in each sub process. Preparation of layer, inner liners and sidewall of the proposed new product in calendar machine, same dimension type of layer, inner liner and sidewall is considered as benchmarking size.

When designing the new product, design engineer try to use existing semi products as much as possible. It is helpful to align new products for lean principles. Otherwise process becomes complex and additional effort to make semi products by changing the machine parameters.

When designing the product, the design engineer should check and study the database of existing product parameters. Then benchmark type should be selected within each sub process.

Table 4.7 Selecting benchmarking product

Product type	Pocket Drum Dia (mm)	Pocket Drum Width (mm)	Building Drum Dia (mm)	Building Drum Width (mm)	Ply type	No of Plies	PLY 1 Cord Type	PLY 1 Cutt. Angle (+/-1)	PLY 1 Width [mm] (+/-10)
7.00-12 12PR SD ED	353	750	362	415	1260, 26E	3	P1	28	680
					1260, 26E	1	P2	29	565
7.00-12 12PR SD ED PLUS	**353**	**750**	**362**	**415**	**1260, 26E**	**3**	**P1**	**29**	**680**
					1260, 26E	**1**	**P2**	**30**	**565**

As an example, when introducing product type of 7.00-12 SD ED PLUS as new tread pattern product, 7.00-12 SD ED is the benchmarking product in the process of tyre building. Because both sizes use same dimension building drums and same number of nylon plies.

4.5. Barrier Identification

This operation is designed to identify barriers of new product implementation and actions are taken in designing stage. New products can be implemented easily with minimum barriers, minimum time and minimum cost. For doing this following steps are proposed.

Step1:

Develop the questions in each sub process, considering the issues of manufacturing the benchmark product which is selected from an early stage. These questions were designed by considering the issues at each work element in sub processes.

Step 2:

Do the survey for covering all three shifts and give rank for each statement

Related table is shown in Table 4.8.

Table 4.8 identifying the issues in each sub process

Identified issues	**Disagree**	**Agree little bit**	**Agree neutrally**	**Almost agree**	**Strongly agree**

Ranking is designed as a five point criteria.

Disagree – 1

Agree little bit - 2

Agree neutrally – 3

Almost agree - 4

Strongly agree -5

Step 3

Find the relationship between issues of manufacturing benchmark products and product design parameters. For this, quality function deployment based model is used. Format of table is shown in Table 4.9.

Table 4.9 Format for QFD based model

Identified issues	Importance	Product design parameters		
Absolute importance				
Relative importance				

The relationship between identified issues and product design parameters can either be weak, moderate, or strong or carry a numeric value of 1, 4 or 9. It is shown in Table 4.10

Table 4.10 Values for relationship factors

Relationship	Symbol	Numerical value
Strong	◉	9
Moderate	○	4
Weak	△	1

Step 4

Identify the critical product design parameters in the QFD based model due to earn high marks. For this, identify the high marks at the row of “relative importance”

Step 5

Propose actions if required for critical design parameters

4.6. Five Products Test

After releasing the testing result, product specification can be released to start the production. So before start the production, five products are planned to prepare. Required materials (semi products) are scheduled for only five products. If there is some failure highlight on product, the manufacturing process can be stopped immediately and adjustment can be done. So, sometimes small quantities of prepared materials have to be rejected. All these five products are made by under the supervision of design engineer and process engineer.

Select a sample size of five

Five sample sizes are selected for five product test based on identifying quality defects. In this study, identifying quality defects were studied on selected three products, while making 10 pieces in each selected three products.

Product AA

Quality defects have been recorded for producing 10 pieces of product AA. These data are shown in Table 4.11 and its behaviour shows in Figure 4.2.

Table 4.11 Quality defects of product AA

Quality defects	1st tyre	2nd tyre	3rd tyre	4th tyre	5th tyre	6th tyre	7th tyre	8th tyre	9th tyre	10th tyre
LCB/B.pre cure					x	x	x		x	x
SM/Bead			x	x			x		x	
SM/SW	x	x		x	x	x			x	
SM/Lug		x	x			x		x		
Total identified defects types (cumulative values)	**1**	**2**	**3**	**3**	**4**	**4**	**4**	**4**	**4**	**4**

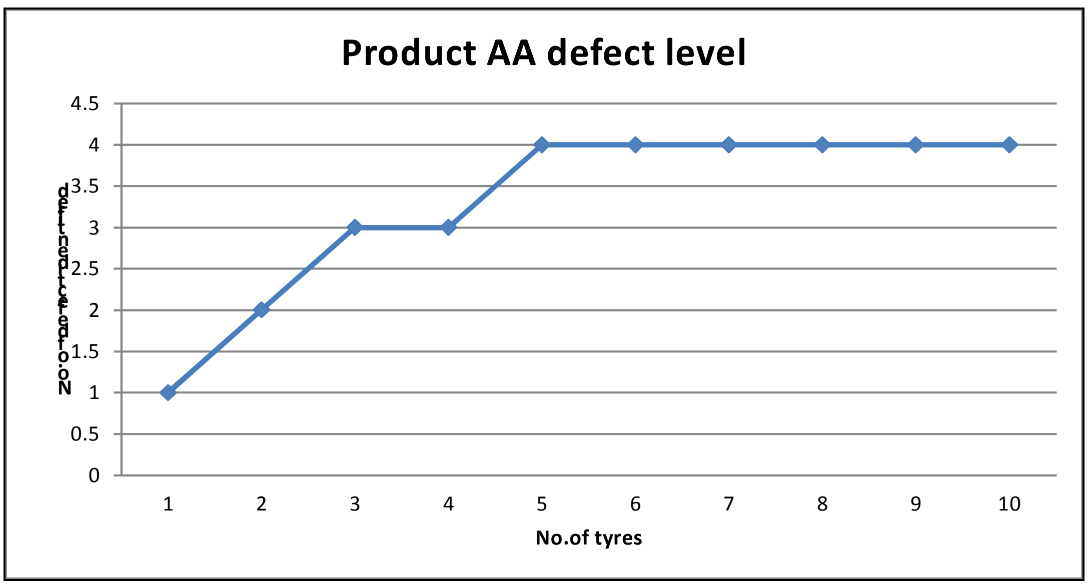


Figure 4.2 Quality defects of product AA and number of tyres

When producing more products, higher number of defects can be identified. According to quality defects of product AA and considering identified defects in first five pieces, four types of defects were identified. They were less compound on bead, short mould on the sidewall, shot mould on bead and short mould on lug. But after producing more than five tyres, any more defects could not be identified other than defect type in first five tyres.

Product AB

During manufacturing of 10 pieces of product AB, following quality defects were identified. It is shown in Table 4.12

Table 4.12 Quality defects of product AB

Quality Defects	1st tyre	2nd tyre	3rd tyre	4th tyre	5th tyre	6th tyre	7th tyre	8th tyre	9th tyre	10th tyre
LCB/B.pre cure						x	x		x	
SM/Bead					x			X		x
SM/SW	x	x	x	x	x	x	x	x	x	x
AB/SW				x						
Less Und. Tread Thickness						x				x
SM/Lug			x	x	x		x		x	
LLT			x	x		x	x	x		
Total identified defects types (cumulative values)	1	1	3	4	5	7	7	7	7	7

Quality behaviour of product AB shows in Figure 4.3.

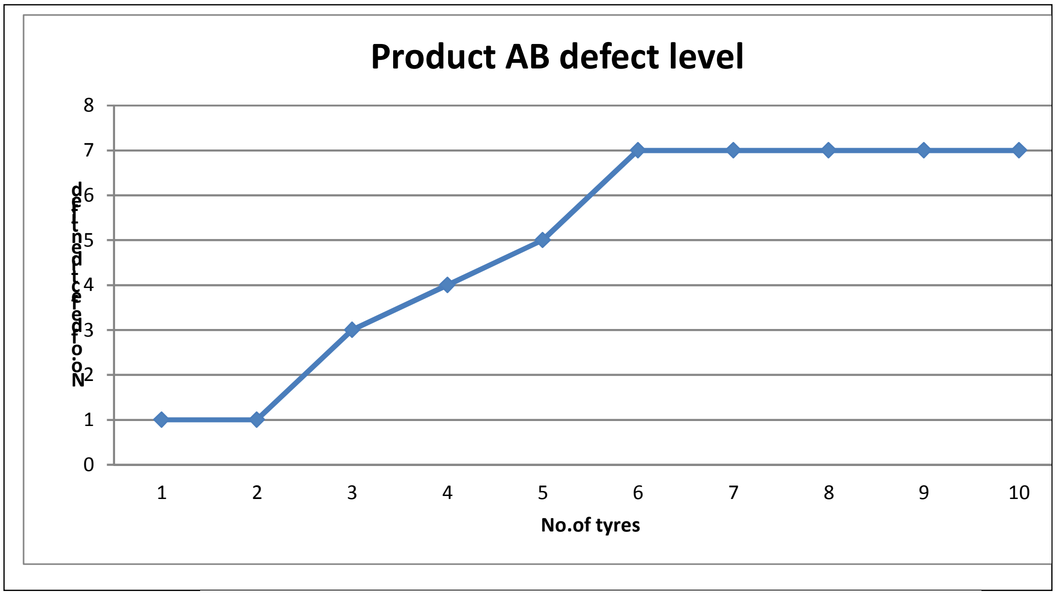


Figure 4.3 Quality defects of product AB and number of tyres

When considering the production of 10 pieces of product AB, seven types of defects were identified during production of first six tyres. But after identifying seven defects on first six pieces, no any further defects were identified other four products. So when producing product AB, all the possible defects can be identified on first six pieces.

Product AC

Following Table 4.13 shows identified quality defects of manufacturing 10 pieces of product AC.

Table 4.13 Quality defect of product AC

Quality defects	1st tyre	2nd tyre	3rd tyre	4th tyre	5th tyre	6th tyre	7th tyre	8th tyre	9th tyre	10th tyre
LCB/B.pre cure				x	x				x	
Bead out			x			x		x		
SM/Bead				x			x			x
SM/SW		x			x				x	
Les Under Tr: Thickness			x			x		x		
SM/Lug		x		x			x		x	
LLT	x					x				x
Total identified defects types (cumulative values)	1	2	5	7	7	7	7	7	7	7

Figure 4.4 shows quality behaviour of product AC.

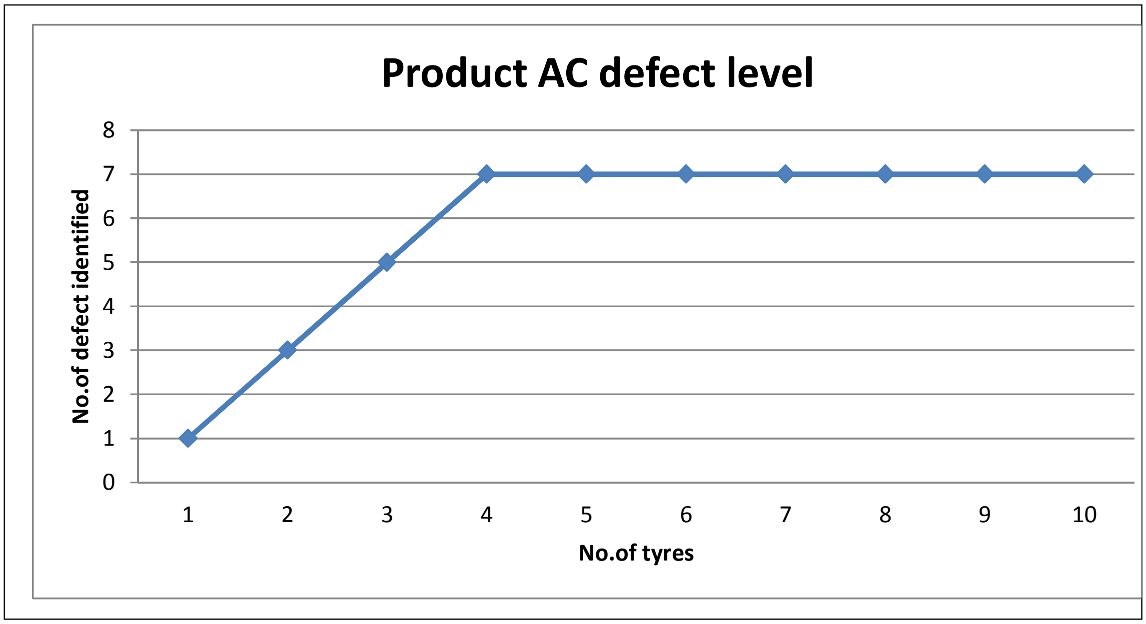


Figure 4.4 Quality defects of product AC and number of tyres

Considering the manufacturing of 10 pieces of product AC, LLT defect was identified in first tyre, beat out defects and less under tread thickness was identified in third tyre. So after producing 4th tyre, seven types of defects could be identified. During manufacturing of the first four pieces, maximum types of defects could be identified.

Considering the manufacturing of 10 pieces of product AA, AB and AC, results of identifying defects shows that producing first five products, maximum types of defects can be identified. So it is enough to make five pieces to identify all the quality issues that may come during the production.

4.7. Ten Products Test

Adjusting the issues of earlier stage and after making good five quality products under the supervision, ten products are planned. Required materials are arranged to schedule only ten products. These ten products are produced without much supervision and only randomly check is done. So this stage acts as a small pilot production. After making seven good quality products as output continuously, pilot production is scheduled to start. Pilot production can be started immediately after finishing the ten product production.

After completing pilot production stage successfully, then it is handed over to mass production stage.

Select a sample size of ten

Sample size of ten pieces is selected based on wastage materials in calendaring process. Calendaring is used to make required layers and inner liners for tyres. This calendar machine has three or four rollers and for making inner liners and layers at least one tyre, rubber materials are required to go through all calendaring rollers. Minimum required length of rubber sheet to form an inner liner in calendar machine is 15 meters and minimum required length to form layer is 17 meters.

Product AA

Required inner liner for making one piece is 1.5m and required layer and sidewall for making one piece is 1.6m. So when making one product of product AA, 13.5m of inner liner and 15.4m of layer have to be rejected. Because these 13.5m of inner liner and 15.4m layers are coming through a calendar machine as waste. Table 4.14 shows meters of wastage materials of product AA.

Table 4.14 wastage of materials in product AA

No.of tyres	Required Inner liners/m	Required layers & SW/m	Wastage of inner liners/m	Wastage of layers/m
1	1.5	1.6	13.5	15.4
2	3	3.2	12	13.8
3	4.5	4.8	10.5	12.2
4	6	6.4	9	10.6
5	7.5	8	7.5	9
6	9	9.6	6	7.4
7	10.5	11.2	4.5	5.8
8	12	12.8	3	4.2
9	13.5	14.4	1.5	2.6
10	15	16	0	1

Figure 4.5 and Figure 4.6 show the behaviour wastage materials of product AA

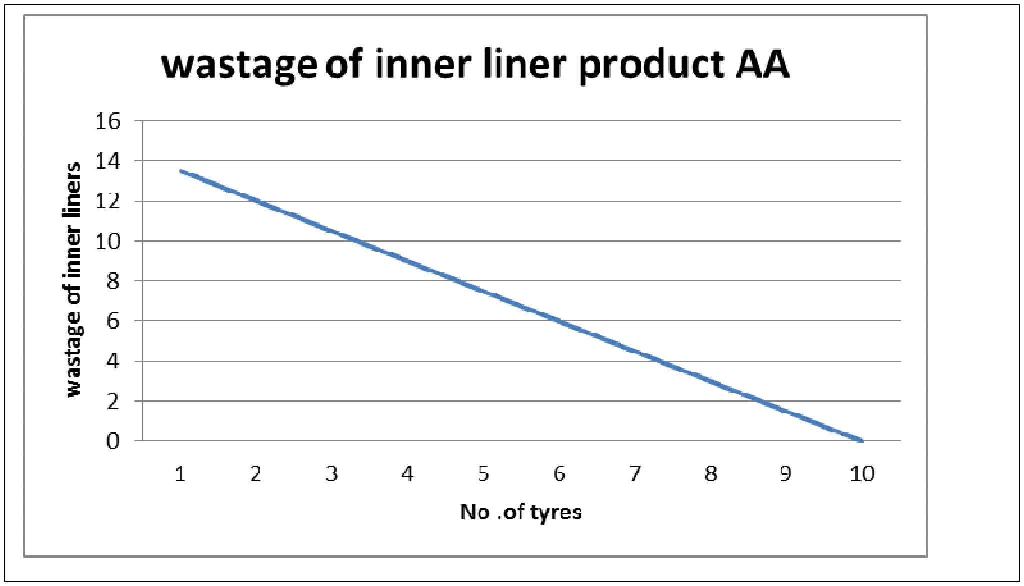


Figure 4.5 wastage of inner liner in product AA

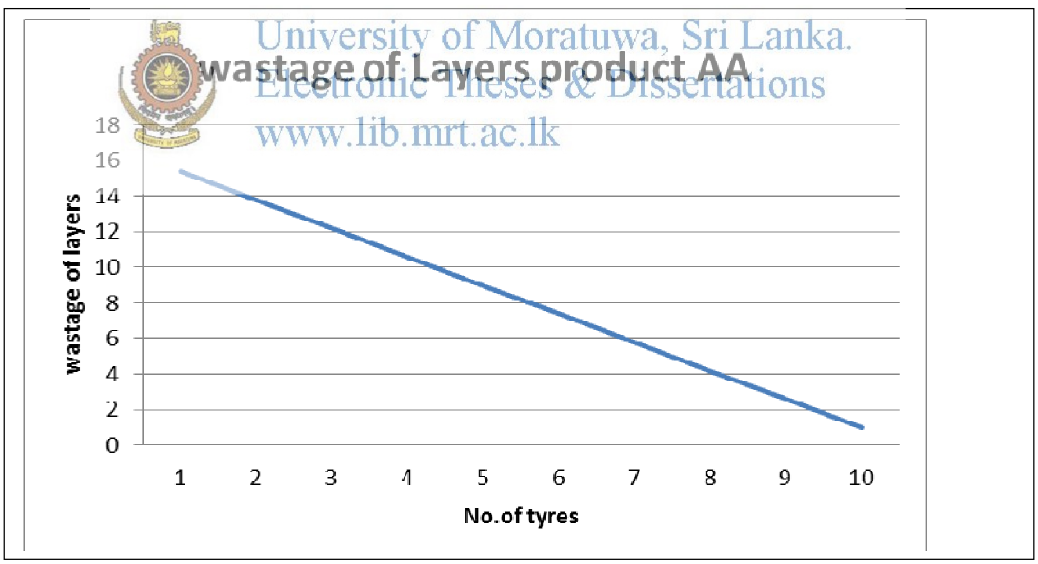


Figure 4.6 wastage of layers in product AA

According to the above results, minimum wastage of materials can be achieved by making 10 products.

Product AB

Required inner liner for making one product of AB is 1.3 m and required layer sheet length is 1.5m. Following table shows required length of rubber sheet for making inner liner and required lengths for making layers. These data are shown in Table 4.15

Table 4.15 wastage of materials in product AB

No.of tyres	Required Inner liners/m	Required layers & SW/m	Wastage of inner liners/m	Wastage of layers/m
1	1.3	1.5	13.7	15.5
2	2.6	3	12.4	14
3	3.9	4.5	11.1	12.5
4	5.2	6	9.8	11
5	6.5	7.5	8.5	9.5
6	7.8	9	7.2	8
7	9.1	10.5	5.9	6.5
8	10.4	12	4.6	5
9	11.7	13.5	3.3	3.5
10	13	15	2	2
11	14.3	16.5	0.7	0.5

Figure 4.7 and Figure 4.8 shows behaviour of wastage materials of product AB

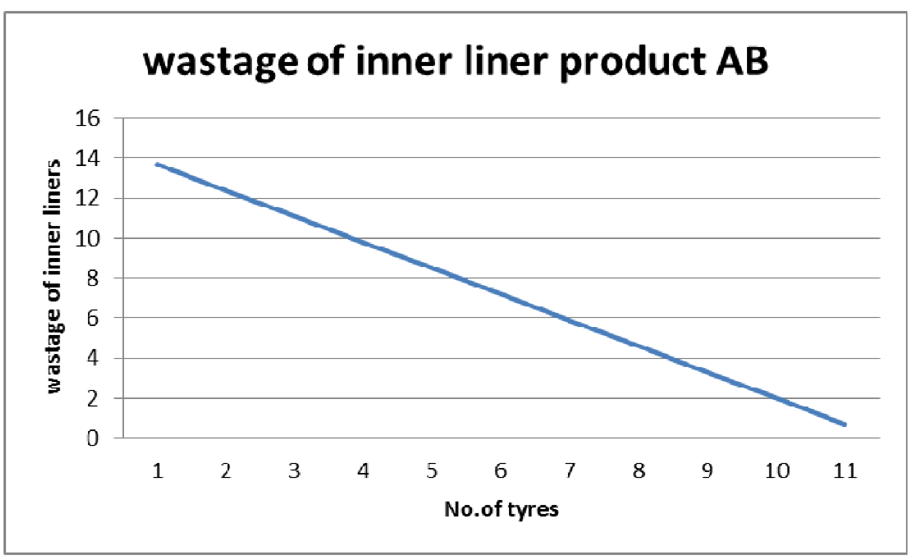


Figure 4.7 wastage of inner liner in product AB

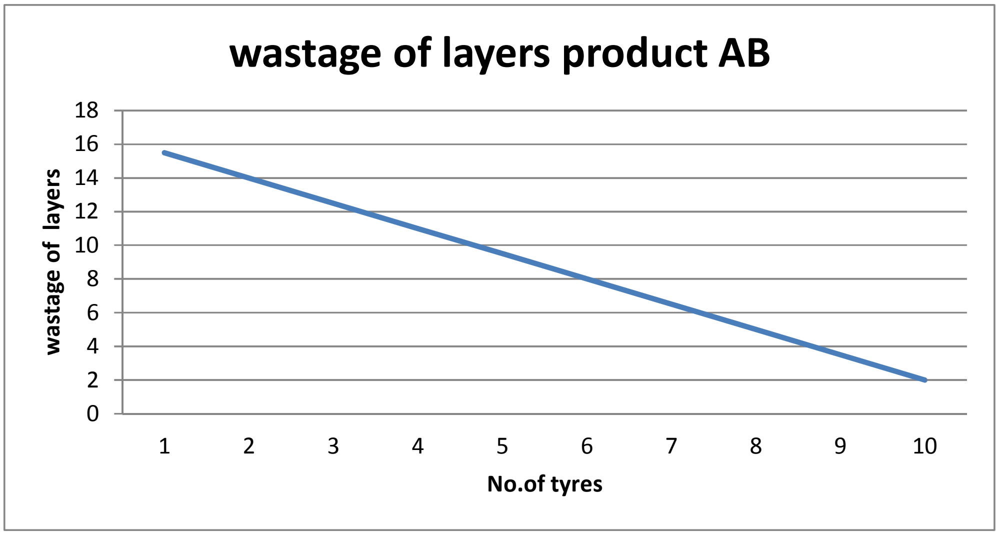


Figure 4.8 wastage of layers in product AB

According to the above data, if eleven products of AB are made, wastage of layers and inner liners can be minimised.

Product AC

Table 4.15 shows required layers and inner liners and their wastage in each piece.

Table 4.16 wastage of materials in product AC

No.of tyres	Required Inner liners/m	Required layers & SW/m	Wastage of inner liners/m	Wastage of layers/m
1	1.6	1.8	13.4	15.2
2	3.2	3.6	11.8	13.4
3	4.8	5.4	10.2	11.6
4	6.4	7.2	8.6	9.8
5	8	9	7	8
6	9.6	10.8	5.4	6.2
7	11.2	12.6	3.8	4.4
8	12.8	14.4	2.2	2.6
9	14.4	16.2	0.6	0.8
10	16	18	-1	-1

4.8. Pilot production

The function of this stage is same as existing models. Pilot production can be started, after the step of ten product test. Before a new product entering to this step, most of the barriers can be eliminated. So the pilot production stage can be continued with less barriers and it can be completed with minimum time and cost

CHAPTER 5 MODEL VALIDATION

5.1 Introduction

For validation of developing a new model, two case studies are going to study in this chapter. In this case study, each step of the proposed model is going to study.

5.2 Case Study 1: New Product IJ-K HA SKS 730

Product description: This was introduced as new tread pattern for IJ-K size and its product parameters shows in Table 5.1.

Table 5.1 Product parameters of IJ-KHA SKS 730

PARAMETERS	
OD (Design/Max) [mm]	833
Section Width [mm]	325
Tread Width [mm]	275
Crown Radius [mm]	900
Weight [kg]	37.1
Number of lugs	21
Inflation Pressure (Bar)	5.6

5.2.1. Design the new product

Calculations were done in designing this product. According to calculation, four plies were used and safety factor of the carcass was 3.6 and safety factor of the bead is 4. Building drum of dia. 490 and width 630 was selected considering the existing machines. Considering the thickness of sidewall area and under tread area, thickness of the layer and sidewall was selected as 4mm. According to volume calculation, tread weight was calculated as 14kg. Proposed specification was attached in Table 5.2.

Table 5.2 Proposed product specification of IJ-K HA SKS 730

POCKET DRUM:			
	DIA [mm]:	477.5	Brand Names:
	Circum(mm)	1500	
	WIDTH[mm]:	1000	
TYRE DRUM:			
	DIA [mm]:	490	
	Circum(mm)	1539	
	WIDTH[mm]:	530	

A : BEAD PACKAGE

BEAD GROMET :

WIRE DIA. [mm]	COMP. CODE	NUMBER OF		INS.DIAM. [mm]	STRIP DIMENS.[mm]		NOTE:
		WIRES	TURNS		WIDTH	THICK.	SINGLE bead
0.95	B 607	8	8	425	12.0	1.5	In the heel

BEAD APEX :

COMP CODE	DIA./WIDTH (mm)	HEIGHT (mm)	LENGTH (mm)	NOTE:
H 492	9.5			

BEAD FILLERING

STRIP [mm]			COMP.	FABRIC	STEP	NOTE :
WIDTH	THICK.	LENGTH	CODE	CODE	[mm]	For the Fillering use cord
30	1.1		C222	1260 D/2	10	from bias cutter.

C : CHAFER

RUBBERIZED FABRIC :

STRIP [mm]			COMP.	FABRIC	NOTE:
WIDTH	THICK.	LENGTH	CODE	CODE	For chafer to use fabric from the bias cutter.
100	2.2		CS 401	420D/1	

D: CARCASS

POCKET: 1

PLIES OR INLINER	COMP. CODE	FABRIC CODE	THICK. [mm]	WIDTH [mm]	LENGTH [mm]	STEPS [mm]	CUTTING ANGLE
In.liner 1	IL 323	-	2.0	700			
In.liner 2	IL 323		1.0	500			
ply 1	C 233	1890,24E	1.1	910	1515	15	37
ply 2	C 233	1890,24E	1.1	910	1526	15	37
ply 3	C 233	1890,24E	1.1	910	1533	15	37
ply 4	C 233	1890,24E	1.1	910	1540	15	37

NOTE : -Put inner liner on the ply 1 on the calender, 82.5 mm from the one edge and 37.5 mm from the other edge.
- Put edge strips ST505(80x1980mm) on the pocket and after ply turn up to cover all steps

POCKET: 2

PLIES OR INLINER	COMP. CODE	FABRIC CODE	THICK. [mm]	WIDTH [mm]	LENGTH [mm]	STEPS [mm]	CUTTING ANGLE
Breaker 1	C 233	1890,24E	1.1	440	1547	-	38
Breaker 1	C 233	1890,24E	1.1	400	1554	-	38

NOTE : -Put chafer after third pocket [Put cushion gum side of the chafer on the carcass]

OUT.PLIES/BREAKERS/INS.STRIPS/CUSH.GUM/FIRST& SECOND LAYER

PLIES OR INSULAT.	COMP. CODE	FABRIC CODE	THICK. [mm]	WIDTH [mm]	LENGTH [mm]	[mm]	CUTTING ANGLE
cush. gum	C 222	-	0.6	670	1620	center.	-
e.g. strips	C 222	-				-	-
layer 1	RDT 843		4.0	690	1620	center.	-
layer 2	RDT 843						-
sidewall 1	LS 345		4.0	120	1620	-	-
sidewall 2						-	-

E : TREAD

COMP.	WIDTH [mm]		WEIGHT [kg]			PR.PRESS.	CIRCUM.
CODE	START	STOP	MILL	REMAIN	NET	[bar]	[mm]
TR 602	440	140	15.5	1.5	14.0	0.8	

5.2.2. Technical feasibility

Feasibility study for each operation were summarised in Table 5.3, Table 5.4, Table 5.5, Table 5.6, Table 5.7 and Table 5.8

Carcass building operation

Table 5.3 Technical feasibility study for carcass building operation of IJ-K HA SKS 730

Selected Parameters	Remark
Proposed buildings drum diameter / (mm)	490
Proposed buildings drum width / (mm)	630
Proposed building machine	MBD 2
Is proposed building machine capable to make this carcass?	Yes
Current capacity of building machine (carcasses per day)	280
Excess capacity of building machine (carcasses per day)	25
Number of carcass requirement per day	20
Shortage of carcass per day	0
% of new carcass building capacity	-

Bead preparation process

Table 5.4 Technical feasibility study for bead preparation of IJ-K HA SKS 730

Selected Parameters	Remark
Is available required bead drum?	Yes
Can required bead wires be loaded?	Yes
Current capacity of bead making machine (Number of beads per day)	2500
Excess capacity of bead making machine (Number of beads per day)	500
Number of beads requirement per day	40
% of new bead machine capacity per day	-

According to this proposed building machine has the capacity to implement this product. So, it has no requirement to order a new machine

Layer, inner liner and side wall preparation process

Table 5.5 shows technical feasibility study for this product.

Table 5.5 Technical feasibility study for calendar machine process- IJ-K HA SKS 730

Selected Parameters	**Remark**
Can required width and thickness be get?	Yes
Current capacity of calendar machine (Number of layer meters per day)	3500m
Excess capacity of calendar machine (Number of layer meters per day)	500m
Number of quantity requirement per day	90m
% of new calendar machine capacity per day	-

Tread rolling process

Table 5.6 shows technical feasibility in tread rolling process

Table 5.6 Technical feasibility study for tread rolling operation of IJ-K HA SKS 730

Selected Parameters	**Remark**
Proposed tread rolling cell or module	Module 03
Is proposed tread rolling unit capable to do this?	Yes
Are required equipment available (bladders, holders)?	Yes
Current capacity of tread rolling unit (Green Tyres per day)	350
Excess capacity of tread rolling unit (Green tyres per day)	55
Number of green tyre requirement per day	20
% of new green tyre tread rolling capacity per day	-

Capacity of the thread rolling machine was also enough to introduce new product. Same type of pre shaping bladder, which used for IJ-K sizes could be used for this size also.

Tyre curing operation

Technical feasibility study for curing process is shown in Table 5.7

Table 5.7Technical feasibility study for tyre curing operation of IJ-K HA SKS 730

Selected Parameters	Remark
Proposed curing press size	BOM Press
Is this curing press capable to make this product?	Yes
Are curing bladders, PCI available?	Yes
Proposed Module	Module 3
Current capacity (number of curing slots)	28
Running/planned capacity (number of curing slots)	28
Excess curing capacity (number of curing slots)	0
Number of curing slots needed for the project	1
Shortage of curing slots	-

This mould could be fixed on Bag-o-matic press in the module 3 area. But there was no excess curing slot to fix the mould. So production of one curing slot has to be stopped and this mould was replaced.

Financial analysis

Technical feasibility study for financial analyse is shown in Table 5.8

Table 5.8 Technical feasibility study for financial analyse of IJ-K HA SKS 730

Selected Parameters	Remark
Unit price of product/ (LKR/Kg)	15,400
Proposed Weight of product/ (Kg)	38.5
Current material and OH cost / (LKR/Kg)	7,000
Annual demand (Number of products)	6000
Target output per day	20
Number of mould required	1

According to feasibility analysis, all required resources were available. Current required demand could be supplied by using single mould.

5.2.3. Benchmarking

This was introduced as new tread pattern for IJ-K size. So a construction was more similar to IJ-K and tread profile was changed.

Carcass building operation

Details of benchmarking of product IJ-K 12PR HA SKS 730 are shows at Table 5.9 in carcass building operation.

Table 5.9 Benchmarking product in bead operation- IJ-K 12PR HA SKS 730

Product size	Building drum diameter /mm	Building drum width /mm
IJ-K 12PR HA SKS	490	630
IJ-K 12PR HA SKS 730	490	630

Bead preparation process

Details are shown in Table 5.10.

Table 5.10 Benchmarking product in bead operation- IJ-K 12PR HA SKS 730

Product size	No. of wires	No.of turns	Inside Dia. [mm]	No of Bead
IJ-K 12PR HA SKS	8	8	425	2
IJ-K 12PR HA SKS 730	8	8	425	2

In bead preparation process, IJ-K 12PR HA SKS was selected as benchmark product. Its beads had the same dimensions as a new product of IJ-K 12PR HA SKS 730. So bead machine was used same condition of IJ-K 12PR HA SKS to make this new product.

Layer, inner liner and sidewall preparation process

Layer preparation

Details of benchmarking products of layer preparation are shown in Table 5.11.

Table 5.11 Benchmarking products in layer preparation- IJ-K 12PR HA SKS 730

Product size	**Compound type**	**Layer width/mm**	**Layer thick./mm**
IJ-K 12PR HA SKS	TR 843	690	4
IJ-K 12PR HA SKS 730	TR 843	690	4

Sidewall preparation

Details of benchmarking products of layer preparation are shown in Table 5.12.

Table 5.12 Benchmarking products in sidewall preparation- IJ-K 12PR HA SKS 730

Product size	**Compound type**	**Sidewall width/mm**	**Sidewall thick./mm**
IJ-K 12PR HA SKS	LS 345	120	4
IJ-K 12PR HA SKS 730	LS 345	120	4

Inner liner preparation (IL)

Details of benchmarking products of layer preparation are shown in Table 5.12.

Table 5.13 Benchmarking products in IL preparation- IJ-K 12PR HA SKS 730

Product size	**Compound type**	**Inner liner width/mm**	**Inner liner thick./mm**
IJ-K 12PR HA SKS	IL 323	790	2
IJ-K 12PR HA SKS 730	IL 323	790	2

For Layer, sidewall and inner liner preparation of new product, IJ-K 12PR HA SKS was selected as benchmarking product. When producing new product of IJ-K 12PR HA SKS, settings of calendar machine was same as the product of IJ-K 12PR HA SKS.

Tread rolling process

Details of benchmarking products of layer preparation are shown in Table 5.12.

Table 5.14 Benchmarking products in IL preparation- IJ-K 12PR HA SKS 730

Product size	Compound type	Tread start width/mm	Tread weight./kg
IJ-K 10PR HA SKS	TR 625	400	14.2
IJ-K 12PR SD SKS 730	TR 625	410	14

Tread profile of IJ-K 10PR HA SKS could be taken as benchmarking tread profile. Its tread profile was slightly changed from the tread profile of new product.

Curing process

A calculated curing time of new product was same as IJ-K 12PR HA SKS and curing press and curing module was same as manufacturing of IJ-K 12PR HA SKS. So for the curing process, IJ-K 12PR HA SKS was selected as benchmarking product.

5.2.4. Barrier identification

The questionnaires were designed to collect the data considering the each work element. It was designed in Sinhala version to collect data easily. Data collection was covered all three shifts. To get better result from these questions, it was advised to select first idea that comes into their mind while reading the questions.

Carcass building operation

Nine questions (Appendix 1) were designed to collect data considering the each work element. Points were given to each question, according to five point criteria. The identified benchmarking product was IJ-K 12PR HA SKS. So, data collected from members who were working on building a machine of MBD 02. Collected results were summarised into one Table 5.15 to take a decision easily.

Table 5.15 Summarised results of questioners in Carcass building operation- IJ-K 12PR HA SKS 730

Shift	Job role	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
A	Operator	2	3	3	2	2	3	1	2	4
A	Helper	1	2	4	1	3	3	2	2	5
A	Team leader	2	2	3	2	3	2	2	2	5
B	Operator	3	1	3	1	4	2	1	2	4
B	Helper	1	1	2	1	2	2	2	3	5
B	Helper	2	1	2	1	2	2	2	3	5
B	QC	2	2	3	2	3	4	2	2	5
C	Operator	1	2	4	3	3	3	2	1	5
C	Helper	2	2	3	2	4	3	3	2	4
C	QC	2	3	3	3	2	3	1	1	5
Mean		1.80	1.90	3.00	1.80	2.80	2.70	1.80	2.00	4.70

According to the results of the collected data, when introducing the new product, it could be produced in less time. Using quality function deployment based model, relationship matrix was constructed by the relationship between identified issues and product design parameters. Table 5.16 shows the relationship.

Table 5.16 (A) QFD based model carcass building operation- IJ-K 12PR HA SKS 730

Que.No.	Identified issues	Importance	Bead		
			bead dia.	No. of turns	No. of wires
Q1	Easy to insert bead into bead pusher	2	◉	○	○
Q2	Easy to insert pocket into building machine	2			
Q3	Easy to do turn up and turn down process	3			
Q4	Easy to cut plies in angle cutters	2			
Q5	Possible to load layers and liners on building machine,loading capacity of servicer	3			
Q6	Easy to put layeres and sidewall	3			
Q7	Easy to apply the chafer on builing machine	2			
Q8	After making the carcass, easy to unloading carcass	2			
Q9	Can be produced in minimum time	5			
	Absolute important		18	8	8
	Relative important		3.05%	1.35%	1.35%

Value of the absolute importance row under bead diameter = 2 x9

=18

Value of the absolute importance row under bead diameter = 2 x9

=18

Value of the relative importance row under bead diameter = 18/591

= 3.05%

Table 5.16 (B) QFD based model carcass building operation- IJ-K 12PR HA SKS 730

IDENTIFIED ISSUES	Importance	chafer		Ply			
		chafer width	thickness	angle	width	No. of plies & pockets	EPI
Easy to insert bead into bead pusher	2						
Easy to insert pocket into building machine	2			○	◎		○
Easy to do turn up and turn down process	3					◎	○
Easy to cut plies in angle cutters	2			◎	◎		◎
Possible to load layers and liners on building machine,loading capacity of servicer	3						
Easy to put layeres and sidewall	3						
Easy to apply the chafer on builing machine	2	◎	◎				
After making the carcass, easy to unloading carcass	2						
Can be produced in minimum time	5		△			◎	
Absolute important		18	23	26	36	72	38
Relative important		3.21%	4.10%	4.63%	6.42%	12.83%	6.77%

Table 5.16 (C) QFD based model carcass building operation- IJ-K 12PR HA SKS 730

IDENTIFIED ISSUES	layer		inner liner		weight of finished carcass
	thickness	width	thickness	width	
Easy to insert bead into bead pusher					
Easy to insert pocket into building machine					
Easy to do turn up and turn down process					
Easy to cut plies in angle cutters					
Possible to load layers and liners on building machine,loading capacity of servicer	◎	◎	◎	◎	
Easy to put layeres and sidewall	◎	◎	◎	◎	
Easy to apply the chafer on builing machine					
After making the carcass, easy to unloading carcass					◎
Can be produced in minimum time	○	○	○	○	
Absolute important	74	74	74	74	18
Relative important	13.19%	13.19%	13.19%	13.19%	3.21%

According to results of this analysis, a high mark for the relative important row was obtained by layer thickness, width and inner liner thickness and width. So designing the product of IJ-K HA SKS 730, mostly concerned design parameters were layer thickness, width and inner liner thickness and width. That means if more concern is given the parameters of layer thickness, width and inner liner thickness and width, it could be implemented with minimum barriers.

Bead preparation process

Under bead preparation process, four questions (Appendix 2) were designed to collect the data. Benchmarking product in bead manufacturing process was IJ-K 12PR HA SKS. Collected data were categorised in Table 5.17.

Table 5.17 Results of questioners in bead preparation process- IJ-K 12PR HA SKS 730

Shift	Job role	Q1	Q2	Q3	Q4
A	Operator	5	4	1	5
A	Operator	4	3	2	4
B	Operator	3	4	1	3
B	Team leader	4	4	3	5
B	Helper	4	4	2	5
B	Helper	3	3	3	4
B	QC	5	4	1	5
C	Operator	4	5	2	4
C	Helper	4	4	2	5
C	QC	3	4	2	5
C	Team leader	5	4	2	4
Mean		4	3.91	1.91	4.45

As a result of this, it was observed that introducing new product should have minimum changeover time. First Question earned four points, which means cycle time for making product should be considered. Relationship matrix between product design parameters and identified issues were shown in Table 5.18.

Table 5.18 QFD based model bead preparation process- IJ-K 12PR HA SKS 730

Ques. No.	Identified issue	Importance	No. of bead wires	No. of turns	Bead dia.
Q1	Can be produced in minimum time	4	○	◎	◎
Q2	Easy to take drum diameter	4			
Q3	Easy to handle bead wires to make bead	2	◎	△	○
Q4	Use minimum change over time	5	○	△	◎
	Absolute importance		54	43	89
	Relative importance		29.03%	23.12%	47.85%

As a result of this study, for better implementing this product, more attention was given to bead diameter.

Layer, inner liner and side wall preparation process

For collecting issues layer and liner preparation process, four questions were prepared. These issues related to calendar machine operations. Data was collected from questionnaires as benchmarking product of IJ-K 12PR HA SKS. Collected data could be summarised as Table 5.19.

Table 5.19 Summarized results of questioners in layer and inner liner preparation process- IJ-K 12PR HA SKS 730

Shift	Job role	Q1	Q2	Q3	Q4
A	Operator	5	4	3	5
A	Operator	4	3	4	4
A	QC	4	4	2	3
B	Team leader	4	4	4	5
B	Helper	3	4	2	5
B	Operator	3	3	4	4
B	QC	4	4	1	5
C	Operator	4	5	4	4
C	QC	5	4	3	5
C	Operator	4	4	2	5
C	Helper	3	4	2	5
C	Team leader	5	4	2	4
Mean		4	3.92	2.75	4.5

According to collected data, fourth question earned highest mark. More concern was given to make product with minimum time. The relationship between identified issues and product design parameters were constructed based on the QFD model as shown in Table 5.20.

Table 5.20 QFD based model layer and inner liner preparation process- IJ-K 12PR HA SKS 730

Ques. No.	Identified issue	Importance	Compound types	Width	Thickness	Numbe of layer, liner SW
Q1	Use minimum change over time	4	◉	◉	◉	○
Q2	Easy to control required parameters	4	△	◉	◉	△
Q3	Easy for centering the layers & liners	3		◉	△	
Q4	Can be produced in minimum time	5		△	○	◉
	Absolute importance		40	104	95	65
	Relative importance		13.16%	34.21%	31.25%	21.38%

Analysing the QFD based model of relationship can be identified implementing issues and product design parameters; it was found that most concerning product parameters were width and thickness of layers, inner liners and sidewalls.

Tread rolling process

Questions about Implementation barriers of IJ-K HA SKS 730 were developed by considering the manufacturing difficulties of IJ-K 10PR HA SKS. Prepared questioners were given in Sinhala version (Appendix 3). Data was collected from members who were working on module-3 thread rolling machine. Collected data from the thread rolling process was summarised as shown in Table 5.21.

Table 5.21 Summarised results of questioners in tread rolling process- IJ-K 12PR HA SKS 730

Shift	Job role	Q1	Q2	Q3	Q4
A	Operator	2	3	2	5
A	Operator	1	2	3	4
B	Operator	3	4	3	4
B	Team leader	2	3	2	5
B	Helper	1	2	3	5
B	Helper	1	2	4	4
B	QC	2	3	4	5
C	Operator	1	1	4	4
C	Helper	2	3	3	5
C	QC	2	3	3	4
C	Team leader	2	3	2	5
Mean		1.73	2.64	3.00	4.55

Considering the data, the most concerned implementation issue for tread rolling process was minimum changeover time. Relationship these issues and product design parameters were constructed in Table 5.22.

Table 5.22 (A) QFD based model tread rolling process- IJ-K 12PR HA SKS 730

Ques. No	Identified issue	Importance	Preshaping bladder type	Start width
Q1	Easy to insert carcass into pre shaping bladder	2		
Q2	Easy to get required shape by using preshaping bladder	3	◎	
Q3	Easy to get tread start width	3		◎
Q4	Use minimum change over time	4	○	○
	Absolute importance		43	43
	Relative importance		22.87%	22.87%

Table 5.22(B) QFD based model tread rolling process- IJ-K 12PR HA SKS 730

Ques. No	Identified issue	Importance	Tread weight	Compound type	Carcass & Raw tyre weight
Q1	Easy to insert carcass into pre shaping bladder	2			◎
Q2	Easy to get required shape by using preshaping bladder	3			
Q3	Easy to get tread start width	3	○		
Q4	Use minimum change over time	4	◎	◎	
	Absolute importance		48	36	18
	Relative importance		25.53%	19.15%	9.57%

According to constructed relationship, product designs factors of pre-shaping bladder type, tread start width and tread weight were the most concerning factor for implementing this new product. As a result, for developing IJ-K size, factor of carcass and raw tyre weight was the lowest concerning factor

Curing process

In studying the curing process of this new product, existing product of IJ-K 12PR HA SKS was taken as benchmarking product. For collecting data of implementing barriers, six questions were designed to get information from module-3 curing line (Appendix 4). Collected data from above questionnaires were summarised as Table 5.23.

Table 5.23 Summarized results of questioners in curing process- IJ-K 12PR HA SKS 730

Shift	Job role	Q1	Q2	Q3	Q4	Q5	Q6
A	Operator	1	2	2	3	2	3
A	QC	2	2	3	2	2	2
A	Operator	1	2	3	2	3	2
A	Helper	3	3	3	3	2	3
B	Operator	3	3	3	2	2	2
B	Helper	1	1	3	1	3	1
B	Helper	1	2	3	2	2	2
B	Helper	1	1	3	2	2	3
B	Operator	2	3	4	3	3	2
C	Operator	2	3	4	4	2	3
C	Operator	1	1	4	4	2	2
C	Helper	2	3	3	3	2	2
C	QC	2	3	3	4	3	3
C	Team leader	2	2	2	3	2	2
Mean		1.82	2.18	3.00	2.73	2.27	2.27

Relationship matrix was constructed between implementing issues and product design factor for curing process, which is shown in Table 5.24

Table 5.24 QFD based model tyre curing process- IJ-K 12PR HA SKS 730

IDENTIFIED ISSUE	Importance	Weight of raw	Cuting time	Curing temperature	Curing pressure	Curing bladder type	Heating system	Complexity of tread
Easy to load the raw tyre into the curing mould	2	○						
Easy to center the raw tyre on curing bladder	2	○				◎		△
Required temperature can be maintained	3			△			◎	
Easy to set curing cyle setting	3		◎	○			△	
Easy to unload the cured tyre	2	○						◎
Required pressure can be maintained	2				○			
Absolute importance		24	27	15	8	18	30	20
Relative importance		16.90%	19.01%	10.56%	5.63%	12.68%	21.13%	14.08%

According to develop a QFD based model, the highest marks for relative importance was earned by factors of curing time and heating system. So more attention should be given to the heating system. Mainly there were two heating systems which were electrical heaters and steam heating. In steam heating system mould could be heated quicker than element heating system.

Handling quality issues

The quality of the product has become more important in product design and manufacturing. In addition, the new product should be implemented quickly. However, sometime developers often have a lack of the time to fully test their product with all quality features.

Analysing the past quality reports of IJ-K sizes, any major quality defects were highlighted. When comparing the defect level of IJ-K with other sizes, this size was a good product in quality wise. Figure 5.1 shows the defect behaviour of product IJ-K sizes.

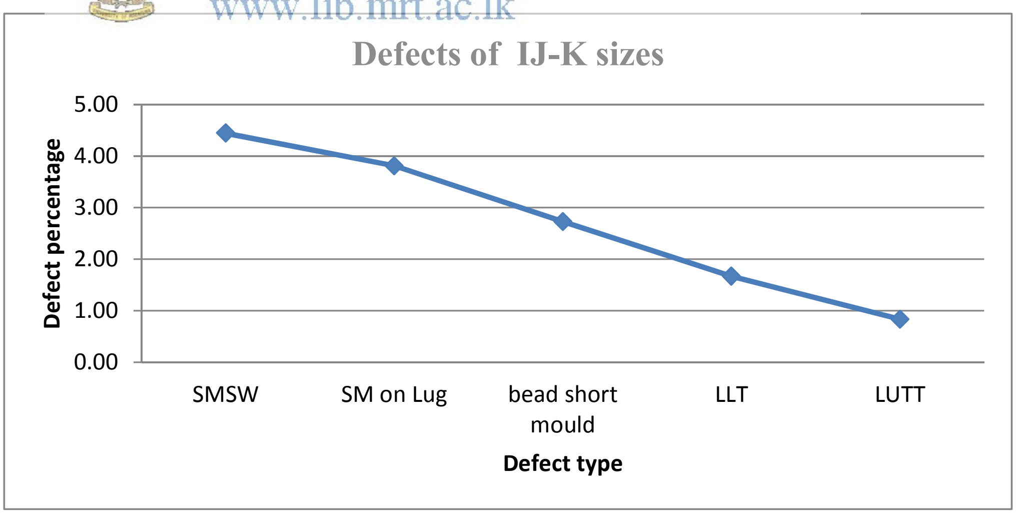


Figure 5.1 defect percentage of IJ-K sizes

Relationship between quality defects and product design parameters was constructed QFD based model (shown in Table 5.25).

Table 5.25 QFD based model quality issues- IJ-K 12PR HA SKS 730

Ques. No.	Quality defects	Importance	Ply angle	Inner liner thickness	Bead construction	Tread weight	Tread start width	No.of venting holes & its orientation
Q1	Short mould on Lug	4				◎	◎	◎
Q2	Short mould on SW	5	◎					◎
Q3	Short mould on bead	3			◎			
Q4	Less liner thickness	2	◎	◎				
Q5	Less under thickness	2				◎	◎	
	Absolute importance		28	18	27	54	54	70
	Relative importance		11.16%	7.17%	10.76%	21.51%	21.51%	27.89%

According to the results of QFD based model, design factor of tread weight, tread start width and orientation of venting holes were major concerning factors, considering the quality of new implemented product.

5.2.5. Five product test

Before starting pilot production, five products were planned to make. So the material was prepared only for five products. So following quantity of material was prepared.

Inner liner – 7.5m

Beads - 10

Layer and sidewall quantity – 8m

Tread compound – 70kg

These five products are made under the supervision of design engineer and process engineer.

5.2.6. Ten product test

Before starting pilot production, another stage was designed as making ten products. Materials were planned for only ten products. These products were made as normal production, which was done supervision of production members such as operators, quality controllers, and team leaders. Design engineer and process engineer were inspected this production randomly.

5.2.7. Pilot production

A sample size of pilot production was selected as 200 pieces. Because this is the smaller size comparing other sizes. This production is run under the main supervision of process engineer.

5.2.8. Timeline for implementation

According to Table 5.26, implementation process of IJ-K HA SKS 730 was assumed to be taken seven weeks. If it was implemented using existing model, it may take eight weeks due to increase the pilot stage up to four weeks.

Table 5.26 Timeline for implementation of IJ-K HA SKS 730

PROCESS	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
Design new product							
Check tech. feasibility							
Benchmarking the products							
Identify the barriers in each sub process							
Make prototype							
Product testing							
Make five products as a test							
Make ten products							
Pilot production							

5.2.9. Cost comparison of implementation

Table 5.27 shows a cost comparison between existing model and the proposed model, when implementing the product of IJ-K HA SKS 730. According to Table 5.27, if the product of IJ-K HA SKS 730 was implemented in the existing model, three tyres could be rejected during a pilot production stage. In the proposed model, it was assumed that two tyres could be rejected. Because it has two high supervision level of five product stage and ten products stage before the pilot production stage.

Table 5.27 Cost comparison of IJ-K HA SKS 730 implementations

	Existing model	**Proposed model**
Number of rejected tyres before mass production/ Pcs	3	2
Cost of rejected product/ LKR	15400	15400
Total cost/LKR	46200	30800

5.3. Case Study 2: New Product Name LM-N 10PR HA SKS 775

Table 5.28 shows the product parameter of LM-N HA SKS 775

Table 5.28 Product parameters of LM-N HA SKS 775

Parameters	
OD (Design/Max) [mm]	777
Section Width [mm]	269
Tread Width [mm]	228
Crown Radius [mm]	-
Weight [kg]	37.5
Inflation Pressure (Bar)	5.3

5.3.1 Design the new product

According to the design calculation, safety factor of the carcass was taken 4.22 and four numbers of plies (material of 24 EPI, 1890 nylon cord) were selected. Safety factor of bead was 6.75. According existing building machines, machine having a diameter of 490mm and width of 510mm was selected. Proposed specification was shown in Table 5.29.

Table 5.29 Proposed product specification of LM-N HA SKS 775

POCKET DRUM:			
	DIA [mm]:	477.5	Brand Names:
	Circum(mm)	1500	
	WIDTH[mm]:	1000	
TYRE DRUM:	(Auto B/M)		
	DIA [mm]:	490	
	Circum(mm)	1539	
	WIDTH[mm]:	510	

A : BEAD PACKAGE

BEAD GROMET :

WIRE DIA. [mm]	COMP. CODE	NUMBER OF WIRES	TURNS	INS. DIAM. [mm]	STRIP DIMENS.[mm] WIDTH	THICK.	NOTE:
0.95	B 607	8	8	424	12.0	1.5	SINGLE bead in the heel

BEAD APEX :

COMP CODE	DIA./WIDTH (mm)	HEIGHT (mm)	LENGTH (mm)	NOTE:
H 492	9.5			

BEAD FILLERING

STRIP[mm] WIDTH	THICK.	LENGTH	COMP. CODE	FABRIC CODE	STEP [mm]	NOTE :
90	1		C222	1260 D/2	10	For the Fillering use cord from bias cutter.

C : CHAFER

RUBBERIZED FABRIC :

STRIP[mm] WIDTH	THICK.	LENGTH	COMP. CODE	FABRIC CODE	NOTE:
90	2.2		CS 401	420D/1	For chafer to use fabric from the bias cutter.

D : CARCASS

POCKET: 1

PLIES OR IN.LINER	COMP. CODE	FABRIC CODE	THICK. [mm]	WIDTH [mm]	LENGTH [mm]	STEPS [mm]	CUTTING ANGLE
in.liner 1	IL 323	-	2.0	650	1500		
in.liner 2	IL 323	-	1.5	370	1513		
ply 1	C 233	1890,24E	1.1	775	1519	15	42
ply 2	C 233	1890,24E	1.1	775		15	42
ply 3	C 233	1890,24E	1.1	775		15	42
ply 4	C 233	1890,24E	1.1	775		15	42

NOTE '-Put inner liner on the ply 1 on the calender, 85 mm from the one edge and 40 mm from the other edge.
- Put edge strips ST5505(80x1980mm) on the pocket and after ply turn up to cover all steps

PLIES OR IN.LINER	COMP. CODE	FABRIC CODE	THICK. [mm]	WIDTH [mm]	LENGTH [mm]	STEPS [mm]	CUTTING ANGLE
BR.1	C 233	1890,24E	1.1	330		-	44
BR.2	C 233	1890,24E	1.1	310		-	44

NOTE : -Put chafer after third pocket [Put cushion gum side of the chafer on the carcass]

OUT.PLIES/BREAKERS/INS.STRIPS/CUSH.GUM/FIRST& SECOND LAYER

PLIES OR INSULAT.	COMP. CODE	FABRIC CODE	THICK. [mm]	WIDTH [mm]	LENGTH [mm]	[mm]	CUTTING ANGLE
cush. gum	C 222	-	0.6	600	1576	center.	-
c.g. strips	C 222	-				-	-
layer 1	RDT 843		4.0	600	1580	center.	-
sidewall 1	LS 345		3.0	100	1605	-	-

NOTE: Put cushion gum and layer 1 together on the calender, centrally.

E : TREAD

COMP. CODE	WIDTH [mm] START	STOP	WEIGHT [kg] MILL	REMAIN	NET	P.R.PRESS. [bar]	CIRCUM. [mm]
TR 843	320	140	19.5	1.5	18.0	0.8	

5.3.2. Technical feasibility

Carcass building operation

Details of technical feasibility of carcass building operation were shown in Table 5.30.

Table 5.30 Technical feasibility study for carcass building operation of LM-N HA SKS 775

Selected Parameters	Remark
Proposed buildings drum diameter / (mm)	490
Proposed buildings drum width / (mm)	510
Proposed building machine	MBD 1
Is proposed building machine capable to make this carcass?	yes
Current capacity of building machine (carcasses per day)	300
Excess capacity of building machine (carcasses per day)	50
Number of carcass requirement per day	20
Shortage of carcass per day	0
% of new carcass building capacity	-

The capacity of this building machine was enough making new product. Same building machine of LM-N sizes could be used to produce this product

Bead preparation process

Details of technical feasibility study are shown in Table 5.31.

Table 5.31 Technical feasibility study for bead preparation of LM-N HA SKS 775

Selected Parameters	Remark
Is available required bead drum?	yes
Can required bead wires be loaded?	yes
Current capacity of bead making machine (Number of beads per day)	2500
Excess capacity of bead making machine (Number of beads per day)	500
Number of beads requirement per day	40
% of new bead machine capacity per day	-

Table 5.32 shows technical feasibility study for calendar machine

Layer, inner liner and side wall preparation process

Table 5.32 Technical feasibility study for calendar machine process- LM-N HA SKS 775

Selected Parameters	Remark
Can required width and thickness be get?	yes
Current capacity of calendar machine (Number of layer meters per day)	3500m
Excess capacity of calendar machine (Number of layer meters per day)	500m
Number of quantity requirement per day	85m
% of new calendar machine capacity per day	-

Tread rolling process

Details about tread rolling process are given in Table 5.33.

Table 5.33 Technical feasibility study for tread rolling operation of LM-N HA SKS 775

Selected Parameters	Remark
Proposed tread rolling cell or module	Module 03
Is proposed tread rolling unit capable to do this?	yes
Are required equipment available (bladders, holders)?	yes
Current capacity of tread rolling unit (Green Tyres per day)	350
Excess capacity of tread rolling unit (Green tyres per day)	55
Number of green tyre requirement per day	20
% of new green tyre tread rolling capacity per day	-

Tyre curing operation

Details about curing rolling process are given in Table 5.34.

Table 5.34 Technical feasibility study for tyre curing operation of LM-N HA SKS 775

Selected Parameters	Remark
Proposed curing press size	BOM Press
Is this curing press capable to make this product?	yes
Are curing bladders, PCI available?	yes
Proposed Module	Module 3
Current capacity (number of curing slots)	28
Running/planned capacity (number of curing slots)	28
Excess curing capacity (number of curing slots)	0
Number of curing slots needed for the project	1
Shortage of curing slots	-

Financial analysis

Deatails of financial analysis is shown in Table 5.35.

Table 5.35 Technical feasibility study for financial analyse of LM-N HA SKS 775

Selected Parameters	Remark
Unit price of product/ (LKR/Kg)	15,000
Proposed Weight of product/ (Kg)	37.5
Current material and OH cost / (LKR/Kg)	6,800
Annual demand (Number of products)	5500
Target output per day	20
Number of mould required	1

According to feasibility study, all required machines and capacities were available to implement this product.

5.3.3. Benchmarking

The behaviour of this product was similar to LM-N sizes. Tread pattern was not match with available sizes. Table 5.36 shows details of carcass building, Table 5.37 shows bead preparation process and Table 5.38, Table 5.39 shows layer, inner liner sidewall preparation process.

Carcass building operation

Table 5.36 Benchmarking product in bead operation- LM-N HA SKS 775

Product size	Building drum diameter /mm	Building drum width /mm
LM-N 10PR HA XD 44L5	490	510
LM-N 10PR HA SKS 775	490	510

Bead preparation process

Table 5.37 Benchmarking product in bead operation- LM-N 10PR HA SKS 775

Product size	No. of wires	No. of turns	Inside dia.(mm)	No of Beads
LM-N 10PR HA XD 44L5	8	8	424	2
LM-N 10PR HA SKS 775	8	8	424	2

Running size of LM-N 10PR HA XD 44L5 was selected as benchmarking product for bead preparation process.

Layer, inner liner and sidewall preparation process

Layer preparation

Table 5.38 Benchmarking products in layer preparation- LM-N 10PR HA SKS775

Product size	Compound type	Layer width/mm	Layer thick./mm
LM-N 10PR HA XD 44L5	TR 843	600	4
LM-N 10PR HA SKS 775	TR 843	600	4

Side wall preparation

Table 5.39 Benchmarking products in sidewall preparation- LM-N 10PR HA SKS775

Product size	Compound type	Sidewall width/mm	Sidewall thick./mm
LM-N 10PR HA XD 44L5	LS 345	100	3
LM-N 10PR HA SKS 775	LS 345	100	3

Inner liner preparation (IL)

Table 5.40 shows details of benchmarking products in inner liner preparation.

Table 5.40 Benchmarking products in IL preparation- LM-N 10PR HA SKS 775

Product size	Compound type	Inner liner width/mm	Inner liner thick./mm
LM-N 10PR HA XD 44L5	IL 323	650	2
LM-N 10PR HA SKS 775	IL 323	650	2

Product of LM-N 10PR HA XD 44L5 was selected as benchmarking products for material preparation through calendar machine.

Tread rolling process

Table 5.41 shows details of benchmarking products in inner liner preparation.

Table 5.41 Benchmarking products in IL preparation- LM-N 10PR HA SKS 775

Product size	Compound type	Tread start width/mm	Tread weight./kg
LM-N 10PR HA XD 44L5	TR 625	320	18.5
LM-N 10PR HA SKS 775	TR 625	320	18

Curing process

Curing time and curing press were similar to LM-N 10PR HA XD 44L5. So on curing process also, this product was taken as benchmarking product.

5.3.4. Barrier identification

Carcass building operation

To collect data, same questionnaire was used in the above case study. Results were summarised in Table 5.41.

Table 5.42 Summarised results of questioners in Carcass building operation- LM-N 10PR HA SKS 775

Shift	Job role	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
A	QC	1	1	2	2	3	3	1	1	3
A	Helper	1	2	2	1	3	4	1	2	5
A	Operator	2	2	3	2	4	2	2	3	5
A	Team leader	1	1	2	2	3	3	1	2	5
B	Operator	1	1	3	1	3	2	1	3	5
B	Helper	1	1	2	1	2	3	2	3	5
B	Operator	2	1	1	1	3	2	1	3	5
B	QC	1	2	2	2	3	4	1	2	5
C	Operator	1	1	2	3	3	3	2	1	5
C	Helper	2	2	3	2	4	3	1	2	3
C	Team leader	1	1	3	2	2	4	1	2	5
Mean		1.27	1.36	2.27	1.73	3.00	3.00	1.27	2.18	4.64

According to results of questionnaire, more concern was given to make product in minimum time. Relationship between design factors and considering factors are shown in Table 5.43

Table 5.43 (A) QFD based model carcass building operation- LM-N 10PR HA SKS 775

Question No.	Identified issue	Importance	Chafer		inner liner		Ply			
			Chafer width	Thickness	Thickness	Width	Angle	Width	No. of plies & pockets	EPI
Q1	Easy to insert bead into bead pusher	1								
Q2	Easy to insert pocket into building machine	1			○		○	◎		○
Q3	Easy to do turn up and turn down process	2				○			◎	○
Q4	Easy to cut plies in angle cutters	2					◎	◎		◎
Q5	Possible to load layers and liners on building machine,loading capacity of servicer	3								
Q6	Easy to put layeres and sidewall	3								
Q7	Easy to apply the chafer on builing machine	1	◎	◎						
Q8	After making the carcass, easy to unloading carcass	2								
Q9	Can be produced in minimum time	5		△	△	△			◎	
	Absolute important		9	14	9	13	22	27	63	30
	Relative important		1.74%	2.70%	1.74%	2.51%	4.25%	5.21%	12.16%	5.79%

Table 5.43(B) QFD based model carcass building operation- LM-N 10PR HA SKS 775

Question No.	Identified issue	Importance	Bead		
			Bead dia.	No. of turns	No. of wires
Q1	Easy to insert bead into bead pusher	1	◉	○	○
Q2	Easy to insert pocket into building machine	1			
Q3	Easy to do turn up and turn down process	2			
Q4	Easy to cut plies in angle cutters	2			
Q5	Possible to load layers and liners on building machine,loading capacity of servicer	3			
Q6	Easy to put layeres and sidewall	3			
Q7	Easy to apply the chafer on builing machine	1			
Q8	After making the carcass, easy to unloading carcass	2			
Q9	Can be produced in minimum time	5			
	Absolute important		9	4	4
	Relative important		1.74%	0.77%	0.77%

Table 5.43(C) QFD based model carcass building operation- LM-N 10PR HA SKS 775

Question No.	Identified issue	Importance	layer		inner liner		Weight of finished carcass
			Thickness	Width	Thickness	Width	
Q1	Easy to insert bead into bead pusher	1					
Q2	Easy to insert pocket into building machine	1					
Q3	Easy to do turn up and turn down process	2					
Q4	Easy to cut plies in angle cutters	2					
Q5	Possible to load layers and liners on building machine,loading capacity of servicer	3	◉	◉	◉	◉	
Q6	Easy to put layeres and sidewall	3	◉	◉	◉	◉	
Q7	Easy to apply the chafer on builing machine	1					
Q8	After making the carcass, easy to unloading carcass	2					◉
Q9	Can be produced in minimum time	5	○	○	○	○	
	Absolute important		74	74	74	74	18
	Relative important		14.29%	14.29%	14.29%	14.29%	3.47%

According to analysing, most considerable factors were layer width, thickness and inner liner width and thickness. So, when giving more concentration on these design factors, it addressed the issues at question number 5, 6 and 9.

Bead preparation process

According to prepared questioner, results were summarised in table 5.43.

Table 5.44 Summarised results of questioners in bead preparation process- LM-N 10PR HA SKS 775

Shift	Job role	Q1	Q2	Q3	Q4
A	QC	4	3	2	4
A	Operator	4	4	1	5
A	Operator	3	4	2	4
B	Operator	3	4	1	4
B	Team leader	4	4	3	5
B	Helper	4	4	2	5
B	Helper	3	3	3	4
B	QC	5	4	1	5
C	Operator	4	3	2	5
C	Helper	4	4	2	5
C	QC	3	5	3	5
C	Operator	4	4	2	4
Mean		3.75	3.83	2.00	4.58

Then relationship matrix was constructed (shown in Table 5.44)

Table 5.45 QFD based model bead preparation process- LM-N 10PR HA SKS775

Que. No.	Identified issues	Importance	No. of bead wires	No. of turns	Bead dia.
Q1	Can be produced in minimum time	4	○	◎	◎
Q2	Easy to take drum diameter	4			
Q3	Easy to handle bead wires to make bead	2	◎	△	○
Q4	Use minimum change over time	5	○	△	◎
	Absolute importance		54	43	89
	Relative importance		29.03%	23.12%	47.85%

According to Table 5.44, critical design parameter was bead diameter.

Layer, inner liner and side wall preparation process

For analysing this process, LM-N 10PR HA XD 44L5 was used as benchmarking product. Details are shown in Table 5.46

Table 5.46 Summarised results of questioners in layer and inner liner preparation process- LM-N 10PR HA SKS 775

Shift	Job role	Q1	Q2	Q3	Q4
A	Operator	4	3	4	5
A	Operator	4	3	4	4
A	QC	4	4	2	3
B	Team leader	5	3	4	5
B	Helper	3	4	3	4
B	Operator	3	4	4	5
B	QC	4	4	1	5
C	Operator	4	5	4	4
C	QC	3	4	3	5
C	Operator	4	4	2	5
C	Helper	4	3	2	5
Mean		3.82	3.73	3.00	4.55

Relationship is constructed in Table 5.47.

Table 5.47 QFD based model layer and inner liner preparation process- LM-N 10PR HA SKS 775

Que. No.	Identified issues	Importance	Compound types	Width	Thickness	Numbe of layer, liner SW types
Q1	use minimum change over time	4	◎	◎	◎	○
Q2	easy to control required parameters	4	△	◎	◎	△
Q3	easy for centering the layers & liners	3		◎	△	
Q4	can be produced in minimum time	5		△	○	◎
	Absolute importance		40	104	95	65
	Relative importance		13.16%	34.21%	31.25%	21.38%

Preparation of layer and inner liner were done by calendar machine. So, considering the production of benchmarking product of LM-N 10PR HA XD 44L5, most important design factors were width and thickness of layer and inner liner.

Tread rolling process

Collected data were summarised in Table 5.47

Table 5.48 Summarised results of questioners in tread rolling process- LM-N 10PR HA SKS 775

Shift	Job role	Q1	Q2	Q3	Q4
A	Operator	2	3	2	4
A	QC	2	3	2	3
A	QC	2	3	2	5
A	Team leader	1	2	3	4
B	Operator	3	4	3	4
B	Team leader	2	3	2	5
B	Helper	1	2	3	5
B	Helper	1	2	4	4
B	QC	2	3	4	5
C	Operator	1	1	4	4
C	Helper	2	3	3	5
C	QC	2	3	3	4
C	Team leader	2	3	2	5
Mean		1.77	2.69	2.85	4.38

Considering the collected data, for deriving the relationship between design factors and implementation issues, QFD based model was developed. It shown in Table 5.49

Table 5.49 QFD based model tread rolling process-LM-N 10PR HA SKS 775

Que.No.	Identified Issues	Importance	Preshaping bladder type	Start width	Tread weight	Compound type	Carcass & raw tyre weight
Q1	Easy to insert carcass into pre shaping bladder	2					◎
Q2	Easy to get required shape by using preshaping bladder	3	◎				
Q3	Easy to get tread start width	3		◎	○		
Q4	Use minimum change over time	4	○	○	◎	◎	
	Absolute importance		43	43	48	36	18
	Relative importance		22.87%	22.87%	25.53%	19.15%	9.57%

So, most important design factors were pre-shaping bladder type, tread start width and tread weight.

Tyre Curing process

For curing process, benchmarking product was selected as LM-N 10PR HA XD 44L5. Summarised the collected data was given in Table 5.50

Table 5.50 Summarised results of questioners in curing process- LM-N 10PR HA SKS 775

Shift	Job Role	Q1	Q2	Q3	Q4	Q5	Q6
A	Operator	2	1	3	2	5	2
A	QC	2	2	3	2	5	2
A	Operator	1	1	2	3	5	3
A	Helper	2	3	3	3	4	3
A	Team Leader	3	3	3	3	5	1
B	Operator	3	3	3	3	5	2
B	Helper	1	2	3	2	3	1
B	Helper	3	2	3	2	5	2
B	Helper	1	1	3	2	5	2
B	Operator	2	3	4	3	5	2
C	Operator	2	3	4	4	4	3
C	Operator	3	1	4	4	4	2
C	Helper	2	2	3	3	5	2
C	QC	2	3	4	4	5	3
C	Team Leader	2	2	2	3	5	2
Mean		2.07	2.13	3.13	2.87	4.67	2.13

Relationships between parameters are shown in Table 5.51.

Table 5.51(A) QFD based model tyre curing process- LM-N 10PR HA SKS 775

Qes.No.	Identified Issues	Importance	Weight of raw tyre/cured tyre	Curing time	Curing temperature
Q1	Easy to load the raw tyre into the curing mould	2	○		
Q2	Easy to center the raw tyre on curing bladder	2	○		
Q3	Required temperature can be maintained	3			△
Q4	Easy to set curing cyle setting	3		◉	○
Q5	Easy to unload the cured tyre	5	○		
Q6	Required pressure can be maintained	2			
	Absolute importance		36	27	15
	Relative importance		19.89%	14.92%	8.29%

Table 5.51(B) QFD based model tyre curing process- LM-N 10PR HA SKS 775

Qes.No.	Identified Issues	Importance	Curing pressure	Curing bladder type	Heating system	Complexity of tread pattern
Q1	Easy to load the raw tyre into the curing mould	2				
Q2	Easy to center the raw tyre on curing bladder	2		◉		△
Q3	Required temperature can be maintained	3			◉	
Q4	Easy to set curing cyle setting	3			△	
Q5	Easy to unload the cured tyre	5				◉
Q6	Required pressure can be maintained	2	○			
	Absolute importance		8	18	30	47
	Relative importance		4.42%	9.94%	16.57%	25.97%

According to QFD based model and benchmark product, most considerable factor was the weight of the tyre and complexity of tread pattern. The Major production issue of benchmark products of LM-N 10PR HA XD 44L5 was the difficulties of de-moulding the finished product. So, this issue could be addressed by considering above highlighted design factors.

Handling quality issues

According past data, major quality defect was analysed (Figure 5.4).

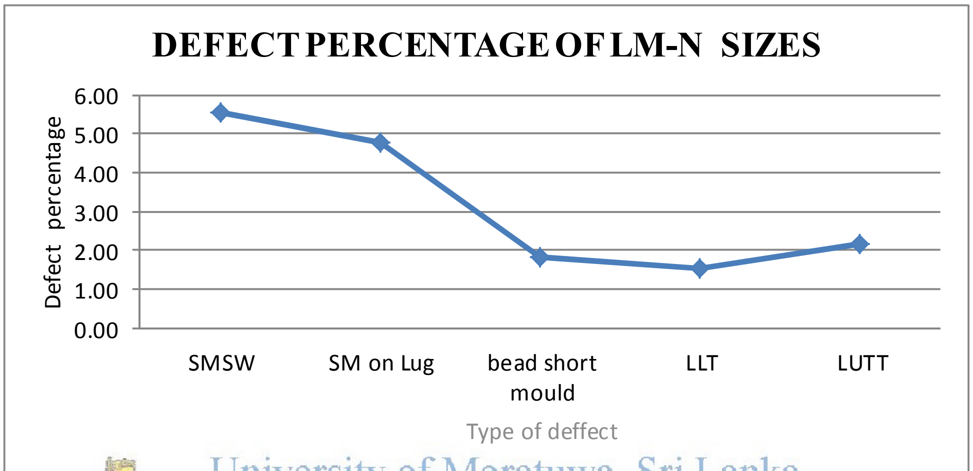


Figure 5.2 defect percentage of LM-N sizes

Relationships between quality issues are shown in Table 5.52

Table 5.52 QFD based model quality issues- LM-N 10PR HA SKS 775

Que. No.	Quality Defect	Importance	Sidewall thickness	Layer thickness	Layer width	Inner liner width	Ply angle	Inner liner thickness	Bead construction	Tread weight	Tread start width	no.of venting holes & its place
Q1	Short mould on Lug	4		△	△					◎	◎	◎
Q2	Short mould on SW	5	◎	△	△		○					◎
Q3	Short mould on bead	3			○	○			◎			
Q4	Less liner thickness	2					○	◎				
Q5	Less under thickness	2		◎						◎	◎	
	Absolute importance		45	27	21	12	28	18	27	54	54	81
	Relative importance		12.26%	7.36%	5.72%	3.27%	7.63%	4.90%	7.36%	14.71%	14.71%	22.07%

The defect behaviour of LM-N was similar as IJ-K. So, for minimizing the quality defects of implementation of this product, more concentration should be given to design factors of tread weight, tread start width and venting holes orientation.

5.2.5. Five product test

For making five products under the supervision of design engineer and process engineer, following quantity of material was planned.

Inner liner – 7.5m

Beads - 10

Layer and sidewall quantity – 8m

Tread compound – 90kg

5.2.6. Ten product test

After making good quality five products, ten products were arranged to make. During this stage, arising issues could be tackled while production running with minimum supervision.

5.2.7. Pilot production

Sample of pilot production was selected as 200 pieces. During this stage, other remaining issues were tried to solve. Defects and implementing issues free products had to be transferred to the next stage of mass production.

Timeline for product implementation is shown in Table 5.53.

5.2.8. Timeline for implementation

Table 5.53 Time line for implementation of LM-N HA SKS 775

PROCESS	Week -1	Week - 2	Week - 3	Week -4	Week -5	Week -6	Week -7
Design new product							
Check tech. feasibility							
Benchmarking the products							
Identify the barriers in each sub processes							
Make prototype							
Product testing							
Make five products as test							
Make ten products							
Pilot production							

5.2.9. Cost comparison of implementation

According to cost comparison table of LM-N HA SKS 775, it could be assumed to save cost of 30% as implementing the proposed model. This achievement could be assumed to get by identifying the issues as much as possible, before implementing as mass production. It is shown in Table 5.54.

Table 5.54 Cost comparison of LM-N HA SKS 775 implementations

	Existing model	**Proposed model**
Number of rejected tyres before mass production/ Pcs	3	2
Cost of rejected product/ LKR	15000	15000
Total cost/LKR	45000	30000

CHAPTER 6 CONCLUSION AND RECCOMENDATION

6.1 Discussion

Competitive pressures, cost challenges and increased customer expectations are driving companies to improve their new product introduction and development processes. The aim of this research was to investigate new product implementation process in a way that brings new products to market more effectively. The QFT model employs a set of activities that if followed will simplify and expedite many business processes to streamline execution and repeatability while removing distance barriers.

Manufacturing process of pneumatic tyre is very complicated, which contains many sub processes. When introducing a new product, it affects the manufacturing of sub processes. If barriers of each small work element of each sub process can be considered during implementing a new product, it will easy to implement product more effectively. The QFT model covers all barriers as much as possible. But in the existing model, all these issues have to be tackled in pilot production stage. If work procedures of each sub process and product specification have to be changed for introducing a new product, it can be done at the design stage in the new proposed model.

In proposing QFT model, it has path to give information to design engineer about requirements of new product, when implementing the product into production floor. Information and feedbacks can be conveyed to design engineer during the four stages of identifying barriers, five product test, ten product test and prototype making in QFT model. So, design engineer can design a good quality product based on this information. But the existing model does not have such path and all the issues have to be solved in pilot production stage. When considering the strength of information path between existing model and the proposed model, the new model has a four times strengthen than existing one.

In QFT model, design engineer can design the product considering the lean principle which requires in each sub process. So, it assists in the identification and steady elimination of waste. As waste is eliminated quality improves while production time and cost are reduced. In existing model, developed product has to be reworked to align it into the lean principle.

QFT model uses QFD based model to construct the relationship between product design parameters and implementation barriers in each sub process. So, design engineers can get an idea and give more concentration on some specific design factors which is derived from the QFD based model.

QFD dictates product design and manufacturing standards from the concept stage. Any problems can be addressed at an early stage of production, dramatically enhancing production efficiency. A natural outcome of increased efficiency is a reduction in overall cost that can be passed on to the customer.
Involving QFD based model for developing model, team work is improved. Because of all the relevant parties are involving to implement it. They are doing communication data and give a contribution to implement it. So it creates a good communication path between relevant parties.

Before pilot stage, there are two stages in QFT model. They are manufacturing five products and ten product stages. So, before new product comes to the pilot production stage, most of the implementation barriers are identified and eliminated. When solving every issue in pilot production stage, it creates more times and more rejected products. In pilot production stage, production is running as a bulk sample continuously. So, when production is stopped immediately due to major defect of the product, more materials have been prepared to make products. So if a product specification is changed due to this quality defect, prepared materials may have to be rejected. Sometime while stopping the production, some rejected products creates. Introducing QFT model, rejected cost can be assumed to reduce up to below one million rupees. When considering the new model, design changes at pilot stage is reduced and design and manufacturing cost is also reduced. Implementing IJ-K HA SKS 730, rejected product cost can be reduced from Rs. 46200 to Rs.30800

Although using a QFD approach increases the time and cost associated with initial project planning and development, it will result in time and dollar savings downstream from reduced changes and conflicts during production.

According to QFT model, it is assumed that new product can be implemented nearly seven weeks. In existing model, this implementation time takes nine or eight weeks. During QFT model, pilot production stage can be completed within two weeks period. But during existing model, this time takes nearly four weeks due to solving more issues.

In this QFT model, stage of technical feasibility is created. So, before implementing product, design engineers can collect data of availability of required machines, its current capacities, and the requirement of new machines, financial analysis. The new product can be implemented in minimum time due to check the all required resources and capacities of the machines available before implementing new product. The feasibility study is an analysis of possible alternative solutions to a problem and a recommendation on the best alternative. It can be decided whether a process be carried out by a new system more efficiently than the existing one. The results of this study are used to make a decision whether to proceed with the project of new product implementation.

This QFT model is proposed to use pneumatic tyre industry, which has complicated product and manufacturing process. Several sub processes and different types of semi products are produced in each sub process. So this QFT model can be used any other complicated products which have several sub processes. If the size of the product is small and it has not complicated design structure and manufacturing process, stages of five product test and ten product test may not be enough. So, number of products may have to be increased depends on the product. Sometime stage of five product test becomes twenty product tests. If a completely new product is going to be introduced, benchmarking process may become difficult. Benchmarking product has to be selected as equalizing to the new product as much as possible.

For getting better result from this QFT model, accuracy of the survey and benchmarking process is very important. The difference between surveyed models in the literature survey and the actual reality of working industry of pneumatic tyre manufacturing are very far apart. But developed new model is structured studying the facing of practical problems in each sub process.

6.2. Conclusion

The pneumatic tyre industry has gradually evolved and become a global enterprise, product design team, manufacturing team, sales team are becoming increasingly more detached, maintaining communication channels is complex, monitoring team progress and achieving targets and goals. Numerous studies have shown that a standard new product implementation model working in all industries, organizational structures and companies does not currently exist.

The available literature on the subject of new product implementation has not fully addressed the global aspects of new product introduction and very few of the theoretical proposals have been supported by actual case studies.

A model was developed for the pneumatic tyre design and production, based on existing models for new product development, reported failures in existing product implementation in the existing pneumatic tyre design and manufacturing process. This model was developed by considering the practical issues of new product implementation and by discussing with operators, quality controllers, leaders who know the practical issues very well. So here more practical based model can be developed.

The model was evaluated using case studies and results show that communication path of all relevant parties got strengthened by four times, new product implementation time can be reduced by 20 percent and cost can be reduced by 30 percent, when compared with the traditional approach to design of pneumatic tyres.

6.3 Further Work

Future work is required to generalise this model to be used in other similar sectors. This model can be used other manufacturing environment other than tyre manufacturing industry. When implementing this model to other manufacturing environment, five product test and ten product test of this model can be changed according to sample requirement. As example vehicle manufacturing industry, this five product test may be changed to one product test.

The system could also be modified by using a computerised system that uses artificial intelligence to be more helpful to the users. All the new product implementation barriers, considering factors can be computerized and when inserting necessary data of new product which is going to implement, idea about expected barriers can be get automatically. So it is helpful to design good product considering all the practical issues with minimum time.

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APPENDIX 1 QUESTIONNAIRES FOR CARCASS BUILDING OPERATION

Aim of this study is identifying the considering factors and implementation barriers of new product in your organization.

Designation:

Shift:

Product name:

Please read following sentences carefully. When producing this product, please choose most suitable answer as you think.

		Disagree	Agree little bit	Agree neutrally	Almost agree	Strongly agree
1	Easy to insert bead into bead pusher					
2	Easy to insert pocket into building machine					
3	Easy to do turn up and turn down process					
4	Easy to cut plies in angle cutters					
5	Possible to load layers and liners on building machine, loading capacity of servicer					
6	Easy to put layers and sidewall					
7	Easy to apply the chafer on building machine					
8	After making the carcass, easy to unloading carcass					
9	Can be produced in minimum time					

මෙම සමීක්ෂණය සිදු කිරීම සඳහා අරමුණ වනුයේ ඔබ ආයතනය තුළ අළුත් නිෂ්පාදනයක් නිපදවීමට යාමේදී ඇති වන බාධක සහ අවධානය යොමු කළ යුතු කරුණු හඳුනා ගැනීමයි.

තනතුර :

සේවා මුරය :

නිෂ්පාදන වර්ගය :

පහත සඳහන් ප්‍රකාශ හොඳින් කියවා, මෙම නිෂ්පාදන වර්ගය නිපදවීමේදී ඔබට හැගෙන පරිදි වඩාත් ගැළපෙන පිළිතුර සළකුණු කරන්න.

	එකග නොවේ	සුළු වශයෙන් එකග වේ	මධ්‍යස්ථ වශයෙන් එකග වේ	බොහො සෙයින් එකග වේ	අතිශයින්ම එකග වේ
බීඩ් රඳවනය මත බීඩ් රුඳවීම පිළිබඳ අවධානය යොමු කල යුතුයි.					
කාකස් නිපදවීම සඳහා බිල්ඩින් මැෂින් එකට පොකට් ඇතුලු කිරීම පිළිබඳ අවධානය යොමු කල යුතුයි.					
ප්ලයි ටර්න් අප් සහ ප්ලයි ටර්න් ඩවුන් ක්‍රියාවලිය සිදු කිරීම පිළිබඳ අවධානය යොමු කල යුතුයි.					
ඇන්ගල් කටර් එක මගින් ප්ලයි කැපීම පිළිබඳ අවධානය යොමු කල යුතුයි.					
ලේයර් හා ඉනර් ලයිනර් පොකට්, බිල්ඩින් මැෂින් එක මතට ගබඩා කිරීම සහ මෙම ද්‍රව්‍ය ගබඩා කිරීම පිළිබඳ අවධානය යොමු කල යුතුයි.					
ලේයර් සහ ඉනර් ලයිනර් බිල්ඩින් මැෂින් සහ පොකට් මැෂින් එක මත දැමීමේ ක්‍රියාවලිය පිළිබඳ අවධානය යොමු කල යුතුයි.					
වේෆර් දැමීමේ ක්‍රියාවලිය පිළිබඳ අවධානය යොමු කල යුතුයි.					
කාකස් නිෂ්පාදනයෙන් පසු බිල්ඩින් මැෂින් එක මතින් කාකස් බෑමේ ක්‍රියාවලිය පිළිබඳ අවධානය යොමු කල යුතුයි.					
අවම කාලයක් තුල නිෂ්පාදනය සිදු කිරීම පිළිබඳ අවධානය යොමු කල යුතුයි.					

APPENDIX 2 QUESTIONNAIRES FOR BEAD PREPARATION PROCESS

Aim of this study is identifying the considering factors and implementation barriers of new product in your organization.

Designation:

Shift:

Product name:

Please read following sentences carefully. When producing this product, please choose most suitable answer as you think.

		Disagree	**Agree little bit**	**Agree neutrall**	**Almost agree**	**Strongly agree**
1	Can be produced in minimum time					
2	Easy to take drum diameter					
3	Easy to handle bead wires to make bead					
4	Use minimum change over time					

මෙම සමීක්ෂණය සිදු කිරීම සඳහා අරමුණ වනුයේ ඔබ ආයතනය තුළ අළුත් නිෂ්පාදනයක් නිපදවීමට යාමේදී ඇති වන බාධක සහ අවධානය යොමු කළ යුතු කරුණු හඳුනා ගැනීමයි.

තනතුර :

සේවා මුරය :

නිෂ්පාදන වර්ගය :

පහත සඳහන් ප්‍රකාශ හොඳින් කියවා, මෙම නිෂ්පාදන වර්ගය නිපදවීමේදී ඔබට හැගෙන පරිදි වඩාත් ගැළපෙන පිළිතුර සළකුණු කරන්න.

	එකග නොවේ	සුළු වශයෙන් එකග වේ	මධ්‍යස්ථ වශයෙන් එකග වේ	බොහො සෙයින් එකග වේ	අතිශයින්ම එකග වේ
අවම කාලයක් තුල නිෂ්පාදනය සිදු කිරීම පිළිබඳ අවධානය යොමු කල යුතුයි.					
අවශ්‍යය බීඩ් විෂ්කම්භය බීඩ් ඩ්‍රම් මගින් පහසුවෙන් ලබා ගැනීමේ හැකියාව පිළිබඳ අවධානය යොමු කල යුතුයි.					
අවශ්‍යය බීඩ්හි වයර් ප්‍රමාණය පහසුවෙන් හැසිරවීම පිළිබඳ අවධානය යොමු කල යුතුයි.					
නිෂ්පාදන අතර අවම කාලයකින් මාරු වීමේ(change over time) හැකියාව පිළිබඳ අවධානය යොමු කල යුතුයි.					

APPENDIX 3 QUESTIONNAIRES FOR LAYER AND LINER PREPARATION PROCESS

Aim of this study is identifying the considering factors and implementation barriers of new product in your organization.

Designation:

Shift:

Product name:

Please read following sentences carefully. When producing this product, please choose most suitable answer as you think.

		Disagree	Agree little bit	Agree neutrall	Almost agree	Strongly agree
1	Use minimum change over time					
2	Easy to get and control required parameters					
3	Easy to center the layers and inner liners					
4	Can be produced in minimum time					

මෙම සමීක්ෂණය සිදු කිරීම සඳහා අරමුණ වනුයේ ඔබ ආයතනය තුළ අළුත් නිෂ්පාදනයක් නිපදවීමට යාමේදී ඇති වන බාධක සහ අවධානය යොමු කළ යුතු කරුණු හඳුනා ගැනීමයි.

තනතුර :

සේවා මුරය :

නිෂ්පාදන වර්ගය :

පහත සඳහන් ප්‍රකාශ හොඳින් කියවා, මෙම නිෂ්පාදන වර්ගය නිපදවීමේදී ඔබට හැගෙන පරිදි වඩාත් ගැළපෙන පිළිතුර සළකුණු කරන්න.

	එකග නොවේ	සුළු වශයෙන් එකග වේ	මධ්‍යස්ථ වශයෙන් එකග වේ	බොහො සෙයින් එකග වේ	අතිශයින්ම එකග වේ
නිෂ්පාදන අතර අවම කාලයකින් මාරු වීමේ(change over time) හැකියාව පිළිබඳ අවධානය යොමු කල යුතුයි.					
අවශ්‍යය කරන පරාමිතීන් පහසුවෙන් ලබා ගෙන පාලනය කල හැකි වීම පිළිබඳ අවධානය යොමු කල යුතුයි.					
ලේයර් සහ ඉනර් ලයිනර් පහසුවෙන් මධ්‍යගත කිරීමට හැකි වීම පිළිබඳ අවධානය යොමු කල යුතුයි.					
අවම කාලයක් තුල නිෂ්පාදනය සිදු කිරීම පිළිබඳ අවධානය යොමු කල යුතුයි.					

APPENDIX 4 QUESTIONNAIRES FOR TREAD ROLLING PROCESS

Aim of this study is identifying the considering factors and implementation barriers of new product in your organization.

Designation:

Shift:

Product name:

Please read following sentences carefully. When producing this product, please choose most suitable answer as you think.

		Disagree	Agree little bit	Agree neutrally	Almost agree	Strongly agree
1	Easy to insert the carcass on relevant tread rolling bladder					
2	Easy to get required shape by tread rolling bladder					
3	Easy to get tread starting width					
4	Change the product with minimum change over time					

මෙම සමීක්ෂණය සිදු කිරීම සඳහා අරමුණ වනුයේ ඔබ ආයතනය තුළ අළුත් නිෂ්පාදනයක් නිපදවීමට යාමේදී ඇති වන බාධක සහ අවධානය යොමු කළ යුතු කරුණු හඳුනා ගැනීමයි.

තනතුර :

සේවා මුරය :

නිෂ්පාදන වර්ගය :

පහත සඳහන් ප්‍රකාශ හොඳින් කියවා, මෙම නිෂ්පාදන වර්ගය නිපදවීමේදී ඔබට හැගෙන පරිදි වඩාත් ගැළපෙන පිළිතුර සළකුණු කරන්න.

	එකග නොවේ	සුළු වශයෙන් එකග වේ	මධ්‍යස්ථ වශයෙන් එකග වේ	බොහො සෙයින් එකග වේ	අතිශයින්ම එකග වේ
කාකස් එක නියමිත ත්‍රෙඩ් රොලින් බ්ලැඩර් එක තුලට දමා ගැනීමේ පහසුව පිළිබඳ අවධානය යොමු කල යුතුයි.					
ත්‍රෙඩ් රොලින් බ්ලැඩර් එක මගින් ත්‍රෙඩ් රොලින් ක්‍රියාවලිය සිදු කිරීමට අවශ්‍යය හැඩය ලබා ගැනීමේ පහසුව පිළිබඳ අවධානය යොමු කල යුතුයි.					
ආරම්භක පළල පහසුවෙන් ලබා ගැනීම පිළිබඳ අවධානය යොමු කල යුතුයි.					
නිෂ්පාදන අතර අවම කාලයකින් මාරු වීමේ(change over time) හැකියාව පිළිබඳ අවධානය යොමු කල යුතුයි.					

APPENDIX 5 QUESTIONNAIRES FOR CURING PROCESS

Aim of this study is identifying the considering factors and implementation barriers of new product in your organization.

Designation:

Shift:

Product name:

Please read following sentences carefully. When producing this product, please choose most suitable answer as you think.

		Disagree	Agree little bit	Agree neutrally	Almost agree	Strongly agree
1	Easy to insert raw tyre into curing mould (easy to moulding)					
2	Easy to center raw tyre on curing bladder					
3	Easy to get and control required temperature					
4	Easy to set the curing parameters on curing press					
5	Easy to remove the cured tyre from the mould (easy de-moulding)					
6	possible to give required curing pressure into the mould easily					

මෙම සමීක්ෂණය සිදු කිරීම සඳහා අරමුණ වනුයේ ඔබ ආයතනය තුළ අළුත් නිෂ්පාදනයක් නිපදවීමට යාමේදී ඇති වන බාධක සහ අවධානය යොමු කළ යුතු කරුණු හඳුනා ගැනීමයි.

තනතුර :

සේවා මුරය :

නිෂ්පාදන වර්ගය :

පහත සඳහන් ප්‍රකාශ හොඳින් කියවා, මෙම නිෂ්පාදන වර්ගය නිපදවීමේදී ඔබට හැගෙන පරිදි වඩාත් ගැළපෙන පිළිතුර සළකුණු කරන්න.

	එකග නොවේ	සුළු වශයෙන් එකග වේ	මධ්‍යස්ථ වශයෙන් එකග වේ	බොහො සෙයින් එකග වේ	අතිශයින්ම එකග වේ
අමු ටයරය මොල්ඩ් ගත කිරිමේ පහසුව පිළිබඳ අවධානය යොමු කල යුතුයි.					
අමු ටයරය මොල්ඩයේ ඇති බ්ලැඩරය මත මධ්‍යගත කිරීමේ පහසුව පිළිබඳ අවධානය යොමු කල යුතුයි.					
අවශ්‍යය උෂ්ණත්වය පහසුවෙන් ලබා ගෙන පාලනය කිරීමේ හැකියාව පිළිබඳ අවධානය යොමු කල යුතුයි.					
කියුරින් සයිකල් එකේ සෙටින්ස් පහසුවෙන් තැබීමේ හැකියාව පිළිබඳ අවධානය යොමු කල යුතුයි.					
නිෂ්පාදිත ටයරය මොල්ඩය තුලින් ඉවතට ගැනීමේ පහසුව පිළිබඳ අවධානය යොමු කල යුතුයි.					
ටයරය නිප්දවීම සඳහා උවමනා කරන පීඩනය ලබා දීමේ පහසුව පිළිබඳ අවධානය යොමු කල යුතුයි.					