A Collaborative Framework for Feasibility Analysis in Automotive Product Development with Global Supply Chain

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DECLARATION

"I certify that this work has not been accepted in substance for any degree, and is not concurrently being submitted for any degree other than that of Degree of Doctor of Philosophy being studied at the University of Greenwich. I also declare that this work is the result of my own investigations except where otherwise identified by references and that I have not plagiarised the work of others".

Signed by *Syed M Hasan*

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Prof. James Gao

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ABSTRACT

In the competitive world, time to market, new technology and innovation are the measures of the performance of New Product Development (NPD). Companies tend to use a conventional approach to NPD by assigning representatives from their own support functions to review and recommend changes as projects evolve. In recent years, this approach has been questioned since it is a costly and time-consuming approach due to its iterative nature. Researchers argue that the time to market process and the cost of NPD can be reduced considerably by involving the support functions of the supply chain to a greater extent and also earlier in the NPD process. There is a potential industrial requirement for a collaborative framework that facilitates the linkage between Supply Chain Management (SCM) and New Product Development (NPD).

This research project focuses on the early stages of the collaborative product development process in the extended enterprise. The research output includes the functional requirements of a framework and a developed prototype methodology with tools and technologies that are tested from case studies within industry. The research also introduces the development and analysis of the framework that allows the integration of the flow of product development related activities within original equipment manufacturers (OEM) and suppliers providing future business benefits. An industrial investigation of an OEM in the automotive industry within the research identified that there are different decision making points in product development and manufacturing. The proposed methodology and framework use key drives to predict and quantify its impact on four main criteria namely: feasibility, time, cost and capability that support or advise on key decision making of OEM’s product development and management process.

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FIGURES

GLOSSARY

ADL – Architecture Description Language

B2B – Business to Business

BOM – Bill of Material

BPD – Business Process Diagram

BPM – Business Process Management

BPMN – Business Process Modelling Notation

BPR – Business Process Re-engineering

BPS – Business Process Simulation

CM – Change Management

CRM – Customer Relationship Management

DR – Design Roadmap

DSM – Domain Specific Modelling

DspM – Discipline Specific Modelling

EDI – Electronic Data Interchange

EDLP – Everyday Low Pricing

EEML – Extended Enterprise Modelling Language

ERP – Enterprise Resource Planning

ESL – Energy System language

FMC – Fundamental Modelling Concept

IDEF - Integrated Computer Aided Manufacturing (ICAM) Definition

IT – Information Technology

JIT – Just in Time

JSP – Jackson Structured Programming

MI – Material Information

MRP – Material Requirement Planning

NPD – New Product Development

OEM – Original Equipment Manufacturer

ORM – Object Role Modelling

PD – Product Development

PM – Project Management

QSAM – Quick Scan Audit Methodology

R&D – Research and Development

RFQ – Request for Quotation

SCM – Supply Chain management

SCOR – Supply Chain Operation Reference Model

SDL – Specification and Description language

SOMF – Service Oriented Modelling Framework

SOP – Standard Operating Procedure

SRM – Supplier Relationship Management

TQM – Total Quality Management

TROPICS – Timescales, Resources, Objectives, Perceptions, Interest, Control and Source

TTM – Time to Market

UML – Unified Modelling Language

VIM – Visual Interactive Modelling

VMI – Vendor Managed Inventory

Chapter 1: INTRODUCTION

1.1 Challenges Facing the Manufacturing Industry

In manufacturing industry, a business trend that has changed the way of doing business in this world from the past two to three decades is through supply chain management (SCM). Starting from the supplier's supplier, through the manufacturer, to the customer's customer, is a chain that has joined different enterprises to form a unique extended enterprise. Although supply chain creates lot of changes within every business segments from infrastructure to strategic levels, these changes could be ignored with the positive changes such as: shorter production lead time, improved communication, low inventory, shorter time to market (TTM), cost competitiveness, shorter product development cycle (Sharifi *et al*., 2006) .

Before the introduction of SCM concepts, all the entities in a single enterprise were working individually. Now after integration at all levels from, lowest starts within a department to highest level of connecting different organisations, the companies can easily feel the difference of implementing the SCM concept. SCM is an integral part of the firm's activities, from the time the customer requirement is generated to the time where the product has been delivered to customer. Hence it also shows that SCM plays an important role within product development aspects.

Existing research carried out relates to investigate the relationships between supply chain and product design (Fisher 1997, Randall and Ulrich 2001) mainly for two reasons: Firstly the initial design phases, that relates to the idea generation of a product being manufactured and then distributed within supply chain. Secondly, the feature that affects the supply chain structure as the product design (Blackhurst *et al.*, 2005; Childerhouse *et al.*, 2002).

Through this research, the aim is to link the product development (PD) within a SCM context for an extended enterprise and to investigate the effect of the integration of SCM with NPD. The possible integration points will provide baseline guidelines to identify the key decision making points within the entire supply chain.

It is evidenced that manufacturing firms in order to be more competitive in market, must continuously update their product offers in order to better satisfy the customers' requirements. Management should use the supply chain features more frequently, as the increased rate of product introductions, demands more from a business and needs more efforts to deliver the new products effectively and efficiently. To deliver the products at the targeted cost, time, and quality, the supply chain must be aligned with new product development (NPD) decisions. This will allow the manufacturing firm to overcome problems such as (partially) failed product launches due to the lack of product availability because of insufficient capacities. The integrated NPD-SCM enterprise has the benefit of increased supply chain capability, thus increasing the effectiveness of new product introductions and improves enterprise's performance (Van Hoek and Chapman, 2007).

1.2 Industrial Problems to be Tackled

This research mainly focuses on automotive sector due to its supply chain environment being the subject of extensive research within its product development integration. The research also introduces the development of a framework that integrates flow of activities within the manufacturing enterprises and shows that this contributes all the business functions. It also aims to focus on using current modelling tools to represent the product development processes of its Original Equipment Manufacturer (OEM), refers to the company that originally manufactured the product, and its suppliers.

Through an industrial investigation of the automotive OEM (an automotive enterprise), it was found that within OEM and its supplier relationship, the OEM normally has more knowledge in fields of technology and marketing compared to the suppliers. This is confirmed through literature studies of OEM-supplier partner relationships that suppliers with strong learning intent usually learn more knowledge and technology from their OEM customers. Furthermore, it revealed that suppliers can learn from their customers and integrate customer knowledge into the NPD process to increase the performance of new products. The main problem in OEM-supplier relationship is that there is no relation exists to analyse key decision making areas in supply chain domain. The other problem is there is no detailed framework exists in NPD – SCM business scenario which can gives the guidelines for the industries. Therefore the main aim of this research is to identify the key decision making points in the relationship of OEM and suppliers within the frame of extended enterprises, and provide the right support timely during real-life operations.

Although this research relates to the product development in the production process, its core focus is on the early stages of the integration process. The final research output is the functional requirements of the system through verified examples. The prototype tool and methodology are considered to apply within the entire industrial environment processes.

1.3 Current Technologies and Limitations

NPD and SCM are the main areas of analysis within this research. NPD gives an opportunity of transforming a market requirement about product technology into a marketable product (Ulrich and Eppinger, 2011). Along with tools from project management and concurrent engineering, different tools have been used to assess and integrate customer needs into product design (Ulrich and Eppinger, 2011).

There is lack of research that relates SCM and NPD to each other, for the product to be designed with the help of NPD tools and distributing the product with help of supply chain features. Only through SCM, it is possible to design, organise, and execute all the activities from planning to distribution within the value chain. SCM benefits by helping to organise and use more productively the network of suppliers, manufacturers and distributors (Childerhouse et al., 2002). The literature suggests that most SCM models and methods assume that product design decisions have been already taken (Chen et al., 2000).

But recently, it has been observed that there is a demand arising for the coordination of SCM and NPD. The approach called “design for supply chain management” (Bhaskar et al., 1994) suggests that the NPD-oriented way of business can identify the supply chain constraints at the early stages of product development. All the support models of the NPD-oriented approach either consider bill-of-materials (BOM) or product architectures.

Looking at existing tools available the researchers use product architecture-based models more frequently than others. It is “the scheme by which the function of the product is allocated to physical components” (Randall and Ulrich, 2001). It has been argued that the product architecture, rather than BOM, will help in addressing more effectively like the trade-offs between product, process, and supply chain design. Many existing models have analysed the relationships between product architecture characteristics and supply chain decisions. The other model existing in literature helps deal with the selection of the appropriate sourcing strategy; whereas other models focus on the placement of the differentiation point in the supply chain (Lee and Feitzinger, 1995).

Through literature studies, it has been identified that there is lack of evidence in comprehensive framework dealing with NPD-SCM alignment even though management needs a tool that explains the impacts of introducing new products on the supply chain. The tool aims to provide guidelines to management team depending on product features and enable them to identify the supply chain decision that leads to high performance. Based on these limitations within current technologies available, two research focus areas has been identified as:

(i) How to relate NPD and SCM variables with each other?

(ii) In reality, how can companies integrate NPD and SCM to gain high performance advantage within Supply chain?

For analysing these research areas, the research path has been divided into two stages. In a first stage, the literature studies dealing with NPD-SCM integration and their dependencies and formulation of generalised features of the framework on the basis of current available literature has been done. This identification of features of generalised framework, developed at an early stage of the research process, improved the understanding of how in supply chain new products are being affected. In second stage, an exploratory case study of OEM and Tier1 supplier relationship, to identify the key decision making points has been done.

On the basis of these new findings, the features of generalised framework has been analysed and then finally combine the findings from the literature and the case study to develop the alignment framework and to formulate four key decision making points indicating the relationships between NPD and SCM variables, i.e. time, cost, capability and performance.

1.4 Research Gaps

The key problem within automotive sector is, supply chain covers a wide area of business cycle whereas the new product development mainly relates only to in-house manufacturing. Therefore, linking the two attributes of the business, i.e., SCM and NPD, is not an easy task to accomplish, which is possibly the major reason that it has not been discussed in detail in existing literature.

The other issue which has been raised by the literature review is that there is substantial lack in literature for a detailed framework that demonstrates the linkage between SCM and NPD. Most business sectors need a tool which shows the impact of linking (Pero *et al*., 2011).

Furthermore, there is a lack of evidence exists which shows that research has been done in identifying and analysing the key decision making points in NPD – SCM business scenario. Therefore, the main goal to achieve in this research is, to investigate and then analyse the key decision making points in the integrated supply chain and then on the basis of this, to identify the functional requirement for the development of the methodology.

1.5 Research Aim and Objectives

Aim

The aim of this research is to develop a collaborative framework for integrating the product development process with supply chain within an extended enterprise for improved performance focusing on key decision making.

Objectives

The research objectives which can be categorised in four phases are:

I. To investigate the current industrial problems and requirements about the integration of product development in supply chain paradigm;
II. To Model the information flow across the supply chain during new product development and identify key decision points;
III. To analyse developed model in various extended enterprise scenarios, identifying effects of key decision points like feasibility, time/cost, and capability/performance in the product development process on the performance of supply chain management and vice-versa; and
IV. To propose a collaborative framework and then test and evaluate the framework for accommodating different business processes like manufacturing and delivery/distribution of collaborating partners in the product development process.

1.6 Research Scope

The main area of the focused domain is the integrated new product development in the automotive supply chain environment. The business context of the project is the product development of OEM in collaboration with main component suppliers in the global automotive sector. The focus of the project is key decision making points in Planning, Production scheduling and Delivery Distribution area on these criteria including:

- Feasibility
- Time
- Cost
- Capability and Performance

Specifically the example used is automotive OEM product development, production and delivery process of car engine body part which includes the following tasks with the above 3 key decision areas, i.e., Planning, Production Scheduling and Delivery/Distribution. The example of collaborating Tier1-supplier is casting part supplier to OEM.

The product development, production and delivery process of a casting part is also modelled and linked to the OEM’s product development, production and delivery process at the 3 key decision making points. The impact of the main influential factors and drivers on the four criteria at 3 key decision making points will be identified and analysed. The factors and drivers can be from both the OEM and suppliers.

Analysis has been done using a case example of the NPD – SCM integrated system. The example part has been used to categorise these analysis which was a small part of the main car engine assembly.

The methodology and framework will be proposed and developed which will make use of key drivers to predict and quantify the impact on the main three criteria (Feasibility, Time and Cost, Capability and Performance) which will automatically support or give advice on key decision making of OEM’s product development management team. In the end the research will benefit the whole enterprise.

1.7 Industrial Benefits

The research outcome could help plan product development schedules and choosing right suppliers based on the recommendation given by proposed framework. The other industrial benefit which can be achieved by this research is to improve the supplier capabilities by improving communications between OEM and suppliers while making feasibility decisions much quicker. The alignment of SCM and NPD should lead to an improvement in the performance of both the OEM and its supply chain (Caplice and Sheffi, 2003).

It is argued that the Time to Market (TTM) and the cost of NPD can be reduced considerably by involving the support functions to a greater extent, and also earlier in the NPD process (Carillo and Franza, 2006; Van Hoek and Chapman, 2006).

The benefit of integrating are that it allows the manufacturer to overcome the problems like partially failed product introduction into the marker because of non-availability of that new product as they got insufficient capacities (Van Hoek and Chapman, 2007).

1.8 Overview of the Research Approach

The research started with the literature survey as shown in Figure 1.1. After the literature survey a brief outline of the research comes out. The brief outline led to a draft of the proposed methodology and some requirements of the data which might need in the research. The draft of the proposed methodology took to verify in an industrial investigation and collected data from the industrial investigations. There might be some changes between the industrial investigations, therefore the feedback arrows in Figure 1.1 is to represent the changes in the research.

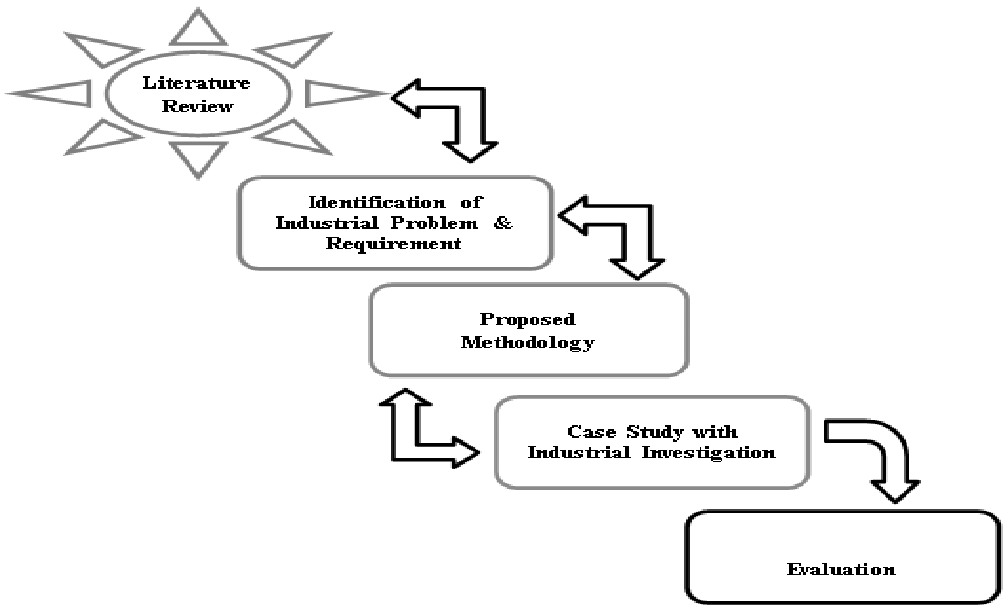


Figure 1.1: Research Approach

The final output of the proposed methodology is the functional requirements for the framework to integrate the two main functions in an extended enterprise. Therefore after the functional requirements finished, the whole methodology needs to be verified and evaluated.

1.9 Thesis Structure

Chapter 1 – Introduction: This chapter has described the background of the research and overview of the project by looking in detail the challenges of the manufacturing firm and their current problems which has to be tackled with the help of existing technologies and If not, then what are the gaps in the current technologies and the tools. Basis of these gaps, the aim and objectives have been discussed also in this chapter with bear in mind the benefits to industry.

Chapter 2 – Research Methodology: This chapter describes the underlying principles of the proposed requirement for integrated framework of new product development within supply chain management to support automotive product development. The methodology consists of a guideline of what are they types exists and which has been chosen for this research and why.

Chapter 3 – Literature Review: This chapter discussed the existing literature in the research domain, including change management and its relevant research, requirement management, new product development with the possible modelling techniques in this project and Supply Chain Management within an extended enterprise. This chapter also contains the evidence and justification of only using automotive business example to integrated NPD – SCM. Furthermore this chapter contains the identification and evaluation of key decision making points in the NPD – SCM integration scenario. The existing framework review and analysis ends this chapter.

Chapter 4 – Industrial Investigation: This chapter gives an introduction to the industrial investigation carried out, such as the brief description of the collaborating company, the purpose of industrial investigation, the details of discussions held with collaborative partners with the description of example part. This chapter also discusses the results of the industrial investigations.

Chapter 5 – Proposed Framework: This chapter introduces the idea behind the framework which, later in this chapter is being proposed to cover the research gap of NPD – SCM integration while keeping in mind the possible key decision making points.

Chapter 6 – Implementation Results and Evaluation: This chapter discussed the example part analysis using the proposed framework to see the effects of key decision making points on possible integrated points in NPD – SCM integrated extended enterprise.

Chapter 7 – Discussion, Conclusions and Further work: This chapter has discussed and evaluated the results of implementation of the proposed framework in the automotive extended enterprise to see the effect on possible integration points. This final chapter states the conclusions of the research project and explores areas of possible future research.

Chapter 2: Research Methodology

2.1 Introduction

Research is important in both business and academic activities, even though there is no consensus in the literature on how it should be defined. One reason for this is that research means different things to different people. However the following characteristics are common in the concept of research:

- Research is a process of enquiry and investigations;
- It is systematic and methodical; and
- Research increases knowledge.

Research may be categorized into two distinct types: qualitative and quantitative (Yin, 1994). The first one concentrates on words and observations to express reality and attempts to describe people in natural situations. The quantitative method places considerable trust in numbers that represent opinions or concepts.

Given that this research is operating within the qualitative paradigm the selection of methods and approaches offers numerous traditions. These ranges from case studies (Stake, 1995; Gummesson, 1998), action research (Gummesson, 1998), grounded theory (Strauss and Corbin, 1994). Indeed Tesch (1990) goes as far as offering as many as 20 types of qualitative methods and Creswell (1994) offers ethnography, grounded theory, case study and phenomenological studies. They also present various methods for consideration. In other words, the array of methods available within the qualitative paradigm is extensive. In this research case study option has been selected as it is more feasible to validate the results in the industrial environment.

2.2 Case Study Research

It is the research in which the subject of the research is studied within its social, political, organizational, or economic context and its limitations, is one of the commonest approaches across the social and management sciences. Many authors cited Yin (2003, 2009), who describes case study research as:

"... an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and

context are not clearly evident". In other words, the subject of the research is comprehensively studied as an example of a real live phenomenon, within the context in which it happens.

Yin (2003) identifies three types of case studies:

1. **Exploratory**: the case study is used to define questions and hypotheses – or to test out a research procedure – for a further piece of research, such as a large-scale survey.
2. **Descriptive**: the case study is used to describe a particular phenomenon within its context. It can be used to expand on a particular theme unearthed by a survey.
3. **Explanatory**: the case study explores cause-effect relationships, and/or how events happen.

According to Woodside (2010) the usefulness of case study research lies in the fact that it encourages research methods that help measure thinking over an ongoing period. It can also be a useful method when the unit of analysis, or the subject under consideration, is a collective entity such as an organization or a community. The most common objection to case study research is that it is insufficiently rigorous. Quite often this criticism relates not to the method as such, but to the way case studies are presented: the author does not leave a clear audit trail detailing his or her research and explaining the conclusions. Case study research is neither a quick nor a soft option. It requires considerable skill on the part of the researcher, who needs to be adept at identifying and analyzing data from a number of different sources. It also requires a skill common to all qualitative researchers: the ability to interpret as well as analyze, to see through spin, and if necessary, check information with another source.

2.3 Research Design

A research design is a plan for getting from the researcher's original question or hypothesis to obtaining workable results from the research, on which the researcher can base defensible conclusions. The first task which has been done in this research was to **decide** what to find out by defining research question.

Carrying out a literature review is an essential precursor to most research, and is a good way of getting ideas for research questions. These research questions need to be **suitable**: large enough to provide sufficient scope for research, but new enough not to have already been answered. Then narrowing down the research question to something more specific, in order to look for relevant evidence. This may take the form of a **proposition**. When considering theoretical position at the outset, it is important not to lose sight of an important practical consideration: will the case which has been chosen cooperate with the research? The industrial requirement has been generated in this research where people will be helpful, leading the author to key informants, providing access to documents, and allowing author to interview or survey staff.

The beginning of the research process is all about defining: not only the phases of research question, but also which is the actual object or entity being studied. After consulting the automotive OEM, the sample part has been selected. The next part is to consider the single or multiple case designs. This simply means choosing whether this research study will include just one or several cases. Both types of case study design have their advantages. Yin (2009) lists five rationales for single cases:

(1) A critical case – i.e. one that can test a particular theory.
(2) An extreme or unique case – for example, a study of a rare disorder.
(3) A representative case – a case that is representative, or typical, of a particular situation.
(4) A revelatory case – one that reveals a phenomenon hitherto unexplored.
(5) A longitudinal case – a study of changes over time.

The major disadvantage of using the multiple case studies that it is resource intensive and it take a lot extra time which was a major control factor of this research. Thus single case study has been chosen to use in this research, however in future research multiple case studies option can be considered also. The next question arises is that single case can be holistic or embedded. A holistic case is one where the case is the unit of analysis; an embedded one is where there are several units of analysis in the case. So in this case single case has been selected due to the limitation of the same major control factor i.e. time. The other major reason for the single case in this research was the lack of interaction with multiple suppliers for more than single part as it will take too much time and efforts and end up doing the same research in double the time allocated. The following quality criteria have been considered during the designing phase of this case study research:

1. Construct validity – this is all about making sure the research uses the right operational measures, appropriate to what is being studied. Construct validity can be improved by:

- Multiple sources of evidence, i.e. data collection methods, which can be triangulated against one another.
- Having a chain of evidence.
- Letting key informants review the draft (Yin, 2009).

2. Internal validity – this seeks to establish a causal relationship, and is relevant for explanatory rather than exploratory cases. The researcher needs to establish that x causes y, and show that there are no other factors that could have played a part in y.

3. External validity – the extent to which it is possible to generalize from the findings of case studies.

Cepeda and Martin (2005) see theory building as a key stage in the case study research process. After the collection of data, there is a stage for reflection, which enables the researcher to update the initial conceptual framework on which the research was based. The result is a cyclical process of theory, producing a research process giving rise to data from which fresh theory can be formulated, and fresh research carried out. Because research takes place "in the field", there is a close relationship between theory and what is happening on the ground, is shown in Figure 2.1.

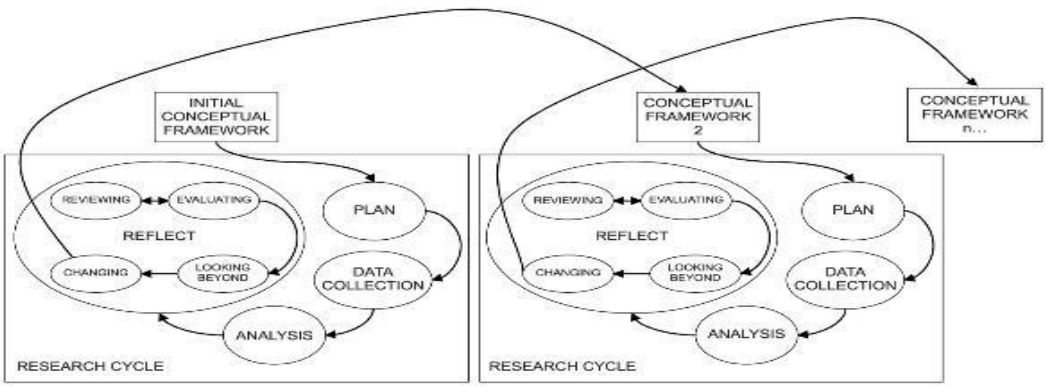


Figure 2.1: Cepeda and Martin's view of conceptual frameworks and the research cycle (2005)

The same principle has been applied in this research which helps in refinement of the framework.

2.4 Data Collection

The data collection process demands that the researcher be actively involved, asking the right questions which link to those that are central to the study, in a manner which does not alienate the subject. The researcher needs to be a good listener, paying attention not only to what is said, but also to what is not said explicitly, perhaps indicated by mood or body language.

There is a need to pay attention to multiple sources of evidence, and be able to handle complexity, and the possibility that new information may lead in a new direction, while at the same time not losing sight of the original research questions. The amount of preparation required for this stage will depend on the complexity of the research. There are five aspects to preparation which has been considered in this research:

- **Ethical guidelines**

The researcher needs to gain the informed consent from the participant, ensuring that they understand the purpose of study and are not deceived; will come to no harm as a result of investigations; and that their privacy and confidentiality is protected. Especial care has been taken while doing this research and the necessary permission has been taken in advance.

- **Training for case study research**

It is beneficial to attend a course on research methods for case studies. In this respect, the online course offered by University of Greenwich and discussion with experienced case study researchers in the department or through the network has been done, and relevant scholarly articles have been read in advance.

2.4.1 Types of Data

Case study researchers are often advised to include more than one source of evidence, in order to facilitate triangulation and increase the richness and multifacetedness of their study. Choosing more than one method also has the advantage that one method's weakness can be balanced out by another's strengths. The most usual sources of information are:

- **Documentation and archival records**

The most important use of documentation lies in providing background to the case. Corroborating, or contradicting, evidence from interviews or other sources and to provide inferential information, for example, about networks, this can be deduced from distribution lists etc. (Yin, 2003). The other reason includes helping make sure that people's names are spelt correctly.

- **Interviews**

Because of the human element of case studies, interviews are one of the most important methods of case study research, and are almost always an element of the research design.

- **Direct and participant observation**

Direct observation occurs when the author observes but does not participate. This way of collecting data is very powerful, because the author is unobtrusive, and can therefore freely observe behavior which is not "edited", as it might be in a laboratory setting, or when the interviewer's questions frame the response (Woodside, 2010).

- **Physical artifacts**

Physical evidence from objects, including technological devices, tools, instruments, works of art, videos etc.

- **Visual data collection**

Because visual communication precedes verbal, visual data collection methods are a powerful way of helping individuals retrieve unconscious thoughts. Woodside (2010) provides detailed accounts of several other methods: for example storytelling, visual narrative art, conversational analysis, and forced metaphor elicitation technique. What these methods have in common is the fact that they are designed to probe below the surface of what is being said, in other words to look at unconscious processes. The following principle will help increase construct validity and reliability.

Use multiple sources of data

There are numerous ways that data can be collected. While many cases use just one source (usually the interview), it is considered good practice to obtain data by several methods. This helps with triangulation, where different lines of enquiry converge, with the findings of one set of data corroborating another. As Rowley puts it (2002):

"Triangulation uses evidence from different sources to corroborate the same fact or finding."

Furthermore, different data sources can support one another with complementary strengths: for example, document analysis is good for establishing facts, whereas interviews enable the researcher to probe. In this research, document data type and informal discussion with the key position personnel of the OEM and the Tier 1 supplier, has been used.

2.5 Research Methodology Used in this Project

According to research plan, research methodology followed in this project is as follows (Figure 2.2):

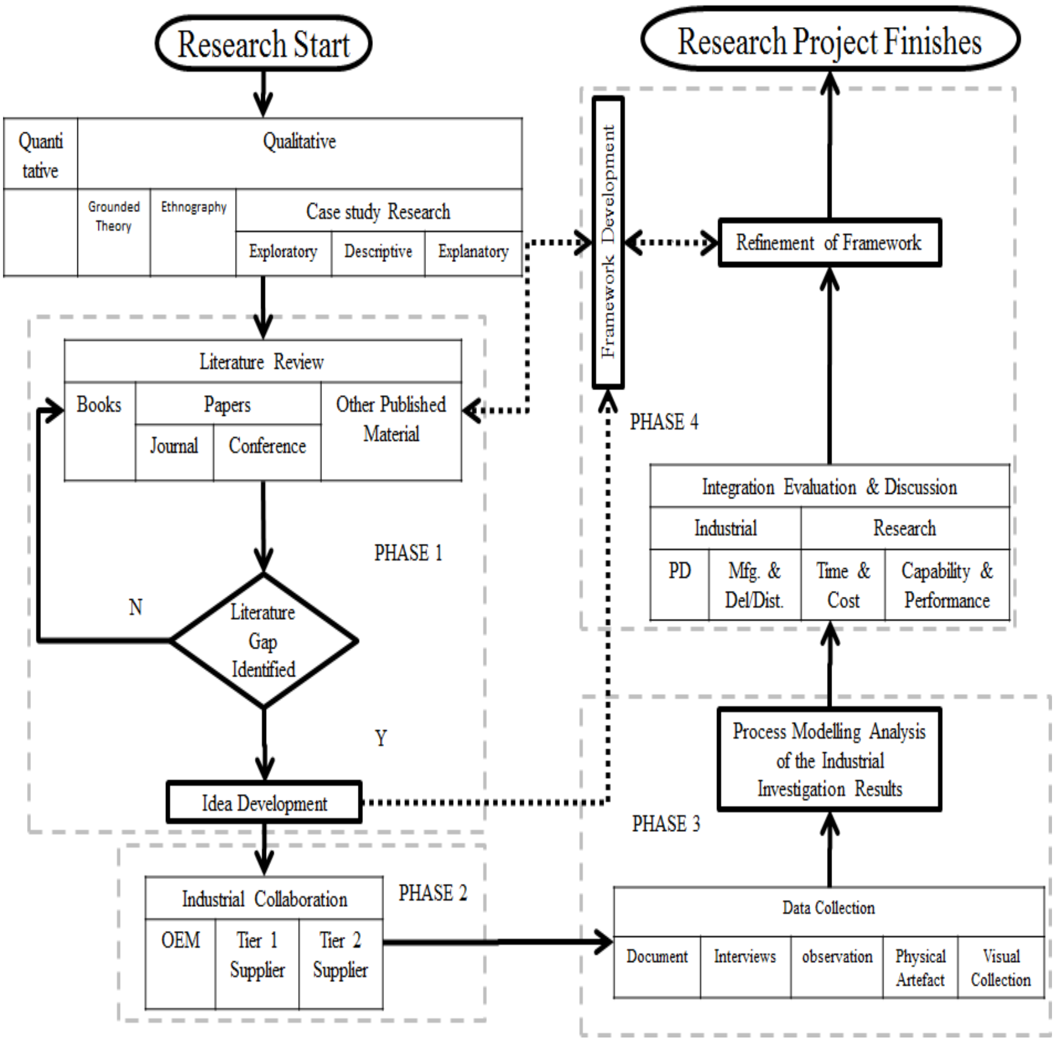


Figure 2.2: Research Methodology in this Project

Summary

In this chapter the research methodology has been discussed which works the basics of the research. In start, different types of existing methodologies and their applicability have been described, which have explained the reason of selecting the case study method in this research. To carry on using the case study approach, the brief description has been given, of how this case study approach is applicable in this research by keeping in mind the scope of this research with limitations due to its industrial nature. Then different types of data collection methods, their applicability and usefulness in getting the optimum output has been discussed and this analysis has facilitated the decision of choosing the applicable data collection technique for this research. Furthermore this has helped in selecting the specific type of data which also has an important impact on the outcome of this research.

Chapter 3: Literature Review

3.1 Introduction

According to the research plan, literature review is the phase 1 of this research. This chapter will focus on first research objective to investigate the current industrial problems and requirements about the integration of product development in supply chain paradigm. The purpose of literature review is to investigate existing research in the proposed domain and gather enough knowledge to support research successfully.

According to the aim of this research, there are 4 key aspects in this project: new product development (NPD), supply chain management (SCM), NPD- SCM collaboration and key decision making points of NPD-SCM integration. Based on these aspects, the literature review has been divided into four stages as shown in Figure 3.1.

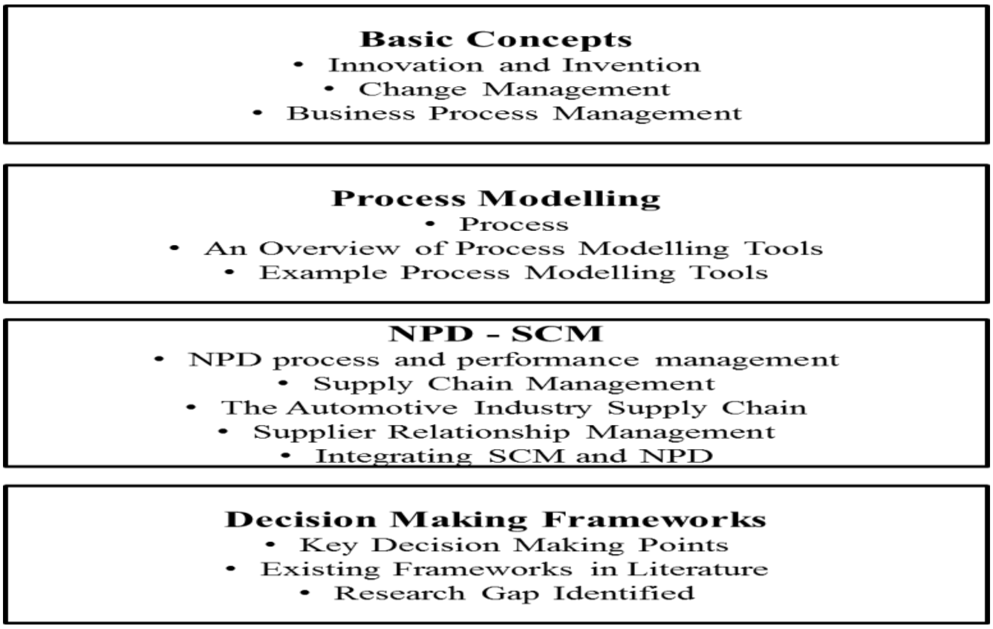


Figure3.1: Literature Review Stages

3.1 Innovation and Invention

Innovation is really a big concept that can be easily understood by the definition given by Myers and Marquis (1969): “Innovation is not a single action but a total process of interrelated sub processes. It is not just the conception of a new idea, nor the invention of a new device, nor the development of a new market. The process is all these things in an integrated fashion”. It has been a topic for discussion from last century and argued to be the driver of growth. Schumpeter (1934, 1939, and 1942) gave importance to new products as catalyst for the growth of economy. He argued that the competition in the current scenario because of new products is creating a far larger effect on the economy or market share instead of changing prices of same old products. For example, economic conditions of countries have experienced more growth by introducing new products like new features in mobile phones rather than just changing the prices of old featured mobile phones. Actually initial analysis of economies gave a trend which shows no regular trend, but instead of steady flow it shows "bursts" of activities. This large scale view of Innovation can be tracked down to mid-nineteenth century. Marx who initially gave the conclusion that innovation can be associated with bursts of economic growth.

Then Schumpeter (1934, 1939), Abernathy and Utterback (1978) have discussed this theory of innovation. They all are agreed on one idea that is at the birth of any industrial sector there has always been an important product innovation which is followed by new trends in production processes. Once this view was of great importance but it failed to offer any understanding of how to get the state of Innovative success. Figure 3.2 provides a list of the types of innovation with examples.

Type of Innovation	Example
Product innovation	The development of a new or improved product.
Process innovation	**The development of a new manufacturing process.**
Organisational innovation	A new venture division; a new internal communication system; introduction of a new accounting procedure.
Management innovation	TQM (Total Quality Management) systems; BPR (Business Process re-engineering).
Production innovation	Quality circles. Just in Time (JIT) manufacturing systems; new production planning software.
Commercial/Marketing innovation	New financing arrangements; new sales approach e.g. direct marketing.
Service innovation	Internet-based financial services.

Figure 3.2: Types of Innovation

Most authors differentiate innovation from invention by giving an idea that innovation is concerned with the commercial and practical application of ideas or inventions. Rothwell’s (1992) equation shows the relationship between the two terms:

Innovation = Theoretical conception + technical Invention + commercial exploitation

The literature suggests different innovation models which have been introduced time to time. The Figure 3.3 shows the basic characteristics of these innovation models.

Date	Model	Characteristics
1950/60s	Technology push	Simple linear sequential process; emphasis on Research & Development (R&D); the market is a recipient of the fruits of R&D.
1970s	Market pull	Simple linear sequential process; emphasis on marketing; the marketing is the source for directing R&D; R&D has a reactive role.
1980s	Coupling model	Emphasis on integrating R&D and marketing.
1980/90s	Interactive model	Combination/s of push and pull.
2000s	Network model	Emphasis on knowledge accumulation and external linkages.

Figure 3.3: The Chronological Development of Models of Innovation

In this research where NPD will be linked with SCM, the business processes have to go through these ideologies where innovation and invention will act as initial concept of this research. This research can be categorised in process innovation.

3.2 Change Management

Change management (CM) is a generalized approach to organisational change in the work organisation. According to Watson (2002) the work organisation may be defined as: Work arrangements involving relationships, understandings and processes in which people are employed, or their services otherwise engaged, to complete tasks undertaken in the organisation’s name. Pena and Reis (2001) suggest that in order to be successful in the application of improvement techniques, it is important to recognise the human element including the resistance to, and, fear of change. Kotter and Schlesinger (1979) have famously identified the following six general approaches to dealing with resistance to change by positively influencing employees:

- education and communication,

- participation and involvement,
- facilitation and support,
- manipulation,
- negotiation and agreement, and
- explicit and implicit coercion

It is interesting to note that although change is an implicit aspect of business improvement, references to CM publications within the operations and supply chain improvement literature are scarce.

Hughes (2007) demonstrates that the comments on the tendency for academic CM literature to avoid the terminology of management tools and techniques. One CM model that makes these connections more explicit is Paton and McCalman's (2000) TROPICS test (See Appendix I). Cardiff University's quick scan audit methodology (QSAM) is also a well-established diagnostic tool that is suited to short timescale interventions (Naim *et al*., 2002a) and provided a ready methodology for the task (See Appendix I).

In terms of taking a more strategic and holistic approach to experience design, Carbone and Haeckel (1994) divided experience design into four phases:

Phase1: Acquisition of service experience design skills;

Phase2: Data collection and analysis;

Phase3: Service clue design; and

Phase4: Implementation and verification.

Later, Carbone (2004) suggested five steps:

Step 1: Build a diverse design team.

Step 2: Drill down to the experience core.

Step 3: Focus on clues.

Step 4: Develop the experience narrative or story line.

Step 5: Prioritise implementation opportunities.

Berry and Carbone (2007) proposed a five-step approach:

Step 1: Identify the emotions that evoke customer commitment.

Step 2: Establish an experience motif.

Step 3: Inventory and evaluate experience clues.

Step 4: Determine the experience gap.

Step 5: Close the experience gap and monitor execution.

Kotter's framework and analysis of change, based primarily on organisational change in the corporate sector, has been articulated and adapted since the mid-1990s. It is well known and widely quoted and applied. The language and philosophy of Kotter's approach appears in many iterations and variations in the literature of organisational change.

- Establish a sense of urgency.
- Form a powerful high level coalition to guide and lead the changes.
- Create a vision of the organisation's future.
- Communicate that vision widely, repeatedly and consistently.
- Empower people in the organisation to act on the vision.
- Plan for visible short-term performance improvements.
- Consolidate improvements and produce more changes.
- Institutionalise new approaches. (See Appendix II)

By contrast Doppelt (2003) analysis provides a newer and less widely known approach to understanding and approaching organisational change. This analysis of the dynamics of organisational change is drawn from wide ranging and long – term analysis of, in particular, public sector organisations and thus may be of particular value and relevance to the higher education sector. In more detail the seven elements in Doppelt's "wheel of change" are shown in Figure 3.2.

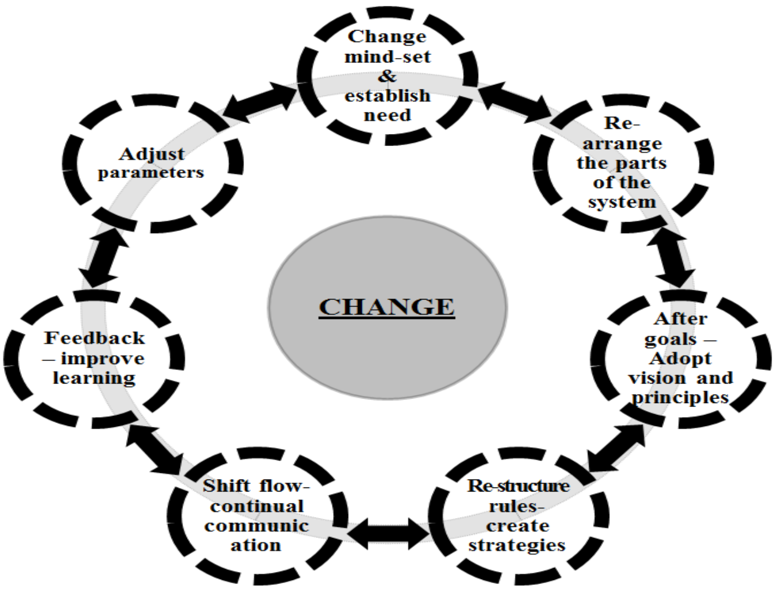


Figure 3.4: Doppelt's wheel of change (Doppelt 2003)
(See Appendix III)

3.3 Business Process Management

Business Process Management (BPM) is a structured approach to analyse and continually improve fundamental activities such as manufacturing, marketing, communications and other major elements of a company's operation. Essentially, BPM is concerned with the main aspects of business operations where there is high leverage and a big proportion of added value, which is shown in Figure 3.5.

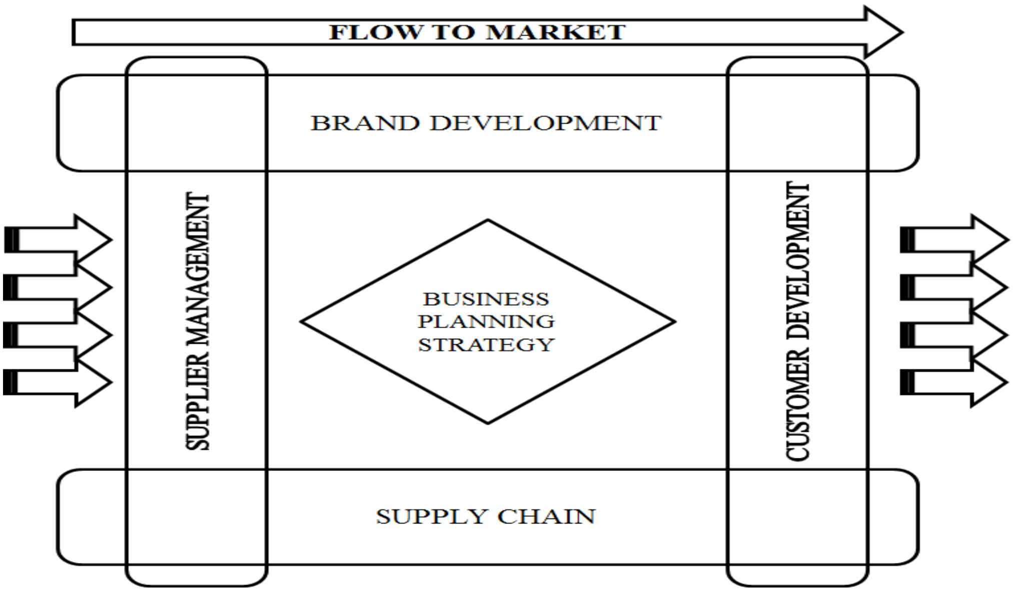


Figure 3.5: Activities in Business Process Management (Zairi 1997)

BPM has to be governed by the following rules:

- Major activities have to be properly mapped and documented.
- BPM creates a focus on customers through horizontal linkages between key activities.
- BPM relies on systems and documented procedures to ensure discipline, consistency and repeatability of quality performance.
- BPM relies on measurement activity to assess the performance of each individual process, set targets and deliver output levels which can meet corporate objectives.
- BPM has to be based on a continuous approach of optimization through problem solving and reaping out extra benefits.

BPM emerged as a succeeding concept to Total Quality Management (TQM) in the 1980s and Business Process Reengineering (BPR) in the 1990s (Hammer and Champy, 1993; Davenport, 1993). Following BPR, several Information Technology (IT) systems such as Enterprise Resource Planning (ERP) and

Customer Relationship Management (CRM) gained organisational focus (Jeston and Nelis, 2008). Given this history of IT systems, BPM initially focused on technical, IT-related aspects of business processes and their design via technology (van der Aalst *et al.*, 2003). Despite an early awareness by some (Zairi, 1997; Armistead and Machin, 1997), researchers have only in recent years more broadly considered BPM to be an integrated approach that moves beyond purely an IT focus (Harmon, 2010).

3.3.1 Business Process Simulation

Business process simulation (BPS) used to be the way to do the analysis of manufacturing systems, but is now being utilised in the management of change in a different way of manufacturing and service platforms. Simulation can be referred to different types of model like spread sheet modelling, discrete event simulation and a system dynamic simulation. A “discrete-event simulation model” is one in which the state of the model changes at only a discrete set of time points Schriber and Brunner (2010). Mostly the discrete-event simulation software uses a graphical interface to produce a model on computer. These are referred to as Visual Interactive Modelling (VIM) systems. BPS is used to assist decision making by providing a tool that allows the ‘AS IS’ behaviour of a system to be analysed. It helps to predict the performance of that system under a number of scenarios created by the decision maker.

3.3.2 Using BPS to Analyse Dynamic Systems

BPR leads to the analysis of business processes using techniques such as flow charts, process maps and simulation software. An important aspect of BPS is its ability to capture the dynamic (i.e., time-dependent) behaviour of a process. There are two aspects of dynamic systems that are addressed below.

Variability: Most business systems contain variability in both the demand on the system (e.g. customer arrivals) and in durations of processes (e.g. customer service times) within the system. The use of deterministic (e.g. average) values will provide some indication of performance, but simulation permits the incorporation of statistical distributions and thus provides an indication of both the range and variability of the performance of the process. This is important in customer-based systems were not only is the average performance relevant, but performance should not drop below a certain level or customers will be lost. Nordgren (1999) states “Without the recognition of the influencing factors of variability on the development of queues, any approach to minimize queues is bound to fail”.

Interdependence: Most systems contain a number of decision points that affect the overall performance of the system. The simulation technique can incorporate statistical distributions to model the likely decision options taken. Also the “knock-on” effect of many interdependent decisions over time can be assessed using the simulation’s ability to show system behaviour over a time period.

3.3.3 The Role of BPS in This Research

Aguilar *et al*. (1999) indicated how BPS could provide support in a process cantered management approach to change. The Figure 3.6 provides an adaption of that model. The model shows the use of simulation not only to predict the performance of the “TO - BE” design before resources are committed, but also to use the technique to construct a model of the “AS - IS” state in order to understand the process and measure the variation that takes place in key performance measures of this research which includes NPD integration within SCM.

PHASE	BPS PROVIDED
“AS IS”	• Build and communicate process map. • Measure and analyse process performance
“TO BE”	• Develop future process design. • Enable and implement future process design

Figure 3.6: From AS – IS situation to a TO – BE situation

3.3.4 Benefits and Limitations of BPS

The main advantage of the BPS analysis is that it allowed the incorporation of variability and interdependence factors in order to obtain an accurate outline of process performance. The simulation could predict process performance along a number of measures such as lead-time, resource utilisation and cost. Once built, the BPS allowed analysis of many potential new designs through its “what-if” capability with little extra effort. Another benefit was provided by the visual animated display which provides a communication forum to both validate the model and to explain the operation of redesigned activities and their role in overall process performance. It has been suggested from the literature that generally high level of support and interest in visual interactive models by decision-makers. In some instances it may be that due to a lack of input data the BPS is used, not for a detailed quantitative analysis, but to facilitate discussion and ideas by the use of the visual interactive display (Kalakota and Robinson, 2002).

A major barrier for many organisations in using BPS is the preparation needed in the successful introduction of the technique to the organisation. The potential that process mapping will lead to too much emphasis on operationalizing existing processes, rather than conceptualizing a new design has been recognised and BPS could be said to increase the scope for over-analysis. However, it should be recognised that when estimating the amount of resource required to construct a BPS, that there should be no attempt to model every aspect of the area of study, but the level of detail and scope of the model should be judged according to the study objectives (Kalakota and Robinson, 2002).

Thus building a sophisticated model must not become the objective of the exercise, the model should be built with just enough details to provide information on which to make decisions. One limitation of BPS in the context of BPR projects is that the BPR team must be careful not to create a “to-be” design based solely on “tweaking” the “as-is” simulation model. Simulation is most useful in comparing ‘as-is’ and ‘to-be’ models, and validating and ensuring the completeness of the ‘to-be’ process model. Bhaskar *et al*., (1994) explain that beyond this simulation has limited ability in creating a ‘to-be’ model”. Thus simulation will not create a new design and design ideas should not be constrained by the complexity of changing the model to simulate the new design. Design ideas should drive simulation design, not the other way around.

Finally it has been suggested by literature that simulation is most useful for the analysis of stable business processes and less useful for dynamic systems that do not reach equilibrium. This may point to potential difficulties in the application of this concept within this research where SCM processes are quite variable in nature.

3.4 Process Modelling

In this stage of literature, literature studies related to process modelling have been done. To understand this research of linking product development and supply chain management in an enterprise, it is necessary to understand clearly about the process first, which is the basis of any business firm. Different tasks that create a value added product is called a business process. The common goals for these different processes are (Marri, et.al, 2002):

- Satisfied customer,
- Return on Investment, and
- Profit in market share.

To understand "AS IS" process the following two-step approach is often used to document a process:

Step One: Define and describe the process in qualitative terms using a technique called relationship mapping. This involves answering questions including:

- Who are the customers of the process and what is the output from it?
- Who are the suppliers to the process and what is their input to it?
- What are the requirements for their input and output of the process?
- What is the internal flow of activities of the process?

Step Two: Construct a flow chart that shows all the activities in the process in a more detailed map.

According to Kenneth Preiss (1999), the primary variable in the flow of process is to look at the flows in and out of a single enterprise. In the dynamic world of rapid change where one maintains interactive relationships in a network of business units, the focus of competitiveness and management becomes core process capability, rather than the products produced. This Kenneth Preiss model has five components. These are the process itself, the inputs which are converted by the process to outputs, the resources used to perform the conversion, and the controls or conditions that may not be violated by the process. The controls are mandated by external conditions and cannot be changed by management of the process. The other four factors can be changed by management.

3.4.1 An Overview of Process Modelling Tools:

Process modeling tools can be graphical or textual

- *Graphical* modeling tools use a diagram technique with named symbols that represent concepts and lines that connect the symbols and represent relationships and various other graphical notations to represent constraints.
- *Textual* modeling tools typically use standardized keywords accompanied by parameters to make computer-interpretable expressions.

Not all modeling tools which use the modeling languages are executable, and for those that are, the use of them doesn't necessarily mean that programmers are no longer required. On the contrary, executable modeling languages are intended to amplify the productivity of skilled programmers, so that they can address more challenging problems, such as parallel computing and distributed systems. A large number of modeling languages appear in the literature. In this research, focus was only on graphical type as textual modeling languages are intended for computer science field.

Example of graphical modeling languages in the field of computer science, project management and systems engineering (Barber et al., 2003):

- **Behavior Trees** are a formal, graphical modeling language used primarily in systems and software engineering. Commonly used to unambiguously represent the hundreds or even thousands of natural language requirements that are typically used to express the stakeholder needs for a large-scale software-integrated system.
- **Business Process Modeling Notation** (BPMN) is an example of a Process Modeling language.
- **EXPRESS** and **EXPRESS-G** (ISO 10303-11) is an international standard general-purpose data modeling language.
- **Extended Enterprise Modeling Language** (EEML) is commonly used for business process modeling across a number of layers.
- **Flowchart** is a schematic representation of an algorithm or a stepwise process,

- **Fundamental Modeling Concepts** (FMC) modeling language for software-intensive systems.
- **IDEF** is a family of modeling languages, which include IDEF0 for functional modeling, IDEF1X for information modeling and IDEF3 for business process modeling, IDEF4 for Object-Oriented Design and IDEF5 for modeling ontologies.
- **Jackson Structured Programming** (JSP) is a method for structured programming based on correspondences between data stream structure and program structure
- **LePUS3** is an object-oriented visual Design Description Language and a formal specification language that is suitable primarily for modeling large object-oriented (Java, C++, C#) programs and design patterns.
- **Object Role Modeling** (ORM) in the field of software engineering is a method for conceptual modeling, and can be used as a tool for information and rules analysis.
- **Petri nets** use variations on exactly one diagramming technique and topology, namely the bipartite graph. The simplicity of its basic user interface easily enabled extensive tool support over the years, particularly in the areas of model checking, graphically-oriented simulation, and software verification.
- **South beach Notation** is a visual modeling language used to describe situations in terms of agents that are considered useful or harmful from the modeler's perspective. The notation shows how the agents interact with each other and whether this interaction improves or worsens the situation.
- **Specification and Description Language** (SDL) is a specification language targeted at the unambiguous specification and description of the behavior of reactive and distributed systems.
- **SysML** is a Domain-Specific Modeling language for systems engineering that is defined as a UML profile.
- **Unified Modeling Language** (UML) is a general-purpose modeling language that is an industry standard for specifying software-intensive systems. UML 2.0, the current version, supports thirteen different diagram techniques, and has widespread tool support.

- **Service-Oriented Modeling Framework** (SOMF) is a holistic language for designing enterprise and application level architecture models in the space of enterprise architecture, virtualization, service-oriented architecture (SOA), cloud computing, and more.
- **Architecture description language** (ADL) is a language used to describe and represent the system architecture of a system.

Examples of graphical modeling languages in other fields of science are as follows:

- **EAST-ADL** is a Domain-Specific Modeling language dedicated to automotive system design.
- **Energy Systems Language** (ESL), a language that aims to model ecological energetic & global economics.

Some of the most common modeling languages have been discussed below in detail which can be used in future work, if the research will target the simulation side of supply chain.

3.4.2 Example Process Modelling Tools

3.4.2.1 Unified Modelling Language

UML is a standardized general-purpose modeling language which includes a set of graphic notation techniques to create visual models of object-oriented software-intensive systems. UML is used to specify, visualize, modify, construct and document the artifacts of an object-oriented software-intensive system under development. UML offers a standard way to visualize a system's architectural blueprints, including elements such as:

- Activities.
- Actors.
- Business processes.
- Database schemes.
- (Logical) components.
- Programming language statements.
- Reusable software components. (See Appendix IV)

3.4.2.2 IDEF

An abbreviation of **Integration Definition** refers to a family of modeling languages in the field of systems and software engineering. They cover a wide range of uses, from functional modeling to data, simulation, object-oriented analysis/design and knowledge acquisition. The IDEF Functional Modeling method is designed to model the decisions, actions, and activities of an organisation or system. It was derived from the established graphic modeling language Structured Analysis and Design Technique (SADT) developed by Douglas T. Ross and SofTech, Inc. In its original form, IDEF0 includes both a definition of a graphical modeling language (syntax and semantics) and a description of a comprehensive methodology for developing models (See Appendix V).

3.4.2.3 Business Process Model and Notation

Business Process Model and Notation (BPMN) is a standard for business process modeling that provides a graphical notation for specifying business processes in a *Business Process Diagram* (BPD), based on a flowcharting technique very similar to activity diagrams from Unified Modeling Language (UML). The objective of BPMN is to support business process management, for both technical users and business users, by providing a notation that is intuitive to business users, yet able to represent complex process semantics (See Appendix VI for detail)

3.4.2.4 Design Roadmap

Design Roadmap (DR) is developed by Park and Cutkosky in (1999). The original purpose is to seek a method to overcome the limitations of process representation discussed above. Park and Cutkosky developed this technique to provide a comprehensive method for the project management (PM). The most basic elements of DR are the task and feature, and the tasks and feature are unique in the DR process map. The task is the primary unit of the process, and it represents the elements which are participant in the process. The feature is the input and output of the tasks. Thus every task needs a feature to be the input, and it also needs another feature to represent the output of this task. The arrows are used to represent the process flow and link the tasks and features together. DR also has the complex dependencies. In these dependences, the feedback dependency is most often to be used (See Appendix VII)

3.4.2.5 Flow Chart

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

Flowcharts are used in designing and documenting complex processes or programs. Like other types of diagrams, they help visualize what is going on and thereby help the viewer to understand a process, and perhaps also find flaws, bottlenecks, and other less-obvious features within it that is the main reason behind selecting this type of process modelling in this research. There are many different types of flowcharts, and each type has its own repertoire of boxes and notational conventions. The two most common types of boxes in a flowchart are:

- A processing step, usually called *activity*, and denoted as a rectangular box.
- A decision usually denoted as a diamond.

A flowchart is described as "cross-functional" when the page is divided into different swim lanes describing the control of different organizational units. A symbol appearing in a particular "lane" is within the control of that organizational unit. This technique allows to locate the responsibility for performing an action or making a decision correctly, showing the responsibility of each organizational unit for different parts of a single process.

Flowcharts depict certain aspects of processes and they are usually complemented by other types of diagram. For instance, Ventre and Fowler (2002) defined the flowchart as one of the seven basic tools of quality control, next to the histogram, Pareto chart, check sheet, control chart, cause-and-effect diagram, and the scatter diagram. Similarly, in UML, a standard concept-modeling notation used in software development, the activity diagram, which is a type of flowchart, is just one of many different diagram types. Common alternate names include: flowchart, process flowchart, functional flowchart, process map, process chart, functional process chart, business process model, process model, process flow diagram, work flow diagram, business flow diagram. The terms "flowchart" and "flow chart" are used interchangeably.

Types of flowchart

Flowcharts can be modeled from the perspective of different user groups (such as managers, system analysts and clerks) and that there are four general types.

- *Document flowcharts,* showing controls over a document-flow through a system
- *Data flowcharts*, showing controls over a data-flow in a system
- *System flowcharts* showing controls at a physical or resource level
- *Program flowchart*, showing the controls in a program within a system

Notice that every type of flowchart focuses on some kind of control, rather than on the particular flow itself. However there are several of these classifications. For example Ventre (1978) named three basic types of flowcharts: the *system flowchart*, the *general flowchart*, and the *detailed flowchart*. That same year Marilyn (1978) stated "in practice, two kinds of flowcharts are used in solution planning: *system flowcharts* and *program flowcharts*." More recently Ventre and Fowler (2002) stated that there are more differences: "Decision flowcharts, logic flowcharts, systems flowcharts, product flowcharts, and process flowcharts are just a few of the different types of flowcharts that are used in business and government". In this research, Document flowchart type has been used as it covers business process aspect also.

3.5 New Product Development Process

In this stage of literature, studies related to NPD – SCM as shown in literature review flow chart have been conducted. New product development (NPD) has been of importance in most of manufacturing organisations.

Actually there is no evidence of single model present which companies can use for new product development process Holtzman (2011).But for a successful product development 5 factors are of great importance: good product quality, lower product cost, less development time, lower development cost, and effective development capability (Kidder, 1981).

That is why; in current scenario where manufacturing is of prime importance these 5 factors become the targets to achieve. NPD relates to most departments in the manufacturing companies. In the main sections, marketing, design and engineering sections should be included in (Katzenbach and Douglas, 1993). Marketing departments are the one to connect industry with customers. Their role is to captures the knowledge of customer requirements, market analysis and opportunities to produce new product. The department who defines product concepts as to meet customer requirements is Design; they are the one who creates realistic requirements after the approval of customer. Manufacturing function is basically an engineering department which defines the requirements for material purchase, distribution, and the whole supply chain. Figure 3.7 shows the basic NPD processes which has been developed after analysing different NPD definitions:

Figure 3.7: General new product development processes

NPD relates to most departments in the manufacturing companies. In the main sections, marketing, design and engineering sections should be included in. Marketing departments are the one to connect industry with customers. Their role is to capture the knowledge of customer requirements, market analysis and opportunities to produce new product. The department which defines product concepts as to meet customer requirements is Design; they are the one who creates realistic requirements after the approval of customer. Manufacturing function is basically an engineering department which defines the requirements for material purchase, distribution, and the whole supply chain. This can be verified by analysing technology push and market pull innovation model as described in earlier section.

The competition in market is the factor which demands customers to be regularly updated about the products and services. A small change in any of them has a critical impact on competitiveness. A saturation level is there in somehow all the market segments so in order to achieve a state where companies get more market share and a product should be made specifically for custom market. From market point of view, competition is really intense in the international market. In some markets there are few competitors who are bunched together to capture the bigger market share so that no one can easily give them a competition. At the end, customers become more sophisticated, as the small change in product and services gives customers more options. But from the point of view of manufacturers, this habit of customers has made them more demanding in terms of having a product specific to their requirement.

It is critical to appreciate that the successful development of products and services is indistinguishably tangled with efficient and effective and ideally optimized development of processes that produces them. Product and service development success is governed by successful and efficient research and development processes.

Most of products are developed by a project team as one independent project. Many people have to cooperate together to define the product. Ulrich and Eppinger (2011) described the main structure of a product development team for a product. The team is consisting of a core team and an extended team. The core team contains team leader, manufacturing engineer, mechanical designer, electronics designer industrial designer, marketing professional and purchasing specialist. The core team identifies all of concepts of the product. The extended team including supplier supports core team with the relevant knowledge and materials.

3.5.1 New Product Development Process Management

A generic new product development process normally contains six phases. The phase 0 is planning, and the purpose of this stage is to identify market objectives and assess the current technologies. Generally, the outputs of this stage are strategic factors, such as business goals, mission statement, key assumption and some constraints.

The second phase (phase 1) is concept development which is one of most important stage in the process. Product concepts are identified, tested and evaluated in this phase. The phase starts at analysing and defining customer needs. There are two possibilities which lead to define product concepts, one is customer requirements, and the other is technology-push. Technology-push product is that an enterprise developed a new proprietary technology, and then it seeks to an appropriate market to apply this technology to develop a product or a set of products. However, the technology-push products are few in the current market, and most of product development is customer needs driven.

After identifying customer needs, the enterprise needs to develop many target specifications which are suitable for the customer needs, thus the output of this stage is a list of specifications. The next stage is to generate product concepts from the list of the target specifications. The purpose of this stage is to explore the space of product concepts which might address the customer needs. And then, a concept should be selected with analysis and eliminated in the set of specification. This product concept is tested with customer needs and other requirements such as design and engineering requirements in the enterprise. If this test is not eligible, the product concept will be selected again from the list of specifications and redo the test until the concept is eligible. After test, the final concept specification is defined, the project plan is developed.

The product concept development should undergo some other activities, such as economic analysis, benchmarking, modelling and prototyping. These activities do not exist in the main process, but they should be adopted in the process, in order to help organisations identify the product concept correctly. After product concept development, the phase 2 is system-level design. This stage contains the definition of product architecture and breakdown of the product into subsystem and each component. Then, the product need to be designed in detail (Phase 3). The detailed design stage contain all of the complete product specifications in engineering view, such as geometry, tolerances and materials, thus this phase actually is engineering design to meet engineering requirements. In this stage, constraints of the product in implementation are identified, in order to control the risks and failures in actual implementation.

The Phase 4 is product test. A sample of product is produced under the constraints and controls. If there are any problems with the sample, it can find where the problems are and avoid large cost due to the failure. The Phase 5 is the product adjustment. After this section, the product will be launched, thus this stage is final opportunity to change the inapposite factors of the product.

Loch *et al*., (2010) studied 90 high-tech companies in Europe, and suggested that a customer-oriented new product development project with completed designed process and assessment, cross-functional integration, high-rank supervisors' support and powerful execution would be the success factors for companies. It has been suggested that with technology development and changeable market, every step in new product development process should be managed simultaneously upon high level of integration. The steps from new product concept development, design, manufacturing to marketing should be upon simultaneous approach to rapidly deliver the products to the consumers. When companies could be ahead in every process of new product development, they would accomplish market share and profits based on, after selecting relevant NPD models defined by different researchers, which are summarised below.

Thomas and Refik (1993) indicated that from the view of product development process, different firms would have different types of new product development according to corporate and product characteristics:

(1) Sequential new product development; (2) Holistic new product development; (3) Overlapping new product development; (4) Chaotic new product development.

Hisrich and Peters (1986) suggested that typical product development process:

(1) Idea generation (2) Screening. (3) Business analysis. (4) Development. (5) Testing. (6) Commercialization.

Cooper and Kleinschmidt (1995) divided new product development process into 7 steps and the process became the criterion for most of the business circle at present and it included:

(1) Idea; (2) Preliminary Assessment; (3) Concept; (4) Development; (5) Test; (6) Trial; (7) Launch.

Veryzer (1998) suggested 8 steps of new product development:

(1) Dynamic trend (2) Convergence stage (3) Forming stage (4) Initial design (5) Assessment preparation (6) Prototype construction (7) Test design (8) Prototype and commercialization.

Crawford (1994) indicated that the key success factors of new product development involved the close connection between the consumers and users, user satisfaction and value and sense of privilege for the users. The said researcher has defined the consumer demand, proper introduction in the market, positive product quality, compatibility of product and marketing personnel and after-assessment and tracking. Based upon above, this study treats (1) new product idea and assessment; (2) new product concept design and development; (3) new product-test and trial; (4) new product mass production in the market as the constructs of new product development process management.

3.5.2 New Product Development Performance Management

Levitt and Pheodore (1966) suggested that most of product innovations were not simply the innovation; they were the imitation and improvement. They defined product innovation as "simple innovation" and "imitation." Keegan *et al.* (1989) suggested that traditional performance measurement system tended to base on financial characteristics in financial statement. Upon these indexes, the companies evaluated performance of the departments and analysed the difference between the measurement results and fixed criteria. Lynch and Cross (1991) proposed the pyramid of performance and transformed strategic vision into business criteria. They suggested that the supervisors should construct overall strategic vision and then fulfil the individual goals. The suggestion on the problems of finance based performance system as:

(1) It focused on the improvement of performance of the departments instead of the process performance;
(2) It could not measure high-rank managers and there was no cost return;
(3) Measurement indexes and corporate strategic vision were inconsistent and unrelated;
(4) Information feedback tended to be deferred.

With regard to the professional managers of new product development, Olson and Walker (1995) suggested that they should probe into the indexes such as new product quality of new product design, design satisfaction, time consumption for profit and loss balance, and accomplishment of sell goal, budget control and time control of special projects.

Cooper and Kleinschmidt (1995) indicated five factors of new product development on performance:

(1) Complete new product development process, (2) Plans, (3) specific strategy, (4) Corporate culture and (5) High-rank supervisors' involvement in new product development.

Song *et al.*, (1997) indicated within the study of fortune 500 and Japanese enterprises that right product design and market selection would influence new product development performance, and emphasised that the companies should perceive the uncertainty of the market. They treated the following as the measurement indexes of new product development performance;

- New products match the expected time to the market;
- Consistency between new product development cost and budget;
- New product matches the expected rates;
- New products meet the expected sales;
- New products match the expected market share;
- The contribution of new products to corporate image;
- Contribution of new products to upgrade the corporate techniques;
- The employees' cognition of the customers' satisfaction with new products;
- The supervisors' satisfaction with new products.

The findings indicated that new product development performance could be measured by new product effectiveness and new product efficiency.

3.6 Supply Chain Management

A supply chain is defined as "the integration of key business processes from end users through original suppliers that provides products, services, and information that adds value for customers and other stakeholders" (Lambert *et al*., 1998). Here, a supply chain includes all the value chain processes from suppliers to end customers. It is vital that each supply chain participant adds value from the perspective of the end customer in the supply chain. This assumes integration of both supply and demand side activities in the value chain. Increasingly, the integration of both supply and demand requires an understanding of the inherent differences.

In this sense, Frohlich and Westbrook (2002) divided such integration into supply chain and demand integration. Trevile *et al*. (2004) defined demand integrations as "integration that supports market mediation, with the primary role of demand integration being the transfer of demand information to facilitate greater responsiveness to changing customer needs." They argued that increased access to demand information throughout the supply chain permits rapid and efficient delivery, coordinated planning, and improved logistics communication.

As Hoole, (2005) described that according to The Supply Chain Operations Reference-model (SCOR®), endorsed by the more than 750 member companies of the Supply-Chain Council, breaks the outbound supply chain into four process elements:

(1)Plan; (2) Source; (3) Make; and (4) Deliver.

"Plan" includes all the supply chain activities related to demand management, sales and operations planning (S&OP), and overall supply chain strategy planning. **"Source"** covers the identification of supply sources and the execution of material and services sourcing on an on-going basis. **"Make"** covers all the conversion activities performed internally. Finally, **"Deliver"** includes the taking of customer orders and their fulfilment, including the management of the distribution infrastructure and outbound transportation. Five critical performance levers have the greatest impact on supply chain performance: (1) Configuration; (2) Management practices; (3) External relationships; (4) Organisation; and (5) Systems.

The timeline of the concept of SCM in industrial background can be described as follows: (Childerhouse and Towill, 2000) (See Appendix VIII)

1980's: Traditional Supply Chain

1990's: Lean Supply Chain

1995's: Integrated Leagile Supply Chain

2000's: Customised Leagile Supply Chain.

There is a lot of focus in supply chain research and literature on the need to integrate supply chains across companies. The reality in supply chains today however, is that companies are not even sufficiently integrated internally. In fact, how can enterprise integrate externally with other companies when they cannot even speak with one voice and are not even in agreement internally on priorities, plans and strategies? Mentzer *et al*., (2004) points out that out of 12 drivers of supply chain performance internal alignment is the most fundamental starting point, without internal alignment all other drivers are useless to pursue.

The integration in the extended enterprise starts with the concept of Baseline Integration in which within the department the supply chain should be integrated. Then the next step is to functionally integrate the department. After this level of integration the enterprise can go towards the internal level of the integration in which now the whole company works in a same supply chain. And then the last stage comes which is of external integration, where different enterprises in the same supply chain links with each other.

Existing research has looked at improving internal alignment between marketing/sales and supply chain (Ellinger *et al.*, 2002) but the new product development – supply chain interface within the company is crucially important as well. In particular in a time where there are pressures for growing product proliferation in order to meet varied demand, where the R&D pipeline is a key focus in companies and in a time where technology life cycles have shortened so much that obsolete inventories and time to market are crucial for R&D output and company margin performance. In that respect it is often pointed out that the impact of supply chain on new product development and product introduction is important in areas such as:

- Shipping product to market fast enough (before product launch dates);
- Ensuring sufficient inventory at the launch data; and
- Ensuring a flow of parts and components for new product manufacturing.

3.7 The Automotive Industry Supply Chain

The automotive industry supply chain has been the subject of extensive research, but this has tended to concentrate on the component supplier-production sections of the chain. The industry has been at the leading edge of innovation in this area, with early adoption of new technologies such as EDI and business-to-business trading exchanges.

In contrast, the production-distribution sections of the chain have been the subject of relatively little academic research, and for many years the structure of the supply chain remained frozen in the pattern established by the middle of the last century. No matter how lean the assembly plants became, with component stocks reduced to a few hours, the distribution system remained “bloated” with typically 60 days of new cars either in transit or held at the dealers (Ali et al, 2004).

The new car supply chain presents a number of challenges, both for management and as a subject for research. For example:

- The complexity of the product – each individual car has a distinct specification in terms of body, engine, trim, colour, etc.;
- The complexity of the supply network – multiple stocking locations from the assembly plant to several hundred dealers in each major market;
- Consumer behaviour – including willingness to wait for a new car to be built-to-order, and the extent to which customers will compromise on specification;
- Demand seasonality – varying between markets, and its effect in combination with manufacturer's preference for level production schedules;
- Ageing of stock – resulting in heavy discounting to sell cars which remain unsold after several months.

The traditional downstream supply chain begins with production scheduling, with the objective of keeping production as stable as possible and ensuring that vehicles are financed by dealers as soon as they are produced. This is achieved by maximising the allocation of orders to dealers at the earliest point possible – up to 60 days before assembly. Once the car is assembled, the vehicle is delivered to the dealer as quickly as possible. The dealer's objective is to sell their available stock, if necessary using aggressive sales techniques to persuade customers to accept a car that is not their first (or even fifth) specification preference. This often involves additional discounts to the customer, encouraged by manufacturer incentives.

Fisher (1997) proposed that functional products should be matched with efficient supply chains, and innovative products matched with responsive supply chains. The downstream supply chain for new cars is based on manufacturers past perception of cars as functional products (due to the high volumes of production on a single assembly line). The car industry, therefore, endeavoured to create an efficient supply chain type similar to other mass-produced consumer goods. However, from the customers' viewpoint each car specification (including factors such as engine, colour, options, and trim level) is unique, even if it is the same model. Moreover, the range of body-styles has increased, with crossovers such as the sports-utility vehicle appearing, as has the speed of introduction of new models. Applying Fisher's criteria, cars are in the awkward position of combining features of both functional and innovative products, while the supply chain can hardly be described as either efficient or responsive.

The lean and agile approaches developed within the context of manufacturing in the early 1990s, and were subsequently applied to supply chain management. They have been defined succinctly by Naylor *et al*., (1999) as:

- Agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile market place.
- Leanness means developing a value stream to eliminate all waste, including time, and to ensure a level schedule.

Christopher (1999) points to the paradox of the automotive industry adopting lean manufacturing whole-heartedly, yet were having a supply chain that can be considered neither agile nor lean. Although originally considered mutually exclusive, Naylor *et al*., (1999) demonstrated that the two paradigms could be successfully combined into a single "leagile" supply chain, using the concept of the decoupling point to separate the lean (upstream) section of the supply chain from the agile (downstream) section.

This concept was quickly recognised as valuable in supply chain design, and in providing a mechanism for moving from the lean to agile models (Childerhouse and Towill, 2002). They have extended the original matrix of Fisher to incorporate a "hybrid" product type, giving automobiles as an example. The hybrid supply chain that is proposed as a desirable match for this product type is very similar to Naylor's leagile supply chain.

Turning to developments within the industry, the move to increase the responsiveness of the supply chain in the UK began in the 1980s with the introduction of stock-locator information systems (Ali et al, 2004). These gave each dealer information about cars held by other dealers, which enabled them to negotiate – not always successfully – an exchange to meet a customer's specific requirements. By 1992, transfers between dealers accounted for 45 per cent of UK sales (ICDP, 1995). However, the creation of this "virtual" pool of stock resulted in a significant increase in costs – not only the physical transfer of vehicles but also the time spent on negotiating the transfer.

In the early 1990s, national sales companies such as BMW, VW, Rover and GM began to introduce distribution centres, reducing stock held at dealers in some cases to showroom cars only. Mathematical analysis of inventory location suggests that this should improve service levels by "pooling" safety and cycle stocks. However, the assumptions made in this analysis are not valid in the case of new cars. For example, the cars in stock are not all identical, and the seasonality of monthly demand means that there is some correlation between demands at each of the dealers. There is also the potential loss of sales caused by the longer lead-time for supplying a car from a distribution centre rather than from stock.

Product variety is a major source of problem in both production and distribution of new cars. Ali et al, (2004) found that the variety of specifications available for 19 models in 1999 ranged from 448 to almost four billion. The variety of VW Golf specifications had increased 20-fold between 1980 and 1999, and was one of several models to have more specifications than UK customers (so every customer could, in theory, have purchased a unique car). The main contributor to this increase in variety is the range of optional equipment, such as sunroof and alloy wheels, particularly where these can be specified individually by the customer. Each option can be either "fitted" or "not fitted", so three options can be fitted in eight (23) combinations. Many manufacturers try to reduce this variety by offering standard packages of options targeted at customer segments, e.g. "sports" or "comfort".

One strategy to manage this problem, successfully applied in sectors such as consumer electronics, computers and clothing, is postponement (Lee and Feitzinger, 1995). Modification of the specification after the car has been through main assembly is impractical for features such as engine capacity or paint colour, but is feasible for many optional features such as in-car entertainment. Performing this at the dealers creates problems such as inventory, quality and reverse logistics, but fitting optional equipment at distribution centres reduces these problems. Postponement clearly offers particular advantages to manufacturers with long distribution times, e.g. vehicles supplied to the UK from assembly plants in Japan. A fully responsive supply chain would permit mass customisation, with every car exactly matching the specification chosen by the customer. A move to build-to-order is seen as one potential means of achieving this, but individual manufacturers are, therefore, likely to use a combination of approaches to move towards complete mass customisation.

3.8 Supplier Relationship Management

With rapidly changing and under very competitive circumstances, the design, development and marketing of new products with creative and innovative features are essential for any company's survival. For new product development to be effective, a systematic approach to the understanding of customer requirements is necessary. These requirements should then be firmly attached to future supplier's product processes.

Within the automotive industry the matching and synchronisation of future complex sub-assemblies and full systems needs to be managed carefully between suppliers and supplier-customer to ensure project success. The innovative product development and production process needs an understanding of continuously changing customer wants and needs. The literature review of supplier relationship management (SRM) has been divided into the sub-sections of

- strategy,
- structure,
- processes and co-ordination (SSPC)

SSPC required within the manufacturing environment, to identify the influence of synchronous supply as it affects these main areas of operations management (Bennett and O'Kane 2006). The aim has been to identify from available literature variation between SSPC and the future working needs and trends in liaisons between automotive suppliers and their customers. The way that other industries have changed dramatically over the past few decades may give the indication as to the future trends of synchronisation in the UK automotive supply industry and if they affect any specific area of SSPC. However, the modern market place is highly varied and cannot be serviced effectively by a single supply chain paradigm (Childerhouse and Towill, 2000).

Strategies have moved some suppliers in the automotive industry into a different field of activity. The assumption being that the vehicle manufacturers (VMs) have empowered the large first tier suppliers to completely develop and produce modules (large sub sections) for their vehicles. This has led to suppliers seeking collaborative relationships or supplier alliances or mergers. Within the structure, or the inter-linking supporting framework to ensure that the whole business relationship is compatible, different social, cultural and economic contexts identify variations between suppliers. These variations can have a marked effect on how the supplier performs in business with its customers.

Processes stated within the literature review, refer to the method of operation in manufacture within the UK automotive supply industry and identifies research that shows that manufacturing decision making can start earlier in the process. As leading first and second tier suppliers move closer towards supplying full systems and modules to VMs, the controlling processes to achieve total system compatibility must become ever more critical to ensure project success. The co-ordination of projects is embracing a form of partnership of which the precise definitions may differ between suppliers and customers. There is evidence to show that the VMs are pursuing a more intensive and interactive relationship with their suppliers, collaborating in areas such as product development, supplier development and information sharing.

Many theoretical works have been published emphasising the importance of a strategic management of the manufacturing function and the management of quality in order to gain competitive advantage. However, the competitiveness of a company is mostly dependent on its ability to perform well in dimensions such as cost, quality, delivery, dependability and speed, innovation and flexibility to adapt itself to variations in demand (Carpinetti et al., 2000). While alignment of the manufacturing function with strategic priorities is core to competitiveness, the continuous improvement of the manufacturing function plays a very important complimentary role in the quest of competitiveness in the long run. Continuous improvement has been defined as a companywide process of focused and continuous incremental innovation (Bessant and Caffyn, 1994). It is thus complimentary to the more radical change normally considered under the term re-engineering.

However, many companies, in their attempts to rapidly adopt world-class management practices such as TQM and many other methods like kanban and lean manufacturing, tend to devote little or no attention at all to the impact of such practices on company strategic objectives, market demands or even performance against competition. This misalignment between operational management practices and competitive strategy can be listed as one of the reasons for unsuccessful TQM implementations (Tatikonda and Tatikonda, 1996). Synchronous supply is essentially a process where components supplied are matched exactly to the production requirements of the customer (Doran, 2001).

However, to ensure that the best performance is attainable, the implementation of Agile manufacturing into the operation method would give an added emphasis for success. Agility means being able to reconfigure operations, processes and business relationships efficiently, while at the same time flourishing in an environment of continuous change. Companies, and this includes automotive suppliers, need to open their collective minds to a paradigm shift in how they design, manufacture and market their products. Co-operation amongst suppliers must improve to support the need for quick decision making and these suppliers must work together to achieve the overall goal of improving manufacturing. This would ensure a gateway for the introduction of synchronous supply but, in addition to being agile the supplier also needs to maintain a leanness of its operation. This requires the development of a value stream to eliminate all waste, including time to enable a level schedule to be produced. SRM is about developing two-way, mutually beneficial relationships with company's most strategic supply partners that deliver greater levels of innovation and competitive advantage than could be achieved by operating independently.

3.8.1 Stakeholder Engagement and Business Support

A Strong and active support for SRM provided by senior management and broad support for SRM from key stakeholders at a functional level are required. A realization that SRM necessitates a consistency of approach and behaviors that foster trust over time brings an alignment in business objectives with those responsible for managing the SRM programmed and those responsible for managing day-to-day relationships with key suppliers. SRM practices are in place with half of the suppliers identified as strategic/top tier, with a plan to engage remaining suppliers during a defined time period. Suppliers demonstrate daily their commitment to a more collaborative way of working through their actions.

3.8.2 Governance and Process

The procurement/supply chain function owns the SRM governance model and processes and facilitates the development of a cross-functional SRM capability.
Supply base segmentation has been conducted using multiple, weighted criteria and reviewed at least annually. For strategic suppliers, a clear and jointly agreed governance framework is required. Process toolkits and templates provide relationship managers with ways to evaluate risk, create joint account plans, track joint performance using balanced scorecards and 360-degree feedback, report progress and facilitate workshops. There is a clear process in place to capture supplier ideas and innovations, direct them to relevant stakeholders, and ensure that they are evaluated for commercial suitability.

3.8.3 People and Skills

Cross-functional teams are assigned to oversee relationships with strategic suppliers and are led by the procurement/SRM function. In a same way, Operational relationships are run by SRM managers who sit within the business. Some are full time, dedicated positions, although relationship management responsibilities may be part of broader roles depending on the type of business, industry sector and organizational philosophy. SRM managers should be responsible for managing no more than three supplier relationships, in order to devote sufficient time to each. Staff involved in SRM activities will have a good combination of commercial, technical and interpersonal skills. Commercial acumen, market knowledge, analytical abilities and project management expertise are important. But “softer” skills around communication, listening, influencing and managing change are critical to developing strong and trusting working relations. SRM managers understand their suppliers’ business and strategic goals and are able to see issues from the supplier’s point of view, while balancing this with their own organization’s requirements and priorities.

3.8.4 Tools and Systems

IT systems are used widely and consistently across the organization to manage the contract lifecycle and capture supplier performance data. For the most strategic and critical suppliers, a web based portal accessible by key customer and supplier stakeholders provides a single point of information about the relationship.

3.8.5 Value and Measurement

SRM delivers a competitive advantage by harnessing talent and ideas from key supply partners and translates this into product and service offerings for end customers. A balanced scorecard includes a mixture of quantitative and qualitative measures, including how key participants perceive the quality of the relationship. Many of these KPIs are shared between customer and supplier and reviewed jointly, reflecting the fact that the relationship is two-way and collaborative, and that strong performance on both sides is required for it to be successful.

3.8.6 Relationship Characteristics

A high level of information sharing and trust, recognition that working collaboratively can produce superior results over the long term, and a willingness to engage and learn from people outside immediate function and organization. Tough negotiations continue to take place periodically for new requirements and contract renewals, but they are conducted in the spirit of a long-term relationship.

3.8.7 Example SRM Software Packages

Example SRM software (Bennett and Klug, 2012) are listed below:

- B2B Connex: Offers two approaches to improving supply chain collaboration that can be used independently or together, depending on the specific client scenario.
- B2B Connex Supplier Portal: Is a Web-based portal providing both Supplier Relationship Management (SRM) and Customer Relationship Management (CRM) functions.
- Mediware Information Systems: Is a leading provider of specialized healthcare solutions with over 30 years of experience developing and delivering innovative software designed to ensure the highest level of safety and efficiency.
- Smart Donor: It delivers a valuable bundle of donor relationship management tools uniquely designed to address the challenges faced by companies.
- Master Control: It produces software solutions that enable regulated companies to get their products to market faster, while reducing overall costs and increasing internal efficiency.
- Technology Group International TGI - ERP Software Solutions for Manufacturing and Distribution Companies.
- Trace Link Inc.: It helps Life Science companies, suppliers and contract partners create a predictable manufacturing and supply network by improving connectivity, visibility and business process collaboration along.
- Material Tracking Continuous, shared visibility into material status and production requirements across the manufacturing lifecycle.
- SAP: Founded in 1972, has a rich history of innovation and growth as a true industry leader. SAP currently has sales and development locations in more than 50 countries worldwide and is listed on several exchanges.

3.9 Integrating SCM and NPD

The integration of supply chain management systems has been the subject of significant debate and discussion. As organizations seek to develop partnerships and more effective information links with trading partners, internal processes become interlinked and span the traditional boundaries of firms. Physical logistics become more dependent on information technologies, and these technologies can also become enablers of further cooperative arrangements. Firms are then faced with the management of an extended enterprise as a network of processes, relationships and technologies creating an inter-dependence and shared destiny. The truly strategic nature of supply chain management thus becomes apparent for participating companies, with successful implementation becoming a source of competitive advantage.

The intent of this literature review is to document and analyse literature relating to the integration and implementation of supply chain management practices. As such, it is organized into the following sub-sections:

- **Supply chain integration**. This section covers issues relating to integration of core processes across organizational boundaries through improved communication, partnerships, alliances and cooperation. It also includes the application of new technologies to improve information flows and coordinate the flow of physical goods between trading partners.
- **Strategy and planning**. Supply chain management as a strategic matter for trading partners, along with factors relating to the amount of planning required.
- **Implementation issues**. Factors critical for successful implementation, as well as issues specific to inter and intra-organizational aspects of supply chain initiatives are contained in this sub-group.

3.9.1 Supply chain integration

The purpose of supply chain management is described by Kaufman (1997) as to being to *". . . remove communication barriers and eliminate redundancies*" through coordinating, monitoring and controlling processes. The integration of supply chains has been described by Putzger as: . . . *attempting to elevate the linkages within each component of the chain, (to facilitate) better decision making [and] to get all the pieces of the chain to interact in a more efficient way [and thus] . . . create supply chain visibility [and] identify bottlenecks* (Putzger, 1998).

The main drivers of integration are listed by Handfield and Nichols (1999) as:

- The information revolution;

- Increased levels of global competition creating a more demanding customer and demand driven markets; and
- The emergence of new types of inter-organizational relationships.

They describe the three principal elements of an integrated supply chain model as being information systems (management of information and financial flows), inventory management (management of product and material flows), and supply chain relationships (management of relationships between trading partners). The basis of integration can therefore be characterized by cooperation, collaboration, information sharing, trust, partnerships, shared technology, and a fundamental shift away from managing individual functional processes, to managing integrated chains of processes (Akkermans et al., 1999). The extent of integration can begin with product design, and incorporate all steps leading to the ultimate sale of the item (Ballou et al., 2000). Some authors also include all activities throughout the useful life of the product including service, reverse logistics and recycling (Coleman and Austrian, 2000).

Cottrill (1997) states that the evolution of the concept of integration has moved over time to one in which the supply chain operates as a corporate entity, spans a virtual enterprise without reference to traditional company boundaries, and can be driven directly by customer demand via access to electronic storefronts. He states that this trend will create major changes in many companies, eventually leading to greater use of outsourced services. He also believes that the key to implementation lies in focusing initially on introducing changes within the company, and then extending the process to include suppliers and customers. The primary benefits resulting could include cost and cycle time reductions. Wood (1997) focuses on the importance of aligning goals across functions through cooperation and collaboration, and cites the traditionally poor alignment of goals between manufacturing and sales/distribution functions as an example of opportunities for better alignment as a precondition for improvement in supply chain management practices.

3.9.2 Strategy and planning

In examining the strategic nature of integrated supply chain management, and business to business e-commerce in general, the example of the computer industry provides a graphic example. Bovel and Martha (2000) use the examples of Gateway and Dell Computer as companies that have managed to move supply chain management from the realm of operations into a source of competitive advantage:

Gateway and Dell, for example, make good personal computers, but so do Hewlett-Packard, IBM, Compaq, and other vendors. Since all are built from fairly standard components and loaded with identical software, it is difficult to say that one is better than another. What differentiates Gateway and Dell in the eyes of customers is the fact that they can build and deliver a customer-configured PC within five business days. What sets them apart in the eyes of shareholders is the fact that they can do this with almost no inventory, absolutely no working capital, and far fewer capital assets than most of their rivals (their asset intensity is one-fifth that of major competitors).

They also make the point that these companies are in the minority, with the focus for differentiation still revolving around price, product innovation and cost cutting, rather than an integrated and coordinated value chain. Porter (2001) offers some support for this view, although he sees the integration of a value chain as complementing traditional strategies. In analysing the potential for internet-based technologies to alter competitive environments Porter pointed out a major opportunity for organizations to differentiate themselves on the basis of a distinctive value chain. In fact, Porter state that this may be one of the few ways in which companies can develop a sustainable competitive advantage using internet technologies, as the overall effect of their adoption will be to intensify competition, lower barriers to entry and increase bargaining power of both buyers and suppliers:

Basic Internet applications will become table stakes – companies will not be able to survive without them, but they will not gain any advantage from them. The more robust competitive advantages will arise instead from traditional strengths such as unique products, proprietary content, distinctive physical activities, superior product knowledge, and strong personal service and relationships. Internet technology may be *able to fortify those advantages, by tying a company's activities together in a more distinctive system, but it is unlikely to supplant them.*

One strategic outcome of supply chain integration can be "channel consolidation", or the concentration of control of distribution channels by a small number of players. In this case there will undoubtedly be winners and losers as suppliers into these channels also will likely be consolidated. Fein and Jap (1999) identify four strategic responses for manufacturers finding themselves confronted with this situation:

- Partner with the winners: appropriate when the winners are easy to spot;
- invest in fragmentation: work with marginalized distributors to create alternative channels;
- Build an alternative route to market by forward integration and (perhaps) use of the internet; and
- Create new channel equity: use differentiation and develop brand equity.

In the context of Porter's analysis of the impact of internet technologies on the competitive environment, the prospect of consolidation is perhaps a very real one in many industries. In this context, the importance of having a coherent supply chain strategy, rather than just a strategy for the operation of the individual enterprise, could become even more important as time goes on.

Hicks (1999) stated that the goal of strategic supply chain planning is *". . . to arrive at the most efficient, highly profitable supply chain system that serves customers in a market"*, and that decisions of this nature typically carry high expenditures and significant risk. He identifies two different approaches to supply chain improvement, focusing on either information technology or logistics.

The first has information as the key to supply chain improvement, with the primary focus being on *". . . collaborative planning, sharing information and getting companies synchronized with suppliers and customers*". The second is more internally focussed and is concerned with quantitative analysis of complex logistical problems. He states that the future of supply chain strategy lies in the convergence of these two paradigms, and recommends a four-step process for strategic planning:

- Step 1: Network optimization: design the least cost network focusing on customer demand;
- Step 2: Network simulation: test alternative models to predict supply chain behaviour;
- Step 3: Policy optimization: develop best operating rules (e.g. how much inventory to carry for each product line); and
- Step 4: Design for robustness: anticipate unforeseen circumstances and possibilities.

This final step is the most difficult, and the most important. As Hicks stated "Optimal answers are not always the best answers". Given the importance of this step, it is interesting that he spends the least amount of time on explaining how this may be achieved. Although it is desirable to model the behaviour of a supply chain in order to make informed planning decisions, the issue of dynamic competitive environments makes this an activity that is at best difficult, and at worst perilous. Some observations from leading supply chain management practitioners perhaps provide some insights into this dilemma.

3.9.3 Implementation issues

Putzger (1998) states that the key criterion in implementation is correct choice of information technology, and that the use of third-party providers for both transportation and information management is the option chosen by successful performers. Bowman (1997) says that many companies are unsuccessful in implementation because they simply are unable to come to agreement on terms. In documenting implementation in a European company, Hammant (1997) list seven critical success factors:

- A committed organization, from the board down;
- Effective programme management;
- Consistent, pre-emptive communications;
- Positive action to identify and manage key risks before they become issues;
- A well-defined and managed programme baseline, changed as necessary;
- A succession of manageable delivery milestones to maintain momentum and confidence; and

- An actionable, owned, manageable and measurable set of business benefits.

Tyndal et al. (2000) identify three critical elements that need to be assessed and balanced to enhance chances of successful implementation. These are value (relationship between cost and benefits), risk (probability of success – dependant on time span for tangible results), and method (the approach adopted by the company to balance value and risk). This means having a practical time frame for deriving a return on their investment, and being realistic about the size of that return. Linked to this notion of return is the need to understand the true nature of supply chain costs. Included, should be internal and opportunity costs, real inventory costs, subcontractor costs, systems costs, support costs and asset costs. They also recommend: mitigating risk by focusing on short-term projects as it will be easier to set action plans, targets and specific time horizons for short term projects; implementing in stages to avoid the temptation of trying for a "silver bullet" solution; and taking care of basics such as data accuracy at an early stage.

In summarizing their approach, Tyndal et al. stated:

The value of working in stages and by segments is best captured in a wholly counterintuitive maxim: do less with more. In other words, put more resources onto fewer, more implementable initiatives, and make them accountable for results.

It is well recognised that the NPD process not only enables management to coordinate the flow of new products efficiently, but also to assist in the ramp-up of sourcing, manufacturing, distribution, and other sales-related activities that support the commercialization of the product (Carillo and Franza, 2006). Therefore, the traditional NPD functions must be coordinated with the support functions (Hilletofth *et al*., 2009; Van Hoek and Chapman, 2007). Companies tend to use a fairly conventional approach to NPD by assigning representatives from support functions to review and recommend changes as the project evolves (Kotler *et al*., 2009). This conventional approach to NPD has in recent years been questioned, since it is a costly and time-consuming approach due to its iterative nature (Sharifi *et al*., 2006). It is argued that the TTM and the cost of NPD can be reduced considerably by involving the support functions to a greater extent, and also earlier in the NPD process (Carillo and Franza, 2006; Van Hoek and Chapman, 2006).

New practices have emerged in the area of NPD to address this lead-time issue (Sharifi *et al.,* 2006). One of these practices is concurrent design or engineering, which involves a multi-functional development team (Portioli-Staudacher *et al*., 2003). This development team is highly structured and infused with greater responsibility and authority (Appelqvist *et al*., 2004). However, concurrent design has mostly focused on internal collaboration while today's global competition may require for concurrent design to be a collaboration in the entire demand-supply chain, as it is an important key to success and profitability.

Much research work has given an idea about the relationships between product design and supply chain (e.g. Fisher, 1997; Randall and Ulrich, 2001). According to (Pero *et al*., 2011), It is important to understand this relationship for two main reasons. Initial, the design phase is the one to create the product to manufacture and distributed within the extended enterprise, thus a large amount of cost is associated with this supply chain.

The next reason is the magnitude of the effects on supply chain by product design and it depends on the type of supply chain, such as the concept of outsourcing, structure of supply chain, location of the production sites and warehouses (Blackhurts *et al.,* 2005), and supply chain strategy (Childerhouse *et al.,* 2002). For a given product design, a specific supply chain leads to a better performance. Although it seems easy, but it is really difficult part to perform because of the increased rate of product introductions. Managers should adapt the supply chain characteristics more frequently to deliver the new products effectively and efficiently. To achieve this target, supply chain must be aligned with product development decisions; as it should be designed and managed in such a way, that "the products are delivered at the targeted cost, time, and quality".

The benefit of integrating are that it allows the manufacturer to overcome the problems like partially failed product introduction into the marker because of non-availability of that new product as they got insufficient capacities (Van Hoek and Chapman, 2007).

The business rules have been changed nowadays, everyday new products and business are born. Customers are increasingly difficult to keep and costly to replace. Companies face intense competition from traditional powerhouses and new players, and must continue to find new revenue opportunities and increase efficiencies. The idea of integrating new product development (NPD) and supply chain is not new as it has been discussed by a lot of researchers. This relationship of NPD-SCM has got a lot of importance as it involves almost all the functional department within the extended enterprise. The main reason for consideration is that the design phase is a part of actual supply chain and it involves the cost also so if the enterprises can integrate them in a way that it will be cost effective, they can easily streamline the supply chain (Hasan, *et al.*, 2012)

The main problem in a traditional supply chain is not sharing the exact information on a timely manner throughout the chain, which creates bull whip effect resulting distortion of information and in the end the cost of producing the product and then distributing it will be costly. So in order to make sure their decisions are aligned with the integration of SCM and NPD the SCM should be deigned in such a way that the products can be delivered within the targeted cost, time and quality (Pero *et al.*, 2011). NPD-SCM alignment is one of the major elements in a marketing strategy (Christopher *et al.*, 2004).

The products and services are the factors on which customers are judging the companies nowadays like for example Apple and its innovative products such as I Pad, on which they spend tremendous amount of resources to generate state of the art innovative product with the reliable services, just to catch the customers and the market share. At the end customers have got interest in looking in details for the evolution of these types of products and services.

Most of the R&D organisations do not view manageable inefficiency as a waste, but as a value-added activity necessary to get the design right. However, in reality, with companies around the world shows that excessive engineering work is a clear indicator of inefficiency and can be sharply reduced without an adverse effect on design outcomes. For example, poorly defined requirements early in the design cycle can cause excessive low value adding effort in later phases, which ultimately increases costs and slows things down.

Other common causes of manageable excessive engineering effort include:

(i) Lack of integration. R&D organisations are becoming more and more sophisticated in their use of computer-aided tools to design and model product parts. However, disconnects can still occur when individual design efforts are not tied into a requirements management process that ensures the separate components will ultimately work together. Not having the right tools, processes, people or data to achieve the necessary integration can contribute to excessive non-value adding activities.

(ii) Poor synchronization across design groups. Different design teams tend to work at different speeds. Unless work is scheduled and prioritized, some groups inevitably fall behind or find themselves waiting on others. This is particularly challenging when the time comes to test that various components work together – especially if some components are mechanical while others are software or electrical.

(iii) Design by committee. Building consensus around decisions can be a valuable exercise. However, excessive deliberation and lack of clearly delineated decision-making roles is counter-productive and can make it difficult or impossible to meet product development deadlines.

(iv) Lack of cross-functional integration. R&D needs to bring other functions into the development process as early as possible. For example, failure to get the manufacturing organisation involved can lead to inadequate tools and shop floor processes. Similarly, failure to involve the after-market service organisation can create costly support problems for the company and its customers. The best design in the world is useless if it cannot be built and properly supported.

The lack of research addressing NPD and SCM coordination is remarkable, since the TTM is affected by numerous SCM activities. It may be argued that the NPD process not only enables management to coordinate the flow of new products efficiently, but also to assist in the ramp-up of supply processes and other related activities (e.g. marketing and sales), that support the commercialization of the product (Carillo and Franza, 2006). Important issues in NPD and their influence on SCM have been summarised in Figure 3.8.

Requirement	Connection to SCM
A holistic view from strategy to commercialization	Different supply chain competences have to be involved in the NPD process to provide feedback. This also creates an opportunity to address NPD and SCD in parallel and as early as possible
Development of products based through market intelligence (customer oriented).	The provided supply chain solutions also need to be developed based on customer demand. This implies that companies when gathering information concerning needs of new products, also should collect information regarding service needs in order to develop the most appropriate supply chain solutions.
Development of products based on a segmentation model	Customers' requirements may also differ when it comes to lead-times and service levels, as well as preferred supply chain solution, implying that several solutions are required to become successful in the market.
Development of new and innovative products in accordance with customer preferences	Unwise to restrict innovation to products, other areas should also be included, such as supply chain solutions. These issues need to be considered in the NPD through involvement of supply chain representatives and by establishing information exchange between NPD and SCM.
Developing products rapidly and moving them quickly and efficiently to the market	Time-to-market is not solely determined in the NPD process but also in, sourcing, manufacturing, and distribution. This implies that supply chain representatives should be involved early in the NPD process to shorten time-to-market
Incorporating all the activities supporting the commercialization (integrative NPD approach)	SCM and NPD need to be coordinated to successfully introduce products on the market, to ensure that the product assortment is updated according to product life cycles, and to ensure that obsolete products are properly out-phased.

Figure 3.8: NPD-SCM Connection Requirement

Many companies consider new product development (NPD) as a key strategic activity and a short time to market (TTM) as critical to long-term success. The majority of research in this field has focused on issues such as reduction of the TTM and process improvement issues in isolation (e.g., Cohen *et al*., 2000;

Gerwin and Barrowman, 2002; Morgan *et al*., 2001). However, research addressing the coordination of NPD and supply chain management (SCM) as necessary for bringing new products to the market is relatively rare (Carillo and Franza, 2006; van Hoek and Chapman, 2007). For instance, Randall and Ulrich (2001) comment that the literature addressing NPD and production ramp-up is sparse, although notable exceptions exist (e.g., Terwiesch and Bohn, 2001; Terwiesch and Xu, 2001; Terwiesch *et al*., 2001).

For this reason, companies need to stop thinking around the edges and begin to coordinate and address these issues in parallel to reduce the TTM as well as to enhance profitability (Van Hoek and Chapman, 2006).

SCM should no longer need to clean up after NPD, but instead be involved from the beginning of product development, with the same level of authority (Van Hoek and Chapman, 2007).

There is a lack of research examining how the different NPD and SCM activities influence each other, how they can be coordinated, what benefits that can be obtained by coordinating them, and what the requirements are to succeed with the coordination (Carillo and Franza, 2006; Van Hoek and Chapman, 2006; Van Hoek and Chapman, 2007).

This means that there is a need for research aiming to increase the understanding of the whys and how's of NPD and SCM coordination.

3.10 Key Decision Making Point

In this stage of literature, literature studies related to decision making frameworks as shown in literature review flow chart has been conducted. During the recent swift progress of network technology and economic globalization, modern automotive industry has been trending towards the increasingly precise division of labour.

Consequently, individual enterprises focus on developing their core capabilities and outsource non-core affairs to other partners or suppliers with different

professional capabilities to upgrade their competitive advantage by applying these external and special sources and technology knowledge.
On the other hand, consumer- behaviour is widely changed because of the increasing consumers' ideology; hence, product lifecycles are becoming shorter and every enterprise must offer diverse and custom made products to immediately satisfy consumer needs. These pressures drive automotive enterprises to actively invest in supply chain management (SCM), and to establish strategic alliances against their competitors.

Generally, SCM occurs when several enterprises establish their own supply chain. These enterprises must find more efficient suppliers to increase supply chain competitiveness.

Among various available suppliers, how to choose more collaborative suppliers who can develop long-term relationships is a key issue in establishing a supply chain and enhancing its efficiency.

Many previous studies on has been done in decision making selection and evaluation. For example, (Dickson, 1966) has surveyed companies to identify factors they considered in awarding contracts.

Out of the 23 factors considered, Dickson concluded that feasibility, time, cost and capability performance are the four most important criteria.

Another study by (Weber et al. 1991) derived key decision making points thought to influence the decisions like Make/Buy decisions. These factors were taken from 74 related articles that have appeared since Dickson's well-known study. Based on a comprehensive review, they summarised that feasibility was the highest-ranked factor, followed by time, cost and capability performance.

Figure 3.9 summarizes some of the criteria that are considered important by Dickson and Weber et al. and has been done by Chen in 2010.

Evaluation Criteria	Dickson Important Ranking	Weber et al. Importance	Reference Quantity
Feasibility	**1**	**Extremely Important**	**61**
Time	**2**	**Very Important**	**48**
Capability and Performance	**4**	**Very Important**	**44**
Cost	**3**	**Very Important**	**40**
Geographic location	20	Very Important	23
Equipment	5	Very Important	22
Technical Capacity	7	Very Important	15
Management and Organisation	13	Important	10
Industrial Reputation	11	Important	8
Financial Situation	8	Important	7
Maintenance Service	15	Important	7
Service Attitude	16	Important	6
Packing Ability	18	Important	3
Production Control Ability	14	Important	3
Training Ability	22	Important	2
Procedure Legality	9	Important	2
Employment Relation	19	Important	2
Communication System	10	Important	2
Mutual Negotiation	23	Important	2
Previous Image	17	Important	2
Business Relation	12	Important	1
Previous Sales	21	Important	1
Guarantee and Compensation	6	Important	0

Figure 3.9: Important Decision Making Criteria from literature
(Adapted from Chen 2010)

These empirical researches revealed that the relative importance of various decision criteria such as feasibility, time, performance and cost is similar. So basis on this existing research the following factors have been chosen to do this research:

- Feasibility,
- Time & Cost,
- Capability and Performance.

3.11 Existing Frameworks in Literature

The following section illustrates the different existing frameworks in literature within supply chain and product development environment.

3.11.1 Conceptual Model on Effective Supply Chain

Fisher (1997) research was the pioneer in supply chain management domain. The initial model which has been proposed by Fisher in 1997 shows only the relationship between physically efficient supply chain and the market responsive supply chain. It has been observed that an effective supply chain has to be designed with respect to the product that is going to be supplied through the chain. The Fisher model has been shown in Figure 3.10.

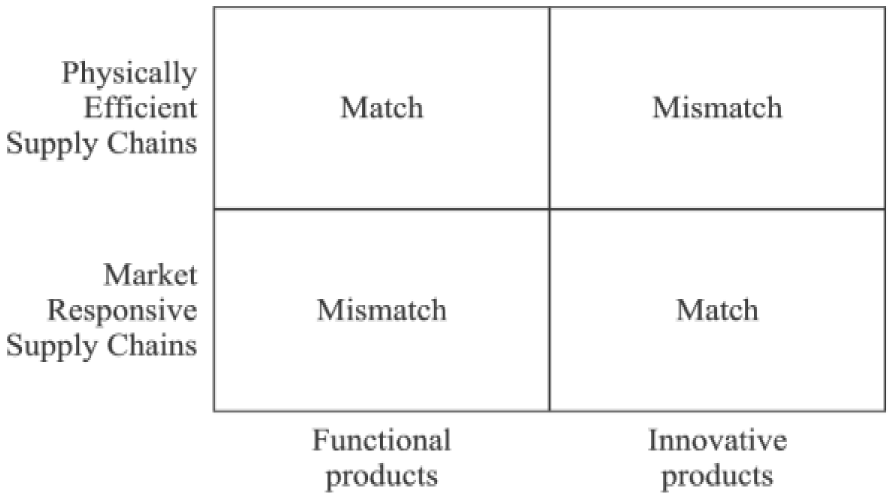


Figure3.10: Fisher's conceptual model (Fisher, 1997)

The foundation for Fisher's theory is that products can be either functional or innovative depending on their demand pattern and market expectations. A supply chain, on the other hand, can emphasize the physical function in delivering the goods or the market mediating function for conveying information. A functional product is assumed to require a physical efficient supply chain, whereas an innovative product would require a market-responsive supply chain. Fisher's model can be considered as a prescription for choosing the right supply chain for a certain product.

3.11.2 PD and SCM Alignment Framework

In Van Hoek & Chapman (2006) research, new avenues for research and practice are offered that can tremendously improve alignment and the contribution of supply chain on new product development, for the good of the company as a whole. Specific research areas have been suggested through this framework to enable research to support the realization of the path forward in this area.

New product development – supply chain alignment has been addressed from a design for supply chain and product availability angle. To satisfy the specific needs of customers, the manufacturers have to update their product/services offers on continuous bases, while staying competitive in the market. Even though it seems easy, but it is really difficult part to perform because of the increased rate of product introductions in this competitive world. The companies should adapt the supply chain characteristics more frequently to deliver the new products effectively and efficiently. Van Hoek and Chapman framework has been shown in Figure 3.11.

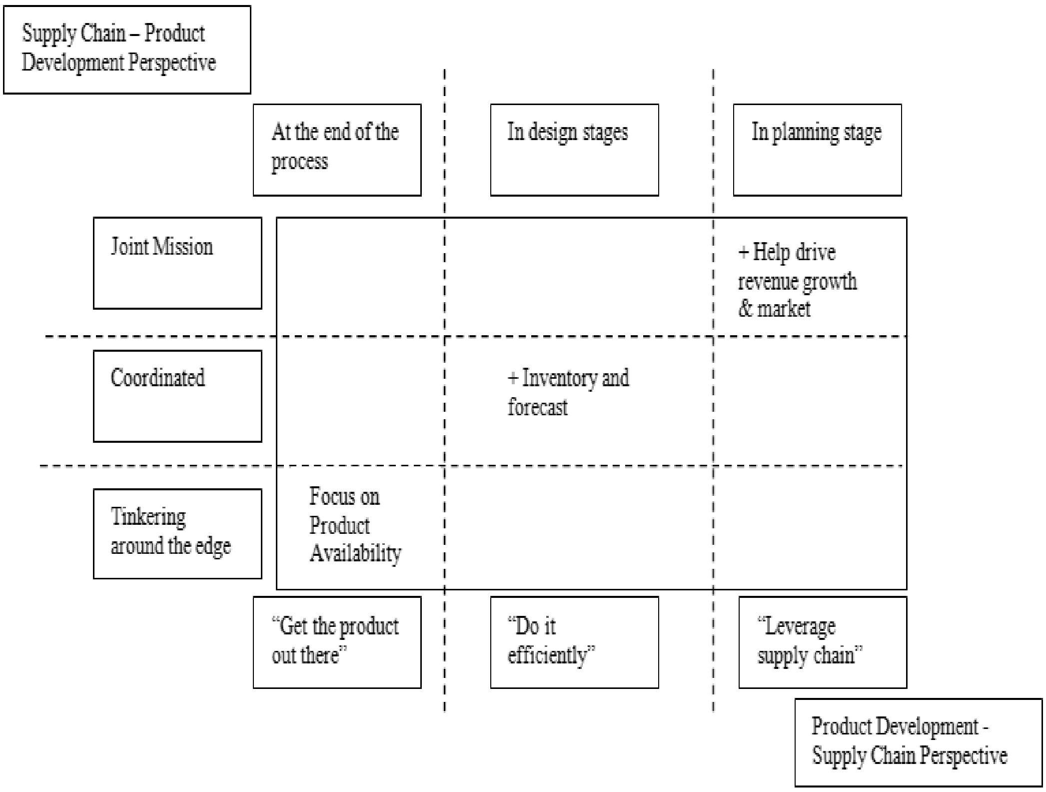


Figure 3.11: Framework of aligning product development and supply chain (Van Hoek & Chapman, 2006)

To achieve this target, supply chain must be aligned with product development decisions; as it should be designed and managed in such a way, that “the products are delivered at the targeted cost, time, and quality”.

The benefit of integrating are that it allows the manufacturer to overcome the problems like partially failed product introduction into the marker because of non-availability of that new product as they got insufficient capacities as shown in the framework by Van Hoek & Chapman. What have been largely missing in research are efforts to leverage supply chain capability as part of the product development team for greater market impact and revenue growth through new product introduction. Bringing in creative supply chain designs can feed into the marketing concept of new products and position the supply chain not just for product availability at the launch data but also for efficiency and an edge in the market.

3.11.3 Supply Chain Collaboration Framework

Matopoulos at al. (2007) has given general research framework for supply chain collaboration. Two pillars are distinguished in the framework for supply chain collaboration.

The first pillar in the framework is related to the design and government of supply chain activities consisting of three elements. The first element is about taking the decision of selecting the appropriate partner. Companies in the real business world are interacting with a number of suppliers and customers. Obviously, not all of them can become close collaborators and under this prism a selection is needed, based on the expectations, perceived benefits and drawbacks, and the “business fit” of companies as shown in Matopoulos et al. 2007 framework in Figure 3.12.

The second element involves selecting the activities on which collaboration will be established. The plethora of the activities constitutes the “width” of collaboration.

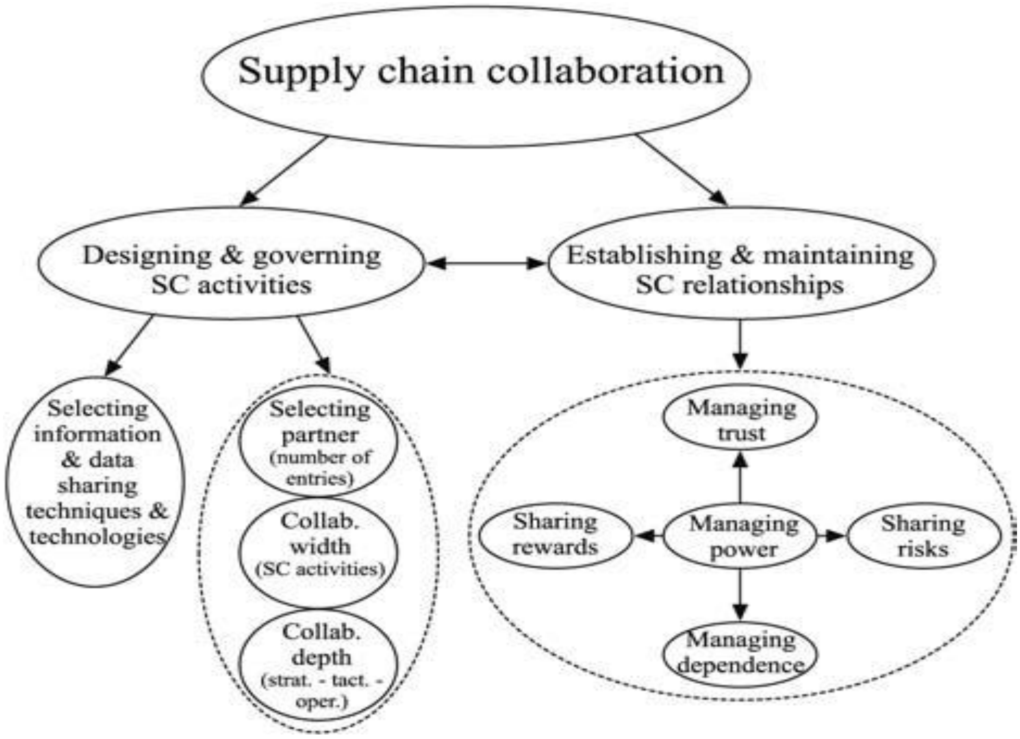


Figure 3.12: Framework for overall supply chain collaboration (Matopoulos et al. 2007)

The third element is to identify in what level companies will collaborate. Finally, another important element for the design and governing of supply chain activities includes the decision of selecting the appropriate technique and technology to facilitate information sharing. It is a very complicated decision, since not all potential collaborators are able to meet the requirements of collaboration in terms of technology and techniques.

These pillars are dealing with the design and the government of supply chain activities, and the establishment and the maintenance of supply chain relationships, respectively. The study has two main limitations. The first limitation is that the research draws from one relationship only. Further qualitative testing of the conceptual model is needed with the aim of literal or theoretical replication. The second limitation is the focus on dyadic relationships; extending the research focus to more complex supply chain relationships across the entire chain would be also useful.

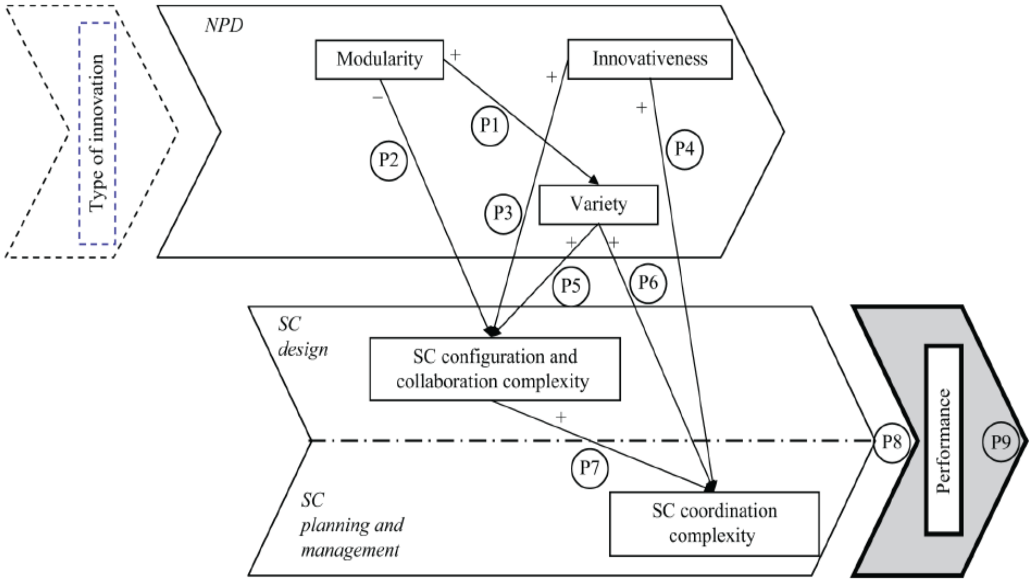
Future research on supply chain collaboration is required in order to develop a more clear understanding of the benefits, as well as, the risks of supply chain collaboration and the way the aforementioned elements of trust, power and dependence interact in the collaboration building process.

3.11.4 NPD Alignment within SC Design Framework

Pero *et al*., (2011) framework provides empirical support to the relationships among the variables within the alignment feature. There is evidence that product innovativeness, a variable so far neglected in the alignment literature, can have a critical impact on the supply chain. Furthermore, supply chain complexity must be adequately adapted, depending on the product features.

The automotive suppliers which have been used to analyse this model produce modules for the original equipment manufacturer (OEM), but their products are not modular and they have to manage a complex network of suppliers. Modularity decreases configuration complexity from the point of view of the original equipment manufacturer (OEM) but not from the suppliers' viewpoint. Supply chain complexity should be adjusted according to the degree of innovation embedded into the product. Managers should take both variables into account before deciding whether module production should be allocated to suppliers. To achieve alignment, firms may not only match product features with the supply chain, but also long term (supply chain configuration and collaboration) and short term decisions (supply chain coordination).

Product variety and modularity are not the only variables that matter when investigating the impacts of NPD on the supply chain. The product line newness level (or degree of innovativeness), a factor controlled during product development, can have considerable impacts on the supply chain. In addition, not only strategic issues such as supply chain design can be affected by new product introductions, but also the supply chain operations issues, which are tightly related to the daily business. In total, the alignment framework includes three NPD variables: modularity, product variety and innovativeness. The analysis shows that modularity does not necessarily reduce configuration complexity. This has been shown in Figure 3.13.



Proposition	Degree of evidence
P1: Modularity increases the level of variety offered to the customer	Partially supported
P2: Modularity reduces the level of supply chain configuration complexity	Not supported
P3: Modularity reduces the level of supply chain collaboration complexity	Supported
P4: Innovativeness increases the level of supply chain collaboration and configuration complexity	Supported – Innovativeness has a stronger effect than variety on supply chain configuration complexity
P5: Innovativeness increases the level of supply chain coordination complexity	Supported – Innovativeness has a stronger effect than variety on supply chain coordination complexity
P6: Variety increases the level of supply chain configuration, collaboration and coordination complexity	Partially supported
P7: Supply chain configuration and collaboration complexity and supply chain coordination complexity	Partially supported
P8: Supply chain performance depends on the matching between NPD and supply chain design	Supported
P9: Supply chain performance depends on the matching between NPD and supply chain planning and management	Supported

Figure 3.13: Framework for NPD and SCM alignment (Pero et al., 2011)

On the other hand, the research gap which arises in this model is that the supply chains are generally investigated with respect to supply chain design and supply chain planning and management.

In addition to the insights which could be gained from this research, this study raises many questions that can serve as directions for future research. The first question, worth investigating, concerns the product features and their impacts of alignment. In order for a firm to achieve alignment, is it actually helpful not to set up all product design variables at their extreme values? Another question, worth examining, is related to the impacts of variety on the supply chain network.

Finally, is it possible to provide stronger evidence that the performance of supply chains strongly depends on NPD-SCM alignment?

3.11.5 Product Design and SC Framework

Khan et al., (2012) has considered an important supply chain aspect that whether or not products can be manufactured to the desired specifications and with the right materials in adequate supply. And whether that final product is packaged and transported in the most efficient manner, which makes design an important pre-cursor to supply chain decisions and highlights the need for better design/supply chain co-ordination. Good supply chain management practice will require businesses to integrate processes such as procurement and logistics along with design to fully reap the benefits of a design driven supply chain.

The differences in both arguments could lie in the methodical framework used to investigate the phenomena, the first is a purely quantitative study while the second a qualitative. One could argue that this has a major impact on the research outcomes in that it is difficult to quantify the benefits of a strategy which does not account for the wider impacts in the supply chain or the intangible benefits of design investment. With customers increasingly demanding greater product variety at lower cost, design has become an important means by which companies can gain a competitive advantage in their supply chains. This has been shown in Figure 3.14

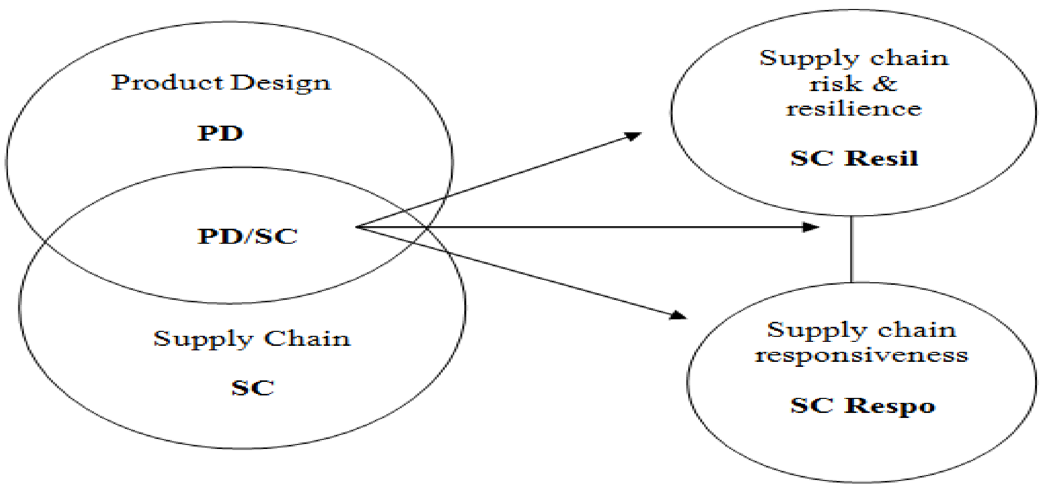


Figure 3.14: Framework for PD and SC (Khan et al., 2012)

The purpose of this paper was to investigate the interface between product design and the supply chain and identify how this interface impacts on a firm's supply chain responsiveness and supply chain resilience. The result of using this model shows the alignment of product design with the supply chain important in improving competitive advantage for the focal company, but it also has a significant impact in improving supply chain resilience and supply chain responsiveness. The alignment of product design and supply chain has contributed to the growth of the company by enabling a quicker development of new products with shorter time to market, and supply chain risk management by avoiding potential supply chain disruptions, due to misalignments between the actual requirements from customers and the "response" of the supply chain.

The results of using this model have a number of theoretical implications, which generates the gap in this proposed model. It only expands and contributes to the growing debate on supply chain risk and signifies the importance of managing product design as a tool for mitigating supply chain risk. Secondly, it only highlights the benefits of adopting a "design centric" approach in supply chain management and third, it only identifies a positive correlation between supply chain responsiveness and supply chain resilience after aligning product design and the supply chain.

3.12 Research Gaps Identified

With only the help from SCM, it is possible to design, organize, and execute all the activities from planning to distribution along the entire value chain There is no second opinion exists that SCM and NPD are related to each other, for the product to be design with the help of NPD tools and then to distributes the product with the help of supply chain features.. The other benefit of SCM, that it helps organising and using more productively the network of suppliers, manufacturers and distributors (Childerhouse et al., 2002; Vonderembse et al., 2006).

The literature suggests that most SCM models and methods, assume that product design decisions have been already taken (Simchi-Levi et al., 2002). But recently, it has been observed that there is a demand arises for the coordination of SCM and NPD (Hult and Swan, 2003; Rungtusanatham and Forza, 2005). The problem lies in automotive sector is that the supply chain covers a wide area of business cycle and on the other hand the new product development relates only to manufacturing. So linking these two attributes of the business is not an easy task to accomplish and possibly the major reason, not to discuss in detail in existing literature. The summarised research gaps have been shown in Figure 3.15.

Topic	Research Gap	Reference	Research Question
Alignment	Lack of case studies describing how companies actually integrate and align product design with the supply chain.	• Kotler and Rath (1984). • Ulrich and Eppinger (2000). • Burkett (2006).	How do companies align product design with the supply chain and what is the impact of product design /supply chain integration?
Change	Lack of evidence on how theory is converted into practice	• Krishnan and Ulrich (2001). • Abecassis (2006).	How do companies confront organisational change?
Design	Lack of evidence of the way concurrent design should be exploited and of the extent of its practical use.	• Dowlatshahi (1996, 1999). • Charles Fine (1998). • Balasubramanian (2001). • Sharifi and Pawar (2002).	How can companies exploit concurrent design practices?
Integration	Lack of investigation on how product development can help companies in integrating with supply chain.	• Fisher (1997). • Van Hoek and Chapman (2006, 2007). • Pero *et al.*, (2011). • Khan, Christopher and Creazza (2012).	How to integrate the interface between product development and the supply chain on improving a firm's supply chain performance? How do companies actually integrate?
Response	Lack of evidence of the way companies can become more responsive by better managing the product design supply chain interface.	• Fawcett (1994). • Christopher and Towill (2000) and Christopher and Peck (2003). • Sharifi *et al.*, (2006) • Ellram *et al.*, (2007).	How does the interface between product design and supply chain impact on improving a firm's supply chain responsiveness?

Figure 3.15: Literature Evidence of Research Gap

The other issue which has been raised by the literature review is that until now there is no evidence of detailed framework exists which shows the linkage between SCM and NPD. In almost every business sector they need a tool which shows the impact of linking (Pero *et al.*, 2011). The existed frameworks covers the aspects of different domain like in Fisher's pioneer model looked at only the relationship between physically efficient supply chain and the market responsive supply chain. The Van Hoek & Chapman's model missed the efforts to leverage supply chain capability as part of the product development team for greater market impact and revenue growth through new product introduction.

In Matopoulos Framework, there is only an aspect of designing and governing the supply chain exists. Matopoulos did not discuss the aspects of decision making points. In the next important framework of Pero, the research gap which arises is that the supply chains are generally investigated with respect to supply chain design and supply chain planning and management. But this aspect was missing and again the other gap which is clearly identified is that the key decision points were not evaluated. In the end the latest existed model of Khan et al, in 2012, the aspects which was discussed is only supply chain risk and resilience so the factor which was largely missing is of product design and the key decision point's impact on the supply chain performance.

By summarising all the relevant research gaps in the domain of alignment, change, design, integration and response, the major literature evidence in the same domain has been discussed and tried to identify the relevant research gap within that literature evidence and the question which arises after analysing these existing literature in table below.

In addition to the insights which could be gain from this research, this existed model study raises many questions that can serve as directions for future research. The first question, worth investigating, concerns the product features and their impacts of alignment. In order for a firm to achieve alignment, is it actually helpful not to set up all product design variables at their extreme values?

Another question, worth examining, is related to the impacts of key decision making points on the supply chain network. Finally, is it possible to provide stronger evidence that the performance of supply chains strongly depends on NPD-SCM alignment? Therefore, the main goal to achieve in this research is, to investigate and then analyse the key decision making points in the integrated supply chain and then on the basis of this identification, the functional requirement for the development of the methodology is required.

3.13 Summary

The above chapter has reviewed the existing literature which has worked as the foundation of the research according to the phases of the research plan. In a start, it has been identified what is the motivational aspect of this research and how the desired output from this research can be achieved. So started with the ideas of innovation and invention, and then described the idea of Change management which leads us to goes towards the business process management. To reach the next phase of the research objective of modelling of the information flow across the supply chain during new product development, different modelling tools have been identified which further leads towards the literature review in the field of NPD process and then SCM. As described in scope of research, the automotive supply chain has been chosen in this research to do the analysis. Then in the middle of this chapter, Integration of NPD with SCM has been reviewed which leads towards the review of the existing framework in the NPD – SCM integrated environment. Then in the end, the research gaps have been identified and summarised with all the relevant existing literature which justifies involvement in this research. Now, to cover these gaps, the next chapter will discuss the evolution of research methodology which is applied in this research.

Chapter 4: Industrial Investigation and Case Study

4.1 Introduction to the Collaborating Company

Large international automotive Original Equipment Manufacturer (OEM) Ford, operating globally in all regions has been considered in this research. Ford Motor Company, a global automotive industry leader based in Dearborn, Michigan in the United States, manufactures or distributes automobiles across six continents. With about 164,000 employees and about 70 plants worldwide, the company's automotive brands include Ford and Lincoln. Ford's business is organized by four regional segments: North America, South America, Europe and Asia Pacific and Africa. North America and Europe are their largest markets. The automotive industry in Europe is intensely competitive, and expected to intensify further. Ford's production with respect to region has been shown in Figure 4.1.

Ford's Regions at a Glance

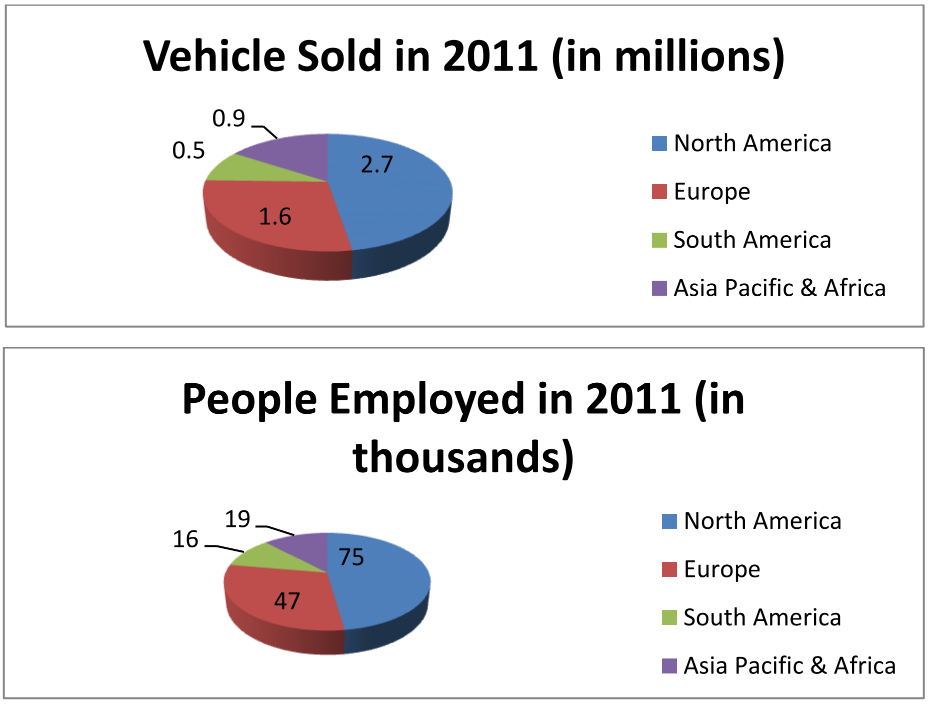


Figure 4.1: Ford Motors Manpower vs. Production rate globally

(Ford Fiscal Report, 2013)

Ford Motors UK

Ford UK is the biggest motor company in the UK, with seven locations and over 550 Dealerships. They also have several large plants, where they manufacture vehicles, engines and transmissions, as well as parts and components. In total, Ford UK and its dealers employ around 35,000 people in product development, manufacturing, sales and marketing, and service roles (Ford, 2013)

They have been Britain's best-selling car brands for over 30 years, and their commercial vehicles have been market leaders since 1965. They currently sell around 440,000 cars and commercial vehicles each year. And one of their biggest success stories has been the Ford Focus: it's been the UK's most popular car each year since its launch in 1998.

The Research and Development Centre in Essex (which has been contacted to do case study in this research) works on new engines, commercial vehicles and transmissions. It is a home to over 3,000 engineers and extensive R&D facilities, including high speed and special surface tracks. There are also indoor laboratories including rolling roads, crash simulators and test cells that can house up to 15 vehicles and 100 engines. All of this means they can really put prototype engines and vehicles through severe testing regimes. That way they can ensure they meet stringent quality standards, long before they reach the customer.

They have four major manufacturing sites around the UK, employing thousands of people. At the Dagenham plant, they produce around a million diesel engines a year, from a 1.4 up to a high performance V8 unit. Thanks to its strategic position on the Thames, plus excellent motorway and rail connections, Dagenham is also their UK transport hub: thousands of vehicles, engines and components pass in and out daily. Their plant in Bridgend, Wales, is the centre of their petrol engine production, for everything from a 1.25 all the way up to a 4.4 litre V8 engine. At Dagenham and Bridgend they make and supply engines to other car brands. The historic port of Southampton is home to the iconic Ford Transit. And finally, Halewood plant is run jointly with transmission specialists Getrag. It is situated on the same site where Jaguar and Land Rover vehicles are assembled. This specialist gearbox plant supplies Ford cars and commercial vehicles.

Ford's Supply Chain

Ford's suppliers are critical allies in helping company to achieve success in the marketplace and meet their sustainability goals. They promote long-term relationships with suppliers and seek alignment with them on sustainability related issues such as greenhouse gas emissions management and human rights.

They work to ensure that Ford and their suppliers have management systems in place to mitigate potential risks, ensure continuity of supply and improve the overall sustainability of the complex global automotive supply chain. Their aim is to leverage supply chain – and their industry – to make a positive impact in the markets in which they do business.

They have taken a three-pronged approach to engagement with suppliers on sustainability issues:

- **Building Capability at Individual Supplier Facilities:** They work with suppliers to encourage the management of sustainability issues. They conduct supplier training supported by assessments and remediation at individual factories.
- **Engaging with Strategic Suppliers:** Ford and their strategic production suppliers work together at the corporate level to align and enhance approaches to a range of sustainability issues.
- **Collaborating with Peers in the Automotive Industry:** To achieve truly lasting change, they are leading work with their counterparts in the automotive industry, through the Automotive Industry Action Group (AIAG), to develop common approaches to a full range of sustainability issues (Ford, 2013)

Ford's Industry Collaboration

Ford believes that collaborative action within their industry allows them to more effectively influence all levels of the automotive supply chain. They have taken an "open book" approach to supply chain work, sharing best practices, challenges and opportunities with others in industry. They primarily work at the automotive industry level through the Automotive Industry Action Group, or AIAG. The AIAG is a North American member-based, non-profit industry group specializing in supply chain issues. It supports industry efforts to establish a seamless, efficient and responsible supply chain. Member companies donate the time of individuals to work at the AIAG, which operates as a non-competitive, open forum that is intended to develop recommendations and best practices for reducing complexity and ensuring alignment on common issues across the industry. This committee currently focuses on five main issues: global working conditions, conflict minerals, greenhouse gases, chemicals management and reporting, and health care value. Ford staff chair three of these work groups: chemicals management and reporting, working conditions, and conflict minerals. Ford has also contributed an "executive on loan" to the AIAG to support the industry's work and share what they have learned from working on these issues within their own operations.

Focus Areas for Industry Cooperation on Supply Chain Management

The work of the companies at the AIAG continues on several fronts (Ford, 2013):

- Exploring an industry response to raw materials sourcing and transparency challenges.
- Providing common guidance and tools for responsible procurement.
- Continuing to expand the factory-level supplier training program for a responsible supply chain.
- Increasing supplier ownership of corporate responsibility issues through an expansion of engagement opportunities.
- Developing additional resources and networks that will ensure the successful communication of responsible procurement expectations throughout the automotive supply chain.

For all work streams, the AIAG and the companies are actively reaching out to others in the automotive supply chain, including global automakers and heavy truck manufacturers, industry associations and major automotive suppliers, as well as cross-sectorial initiatives. Broader participation will be needed to achieve the vision of an industry-wide approach to promoting supply chain sustainability.

Among their thousands direct and indirect supplier, one of the UK local Tier 1 suppliers has been contacted with the consultation of OEM. This company is OEM's Tier1 direct supplier which provides them machined casting parts for their car engines body. Tier 1 has got one sub supplier named Tier 2 supplier which provides them material of casting parts. The relationship of OEM, Tier 1 supplier and Tier 2 supplier has been shown in Figure 4.2.

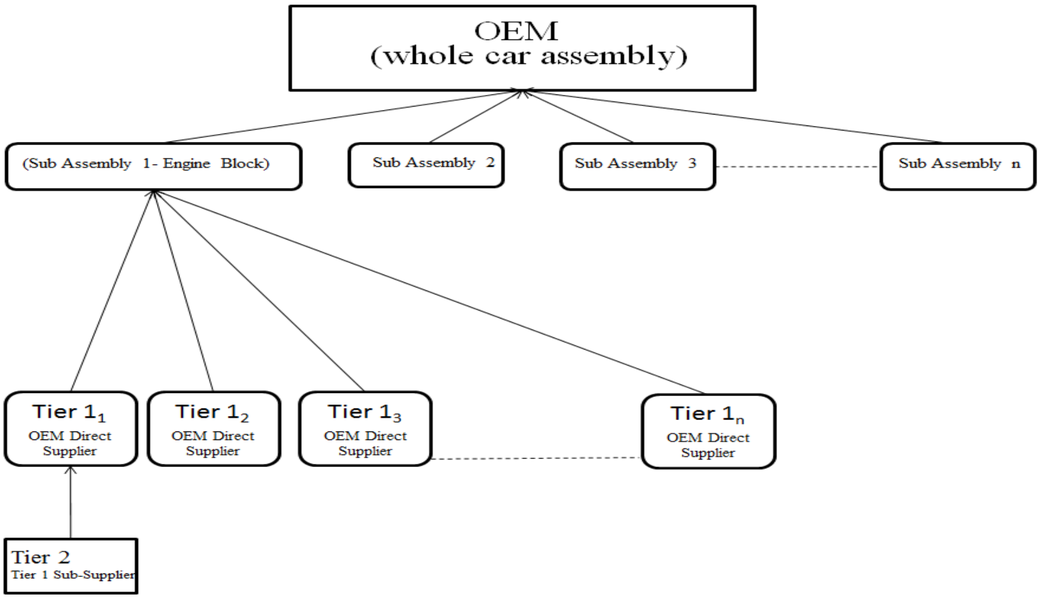


Figure 4.2: OEM relationship with Tier 1 and Tier 2 supplier

For the purpose of Industrial analysis, the OEM and Tier 1 relationship has been analysed in this research. The following section will presents the industrial investigation results.

4.2 Purpose of Industrial Investigation

To reach the goal of industrial case analysis, it is to understand clearly the purpose of the investigation. . In this methodology, model needs to be executed based on a real structure of an enterprise, so the informal discussion points has been used in order to get the correct AS – IS Industrial situation and to suggest TO – BE situation.

Initial point of contact was the OEM’s drive line supervisor. In the next stage the basic research on the OEM, like their sales, product range, suppliers, supply chain players and their stake holders has been done in order to get the clear business picture.

After looking at the overall picture of OEM and their supplier relationship, the informal discussion points has been developed which will be shown in the next section. The people who have been contacted to do the industrial investigations are as follows.

In this research, OEM‘s Product development facility is being considered as OEM which is based in Essex–UK. It works on new engines, commercial vehicles and transmissions. The department which has been contacted is the engine block assembly. The documentary evidence related to industrial investigation is attached with this thesis and will kept be the University of Greenwich. The personnel who have been contacted for informal discussions are:

- PD Manager.
- Supervisor Drive line Assembly.
- Supervisor Production.
- Sales Manager.
- PD Engineer.
- Procurement Manager.

OEM’s direct supplier (Tier Supplier) for machined casting part named Amtek Auto Group, comprised of Amtek Auto, Amtek India and Ahmednagar Forgings, is one of the largest integrated component manufacturers in India, with a strong global presence. It has 43 world class manufacturing facilities located in India (39) and Europe (4). The personnel who have been contacted for discussions are:

- Sales Director.
- Production Manager.
- Engineering Manager.
- PD Manager.
- Process Engineer

Tier1’s sub supplier (Tier 2 supplier) for casting parts as they do only manufacturing for Tier 1 supplier. The personnel who have been contacted for discussions are:

- Production Manager.
- Head of Casting Department.
- Sales Manager.

4.3 Proposed Discussion Points for Tier 1 Supplier

The points which have been used to do the discussion with the personnel of OEM and Tier 1 supplier are described below.

(i) Does a high level flow chart exist which captures the key inputs, outputs and required decisions at the various stages from initial concept through to Product development, onwards to the final stages of Manufacturing and Distribution?

(ii) What are your internal methods/approaches/considerations for the following?

- Design and Manufacture feasibility.

(iii) What are the internal aspects that need to be considered to overall feasibility, such as Make/ Buy Decision?

- Cost analysis – all the various inputs considered to ensure a sustainable business
- Product Capacity Planning -Different considerations such as machine utilization, forecasting etc.
- Inventory considerations/management - Cost associated with inventory, buffer analysis.

(iv) Open discussion about the kind of problems/challenges faced during the above phases?

(v) Manufacturing planning and logistics:

- Material Requirement Planning (MRP)
- Scheduling
- Inventory
- Goods inwards
- Warehouse/Distributor dispatch

4.4 OEM Generalised Product Development Process

To conduct the industrial investigation in OEM, generalised product development processes has been shown to verify the AS-IS situation. It shows that when program initiate (where OEM links with Tier 1 supplier), it goes through six different phases. Starts with Program initiation which leads to program planning phases, in which the OEM creates the plan for the part to follow in the whole cycle of collaboration. In the next stage, product confirmation phase comes in, where the Tier 1 supplier gets all the confirmations from the OEM after showing the desired output beforehand. Then OEM has to go through the design validation phase, where OEM re confirms the entire design attributes with the consultation of the Tier 1 suppliers. Next phase is of process validation, where Tier 1 suppliers cross checks their finance side of the project to make sure they achieved their desired cost benefit analysis. In the end the whole cycle of processes goes in the stage where it gets the approval of starting the production.

The other complexity is as it involves different suppliers with varied supply chain strategy for each sub part and it takes too much cost and time to finish that. So the detailed OEM product development process has been generated in light of literature review to keep it within the scope of this research and to work for proposed framework is described in next chapter.

4.5 Tier 1 Product Development Process

After analysing the OEM's product development process in line of integrating with supply chain, it has been observed that in the first step when OEM asked their Tier1 supplier for the quotation through RFQ (Request for Quotation) document. By looking at the Figure 4.4, it can be seen that when the OEM contacts the Tier 1 supplier through RFQ (Request for Quotation), they send the enquiry to supplier. At that point Tier 1 supplier cross check the priority of that order. If it is required to send it through, then the sales department send it to sales administration which load this request into the main frame of the company and then pass it to the engineering administration department.

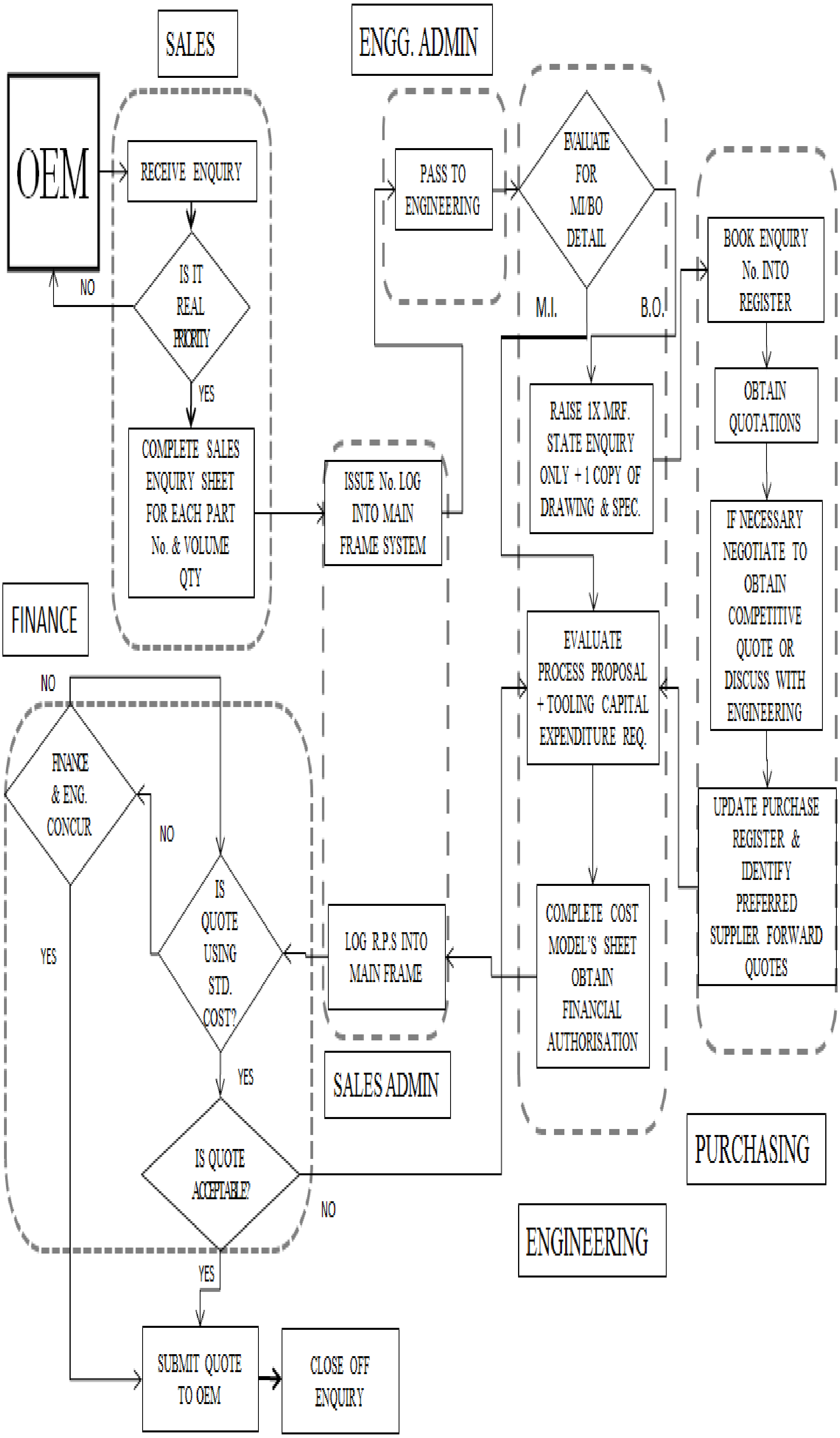


Figure 4.4: RFQ Process Overview between OEM and Tier 1 Supplier

When it reaches the engineering department, they have to generate the MI (Material Information) and Design BOM (Bill of material) of that part. For BOM they need to analyse the engineering drawing and then after cross checking the inventory, they contact the purchasing department if required to order more material.

On the other hand for MI, engineering department evaluates the tooling capital expenditure and process proposal. In the end, the engineering department completes the cost model sheet which includes the overall cost of the production and sends it to finance department for authorisation.

In the last stage of RFQ process, the finance department does the cost benefit analysis and gives approval or disapproval to the company based on the recommendation of the entire concerned departments. As a whole in the above process, company's sales, engineering and purchasing departments are involved.

4.6 Tier 1 Contract Review Process

During the same initial phase while they were negotiating with the Tier 1 supplier for their casting part of the engine block assembly, they have to consider a lot of factors which potentially can affect their performance. They have to go through to review of the contract. The processes they follow to review the contract is described in Appendix IX.

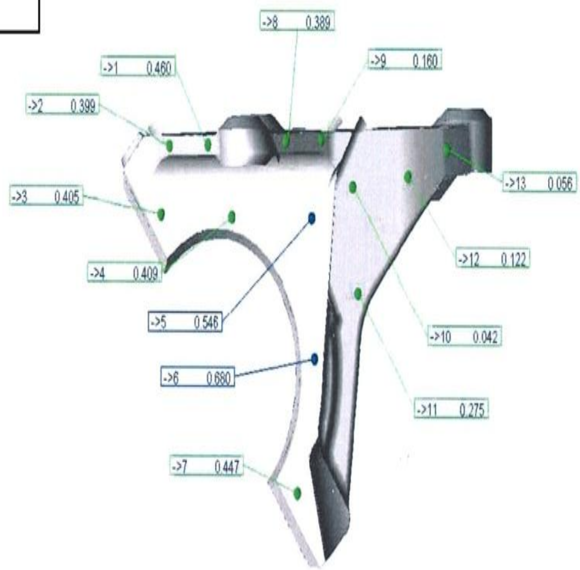
4.7 Description of the Example Part

The example part which is considered in this case study was a casting part of an engine block assembly. Tier 1 supplier performs machining operations on the casting part which is supplied by Tier 2 supplier. The casting operations are carried out over there at Tier 2 premises, So manufacturing data from Tier 1 supplier is not available. Tier 2 manufacturing data has to be taken under consideration in this research, as well as Tier 1 manufacturing data. The drawing of that example part has several views (See Appendix X for details). One of the views has been shown in Figure 4.5.

6S61-3K305-AA

User name | Date

Company Logo



6S61-3K305-AA
Impression 7
view 1

Sheet Thickness	0.000 mm	
Meas. mode surf		Meas. mode edge
Max. deviation	0.680 mm(6)	Max. Deviation
Mean deviation	0.338 mm	Mean Deviation
Min. deviation	0.042 mm(10)	Min. Deviation

Bestfit
Move
Rot.

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Figure 4.5: Drawing of the example part- View 1 (Courtesy of Ford)

4.8 The process plan

As Tier 2 supplier are the manufacturers of the example cast part, the process plan which they use for casting operations is described in Figure 4.6. It includes 15 processes, which starts from incoming of goods which are in shape of steel scrap. After having a quality check for different processes like pig iron, furnace additions and sand moulding at the incoming stage, the process goes in the domain of metal melting phase. In the next stage it goes in the metal treatment phase which leads to the phase of pouring the molten metal into the moulds.

Process Plan

FMEA Number : AA000683
Issue : 1
Part Number : 6S61-3K305-AA
Customer :

First Created :
Latest Issue Date :
Description :
Plant :

Process Number	Process Name Process Description
1	STEEL SCRAP GOODS INWARDS CHECK
2	PIG IRON GOODS INWARDS GOODS INWARDS CHECKS
3	FURNACE ADDITIONS GOODS INWARDS CHECK
4	MOULDING SAND GOODS INWARDS CHECK
5	METAL MELTING GREENSAND DUCTILE IRON PRODUCTION
6	METAL TREATMENT / INOCULATION DUCTILE IRON PRODUCTION
7	POURING MOULDS 3, 4& 5 BAY DUCTILE IRON TREATMENT LADLE
8	POURING MOULDS 3, 4 & 5 BAY DUCTILE IRON POURING LADLE
9	GREENSAND MOULDING 3 & 5 BAY DISAMATIC MOULDING LINES
10	SHOT BLASTING CLEANING CASTINGS WITH STEEL SHOT
11	INITIAL INSPECTION FOR CASTING & MOULDING DEFECTS
12	AUTO-GRINDING DRESSING OF CASTINGS WITH AUTOMATED GRINDING M/C
13	COINING PRESSING OPERATIONS
14	DUCTILE CASTINGS FINAL INSPECTION GRINDING & PRESSING DEFECTS
15	DESPATCH PACKAGING AND SENDING OF GOODS

Report : PROCESS PLAN REPORT Printed on : Time : by : Page 1 Authorisation

Figure 4.6: Process Plan of the example part at Tier 2 supplier (Courtesy of Tier 2 supplier)

Furthermore it goes in the phase of greensand moulding and after that it goes through the process of shot blasting. Then it goes in the initial inspection phase, where the quality aspects can be cross checked according to the customer requirement. In the next stage it goes into the auto grinding phase where the automatic grinding machine removes the remaining wastages and brings the part into the desired level of customer. After that process, the part goes into the phase of coining (pressing operation) and then before packaging and sending of part to the customer it goes into the second last stage of ductile casting final inspection. The detailed production flow chart is shown diagrammatically in Appendix XI

4.9 Quality Control Plan of the Example Part

In the next phase, when the part is being manufactured at Tier 2 supplier, it goes through this quality control plan which can be summarised in Figure 4.7.

Process No.	Process Name	Process Description
1	Raw Material Goods Inward	Laboratory Control
2	Material Control I	Base Metal & Inoculation Control
3	Moulding Control	Pattern & Sand Property Control
4	Material Control II	Pattern & Sand Property Control
5	Material Control III	Mechanical property Check
6	Ultrasonic Check	Sorting Suspect Material
7	Heat Treatment (Rework Only)	Control of Casting Heat Treatment
8	Shot Blasting	Initial cleaning of part after casting process
9	Inspection	Initial Inspection of Casting defects
10	Processing – Grinding / Fettling Operation	Finishing Operation Control
11	Coining	Pressing Casting to Required Dimension
12	Final Inspection	Inspection for Casting and Processing Defects
13	Despatch	Despatching goods to customer

Figure 4.7: Quality Control Plan of Tier 2 Supplier

The detailed quality control plan is described in Appendix XII. As the quality control plan has been applied to the example part, the laboratory material report has to be generated by the Tier 2 supplier. At the same time, the parts inspection report has to send to the OEM for approval before it goes to the final mass production. In the last stage, after getting approval from OEM, the part has to be submitted for final approval from OEM. These reports are described in Appendixes.

- Laboratory Material Report (Appendix XIII)
- Sample Inspection Report (Appendix XIV)
- Part Submission Warrant (Appendix XV)

4.10 Summary

In this chapter, the AS – IS industrial situation of the OEM Company has been defined. To start with, the brief introduction of the automotive OEM has been given. Then follow it up to discuss the example part, which has been decided after consulting the OEM. All the aspects relevant to the example part from process plan to production flow chart and the quality standards required to maintain the quality at the supplier ends has been discussed. In mid of the chapter, the RFQ process overview of OEM and Tier 1 supplier has been shown, which shows the integrated view within automotive supply chain context. In the end, the industrial investigation results has been described and evaluated. In the next chapter, the proposed framework will be discussed, which will cover the research gap and shows the linkage points in the integrated NPD-SCM environment.

Chapter 5: The Proposed Framework

5.1 Introduction

In previous chapters, the AS –IS processes have been identified in supply chain management of an automotive OEM through the use of industrial case study. Now the time is to propose the framework to cover the research gaps which was identified earlier for this research. In this chapter, the proposed framework will be discussed in detail.

The idea of integrating product development phases in supply chain has got so many different aspects, including the one which is focused that is, to identify the key decision making points in OEM and supplier relationship.

First, the aspects of new product development and then the supply chain processes of an automotive firm through AS - IS situation has been analyzed. Based on the simple supply chain concept of supply chain in which product starts from customer requirement and goes to the final stage where it has been delivered to customer in a market. The features of product development have been linked with the features of supply chain to get the benefits of the improved performance of the extended enterprise. As the literature suggests that supply chain covers the whole business aspects of the extended enterprise from suppliers' supplier to the customers' customer.

So in order to integrate the features of SC, the four basic drivers of supply chain (information, facilities, inventory and transportation), supply chain design (competitive or flexible w.r.t time response) and the supplier relationship has to linked up with the features of product development. On the other hand product development looks after only manufacturing aspect of the enterprise, so the features which can be linked are related to product manufacturing only.

The Figure 5.1 shows the overall view of the integrated NPD – SCM enterprise, which will enhance the performance in several aspects, which has been discussed in existing literature.

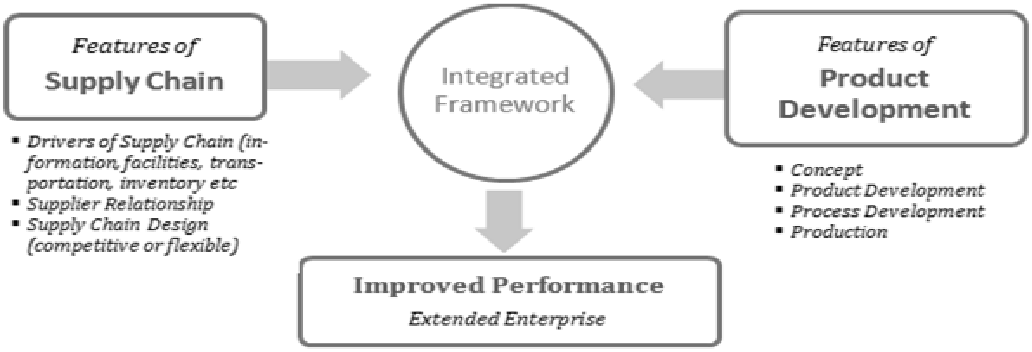

Figure 5.1 Idea of proposed framework to integrate features of supply chain with product development

5.2 Integrated Framework

The initial idea of framework which becomes the concept of developing the generalized framework has been developed in the early stages of this research while keeping in mind the entire research objectives.

The framework is derived from the generalised process extracted from AS – IS process. The basic activity which starts from customer requirement that leads to product development process and then production. After production, the delivery/distribution departments deliver the product to customer. These typical activities are shown in simplified flow in Figure 5.2.

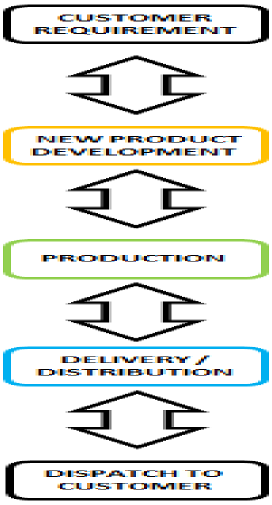

Figure 5.2: Typical Product Development and Manufacturing Activities

After placing the basic activities in initial idea of generalised framework, to make it more business oriented, it has been transformed into Figure 5.3, which illustrates the starting of the generic process between OEM, Tier 1 and Tier 2 suppliers. By looking at Figure 5.3, the relationship between OEM with suppliers is quite clear. In this research, the OEM (car assembly)'s Product development processes has been interlinked with OEM (sub-assembly engine block) product development processes.

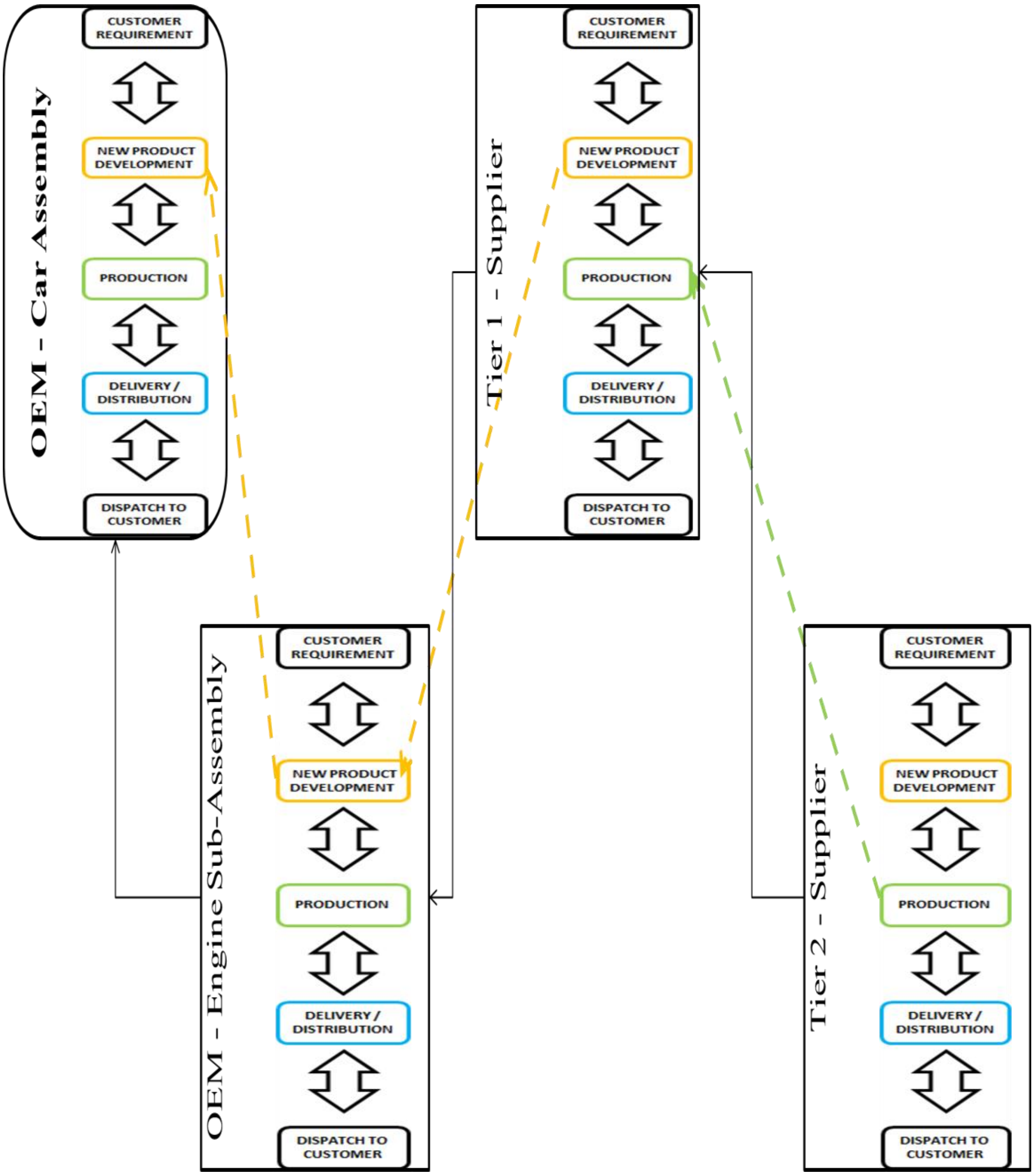

Figure 5.3: Initial idea of generalized framework within SCM Context

Engine block sub-assembly parts of OEM's PD processes are directly linked with Tier 1 supplier's PD processes, which is the main focus of this research. They work together with OEM on product development processes. Furthermore, Tier 1's production processes are interlinked with Tier 2 product processes. After analysing this relationship of OEM with Tier 1 and Tier 2 supplier, the generalised framework has been proposed which shows the true linkages among them in Figure 5.4.

5.3 Description of the Proposed Framework

This research analyzed the extended enterprise basic business processes, starts from customer requirement and leads into the new product development phase which gives instructions to the production department. After producing the product, the information goes into the delivery/ distribution department which eventually deliver the product to customer on requirement. The Proposed framework is shown in Figure 5.4.

By looking at the details of the extended enterprise in this research, the OEM generalized product development processes in the proposed framework which starts from program initiation step then goes in the program planning step.

Then after confirming the product, its design has to be validated according to design requirement. In the end, before it goes into the step of production, the process has to validate also according to the requirement generated in the early stages of NPD.

OEM (car assembly)'s generalised PD processes are linked with OEM (Engine block sub-assembly)'s PD processes which has got the same generalised PD processes like the OEM(car assembly) but with different detailed PD processes which is also linked with the same colour coding.

In OEM (engine block sub-assembly), the process starts off with the first phase of program initiation which is divided into four processes; first process is program start which leads into program strategy confirmation process which further goes into the program target compatibility check process and finally in the last process of the first phase is feasibility analysis. The detailed framework has been shown diagrammatically in Figure 5.4, which shows the true linkages among the OEM (Car Assembly), OEM (Engine Block Sub-Assembly), Tier 1 Supplier and Tier 2 supplier.

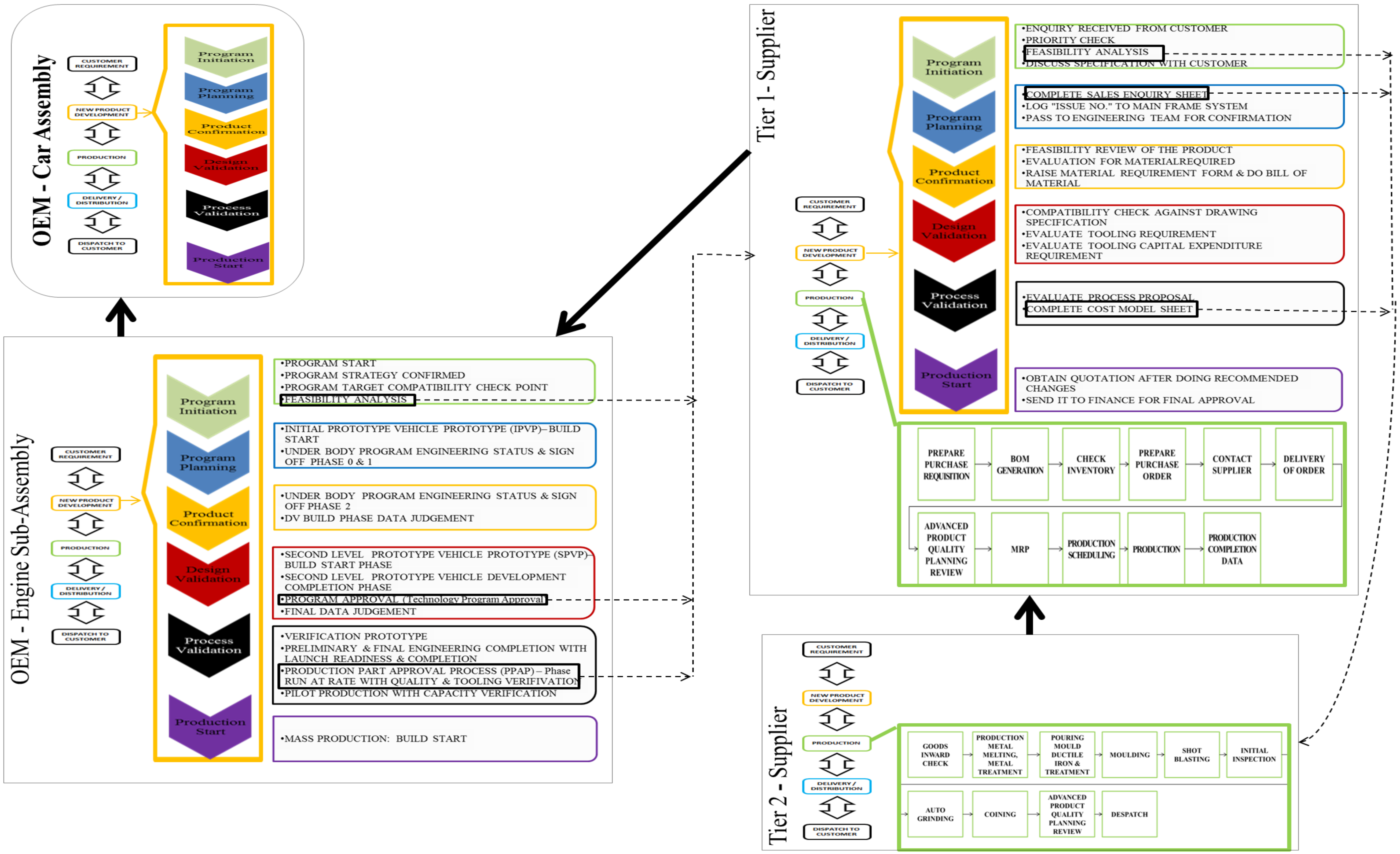

Figure 5.4: Detailed Collaborative framework in Product Development within Global Supply Chain

In the second phase i.e. Program planning phase, it can be divided into two processes. In first process of Initial prototype vehicle prototype (IPVP) the OEM does the build start stage which leads them into the next process of IPVP – Phase. Then the process comes of under body program, where under body engineering Phase 0 and then Phase 1 has been sign off.

Furthermore in the third phase of product confirmation, the OEM has divided it into two processes i.e. signing off the under body program phase 2 and then DV Build phase and Data judgement. The fourth phase design validation, has been sub divided into four processes i.e. Generation of second level prototype vehicle prototype (SPVP)-Build start, and then its complete sub phase. In the next process, the second level prototype vehicle development has to be completed and then in it goes for approval through technology program approval. In the last process it goes for final data judgement.

In the fifth phase of process validation, the OEM has divided it into four processes. Initially it starts with building of verification prototype which leads it into preliminary engineering completion. Then the final engineering completion step comes in play which creates launch reediness in the product line and then it goes for launch sign off step. Then in the process of production part approval phase 0 the product finally goes for quality verification in the next process of this phase. Later the step of tooling trial comes in play which leads the product into production verification through pilot production. In the last process of this phase, the capacity has been verified which send the product in the last phase of production start.

In the sixth phase of production start, the product starts off with mass production 1 build, leading it into job 1 step and finally mass production 2 build which ends the product development process at the OEM (Engine block sub-assembly)'s end.

In the proposed framework, it has been shown that the OEM (engine block sub-assembly)'s PD processes are interlinked with Tier 1's PD processes. To understand the Tier1's PD process, it is to be divided into the same generalised

PD processes. In a first phase of program initiation, the Tier 1 supplier cross check the priority of that order. If it is required to send it through, then the detailed specification has to be discussed with the OEM (engine block sub-assembly). Then in the next process, the feasibility analysis has to be done which is the main focus of this research.

Then in the next phase of program planning, the sales department send it to sales administration which load this request into the main frame of the company and then pass it to the engineering administration department. In the third phase of product confirmation, when it reaches the engineering department, they have to generate the MI (Material Information) and BOM (Bill of material) of that part.

In the fourth phase of design validation, for BOM they need to analyse the engineering drawing and then after cross checking the inventory, they contacts the purchasing department if required to order more material. On the other hand for MI, engineering department evaluates the tooling capital expenditure and process proposal.

In the fifth phase of process validation, the engineering department completes the cost model sheet which includes the overall cost of the production and sends it to finance department for authorisation.

In the last phase of production start, the finance department does the cost benefit analysis and gives approval or disapproval to the company based on the recommendation of the entire concerned departments. As a whole in the above process, company's sales, engineering and purchasing departments are involved.

At the same Tier 1 supplier's end, the production process has been interlinked with Tier 2 supplier's production process. Tier 1's production process, has been divided into several key important sub processes. It starts with the preparation of the purchase requisition based on the Bill of Material (BOM) which is generated in the second sub process. Then in the next process, the inventory has to be checked and then if required purchase order has to be generated and sends it to the supplier, who delivers the order back to production department which then does the Advanced Product Quality Planning Gateway Review, which is the main focus of this research, in production processes. In this APQP review process, the Tier 2 Supplier has been interlinked with Tier 1 supplier. Then in the next process of Tier 1's production process, Material Requirement Planning (MRP) has to be generated. This MRP facilitates the scheduling of the production which eventually gives the information to the production department to manufacture that part and finally in the end after production the data has to be generated which links the delivery/ distribution process of OEM to take the product for final assembly.

The Tier 2 supplier's end where the casting has been done as a production process has been interlinked with Tier 1's production process. At Tier 2 end, the production process starts with includes 15 sub processes, which starts from incoming of goods which are in shape of steel scrap. After having a quality check for different processes like pig iron, furnace additions and sand moulding at the incoming stage, the process goes in the metal melting phase. In the next process it goes in the metal treatment phase which leads to the process of pouring the molten metal into the moulds.

Furthermore it goes in the sub process of greensand moulding and after that it goes through the sub process of shot blasting. Then it goes in the initial inspection phase, where the quality aspects can be cross checked according to the customer requirement. In the next stage it goes into the auto grinding where the automatic grinding machine removes the remaining wastages and brings the part into the desired level of customer.

After that process, the part goes into the phase of coining (pressing operation) and then before packaging and sending of part to the customer it goes into the second last stage APQP review process as the final quality check with Tier 1's production department which is the main focus of this research. Then the product has to be shifted into the warehouse which then informs the logistics provider (either in-house or 3pl) to create the delivery order and finish the business process by delivering the product to the Tier 1 supplier of the OEM.

5.4 Summary

In this chapter, the description started off with the background requirement of NPD – SCM integrated framework. In the next step, the idea of linking features of SC like drivers of SC etc. with the features of NPD has been discussed. Then to carry on in the same theme, the basic idea of integration has been shown diagrammatically which leads the research in developing the initial idea of generalized framework based on the basic supply chain processes. After implementing these sub process the idea of generalized framework has been shown. Then on the basis of the industrial investigation and the literature review, the detailed framework which shows the relationships involved in NPD – SCM integration has been discussed in complete detail. OEM, Tier 1 supplier and Tier 2 supplier linkage has been completely described in the proposed framework which has been used to testify in the case study and the results will be discussed in the next chapter.

Chapter 6: Implementation Results and Evaluation

6.1 Introduction

According to research plan, after proposing the framework, the implementation results will be shown in this chapter.

6.2 Detailed NPD Processes of OEM

By using the same colour coding as used in the Figure 4.3 to elaborate the OEM product development processes, the detailed product development processes of OEM are shown graphically in Figure 6.1.

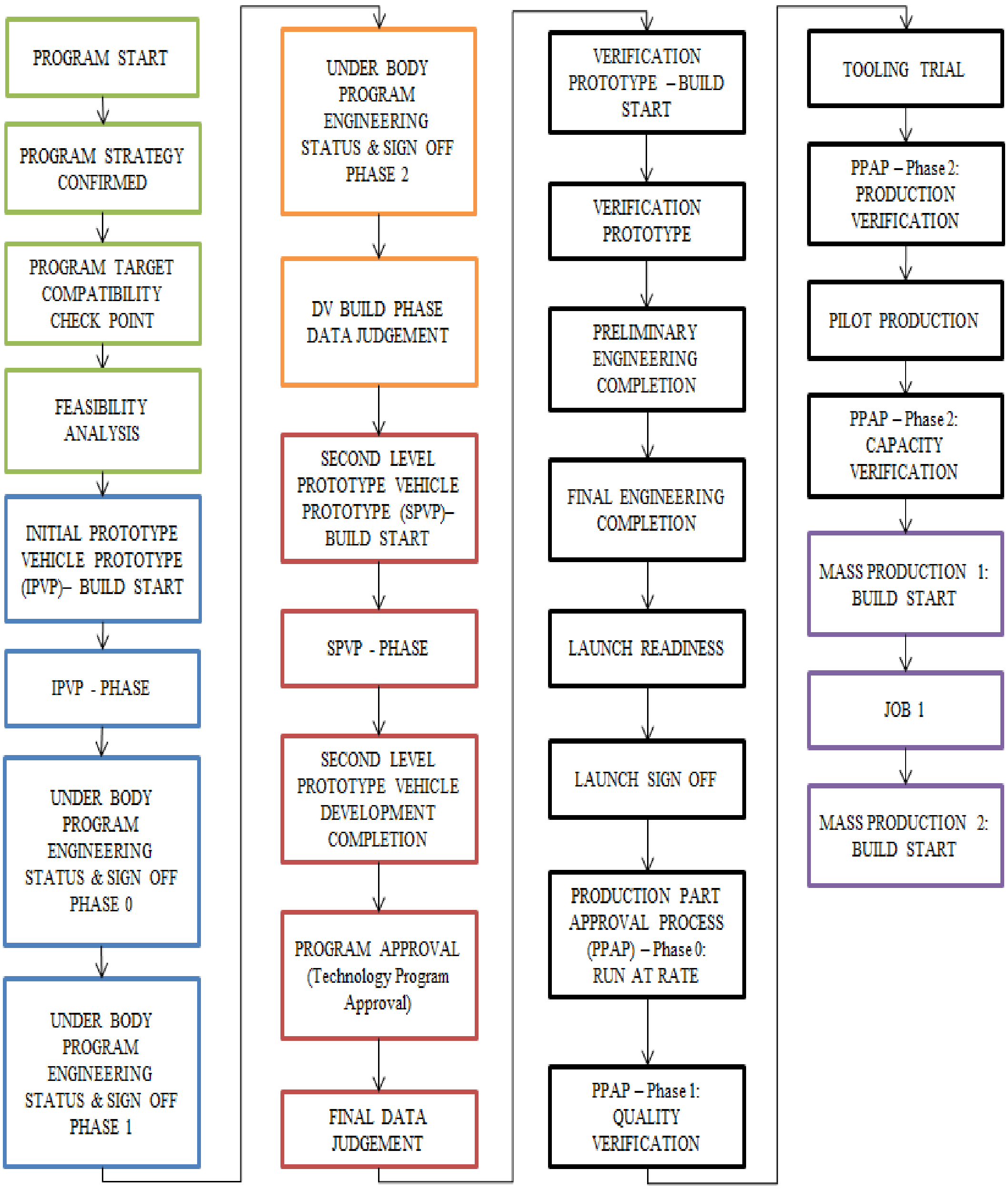

Figure 6.1: OEM's Detailed Product Development Processes

The process starts off with the first phase of program initiation which is divided into four stages; first step is program start then leads it into program strategy confirmation step which further goes into the step where program target compatibility check can be done and finally in the last step of the first phase is feasibility analysis.

In the next phase i.e. Program planning phase, the processes can be divided into four steps also. In first step of Initial prototype vehicle prototype (IPVP) the OEM does the build start stage which leads them into the next step of IPVP – Phase. Then the stage comes of under body program, where under body engineering Phase 0 and then Phase 1 has been sign off.

Furthermore in product confirmation phase, the OEM has divided it into two steps i.e. signing off the under body program phase 2 and then DV Build phase and Data judgement. The next phase design validation, has been sub divided into five steps i.e. Generation of second level prototype vehicle prototype (SPVP)-Build start, and then its complete phase. In the third step, the second level prototype vehicle development has to be completed and then in fourth step it goes for approval through technology program approval. In the fifth and the last step it goes for final data judgement.

In the fifth phase of process validation, the OEM has divided it into twelve sub steps. Initially it starts with building of verification prototype which leads it into preliminary engineering completion. Then the final engineering completion step comes in play which creates launch reediness in the product line and then it goes for launch sign off step. Then in the step of production part approval phase 0 the product finally goes for quality verification in the next step of this phase. Later the step of tooling trial comes in play which leads the product into production verification through pilot production. In the last sub step of this phase, the capacity has been verified which send the product in the last phase of production start.

In the sixth phase of production start, the product starts off with mass production 1 build, leading it into job 1 step and finally mass production 2 build which ends the product development process at the OEM's end. As Tier 1 supplier, is involved in the project review process, in which apart from the obvious involvement of the manufacturing department, their quality department has now a role to play also. At the same time the Tier 1 supplier have to do the Feasibility Review, to identify their key decision making points which will be discussed in next chapter. After the Feasibility review Tier 1 supplier goes for the advanced product quality planning gateway review, which is the last stage before the part goes on a production.

6.3 Linking Product Development of OEM and Tier 1 Company

By transforming the detailed product development processes of OEM in the generalised product development process, while using the same colour coding as used in Figure 4.3 to elaborate OEM generalised product development processes, with sub-processes as shown in Figure 6.2.

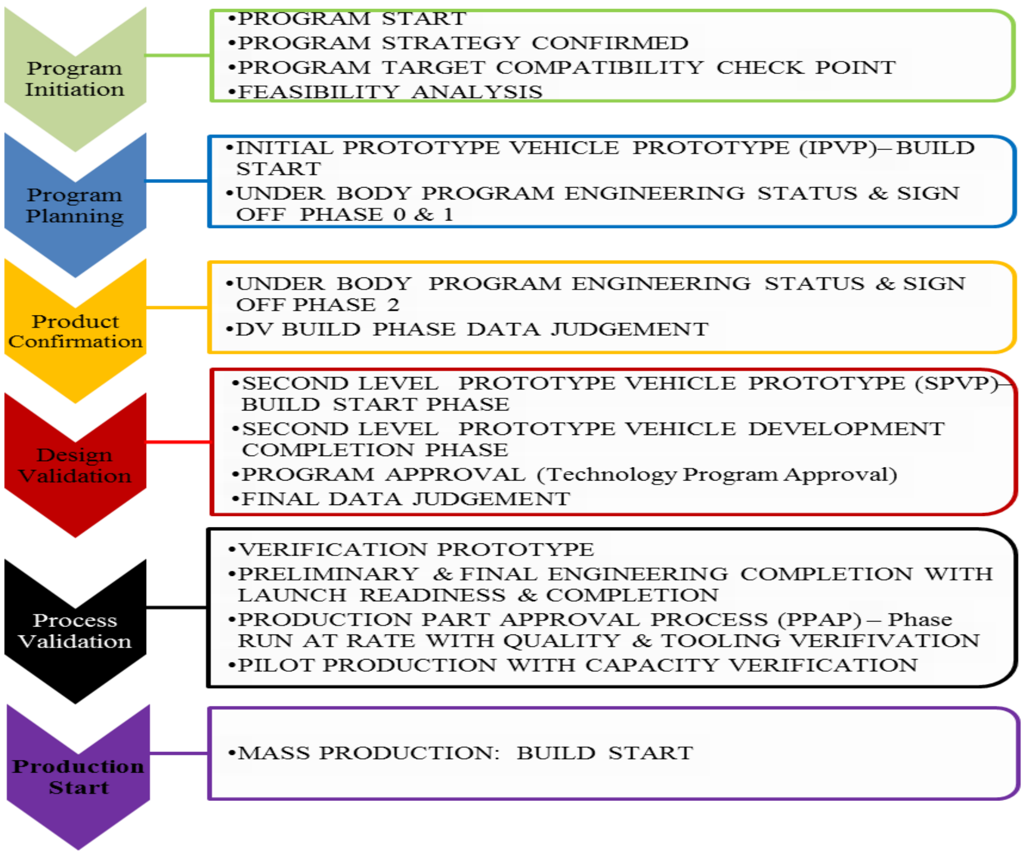

Figure 6.2: OEM detailed Product Development Processes

In the same way, when the OEM asked their Tier1 supplier for the quotation through RFQ (Request for Quotation) document, the Tier 1 supplier goes through these detailed product development processes which are described in Figure 6.3, while keeping in mind the same colour coding used in OEM detailed product development processes.

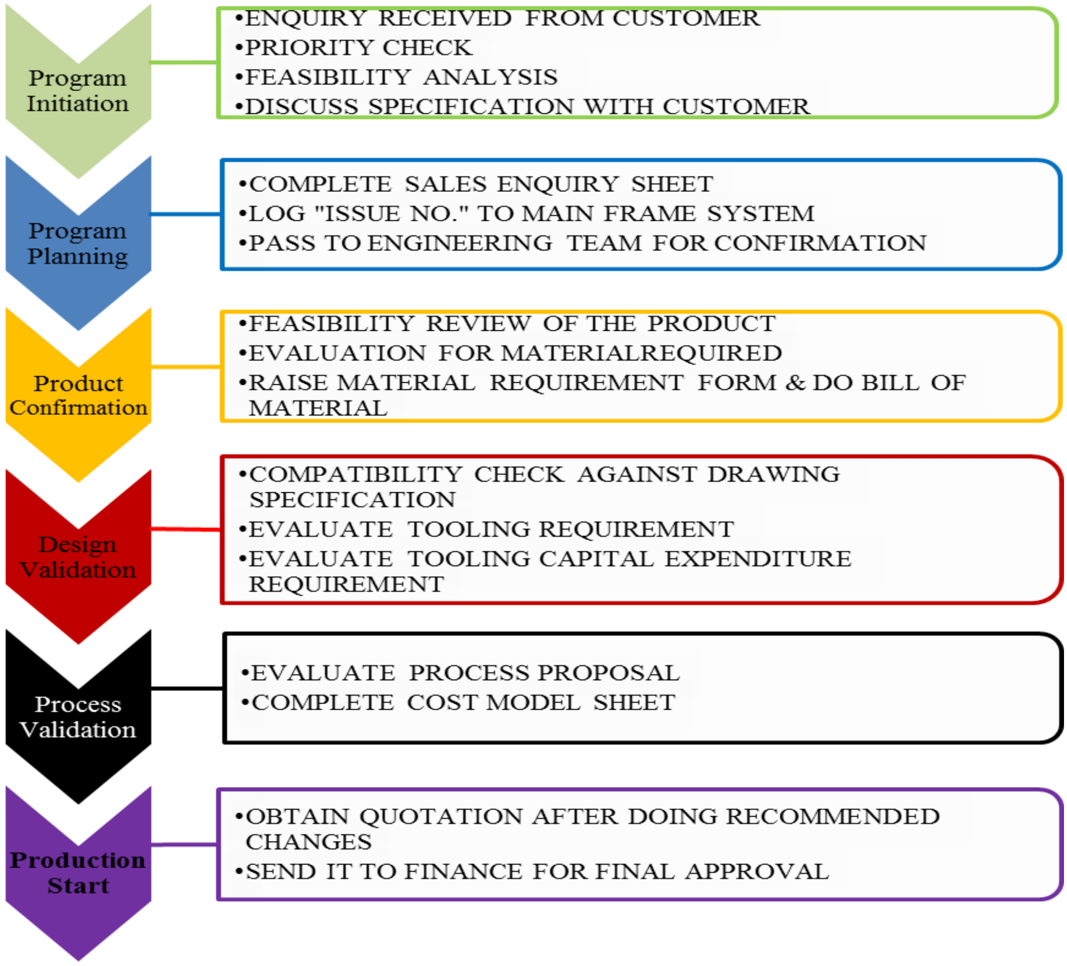

Figure 6.3: Tier 1 Product Development Processes

By looking at Figure 6.2 and 6.3, it is evident that there are different integrated points exists. These integrated points can further be analyzed to see the key decision making stages and the effect of these key decision making points.

In order to see the integrated points, these detailed product development processes of the OEM and the Tier 1 supplier has to be linked together. This has been done in the Figure5.4.

By looking at the details of the extended enterprise in this research in Figure 5.4, the OEM generalized product development processes in the proposed framework which starts from program initiation step then goes in the program planning step.

Then after confirming the product, its design has to be validated according to design requirement. In the end, before it goes into the step of production, the process has to validate also according to the requirement generated in the early stages of NPD.

OEM (car assembly)'s generalised PD processes are linked with OEM (Engine block sub-assembly)'s PD processes which has got the same generalised PD processes like the OEM(car assembly) but with different detailed PD processes which is also linked with the same colour coding.

By looking at the Figure 5.4, the product development processes of the OEM can easily be identified. It starts from Program Initiation phase which is divided into four processes; first process is program start which leads into program strategy confirmation process which further goes into the program target compatibility check process and finally in the last process of the first phase is feasibility analysis, where feasibility analysis has to be done and then leads to program planning phase where the initial prototype of vehicle is generated.

Program planning phase can be divided into four processes. In first process of Initial prototype vehicle prototype (IPVP) the OEM does the build start stage which leads them into the next process of IPVP – Phase. Then the second process comes of under body program, where under body engineering Phase 0 and then Phase 1 has been sign off.

In the following phase of product confirmation, the OEM has divided it into two processes i.e. signing off the under body program phase 2 and then DV Build phase and Data judgement.in which the under body program has to be initiated which leads the PD into the next phase of Design validation.

Design validation phase has been sub divided into five processes i.e. Generation of second level prototype vehicle prototype (SPVP)-Build start, and then its complete sub phase. In the next process, the second level prototype vehicle development has to be completed and then in third process it goes for approval through technology program approval. In the last process it goes for final data judgement. In summary, the second level of the vehicle prototype has to be generated and then the product's final data has to be checked before it goes for program approval.

The next phase is of process validation, the OEM has divided it into twelve processes. Initially it starts with building of verification prototype which leads it into preliminary engineering completion. Then the final engineering completion step comes in play which creates launch reediness in the product line and then it goes for launch sign off step. Then in the process of production part approval phase 0, the product finally goes for quality verification in the next process of this phase. Later the step of tooling trial comes in play which leads the product into production verification through pilot production. In the last process of this phase, the capacity has been verified which send the product in the last phase of production start. In summary, this phase provides a prototype which has to be verified and all the quality and tooling verification needs to done which leads the product into the last phase of production start.

In the sixth phase of production start, the product starts off with mass production 1 build, leading it into job 1 step and finally mass production 2 build which ends the product development process at the OEM (Engine block sub-assembly)'s end.

In the proposed framework, it has been shown that the OEM (engine block sub-assembly)'s PD processes are interlinked with Tier 1's PD processes. To understand the Tier1's PD process, it is to be divided into the same generalised PD processes. Tier 1 supplier runs through the same phases but with different processes. Like in first phase of program initiation, the supplier has to cross check the priority and discuss the requirement by the OEM. If it is required to send it through, then the detailed specification has to be discussed with the OEM (engine block sub-assembly). Then in the next process, the feasibility analysis has to be done which is the main focus of this research.

In the next phase of program planning, the sales department send it to sales administration which load this request into the main frame of the company and then pass it to the engineering administration department and supplier has to complete the sales enquiry sheet which then passes it to engineering admin for the next phase of product confirmation.

In this phase, the supplier does the evaluation of material requirement in a form of MI and BOM. For BOM they need to analyse the engineering drawing and then after cross checking the inventory, they contacts the purchasing department if required to order more material. On the other hand for MI, engineering department evaluates the tooling capital expenditure and process proposal.

Furthermore, in the next phase of design validation, the supplier checks the tooling requirement and does the compatibility check against the drawing of the part which leads to the capital expenditure calculation.

In the phase of process validation, the evaluation of the process proposal has to be done with the completion of cost model sheet. In the last phase of production start, the finance department does the cost benefit analysis and gives approval or disapproval to the company based on the recommendation of the entire concerned departments. As a whole in the above process, company's sales, engineering and purchasing departments are involved.

At the same Tier 1 supplier's end, the production process has been interlinked with Tier 2 supplier's production process. Tier 1's production process, has been divided into several key important sub processes. It starts with the preparation of the purchase requisition based on the Bill of Material (BOM) which is generated in the second sub process. Then in the next process, the inventory has to be checked and then if required purchase order has to be generated and sends it to the supplier, who delivers the order back to production department which then does the Advanced Product Quality Planning Gateway Review, which is the main focus of this research, in production processes.

In this APQP review process, the Tier 2 Supplier has been interlinked with Tier 1 supplier. Then in the next process of Tier 1's production process, Material Requirement Planning (MRP) has to be generated. This MRP facilitates the scheduling of the production which eventually gives the information to the production department to manufacture that part and finally in the end after production the data has to be generated which links the delivery/ distribution process of OEM to take the product for final assembly.

The Tier 2 supplier's end where the casting has been done as a production process has been interlinked with Tier 1's production process. At Tier 2 end, the production process starts with includes 15 sub processes, which starts from incoming of goods which are in shape of steel scrap. After having a quality check for different processes like pig iron, furnace additions and sand moulding at the incoming stage, the process goes in the metal melting phase. In the next process it goes in the metal treatment phase which leads to the process of pouring the molten metal into the moulds.

Furthermore it goes in the sub process of greensand moulding and after that it goes through the sub process of shot blasting. Then it goes in the initial inspection phase, where the quality aspects can be cross checked according to the customer requirement. In the next stage it goes into the auto grinding where the automatic grinding machine removes the remaining wastages and brings the part into the desired level of customer. After that process, the part goes into the phase of coining (pressing operation) and then before packaging and sending of part to the customer it goes into the second last stage APQP review process as the final quality check with Tier 1's production department which is the main focus of this research.

Then the product has to be shifted into the warehouse which then informs the logistics provider (either in-house or 3rd party Logistics provider) to create the delivery order and finish the business process by delivering the product to the Tier 1 supplier of the OEM.

6.4 Tier 1 Feasibility Review Process

In the same phase the Tier 1 supplier goes through the feasibility review process which is described in Figure 6.4.

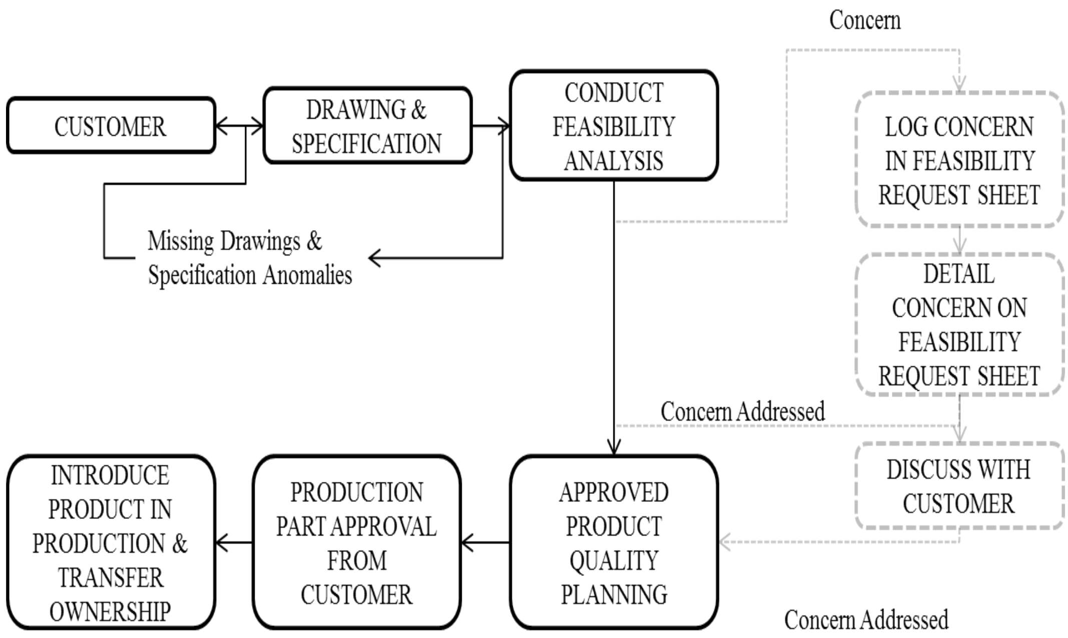

Figure 6.4: Feasibility review processes of Tier 1 Supplier

In this phase, when OEM contacts the Tier1 supplier, the supplier gets the engineering drawing from the OEM and check the specification with respect to customer (OEM) demand. After analysing the drawing features and specifications the Tier 1 supplier does the feasibility analysis. In which they cross check their capability against the customer requirement. They discuss with customer to address the concerns if arises and log these concerns in feasibility request sheet. After consulting with customer the supplier goes for the advanced product quality planning gateway review, which is the last stage before the part goes on a production and the transfer of ownership.

6.5 Tier 1 Advanced Product Quality Planning Gateway Review

In this Advanced Product Quality Planning phase in feasibility review process, all the relevant aspects has to be cross checked according to the requirement generated by customer in the initial phase of product development process. The APQP process start off with quality planning team check, where they perform the entire relevant quality control plan, which is described in chapter 4 and the details exists in Appendix.

After quality control check, the process Failure Mode and Effect Analysis has to be carried out, where all the relevant product safety issues have to be concerned. In the next stage, the control plan is introduced where simultaneous engineering teams works in product packing and measurement system validations which further takes the process into the preliminary process capability. Then in the next stage the initial sample trial has to be generated and on the basis of this, the product approval process comes in effect which leads the APQP process in the final stages of process monitoring and operator instruction generation. The detailed APQP gateway review process has been described graphically in Figure 6.5.

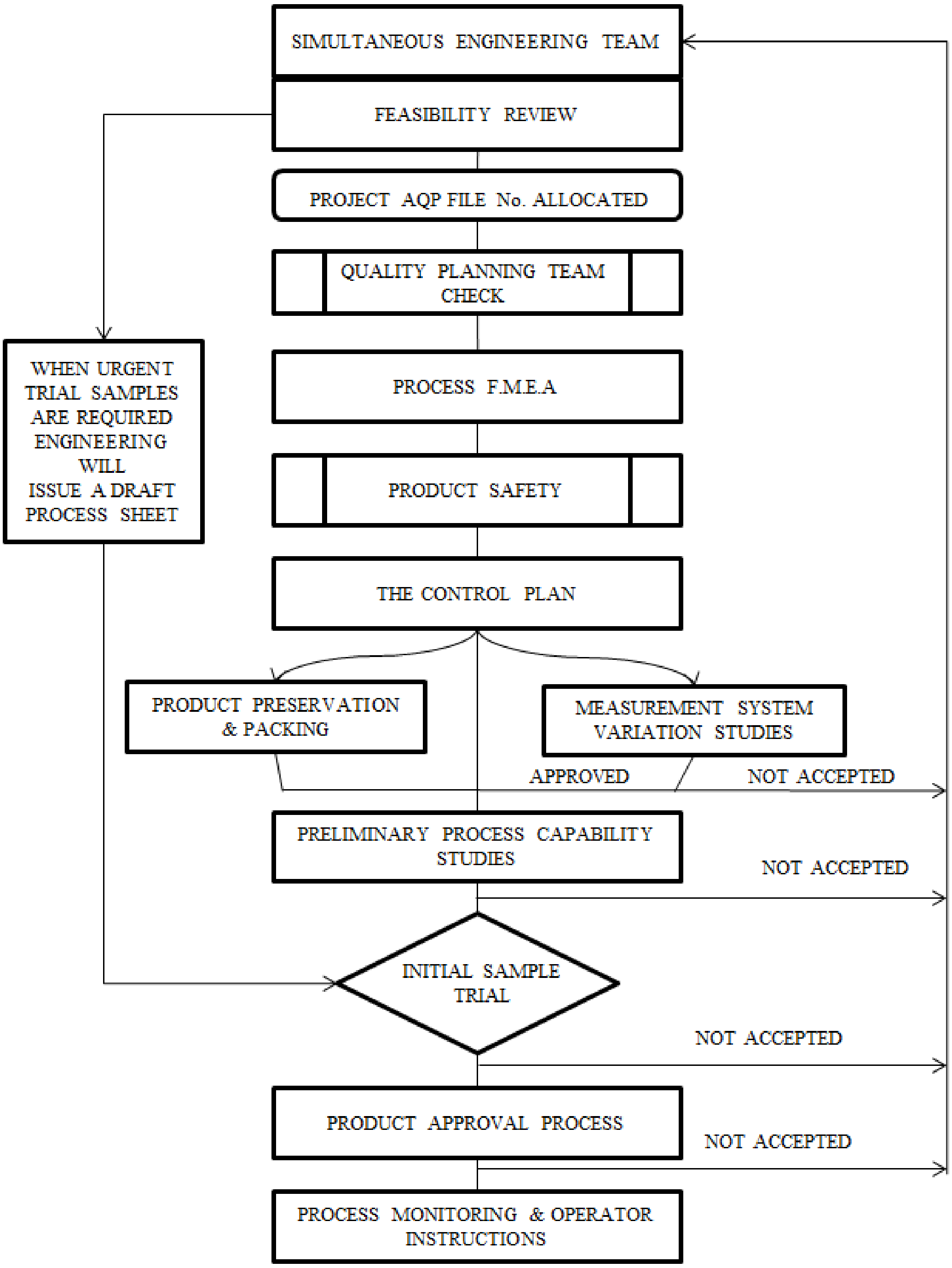

Figure 6.5: Advanced product quality planning gateway review of Tier 1 Supplier

6.6 Decision Points in Production, Warehouse, Logistics and Retailer

To start with, the famous Kenneth Preiss (1999) model has been considered, which says the primary variable in the flow of process is to look at the flows in and out of a single enterprise. The standard Kenneth Preiss model of a process has been developed while keeping in mid the basics of the principle and is shown in Figure 6.6.

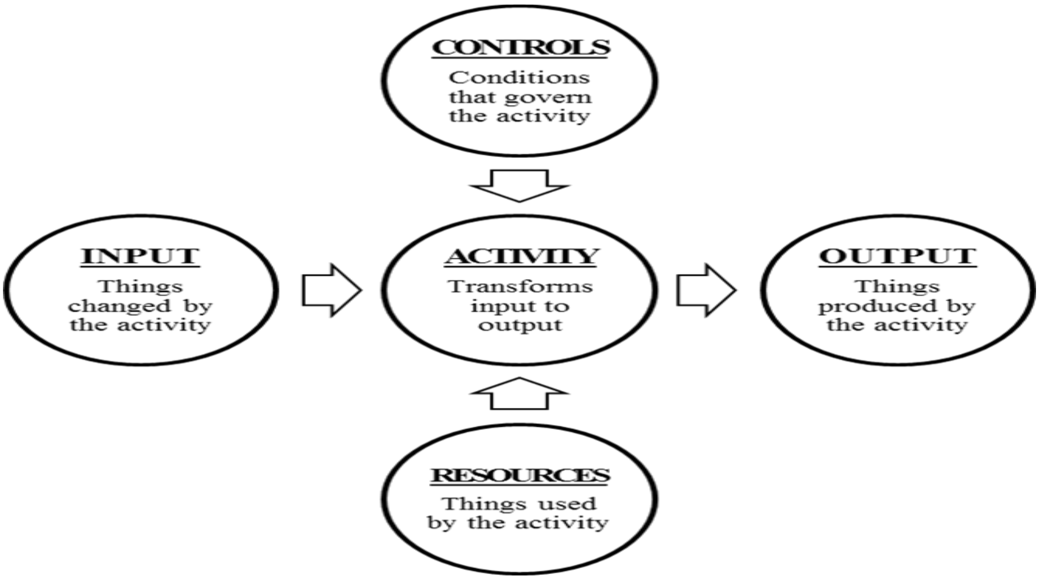

Figure 6.6: The description of Process based on Kenneth Preiss Model

According to the existed model, the activity is the attribute which transforms input into output. The input is the attribute which will feed the activity to transform into the output, which is the end result of the whole process. At the same time, the control attribute plays an important role in any business process which governs the conditions of the activity while using the resource activity which helps in giving the output.

Based on the concept of Kenneth Preiss (1999), about the process, it has been analysed that for any process, the following decision points has to be identified functionally. These features are as follows:

(1) Functions,

(2) Control,

(3) Input and

(4) Attributes.

The Kenneth Preiss model concept has been kept in mind while the decision point analysis has been done in the selected domain for case study (i.e., production and delivery/distribution) and is shown in Figure 6.7.

	PRODUCTION	DELIVERY / DISTRIBUTION		
		Warehouse	Logistics	Retailer
Functions	• Demand Planning • Select routing • BOM generation • Check Inventory • Generate order to production Dept. • MRP • Production Scheduling • Production	• Order completion data received • Stock allocation list check • Generate picking list • Product transfer to warehouse • Update inventory at warehouse	• Received update of inventory • Create delivery order • Delivery schedule	• Delivery schedule • Delivery
Control	• Market Trend Report. • Customer Requirement • Logistics • Urgent release Orders	• Production order • Warehouse demand	• Market requirement • Distributors requirement	• Sales analysis • Trend analysis
Input	• Concept development • Market Survey • Inventory level • Cost • Market analysis	• Inventory level • Urgent customer demand	• Customer requirement • Urgent customer demand	•Market requirement •Seasonal demand
Attributes	• Batch Size • Stoppages • Shift • Time • Pull or Push • Actions on Input/output	• Queue to hold orders for pick • Activity to pick • Queue to hold order for delivery • Picking quantity • Queue to hold goods ready for sale • Activity to model customer demand • Activity to generate urgent orders • Goods for delivery	• Batch size • Duration • Priority	• Customer demand • Maximum arrival First arrival • Interval • Lot size

Figure 6.7: Decision Points in Production and Delivery/Distribution

By looking at the basic framework of supply chain in which product starts from customer requirement and goes to the final stage where it has been delivered to customer in a market, there are many steps that a product has to go through before goes to the end of the production line. According to research plan, the next stage is to evaluate the results. So in continuation, the evaluation has been divided into the following categorise, which has been shown in Figure 6.8.

- Industrial Analysis
- Research Analysis

Analysis has been done in two phases

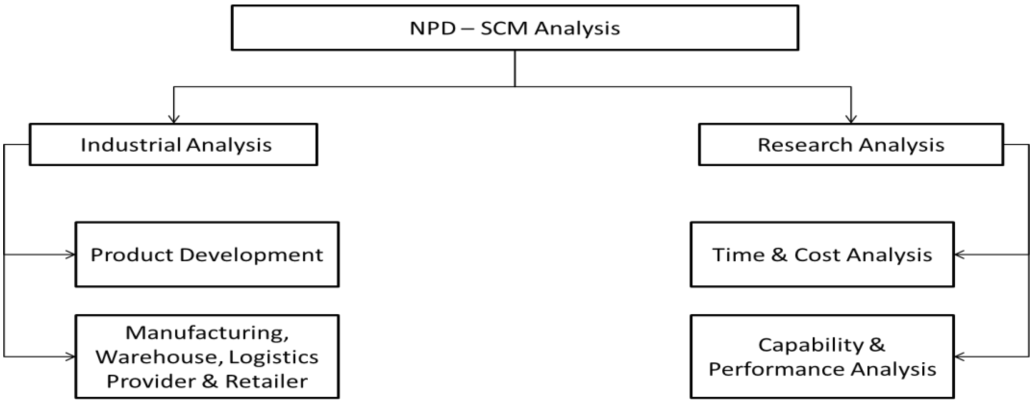

Figure 6.8: NPD-SCM Analysis Phase Description

Industrial analysis has been sub-divided into two sides i.e. Product development and Manufacturing, warehouse, logistics & retailer. These two analyses have been done in the start of the chapter. Now in the following section, evaluation of the research analysis has been done.

6.7 Time and Cost Analysis

To do the time and cost analysis, start with the concept of time as for any information flow times acts as a major consideration for any business sector as shown in Figure 6.9.

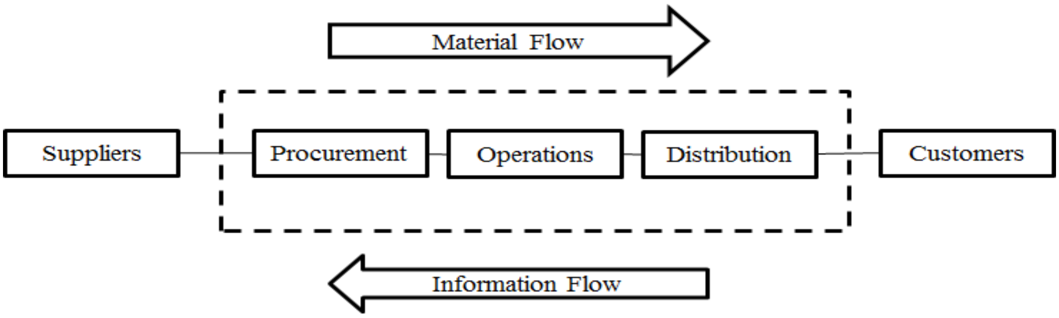

Figure 6.9: Material and Information Flow in Basic Supply Chain

According to the scope of this research, the modelling of information and material flow is required to analyse the integrated NPD – SCM extended enterprise. Information helps reduce variability in the supply chain as it helps suppliers make better forecasts, accounting for promotion and market changes. It also enables the co-ordination of manufacturing and distribution systems and strategies while at the same time enabling retailers to better serve their customers by offering tools for locating desired items.

The retailers react and adapt to supply chain problems more rapidly with the help of information which enables Lead time reductions. Even after considering so many positive results achieved by information flow analysis unfortunately, using information effectively makes the design and management of the supply chain more complex because more issues have to be considered. In recent years many suppliers and retailers in different business sectors have observed that while customer demand for specific products does not vary much, inventory and back-order levels fluctuate considerably across their supply chain. This increase in variability is known as the bullwhip effect. For the time responsive SC, it is really difficult to control this effect so not to effect the performance of the entire enterprise.

The Figure 6.10 represents a simple four stage supply chain. To understand the impact of variability considers the example of wholesaler: The wholesaler receives orders from the retailer and places orders to their supplier, the distributor. To determine these order quantities, the wholesaler must forecast retailer demand. If the wholesaler does not have access to the customer demand data, they must use orders previously placed by the retailer to perform their forecasting.

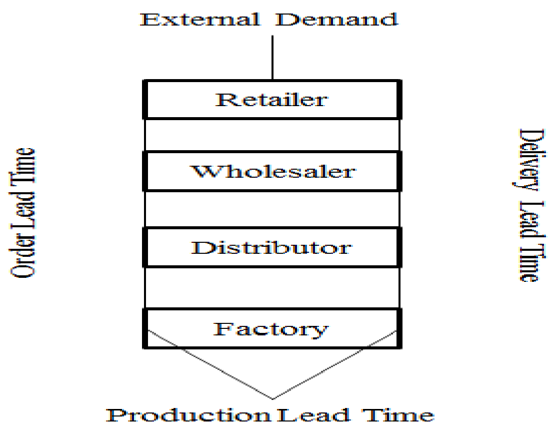

Figure 6.10: Simple four stage Supply Chain with Order Lead Time and Delivery Lead Time

Since variability in orders placed by the retailer is significantly higher than variability in customer demand, the wholesaler is forced to carry more safety stock than the retailer or else maintain a higher capacity than the retailer in order to meet the same service level required by the supply chain drivers. This analysis can be carried out over to the distributor as well as the factory resulting in even higher inventory levels and therefore higher costs at these facilities.

It is important to identify techniques and tools that will allow to control the bullwhip effect, that is, to control the increase in variability in the supply chain in order to gain the improved performance results as been discussed in earlier stages of this research.

6.7.1 Variability in the Supply Chain

For this purpose there is a need to understand the factors contributing to the increase in variability in the supply chain.

Traditionally inventory management techniques practised at each level in the supply chain lead to the bullwhip effect. An important characteristic of forecasting techniques is that when OEM observed more data, they modify the estimates of the mean and standard deviation (variability) in customer demand. Since safety stock and order-up-to levels are based on these estimates, the user is forced to change order quantities thus increasing variability.

For automotive supply chain, to calculate safety stock and reorder points, the OEM does multiply the average and standard deviation of the customer demand by the lead time. Thus with longer lead times, a small change in the estimate of demand variability implies a significant increase in safety stock, reorder level and thus in order quantities. This of course leads to an increase in variability and creates a negative impact on the performance of the supply chain by using more cost and time.

If the retailer, for example uses batch ordering, as happens when using a min-max inventory policy, then the wholesaler will observe a larger order, followed by several periods of no orders, followed by another large order and so on. This of course leads to an increase in variability also and is not good for the automotive supply chain.

Price fluctuations can also lead to the bullwhip effect even though it doesn’t affect too much in automotive but it does in other business sectors. If prices fluctuate, retailers often attempt to stock up when the prices are lower. This is accentuated by the prevailing practice in many industries of offering promotions and discounts at certain times or for certain quantities.

This Inflated order factor is not contributing a lot difference in automotive but in FMCG sector it creates a huge difference. Inflated order placed by retailers during shortage periods tends to magnify the bullwhip effect.

Such orders are common when retailers and distributors suspect that a product will be in short supply and therefore anticipate receiving supply proportional to the amount ordered. When a period of shortage is over, the retailer goes back to its standard orders, leading to all kinds of distortions and variability in demand estimates.

6.7.2 Methods for Coping with the Bullwhip Effect

The ability to identify and quantify the causes of the bullwhip effect leads to a number of suggestions for reducing the bullwhip effect by eliminating its impact.

One of the most frequent suggestions for decreasing or eliminating the bullwhip effect is to reduce uncertainty throughout the automotive supply chain by centralising demand information; that is by providing each stage of the supply chain with complete information on actual customer demand. Even if each stage uses the same demand data, they may still employ different forecasting techniques and different buying practices, both of which may contribute to the bullwhip effect.

In addition, even when each stage uses the same demand data, the same forecasting techniques and the same ordering policy, the bullwhip effect, although minimised will continue to exist.

In the other business sectors especially in FMCG's the bullwhip effect can be diminished by reducing the variability inherent in the customer demand process. The reduction in the variability of customer demands through, for example, the use of an everyday low pricing (EDLP) strategy can be achieved. When a retailer uses EDLP, it offers a product at a single consistent price, rather than offering a regular price with periodic promotions. This can lead to more stable (fewer variables) demand patterns.

Reducing lead times in automotive sector can have a dramatic effect on the variability at each stage of the supply chain. Lead times typically consist of two components: the order lead time (the time taken to produce and ship an item) and information lead time (the time it takes to process and order). Order lead times can be reduced by, for example, the use of cross-docking and information lead times can be reduced through EDI (electronic data interchange).

The bullwhip effect can be eliminated by engaging in a number of strategic partnerships in automotive supply chain. These strategic partnerships change the way information is shared and inventory is managed throughout the supply chain. For example, in vendor managed inventory (VMI), the manufacturer manages the inventory of its product at the retailer outlet and therefore determines for itself how much inventory to keep on hand and how much to ship to the retailer in each period.

6.7.3 Effective Forecast

Information leads to more effective forecasts. The more factors that predictions of future demands can take into account, the more accurate these predictions can be. For example, retailer forecasts are typically based on analysis of previous sales. However, future customer demands are clearly influenced by pricing, promotions and the release of new products, etc. Some of these issues are controlled by the retailer others are controlled by the distributor, wholesaler and manufacturer or competitors. If this information is available to the retailers forecasters the forecasts will obviously be more accurate. Similarly distributor and manufacturer forecasts are influenced by factors under the retailers control etc. For these reasons many supply chains are moving towards co-operative forecasting systems.

In these systems sophisticated information systems enable an iterative forecasting process, in which all the participants in the supply chain collaborate to arrive at an agreed upon forecast. This implies that all components of the supply chain share and use the same forecasting tool, leading to a decrease in the bullwhip effect.

Within an automotive supply chain are many systems, including manufacturing, storage, transportation and retail systems. Managing any one of these systems involves a series of complex trade-offs. However all these systems are connected, specifically, the outputs from one system within the supply chain are the inputs to the next system. Thus trying to find the best set of trade-offs is not sufficient. For this aspect, the OEM needs to consider the entire system and co-ordinate decisions. If there is one common owner of the supply chain it is clearly in the owners best interests to ensure that the overall cost is reduced. Even if there is no common owner, however, the various systems still need some kind of co-ordination to operate effectively. The issue is whose best interest is it to reduce the overall cost and how will these savings is shared among the system owners.

6.7.4 Global Optimisation

When the system is not co-ordinated each facility in the supply chain does what is best for that facility - the result is local optimisation. The alternative is global optimisation, which implies that one identifies what is best for the entire system. In this case:

i. *Who will optimise?*
ii. *How will the savings obtained through the co-ordinated strategy be split between the different supply chain facilities?*

To co-ordinate these facets of the supply chain, information must be available. Specifically, the knowledge of production status and costs, transportation availability and quantity discounts, inventory costs, inventory levels and various capacities and customer demand is necessary to co-ordinate systems, especially in cost-effective ways.

There is more than one way to meet customer demand in automotive supply chain. Typically, for a make to stock system, the OEM thinks of meeting customer demand from retail inventory if at all possible. However there are other ways to meet customer demand. Being able to locate (through a database) and deliver goods is sometimes as effective as having them in stock (Distributor Integration).

6.7.5 Lead Time Reduction

Reduction in lead time typically leads to:

1. The ability to quickly fill customer orders that can't be filled from stock.
2. Reduction in the bullwhip effect.
3. More accurate forecasts due to decreased forecast horizon.
4. Reduction in finished goods inventory levels (because raw materials and sub-assemblies can be stocked to reduce finished goods cycle time)

For all these reasons, automotive OEMs are actively searching for suppliers with shorter lead times and many potential customers consider lead time very important criteria in vendor selection. Much of the manufacturing revolution in the past 30 years led to reduced lead times. Effective information systems cut lead times by reducing that portion of the lead time linked to order processing, paperwork, stock picking, and transportation delays and so on. Often these can be a substantial portion of the lead time, especially if there are many different stages at a time. Clearly if a retailer order rapidly propagates up the supply chain through the tiers of suppliers as far back as necessary to meet the order, lead time can be greatly reduced. Similarly in other business sectors, transferring point-of-sale (POS) data from the retailer to its supplier can help reduce lead time significantly because the supplier can anticipate an incoming order by studying POS data.

6.7.6 Integrating the Supply Chain

One of the problems of automotive supply chain management is that conflicting stages of the supply chain have different goals and it is exactly these conflicts which necessitate the integration of the different elements of the supply chain. By carefully using the available information the companies can reduce the cost of the system whilst accounting of these goals and objectives. This is obviously easier in a centralised system but integration is equally important in a decentralised system.

6.7.7 Designing the Supply Chain for Conflicting Goals

In the past the supply chain was viewed as a set of trade-offs. Typically high inventory levels and shipping costs, and less product variation enabled manufacturers and retailers to come closer to meeting their goals. At the same time customer expectations were not as high as they are today.

Now customers' demand high variety and low cost and there is an increased pressure to control inventory and transportation costs in automotive sector. Fortunately, the large amount of information now available allows supply chains to be designed so that they come closer to meeting all these apparently conflicting goals. In effect some of the trade-offs which were considered inherent in the supply chain a few years ago may not be trade-offs at all. The following part will discuss many of these perceived trade-offs and how through the use of advanced information technology and creative network design, they can be reduced or eliminated.

Lot Size-Inventory Trade-Off

Usually manufacturers would like to have large lot sizes - typically set-up costs are reduced manufacturing expertise is increased and processes are easier to control. Unfortunately typical demand doesn't come in large lot-sizes - so large lot sizes result in high inventory. Set-up Reduction, Kanban and other lean manufacturing practices are typically geared to reducing inventories and increasing responsiveness. This approach to manufacturing has far reaching effects beyond the manufacturing environment to the supply chain. Retailers and distributors would like short delivery lead times and wide product variety to respond to the needs of their customers. Lean manufacturing techniques enable the supply chain to meet these needs by enabling them to respond more rapidly to customer requirements. This is especially true if information is available to ensure that the manufacturer has as much time as possible to react to the needs of the downstream supply chain. Similarly if the retailer and distributor have as much time as possible to observe factory status and inventory, they can quote lead times more accurately. With this information comes greater understanding and confidence which lead to reduction in inventory levels throughout the supply chain.

Inventory-Transportation Trade-Off

In Tier 1 supplier and OEM case, full truck loads minimize transportation costs. In many cases demand is in units far less than a single truck load. When items are delivered in full truck loads the customer has a longer time to wait and/or high inventory costs. This trade-off cannot be eliminated completely. However with information technology the effect can be reduced. For example advanced production control systems can be used to manufacture goods as late as possible to ensure full truck loads, similarly distribution control systems may allow a materials management manager to combine shipments of particular products from warehouses to stores in order to fill trucks. This requires knowledge of orders and demand forecasts as well as supplier delivery schedules.

Recent advances in decision support systems allow the supply chain to find an appropriate balance between transportation and inventory costs by taking into account all aspects of the supply chain. Lead time is made up of time devoted to processing orders, to procuring and manufacturing items and to transporting items between various stages of the automotive supply chain. Transportation costs are lowest when large amounts of items are moved - however lead times can be reduced if items are transported immediately after they have been manufactured or arrive from suppliers. This trade off cannot be completely eliminated, but information can be used to reduce its effect. Transportation costs can be controlled by, for example, utilising advanced travel modes and carrier selection programs reducing the need to hold items until a sufficient number accumulate. In addition, improved forecasting techniques and information systems reduce the other components of lead time which means that reducing transportation costs may not be so critical.

Product Variety - Inventory Trade-Off

Product variety greatly increases the complexity of the automotive supply chain. Manufacturers that make a large variety of products with smaller lot sizes often find their manufacturing costs increase and their manufacturing efficiency decreases. To maintain the same lead time as a company with fewer products, fewer amounts will probably be shipped so warehouses will need to hold a larger variety of products. Increasing product variety therefore increases transportation and housing costs. Also because it is more difficult to forecast demand for a large variety of products, higher inventory levels must be maintained to ensure the same service level.

The Cost-Customer Trade-Off

All of these trade-offs are example of the cost-customers trade off. Reducing inventories, manufacturing costs, and transportation costs typically come at the expense of customer service. The level of customer service can be maintained however by using information and appropriate supply chain designs. Of course customer service could mean the ability of the retailer to meet a customer's demand quickly.

However advanced supply chain management techniques and information systems could be used to give customers the kind of service they have never been able to realise before and for which suppliers could charge a premium. One such example is the concept of mass customisation which involves delivering highly personalised goods and services to customers at reasonable prices and at high volume.

6.8 Capability and Performance Analysis

Based on the same concept of integration of Product development within automotive supply chain, the other way to enhance supply chain performance is through implementing the right strategy to send the product to customer. For supply chain strategy, there are two ways to deliver the product to improve the supply chain performance, which has been discussed briefly in next section.

6.8.1 Competitive and Supply Chain Strategies

A company's competitive strategy defines the set of customer needs that it seeks to satisfy through its products and services. To understand the relationship between competitive and supply chain strategy it is necessary to examine the value chain of any organisation, which is shown in Figure 6.11.

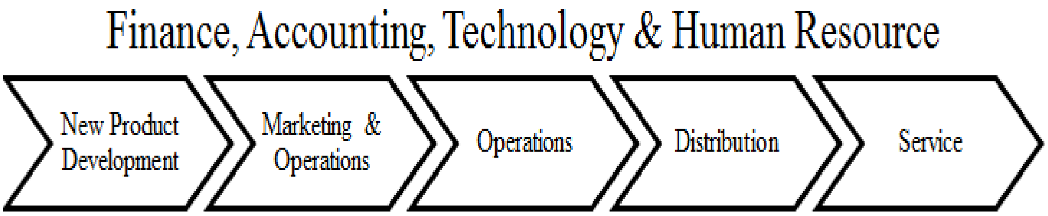

Figure 6.11: Simple Value Chain

A supply chain strategy determines the nature of procurement of raw materials, transportation of materials to and from the company, manufacture of the product or operation to provide the service and distribution of the product to the customer, along with any follow up service. From a value chain perspective, supply chain strategy specifies what operations, distribution and service will try to do particularly well.

6.8.2 Achieving Strategic fit

Strategic fit means that both the competitive and supply chain strategies have the same goal. It refers to consistency between customer priorities that the competitive strategy is designed to satisfy and the supply chain capabilities that the supply chain strategy aims to build. The strategic fit could be achieved by the following two methods.

First a company must understand the customer needs for each targeted segment. These needs help the company define the desired cost and service requirements. The other factors which are of importance are the quantity of the product needed with the response time the customers are willing to tolerate for the variety of products they want at desired service level. The factor of cost is also of great importance while keeping in mind that demand uncertainty always exists in other business sectors. There are many types of automotive supply chains, each of which is designed to perform its tasks well. A company must understand what its supply chain is designed to do well. Supply chain responsiveness includes the supply chain ability to respond to: wide ranges of quantities demanded, short lead times, a large variety of products, building highly innovative products, meeting a very high level of service. At the same time supply chain efficiency is the cost of making and delivering a product to the customer. Thus for every strategic choice to increase responsiveness, there are additional costs that lower efficiency. Thus, if any mismatch exists between what the supply chain does particularly well and the desired customer needs, the company will either need to restructure the supply chain to support the competitive strategy or alter its strategy.

6.8.3 Supply Chain Drivers

Strategic fit requires that a company achieve the balance between responsiveness and efficiency in its supply chain that best meets the needs of the company's competitive strategy. To understand how an OEM can improve supply chain performance in terms of responsiveness and efficiency, four drivers of supply chain performance has been examined. The Figure 6.12 shows a visual framework for supply chain decision making. Most companies begin with a competitive strategy and then decide what their supply chain strategy ought to be. The supply chain strategy determines how the supply chain should perform with respect to efficiency and responsiveness.

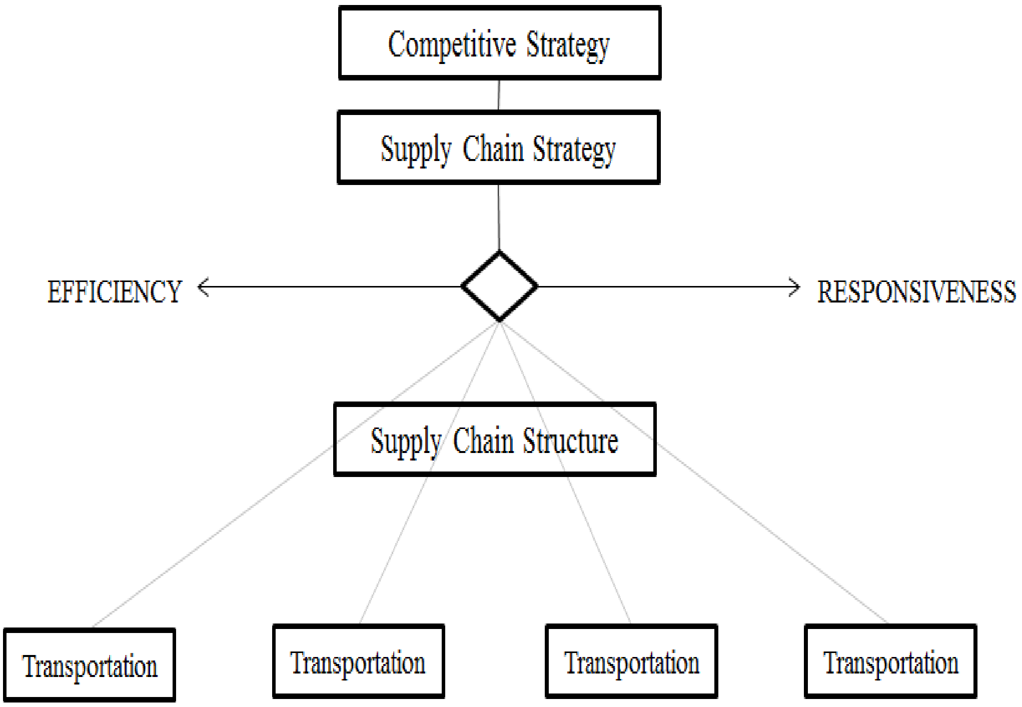

Figure 6.12: Four Basic Drivers of supply Chain

The supply chain must then use the supply chain drivers to reach the performance level the supply chain strategy dictates. Although this framework is generally viewed from the top down, in many instances, a study of the four drivers may indicate the need to change both the supply chain and potentially even the competitive advantage.

(1) Inventory.
(2) Transportation.
(3) Facilities.
(4) Information.

- **Inventory**

Inventory is all raw materials, work in progress, and finished goods within the supply chain. Inventory is an important supply chain driver because changing inventory policies can dramatically alter the supply chain's efficiency and responsiveness.

Inventory exits in the supply chain because of a mismatch between supply and demand (often intentional). An important role that inventory plays in the supply chain is to increase the amount of demand that can be satisfied by having a product ready and available when the customer wants it.

If a firm's competitive strategy requires a very high level of responsiveness, a company can use inventory to achieve this responsiveness by locating large amounts of inventory close to the customers. Conversely a company can also use inventory to make it more efficient by reducing inventory through centralised stocking.

Cycle inventory is the average amount of inventory used to satisfy demand between supplier shipments. The size of inventory cycle is a result of the production or purchase of a material in large lots. The basic trade-off is the cost of holding larger amounts of inventory (high cycle inventory verses the cost of ordering product infrequently). Safety Stock is inventory held just in case demand exceeds expectation Cycle inventory, it is held to counter uncertainty. Seasonal Inventory is inventory that is built up to counter predictable variability in demand in other business sectors. Companies using seasonal inventory will build up inventory in periods of low demand and store it for periods of high demand.

- **Transportation**

Transportation involves moving inventory around from point to point in the supply chain. It can take the form of many combinations of modes and routes, each with its own performance characteristics.

Faster transportation between stages in a supply chain has a large impact on responsiveness but reduces efficiency. The type of transportation a company uses also affects the inventory and facility locations in the supply chain.

If a customer's demands a very high level of responsiveness and that customer is willing to pay for this responsiveness then a firm can use transportation as one driver for making the supply chain more responsive. Alternatively if the customers' main decision criterion is price, then the company can use transportation to lower the cost of the product at the expense of responsiveness.

  - Mode of Transportation. Choice is between: Air, truck, rail, ship, pipeline, electronic transportation.
  - Route and Network Selection. Route is the path along which the product is to be shipped and a network is the collection of locations and routes along which a product can be shipped.
  - In House or Outsource. Increasingly transportation (and entire logistics systems) is outsourced.

- **Facilities**

Facilities are the places in the supply chain network where inventory is stored as assembled or fabricated. The two major types of facilities are production sites and storage sites. Decisions regarding location, capacity and flexibility of facilities have a significant impact on the supply chains performance.

If a company thinks of inventory as what is being passed along the supply chain and transportation as how it is passed along, then facilities are the where of the supply chain. They are the locations to or from which the inventory is transported. Within a facility, inventory is either transformed into another state (manufacturing) or stored before being shipped to the next stage warehousing).

Companies can gain economies of scale when a product is manufactured or stored only in one location; this centralisation increases efficiency. Alternatively locating facilities close to customers increases the number of facilities needed and consequently reduces efficiency. However if the customer demands and is willing to pay for the responsiveness then this facilities decision helps meet the company's competitive strategy goals.

- Location. A basic trade-off is whether to centralise to gain economies of scale or decentralise to become more responsive by being closer to the customer. Other issues include macro-economic factors, strategic factors, cost and quality of workers, availability of infrastructure, proximity to customers and the rest of the network and tax effects.
- Capacity (Flexibility versus Efficiency). Excess capacity allows flexibility but is expensive; a highly utilised facility will be efficient but less responsive to demand fluctuations.
- Manufacturing Methodology Product focused factories perform many different functions (such as fabrication and assembly) or functional focused factories performing few functions (e.g. only fabrication). Product focus tends to result in more expertise about a particular type of product at the expense of functional expertise.
- Decisions must also be made on flexible (many types of products) capacity verses dedicated (limited number of products) capacity.
- Warehousing Methodology including:
- Store-keeping unit (SKU) storage: a traditional warehouse that stores all of one type of product together.
- Job lot storage: in which all the different types of products needed to perform a particular job or satisfy a particular customer are stored together. (More storage space but more efficient picking and packing).
- Cross docking in which goods are not warehoused but broken down into smaller lots and shipped.

- **Information**

Information consists of data and analysis regarding inventory, transportation, facilities and customers throughout the supply chain. Information is potentially the biggest driver of performance in the supply chain as it directly affects each of the other drivers. Information presents management with the opportunity to make supply chains more responsive (for example by forecasting demand) and efficient (for example by providing shipping options).

Information serves as a connection between the supply chains' various stages allowing them to co-ordinate their actions and brings about many of the benefits of maximising total supply chain profitability. Information is crucial to the daily operation of each stage of the supply chain. For example, a production scheduling system uses information on demand to create a schedule that allows a factory to produce the right products in an efficient manner.

The tremendous growth of information technology is a testimony to the impact information can have on a company. Like all the other drivers however, even with information companies reach a point where they make a trade-off between efficiency and responsiveness. Another key decision involves what information is most valuable in reducing cost and improving responsiveness in the supply chain. This will vary depending on supply chain structure and the market sector.

Push verses Pull. When designing processes in the supply chain, managers must determine whether these processes are part of the push or pull phase of the chain (Push requires MRP, pull requires demand information etc.).

Co-ordination and Information Sharing Supply chain co-ordination occurs when all the different stages of a supply chain work toward the objective or maximising total supply chain profitability rather than each stage devoted to its own profitability. Forecasting is the art and science of making projections about what the future conditions will be. (Used to schedule production and determine whether to build new plants etc.). Aggregate Planning transforms the forecasts into plans of activity to satisfy the projected demand. The aggregate plan becomes a critical piece of information to be shared throughout the supply chain - it affects the demand on the company's suppliers and the company's supply to its customers.

Many technologies exist that share and analyse information in the supply chain. Managers must decide which technologies to use and how to integrate these technologies into companies and their partners. These include:

- Electronic Data Interchange (EDI).
- The Internet.
- Enterprise Resource Planning systems.
- Supply Chain Management (SCM) Software.

There are so many hindrances exist in achieving strategic fit. Some of them are listed below:

- Increasing Variety of Products.
- Decreasing Product Life Cycles.
- Increasingly Demanding Customers.
- Fragmentation of Supply Chain Ownership.
- Globalisation.
- Difficulty Executing New Strategies.

6.9 Summary

In this chapter, phase 4 of the research plan has been discussed. Initially the new product development process of the entire car engine has been analysed which leads the research into the area of advanced product quality gateway as the normal process of OEM. Results of the data collection and the analysis of that result have been discussed in the light of proposed framework which was described in chapter 5. Time and cost analysis and the capability and performance analysis have been discussed in the end of the chapter.

Chapter 7: Discussions

7.1 Discussion About Literature Survey Outcome and Research Approach

Initially the investigation has been done to see the types of research which leads the research into defining the scope of this research and the type of the research methodology. Case study research design has been finalised after looking at all the aspects of this research and the available resources and their limitations.

In a start, the basic concepts of change has been discussed which is the idea behind the birth of this research. It is to look at the AS–IS situation of the automotive firm and then suggest the TO–BE situation after implementing the proposed methodology. Started off with the innovation and invention concept this has led to explore the area of change management and the tools used in change management while trying to cover all the relevant aspects of change management. Further investigation in the domain of change management tools has been done with the concept of business process management as it is also the important focus of this research where the aim is to integrate new product development with the business processes of supply chain management.

In the next stage, the basic process has been looked in detail which is a ground concept for any business firm, as understanding the concept of process is quite important for the management team also so that they can work for the betterment of the company. The four domains of process have been identified such as, Input, Output, Control and Resources after looking in detail of Kenneth Preiss model which directed the research into the domain of process modelling.

In the next stage, the investigation on different types of process modelling and the available tools has been done as they are the most important aspect of describing the AS-IS situation of any business process. After analysing all the relevant process modelling techniques, flow chart has been selected in this research to model the process.

Furthermore, the research went into the domain of new product development which has opened a way to investigate more in detail. In this stage, according to research plan is to investigate about the new product development process and the performance. So all the relevant type of product development model has been discussed and eventually a generalised PD process has been formalised which will be used in this research to analyse and evaluate the current and the future state of industry.

Following to this investigation, the next stage comes is to investigate about the supply chain in detail. In this stage, the supply chain evolution has been discussed with the description of integration levels in supply chain. This detailed description of supply chain has eventually leads the research in automotive supply chain, which is the key focus of this research. In automotive supply chain discussion has been done in the detailed analysis of the automotive industry with respect to supply chain and specifically in UK and European market.

From there the investigation has went into the stage of supplier relationship management and then finally into the domain of NPD – SCM integration. In this NPD – SCM integration domain, the aspects which have become consideration were: Integration, Planning & Strategy and in the end Implementation issues. The literature review in the integration domain directed this research into the main focussed area of key decision making points. Then the literature evidence has been discussed relevant to key decision making points.

To finish off the phase 1 of this research, the investigation in existing decision making frameworks has been done and the analysis on these frameworks has been carried out which finally identified the gaps in existing literature. These research gaps have verified the research aim and objectives which has worked in this research.

7.2 Discussion About Industrial Investigation Outcomes

In this stage, the collaborating company has been finalised after discussing with initial point of contact. A global automotive OEM named Ford Motor Company based in UK with hundreds of direct (Tier 1) and Indirect (Tier 2) suppliers has been finalised. To continue working in the same area, after consultation with the OEM, one of their direct (Tier-1) suppliers has been finalised and contacted to do the further analysis. The details of the OEM with their Tier 1 and Tier 2 supplier have been discussed to see the existing linkage among them.

Furthermore, the research went into the domain of capturing the AS-IS situation with the use of process modelling tools which have been selected in the phase 1 of the research earlier. The purpose of dong industrial investigation has been discussed there. In industrial investigation stage, after consulting the OEM, the proposed discussion points have been finalised for informal discussion which has worked as the key tool to capture the relevant information regarding the OEM with Tier 1 and Tier 2 supplier relationship.

During the same stage, document analysis and the direct observation with the OEM and the Tier 1 and 2 supplier's personnel, has been done which helped in identifying the whole supply chain processes of the example part. The generalised product development process of OEM has been identified which has worked as the tool to cross check the integration points in the whole supplier relationship. After capturing the OEM generalised PD processes, the Tier 1 supplier's generalised product development process has been identified too which shows some integrated points too.

In the same stage, the contract review process has been discussed too. Then the research led to analyse the example part. In this stage of research, initially the generalised product development process of the whole car has been identified. After consulting with OEM and Tier 1 supplier the example part has been identified that worked as the main research component in this case study.

Furthermore the industrial investigation has been done to get the complete description of the example part with all the relevant aspects like: brief description, supplier, drawing view etc., the overall collaborative view of OEM and Tier 1 supplier has been identified which has worked as the starting point to identify the initial concept of framework based on the industrial investigation result.

At the same time, Tier 2 supplier's production flow chart with brief description of quality control plan and relevant topics has been discussed. This whole description, has helped in identifying the correct AS-IS situation in this research.

Later, the idea of integrating product development with supply chain has been discussed. The key problem within automotive sector is that supply chain covers a wide area of business cycle whereas the new product development mainly relates only to manufacturing. Therefore, linking the two attributes of the business, i.e., SCM and NPD, is not an easy task to accomplish, which is possibly the major reason that it has not been discussed in detail in existing literature too.

After generating the initial concept of integrated NPD- SCM framework, the relationship between OEM and their Tier 1 and Tier 2 supplier's has been taken into consideration. The relationship has been shown diagrammatically at this stage of the research. On the basis of this relationship, the generalised supply chain process of the whole enterprise has been generated.

Then framework has been proposed which shows the generalised PD process of OEM (whole car assembly), generalised PD process with details of OEM (Sub-Assembly – Engine), generalised PD process with details of Tier 1 supplier and the detailed production process of Tier 2 supplier.

In the end, the research has been done to identify the key decision making points in all these product development process within the context of generalised supply chain. In this aspect, research has been done to analyse the current product development process and then it has been analysed with reference to the proposed framework.

7.3 Discussion About the Developed Framework

The proposed model has been tested in the existing scenario to evaluate the impact of the developed methodology. Initially the detailed product development processes of the OEM have been generated on the basis of the framework and the existing literature. Then linking NPD with SCM stage has come, where all the relevant product development processes have been linked together to see the integrated points.

Then the model has been analysed in two ways i.e. industrial way and the research way. For industrial analysis, the product development part has been analysed in the domain of proposed methodology with further analysis has been done in the key decision making point of feasibility in detail. In the same way the decision making points in manufacturing, warehouse, logistics and retailer has been identified also which has been analysed with the help of proposed methodology and the existing literature too.

In the next stage, the research analysis has been conducted to see the effect of other business processes like delivery/distribution. For this aspect, the analysis has been done in field of other key decision making phases of time & cost and then finally in the field of capability & performance of the supply chain. This evaluation has eventually helped in refining of the proposed methodology.

Chapter 8: Conclusions and Future Work

8.1 Conclusions

A philosophy that has changed the way of doing business in this world from the past 2-3 decades is supply chain management (SCM). Starting from supplier's supplier to go through the manufacturer to the customer's customer is a chain that has joined different enterprises to form a unique extended enterprise. Even though it creates a lot of changes in every segment of business from infrastructure to highest level but these frustration can be easily ignored after looking at the positive results achieved by SCM like: shorter production lead time, improved communication, low inventory, shorter delivery time, cost competitiveness, shorter product development cycle etc. Before the introduction of the SCM concept all entities including that of a single enterprise were working individually.

Existing research has looked at improving internal alignment between the new product development– supply chain interfaces. In particular in a time where there are pressures for growing product proliferation in order to meet varied demand, where the Research & Development pipeline is a key focus in companies and in a time where technology life cycles have shortened so much that obsolete inventories and time to market are crucial for Research & Development output and company margin performance. In that respect it is often pointed out that the impact of supply chain on new product development and product introduction is important in a time when they integrate with each other.

Companies tend to use a conventional approach to NPD by assigning representatives from support functions to review and recommend changes as projects evolve. This approach has, in recent years, been questioned since it is a costly and time-consuming approach due to its iterative nature. It is argued that the time to market process and the cost of NPD can be reduced considerably by involving the support functions of a supply chain to a greater extent and also earlier in the NPD process. There was a clear industrial requirement for a collaboration framework which facilitates the linkage between Supply Chain

Management and new product development. So far there is no evidence of detailed framework existed which describes the true linkage.

After identifying research gaps which is summarised in the initial stage of this research, the aim was identified to develop the methodology which will work to investigate the AS-IS situation and then by proposing the framework, TO-BE solutions can be analysed. So the key focus was on the methodology which is by far according to research scope is completed.

This research introduces the development and analysis of the framework that allows the integration of the flow of product development related activities within original equipment manufacturers (OEM) and suppliers thus providing future business benefits. The proposed framework use key drivers to predict and quantify its impact on the four main criteria namely: feasibility, time, cost and capability that support or advise on key decision making of OEM's product development and management teams.

For this aspect, in this research, a large international automotive company operating globally in all regions which manufactures or distributes automobiles across six continents, has been considered. With about 164,000 employees and about 70 plants worldwide, this OEM has got thousands direct and indirect suppliers. One of the UK local Tier1-supplier has been contacted with the consultation of OEM. This Tier 1-supplier is OEM's direct supplier which provides them casting parts for their car engines body.

The industrial investigation showed different key decision making points in linkage of OEM and supplier. By looking at the bigger picture, OEM with Tier 1 supplier's generalised Product development processes has been identified which works as final outcome in this research, as these generalised product development process can be used in future to do the analysis on other sub-assemblies of OEM like chassis sub-assembly, gear box sub-assembly etc., linked by Tier 1 Supplier Product development processes.

The other outcome in this research is the generation of generalised PD and other manufacturing activities flow within the SCM context. As this generalised SCM process flow has been verified by the industrial case study that it can work as a common feature in SC activities of either OEM or Tier 1 or Tier 2 suppliers of any sub-assembly.

Analysis has been done using a case example of the NPD – SCM integrated system. The example part has been used to categorise these analysis which was a small part of the main car engine assembly. The whole large products are too complex to simulate as the example, as it involves too many different suppliers with different supply chain strategy for each sub part and it take too much cost and time to finish that. The research has investigated and fulfilled all the four research objectives. The final output of the research includes the functional requirements of a framework and a developed framework with prototype methodology with tools and technologies that are tested with case studies in the industrial environment. This generalised framework can be used in the different sub-assemblies of the same OEM. Furthermore, it can be used in any automotive firm to see the effect of decision making points in Tier 1 and Tier 2 environment. The other aspects which is covered in this research is an research analysis of other key decision making points i.e. time and cost, capability and performance in the automotive sector while considering the other business sectors also which again is the novelty of this research.

In summary, the following conclusions have been obtained through this research:

Current industrial problems like OEM-supplier relationship, that there is no relation exists to analyse key decision making areas and non-existence of detailed framework in NPD – SCM business scenario which can gives the guidelines for the industries, have been identified through literature survey and are verified by industrial case study.

Research gaps like; difficulty in linking NPD and SCM in business scenario and NPD – SCM integration issues has been identified and summarised which shows that existing technology and tools are not sufficient enough to solve these problems.

Generalisation of product development process has been proved possible in this research which can work in any manufacturing firm, either OEMs or suppliers of any level in the supply chain

Detailed product development processes for the considered example casting part have been identified in industrial investigation which has been used to prove the generic process.

Generic supply chain activities have been developed in the industrial case study which shows different integrated points.

Key decision making points have been identified and analysed in the industrial case study which shows the true linkage of NPD – SCM in any business firm.

Analysis of time and cost, and capability and performance within the same industrial environment has been done which has given the generic analysis for any other business firm too.

8.2 Future Work

Through this research the author has tried to explore the link of product development (PD) within a SCM context for an extended enterprise. The author has fulfilled the aim of this research which states "To develop a methodology for integrating the product development process with supply chain within an extended enterprise for improved performance". To achieve this aim, four objectives have been set within this research and author has explored all the aspects which were defined in scope of this research in first chapter.

The industrial investigation has been done in automotive sector to investigate the effect of the integration of SCM with NPD. The future work for this research, can lead to the refinement of the proposed framework within the other business sectors which can be evaluated and the possible integration points will provide baseline guidelines to identify the key decision making points within the entire supply chain.

In this research, the automotive scenario within information flow has been analysed that leads the way of analysing the material flow for future research either in the automotive sector or any other business sector which follows basic product development processes like FMCG (fast moving consumer goods) and pharmaceutical sector which shows the potential direction for this research.

The future dimension of this research can lead to develop an ideal development of methodology for NPD-SCM integration based on enterprise framework for everything in enterprise rather than just for new product development. Therefore, in future, other Enterprise Framework methodologies can be merged within this proposed framework.

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APPENDIXES

PUBLICATIONS

- Hasan S M., Shah S. and Gao J. (2013), "A collaboration framework to support decision making in new product development with the supply chain", accepted by the *International Conference on Manufacturing research*, 19-20 September 2013, Cranfield University, UK.
- Hasan S. M., Shah S. and Gao J. (2012), "A collaboration framework for product development in extended enterprise", *Proceedings of 10th international conference on manufacturing research - Advances in Manufacturing Technology,* XXVI, Vol. 2, ISBN 9781905866601, 11-13 September 2012, pp. 736-741.

Appendix I - TROPICS

This model is intended to help managers to get a feel for the nature of change and thus to establish an optimal route forward, including the choice of solution methodology, where "hard" refers to a system-based, mechanistic solution methodology, and "soft" refers to an organisational development, complex solution methodology.

Tropics Factor	"Hard" Solution Methodology	"Soft"Solution Methodology
Timescales	Clearly defined: Short to medium term	Ill define: Medium to long term
Resources	Clearly defined and reasonably fixed	Unclear and variable
Objectives	Objective and quantifiable	Subjective and visionary
Perceptions	Shared by those affected	Creates conflicts of interest
Interest	Limited and well define	Widespread and ill defined
Control	Within the managing group	Shared out with the group
Source	Originates internally	Originates externally

(Adapted from TROPICS Model by Paton and McCalman, 2000)

In its original form, QSAM addresses supply chain improvement through the identification of: short-term actions ("quick hits"); to be implemented by an implementation team, and medium-term actions; to be implemented by a re-engineering task force (Cardiff LSDG, 2007).

QSAM's call to prioritization is pragmatic, but some weaknesses of the methodology are that it: "offers limited opportunity for the business employees to participate as team members", and that it "is not easily transferrable to business as a change management tool" (Naim *et al.*, 2002a).

Appendix II - Kotter's "eight step" change model

Kotter's framework and analysis of change, based primarily on organisational change in the corporate sector, has been articulated and adapted since the mid-1990s. It is well known and widely quoted and applied. The language and philosophy of Kotter's approach appears in many iterations and variations in the literature of organisational change. Kotter's prescription for success is to recognise the importance of a staged and sequential approach, not to rush and/or to fall victim to the illusion of speed, and to look out for and correct the pitfalls that accompany each of these stages of change:

(1) Establish a sense of urgency – about the need to make changes.

(2) Form a powerful high level coalition to guide and lead the changes – a group with enough power and influence in the organisation to lead the change effort.

(3) Create a vision of the organisation's future – to help focus and direct the change.

(4) Communicate that vision widely, repeatedly and consistently – from the leadership level down through all organisational levels, in language and in actions and behaviours.

(5) Empower people in the organisation to act on the vision – remove obstacles to change, improve processes and systems, encourage and enable people to take risks, engage in non-traditional thinking and activities.

(6) Plan for visible short-term performance improvements – enable these to occur and recognise their achievement and the work of those who have enabled that achievement.

(7) Consolidate improvements and produce more change – as change takes effect build on the credibility and confidence that results, extending the reform or structures, systems and processes and encouraging and growing change agents in the organisation.

(8) Institutionalise new approaches – clearly articulate the connections between the new ways of working and organisational successes, encourage and develop on-going leadership of change and anchor the changes into the organisational culture.

Appendix III - Doppelt's "wheel of change" model

By contrast Doppelt's (2003) analysis provides a newer and less widely known approach to understanding and approaching organisational change. This analysis of the dynamics of organisational change is drawn from wide ranging and long – term analysis of, in particular, public sector organisations and thus may be of particular value and relevance to the higher education sector. In more detail the seven elements in Doppelt's "wheel of change" are shown below.

(Adopted from Doppelt 2003)

The model's primary focus is achieving organisational change in the context of achieving environmental sustainability. However, his concept can be readily applied to organisational change in any context. His research views the process of change as being a cycle or a wheel. He articulates seven points at which interventions may be made or leverage applied to effect change. Significantly, and in variance to Kotter's view of the primacy of strict ordering of sequential steps in the process of change, Doppelt argues that interventions may be made at any point in the cycle – provided that all steps are carried through. He also acknowledges change as a messy and far from linear process and suggests that, while implementation of all seven components or leverage points is essential for achieving organisational effectiveness, it is possible to enter the change cycle at any point and to work with any of the leverage points and with vary degrees of attention to each. This process of (potentially) multiple and non-sequential interventions and actions builds momentum for change.

Doppelt (2003) identified seven key leverage/intervention points in a change process. Like Kotter, Doppelt says that for change to be effective all elements in the framework must be implemented. However, a key point of difference is that Doppelt does not insist that these interventions must occur in strict sequence.

Commonalities and differences – Kotter and Doppelt

There are some common features, and some differences in these two models. Both Kotter and Doppelt emphasise similar themes – albeit described differently. These are the importance of:

- Establishing a sense of urgency about the need to change and disrupting business-as-usual mind-sets and set ways of working;
- Creating a vision of the ideal future and engaging people in the organisation with the change agenda overall and with actions to achieve the change;
- Communicating the change vision widely and consistently and at all levels of the organisation;
- Empowering people in the organisation to do think and act differently to take risks, explore new ways of working and overcome barriers to innovation and individual/organisational learning;
- Enabling feedback loops in the organisation, recognising success in achieving change (in turn encourage more change in an exponential cycle which builds on success); and
- Institutionalizing new/changed approaches to working – embedding change and making it stick.

Appendix IV - Unified Modelling language

UML is a standardized general-purpose modeling language which includes a set of graphic notation techniques to create visual models of object-oriented software-intensive systems. UML is used to specify, visualize, modify, construct and document the artifacts of an object-oriented software-intensive system under development. UML offers a standard way to visualize a system's architectural blueprints, including elements such as:

- activities
- actors
- business processes
- database schemas
- (logical) components
- programming language statements
- reusable software components

Structure diagrams

Structure diagrams emphasize the things that must be present in the system being modeled. Since structure diagrams represent the structure, they are used extensively in documenting the software architecture of software systems.

- Class diagram: describes the structure of a system by showing the system's classes, their attributes, and the relationships among the classes.
- Component diagram: describes how a software system is split up into components and shows the dependencies among these components.
- Composite structure diagram: describes the internal structure of a class and the collaborations that this structure makes possible.
- Deployment diagram: describes the hardware used in system implementations and the execution environments and artifacts deployed on the hardware.
- Object diagram: shows a complete or partial view of the structure of an example modeled system at a specific time.
- Package diagram: describes how a system is split up into logical groupings by showing the dependencies among these groupings.
- Profile diagram: operates at the metamodel level to show stereotypes as classes with the stereotype, and profiles as packages with the profile

stereotype. The extension relation (solid line with closed, filled arrowhead) indicates what metamodel element a given stereotype is extending.

Behavior diagrams

Behavior diagrams emphasize what must happen in the system being modeled. Since behavior diagrams illustrate the behavior of a system, they are used extensively to describe the functionality of software systems.

- Activity diagram: describes the business and operational step-by-step workflows of components in a system. An activity diagram shows the overall flow of control.
- UML state machine diagram: describes the states and state transitions of the system.
- Use case diagram: describes the functionality provided by a system in terms of actors, their goals represented as use cases, and any dependencies among those use cases.

Interaction diagrams

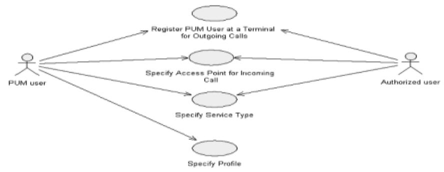
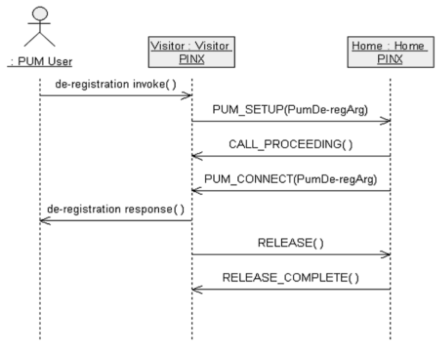
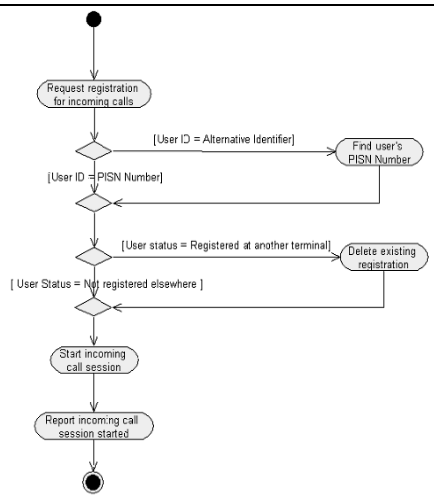
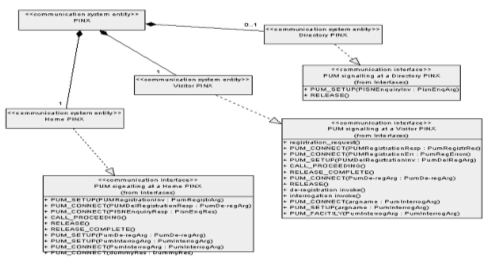
Interaction diagrams, a subset of behavior diagrams, emphasize the flow of control and data among the things in the system being modeled:

- Communication diagram: shows the interactions between objects or parts in terms of sequenced messages. They represent a combination of information taken from Class, Sequence, and Use Case Diagrams describing both the static structure and dynamic behavior of a system.
- Interaction overview diagram: provides an overview in which the nodes represent communication diagrams.
- Sequence diagram: shows how objects communicate with each other in terms of a sequence of messages. Also indicates the lifespan of objects relative to those messages.
- Timing diagrams: a specific type of interaction diagram where the focus is on timing constraints.

Examples of some UML types:

- Use Case diagram
- Sequence diagram

- Activity diagram
- Object diagram
- Class diagram

Diagram Type	**Description**	**View**
Use Case diagram	The creation of a use case model is an excellent vehicle for elicitation of functional requirements.	
Sequence diagram	When describing the details of a use case (service), a sequence diagram is one of the possible diagram kinds to choose from in UML.	
Activity diagram	An activity diagram is another way to describe use case behaviour, focussing on how the behaviour can be broken down in functions, internal to the system or system part.	
Class diagram	Class diagrams typically describe the different entities of a system as classes and the relation between these	

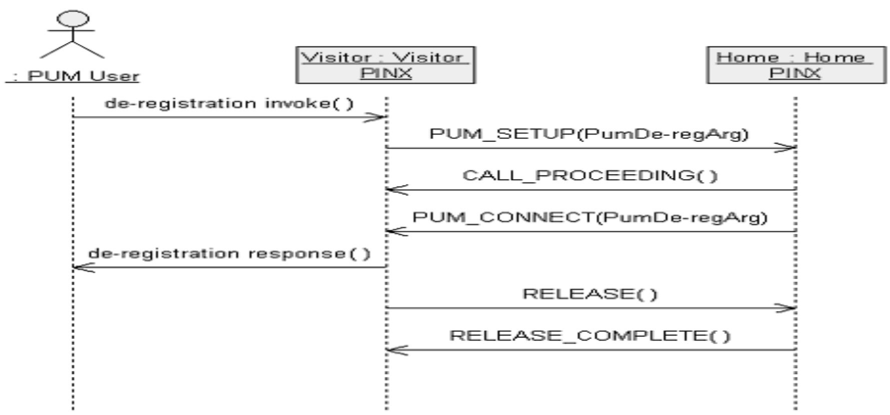
Use Case diagram

The creation of a use case model is an excellent vehicle for elicitation of functional requirements. The activity consists of identifying use cases and actors and describing the details of each use case.

The use case diagram above describes what services (use cases) that are available for different categories of users

Sequence diagram

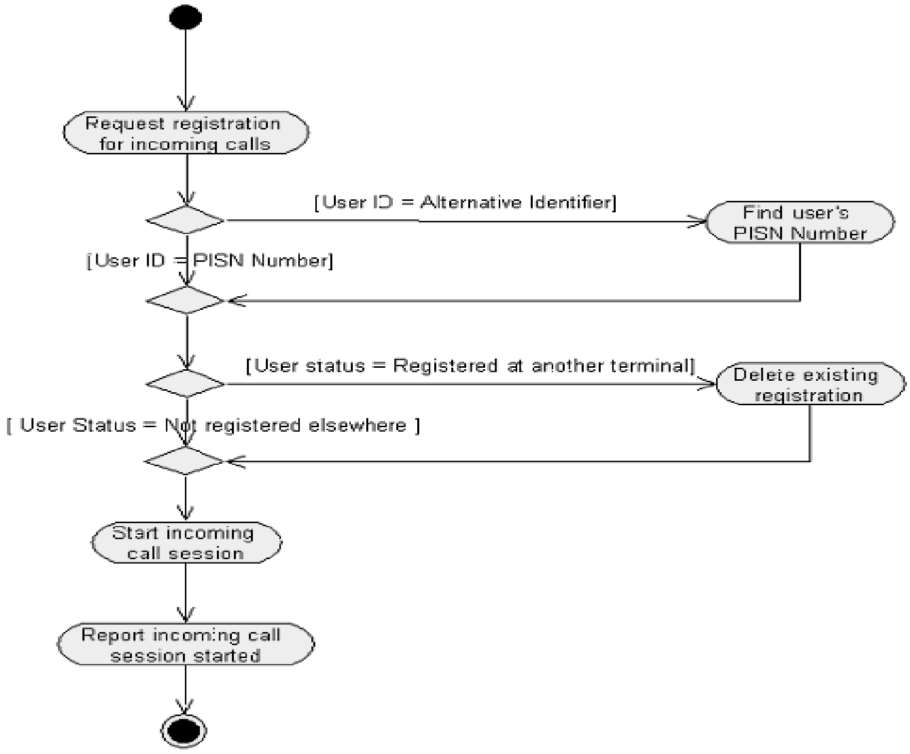
When describing the details of a use case (service), a sequence diagram is one of the possible diagram kinds to choose from in UML. When making sequence diagrams, focus on describing the sequences of message interactions between communicating entities.



The sequence diagram above describes how the actor (PUM User) initiates the de-registration use case and how the distributed system entities (Visitor, Home) interacts by message interchange in order to carry out the service

Activity diagram

An activity diagram is another way to describe use case behaviour, focussing on how the behaviour can be broken down in functions, internal to the system or system part.

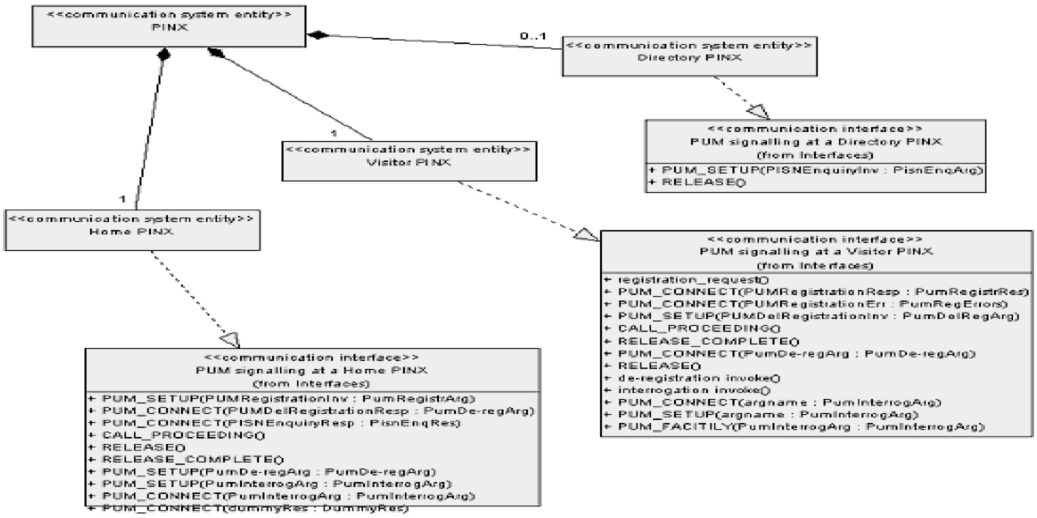


The activity diagram above describes in what order different functions should be carried out and, if they are optional, under what circumstances the functions should be invoked.

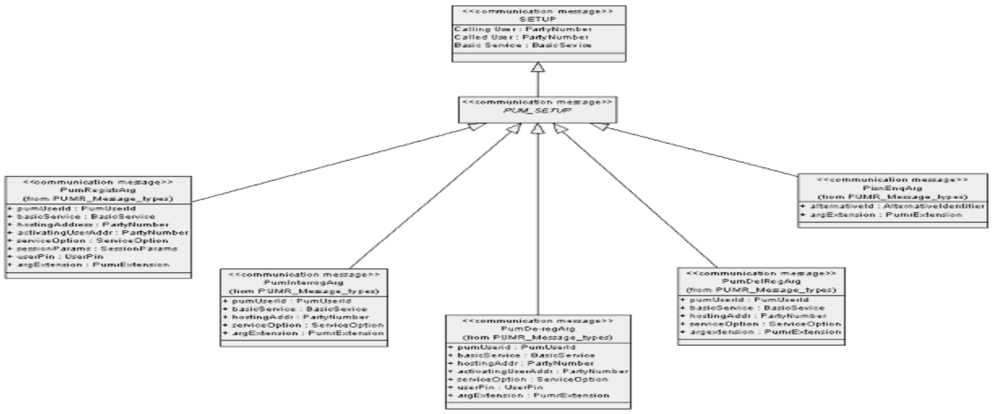
Class diagram

Class diagrams typically describe the different entities of a system as classes and the relation between these. This may for example include

- system parts and their relation
- system data
- interfaces of communicating parts
- messages and operations of interfaces



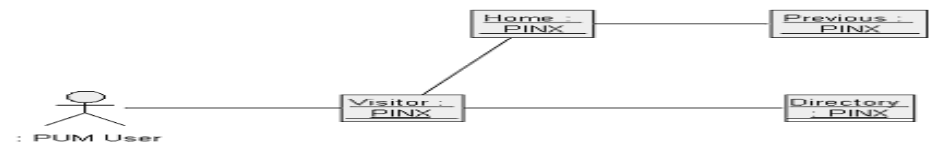
The class diagram above describes the communicating entities of the PUMR model (Home PINX, Visitor PINX, and Directory PINX) and the interfaces with operations/messages that these entities must realize.



The class diagram above shows the different setup messages of the PUMR model and the data these messages carry.

Object diagram

The object diagram puts the classes in the class diagrams into context and shows how individual instances of classes relate to each other.



The object diagram above describes how the communicating entities in the PUMR system environment relate and the means for communication that exist.

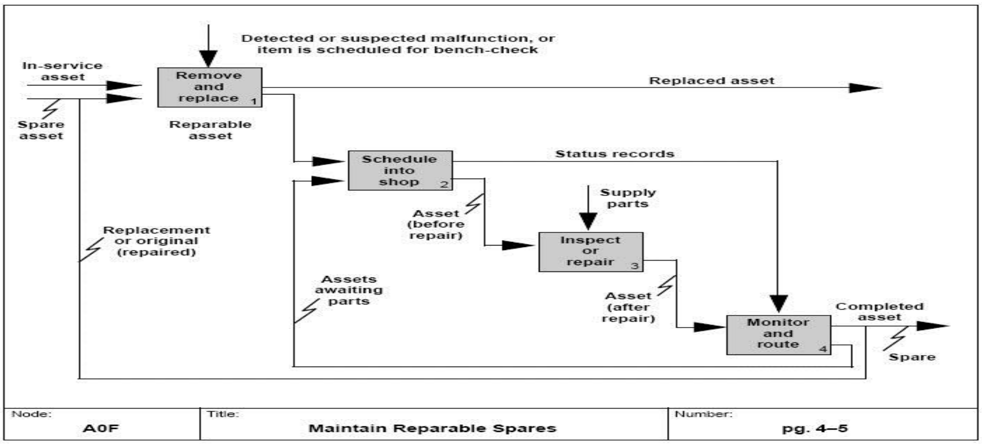
Appendix V - IDEF

An abbreviation of **Integration Definition** refers to a family of modeling languages in the field of systems and software engineering. They cover a wide range of uses, from functional modeling to data, simulation, object-oriented analysis/design and knowledge acquisition. The IDEF Functional Modeling method is designed to model the decisions, actions, and activities of an organisation or system. It was derived from the established graphic modeling language Structured Analysis and Design Technique (SADT) developed by Douglas T. Ross and SofTech, Inc. In its original form, IDEF0 includes both a definition of a graphical modeling language (syntax and semantics) and a description of a comprehensive methodology for developing models.

An abbreviation of **Integration Definition** refers to a family of modeling languages in the field of systems and software engineering. They cover a wide range of uses, from functional modeling to data, simulation, object-oriented analysis/design and knowledge acquisition.

The IDEF modeling languages

IDEF 0

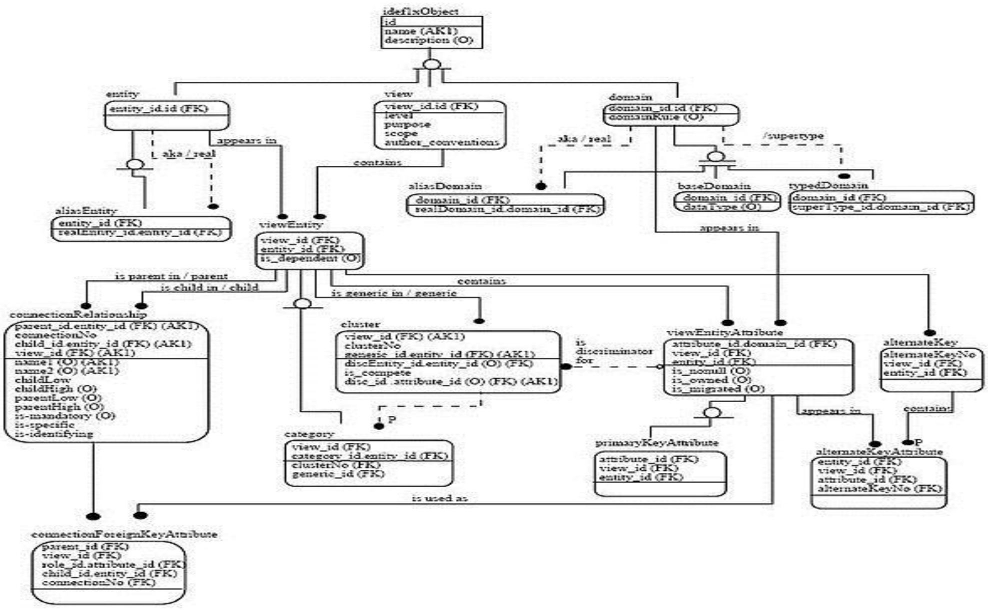


Example of an IDEF0 diagram: A function model of the process of "Maintain Reparable Spares".

The IDEF0 Functional Modeling method is designed to model the decisions, actions, and activities of an organization or system. It was derived from the established graphic modeling language Structured Analysis and Design

Technique (SADT) developed by Douglas T. Ross and SofTech, Inc.. In its original form, IDEF0 includes both a definition of a graphical modeling language (syntax and semantics) and a description of a comprehensive methodology for developing models. The US Air Force commissioned the SADT developers to develop a function model method for analyzing and communicating the functional perspective of a system. IDEF0 should assist in organizing system analysis and promote effective communication between the analyst and the customer through simplified graphical devices.

IDEF1X



Example of an IDEF1X Diagram.

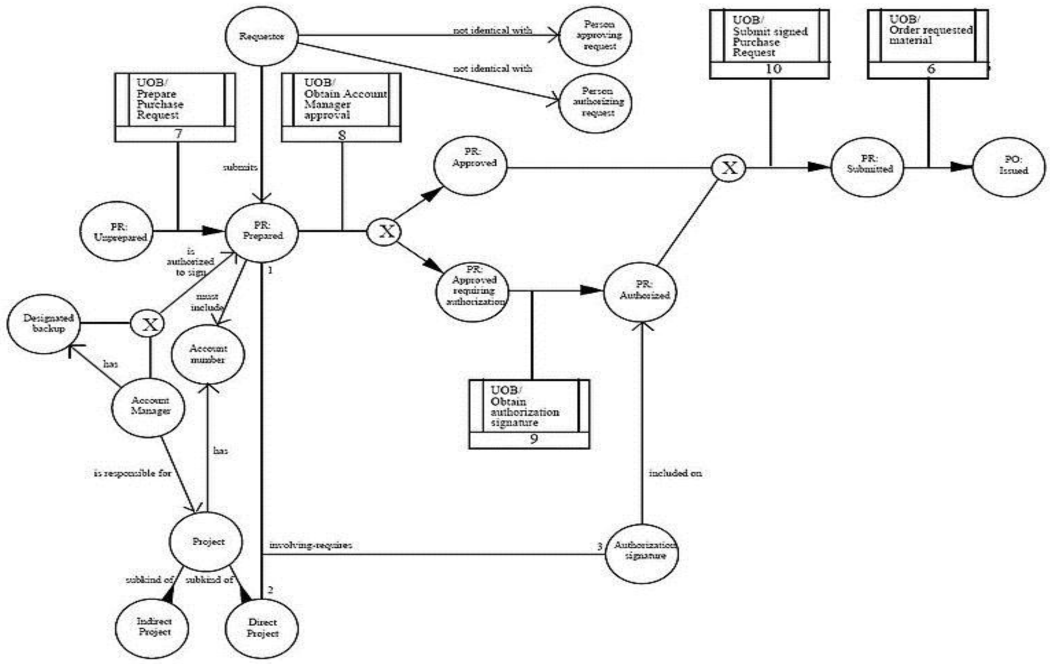
To satisfy the data modeling enhancement requirements that were identified in the IISS-6202 project, a sub-contractor, DACOM, obtained a license to the Logical Database Design Technique (LDDT) and its supporting software (ADAM). LDDT had been developed in 1982 by Robert G. Brown of The Database Design Group entirely outside the IDEF program and with no knowledge of IDEF1. LDDT combined elements of the relational data model, the E-R model, and generalization in a way specifically intended to support data modeling and the transformation of the data models into database designs. The graphic syntax of LDDT differed from that of IDEF1 and, more importantly, LDDT contained interrelated modeling concepts not present in IDEF1. Mary E.

Loomis wrote a concise summary of the syntax and semantics of a substantial subset of LDDT, using terminology compatible with IDEF1 wherever possible. DACOM labeled the result IDEF1X and supplied it to the ICAM program.

Because the IDEF program was funded by the government, the techniques are in the public domain. In addition to the ADAM software, sold by DACOM under the name Leverage, a number of CASE tools, such as ERwin, use IDEF1X as their representation technique for data modeling.

The IISS projects actually produced working prototypes of an information processing environment that would run in heterogeneous computing environments. Current advancements in such techniques as Java and JDBC are now achieving the goals of ubiquity and versatility across computing environments which was first demonstrated by IISS.

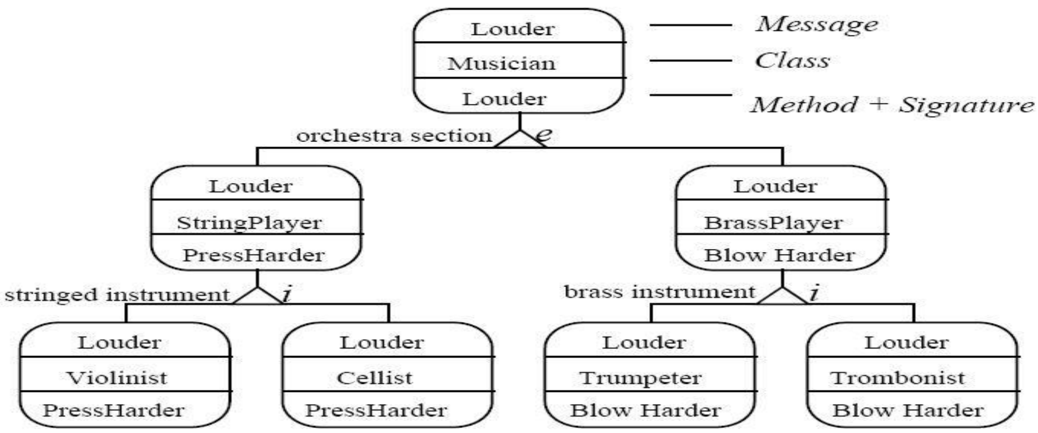
IDEF2 and IDEF 3



Example of an Enhanced Transition Schematic, modeled with IDEF3.

The third IDEF (IDEF2) was originally intended as a user interface modeling method. However, since the Integrated Computer-Aided Manufacturing (ICAM) Program needed a simulation modeling tool, the resulting IDEF2 was a method for representing the time varying behavior of resources in a manufacturing system, providing a framework for specification of math model based simulations. It was the intent of the methodology program within ICAM to rectify this situation but limitation of funding did not allow this to happen. As a result, the lack of a method which would support the structuring of descriptions of the user view of a system has been a major shortcoming of the IDEF system. The basic problem from a methodology point of view is the need to distinguish between a description of what a system (existing or proposed) is supposed to do and a representative simulation model that will predict what a system will do. The latter was the focus of IDEF2; the former is the focus of IDEF3.

IDEF 4

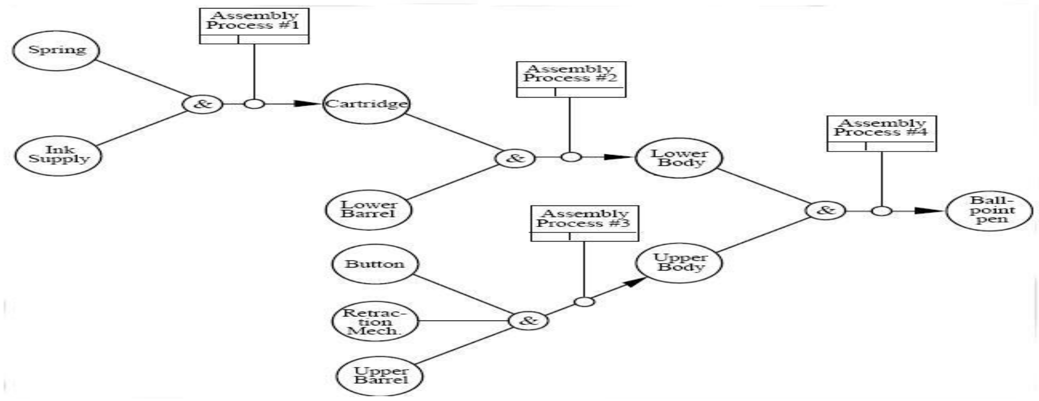


Example of the IDEF4: A Behavior Diagram for methods implementing Louder.

The development of IDEF4 came from the recognition that the modularity, maintainability and code reusability that results from the object-oriented programming paradigm can be realized in traditional data processing applications. The proven ability of the object-oriented programming paradigm to support data level integration in large complex distributed systems is also a major factor in the widespread interest in this technology from the traditional data processing community.

IDEF4 was developed as a design tool for software designers who use object-oriented languages such as the Common Lisp Object System, Flavors, Smalltalk, Objective-C, C++, and others. Since effective usage of the object-oriented paradigm requires a different thought process than used with conventional procedural or database languages, standard methodologies such as structure charts, data flow diagrams, and traditional data design models (hierarchical, relational, and network) are not sufficient. IDEF4 seeks to provide the necessary facilities to support the object-oriented design decision making process.

IDEF 5

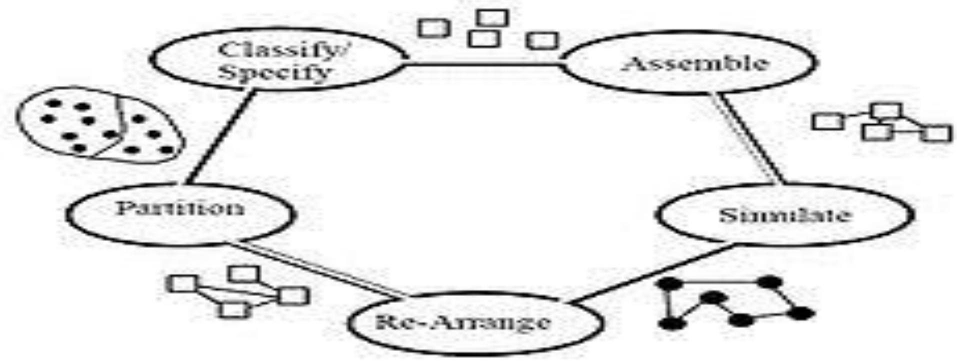


Example of an IDEF5 Composition Schematic for a Ballpoint Pen.

IDEF5, or *Integrated Definition for Ontology Description Capture Method*, is a software engineering method to develop and maintain usable, accurate, domain ontologies. In the field of computer science ontologies are used to capture the concept and objects in a specific domain, along with associated relationships and meanings. In addition, ontology capture helps coordinate projects by standardizing terminology and creates opportunities for information reuse. The IDEF5 Ontology Capture Method has been developed to reliably construct ontologies in a way that closely reflects human understanding of the specific domain.

In the IDEF5 method, ontology is constructed by capturing the content of certain assertions about real-world objects, their properties and their interrelationships, and representing that content in an intuitive and natural form. The IDEF5 method has three main components: A graphical language to support conceptual ontology analysis, a structured text language for detailed ontology characterization, and a systematic procedure that provides guidelines for effective ontology capture.

IDEF 6



IDEF6 model of IDEF4 Design Activities

IDEF6, or *Integrated Definition for Design Rationale Capture,* is a method to facilitate the acquisition, representation, and manipulation of the design rationale used in the development of enterprise systems. Rationale is the reason, justification, underlying motivation, or excuse that moved the designer to select a particular strategy or design feature. More simply, rationale is interpreted as the answer to the question, “Why is this design being done in this manner?” Most design methods focus on what the design is (i.e. on the final product, rather than why the design is the way it is).

IDEF6 will be a method that possesses the conceptual resources and linguistic capabilities needed (i) to represent the nature and structure of the information that constitutes design rationale within a given system, and (ii) to associate that rationale with design specifications, models, and documentation for the system. IDEF6 is applicable to all phases of the information system development process, from initial conceptualization through both preliminary and detailed design activities. To the extent that detailed design decisions for software systems are relegated to the coding phase, the IDEF6 technique should be usable during the software construction process as well.

IDEF 8

IDEF8, or *Integrated Definition for Human-System Interaction Design*, is a method for producing high-quality designs of interactions between users and the systems they operate. Systems are characterized as a collection of objects that perform functions to accomplish a particular goal. The system with which the user interacts can be any system, not necessarily a computer program. Human-system interactions are designed at three levels of specification within the IDEF8 method. The first level defines the philosophy of system operation and produces a set of models and textual descriptions of overall system processes. The second level of design specifies role-centered scenarios of system use. The third level of IDEF8 design is for human-system design detailing. At this level of design, IDEF8 provides a library of metaphors to help users and designers specify the desired behavior in terms of other objects whose behavior is more familiar. Metaphors provide a model of abstract concepts in terms of familiar, concrete objects and experiences.

IDEF 9

Strategic Planning
- Business Forecasting
- Market Analysis
- Market Research
- Mission Planning
- Resource Allocation
- Cost Planning and Control
- Total Quality Management

Tactical Planning
- Operational Policy Release
- Manpower Planning
- Manpower Allocation
- Material Planning
- Quality Planning
- Manufacturing Planning
- Manufacturing Cost Estimation
- Concurrent Engineering Planning
- Information Systems Planning
- Business Re-engineering Planning

Customer Support
- Inquiry Processing
- Warranty Management
- Product Support
- Liability Control
- Customer Information

Order Processing and Control
- Order Analysis and Entry
- Order Control
- Order Cancellation
- Order Release
- Order History Maintanance
- Customer Order Servicing
- Accounts Receivable
- Credit Control
- Rapid Response/Emergency Order

Packaging

Shipping

Master Production Schedule Planning
- Stock Replenishment Planning
- Capacity Requirements Planning
- Resource Requirements Planning
- Material Requisitioning
- Order and Delivery Scheduling
- Facilities Modernization Planning
- Facilities Planning
- Fabrication Process Planning
- Assembly Process Planning
- Inspection Planning

Scrap Recovery/Reclamation

Manufacturing Activity Management and Control
- Manufacturing Activity Planning
- Work-In-Process Control
- Manufacturing Activity Reporting
- Production Process Monitoring and Control
- Statistical Process Control
- Material Handling Planning, Scheduling, and Control
- Manufacturing Quality Control
- Production Data Management and Control
- End-of-Shift Reporting
- Error Reporting

Personnel Management
- Certification and Training
- Payroll
- Attendance and Labor Reporting
- Security
- Job Performance Tracking
- Job Assignment
- Reporting
- Overtime Authorization
- Quality of Life
- Pension Planning and Investment

Purchasing
- Purchase Planning
- Supplier Identification
- Supplier Evaluation
- Supplier Selection
- Receiving and Inspection

Inventory Management and Control
- Inventory Planning
- Inventory Accounting
- Inventory Control
- Kit Preparation & Tracking

Conformance Testing

Tool Management and Control
- Tool Requirements Planning
- Tool Identification
- Tool Checkout

Design support (CAD)

Engineering support (CAE)

Engineering Data Management & Control
- Bills of Material
- Engineering Drawings
- Manufacturing Process Planning
- Engineering Change Planning
- Engineering Change History
- Configuration Control
- Requirements Tracking

Safety
- Safety Inspection
- Safety Reporting
- Standards Compliance
- Hazardous Material Notices

Maintenance Planning
- Preventive Maintenance
- Unscheduled (Breakdown or Emergency) Maintenance

Product Research and Development

New Business Generation
- Bid, Quote, and Proposal Preparation
- Bid and Proposal Tracking
- Contact Management

Typical business systems.

IDEF9, or *Integrated Definition for Business Constraint Discovery*, is designed to assist in the discovery and analysis of constraints in a business system. A primary motivation driving the development of IDEF9 was an acknowledgment that the collection of constraints that forge an enterprise system is generally poorly defined. The knowledge of what constraints exist and how those constraints interact is incomplete, disjoint, distributed, and often completely unknown. This situation is not necessarily alarming. Just as living organisms do not need to be aware of the genetic or autonomous constraints that govern certain behaviors, organizations can (and most do) perform well without explicit knowledge of the glue that structures the system. In order to modify business in a predictable manner, however, the knowledge of these constraints is as critical as knowledge of genetics is to the genetic engineer.

IDEF 14

IDEF14, or *Integrated Definition for Network Design Method*, is a method that targets the modeling and design of computer and communication networks. It can be used to model existing ("as is") or envisioned ("to be") networks. It helps the network designer to investigate potential network designs and to document design rationale. The fundamental goals of the IDEF14 research project developed from a perceived need for good network designs that can be implemented quickly and accurately.

Appendix VI - BPMN Version Comparison

BPMN versions comparison has been done, in order to see the capabilities and their limitations.

Attributes	BPMN 1.0	BPMN 1.1	BPMN 1.2	BPMN 2.0 – Beta 1
Date release	May 2004	January 2008	January 2009	August 2009
Models	• Collaborative (public) B2B processes, • Internal (private) business processes.			• Collaborative (public) B2B processes, • Internal (private) business processes, • A choreography – expected behaviour between two or more business participants, • Collaborations, which is a collection of participants and their interaction and • A conversation – the logical relation of message exchanges.
Event	• start (none, message, timer, rule, link, multiple) • intermediate (none, message, timer, error, cancel, compensation, rule, link, multiple) • end (none, message, error, cancel, compensation, link, terminate, multiple)	• start (none, message, timer, conditional, signal, multiple) • intermediate (none, message, timer, error, cancel, compensation, conditional, link, signal, multiple) • end (none, message, error, cancel, compensation, signal, terminate, multiple)		• start ○ top-level (none, message, timer, conditional, signal, multiple, parallel multiple) ○ event sub-process interrupting (message, timer, escalation, conditional, error, compensation, signal, multiple, parallel multiple) ○ event sub-process non-interrupting (message, timer, escalation, conditional, signal, multiple, parallel multiple) • intermediate ○ catching (message, timer, conditional, link, signal, multiple, parallel multiple) ○ boundary interrupting (message, timer, escalation, conditional, error, cancel, compensation, signal, multiple, parallel multiple) ○ boundary non-interrupting

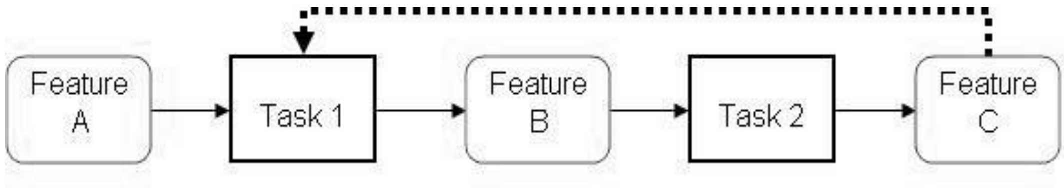
			(message, timer, escalation, conditional, signal, multiple, parallel multiple, terminate) ○ throwing (none, message, escalation, link, compensation, signal, multiple, parallel multiple) • end (none, message, escalation, error, cancel, compensation, signal, multiple, terminate)
Activity	• task (atomic) • process/sub-process (non-atomic) ○ collapsed sub-process ○ expanded sub-process		• task (atomic) • choreography task ○ collapsed choreography sub-process ○ expanded choreography sub-process • process/sub-process (non-atomic) ○ collapsed sub-process ○ expanded sub-process
Gateway	• XOR – exclusive decision and merging. Both data-based and event-based. Data-based can be shown with or without the "x" marker. • OR – inclusive decision and merging complex – complex conditions and situations • AND – forking and joining	• Exclusive decision and merging. Both data-based and event-based. Data-based can be shown with or without the "x" marker. • Inclusive decision and merging. • Complex – complex conditions and situations. • Parallel forking and joining.	• Exclusive decision and merging. Both data-based and event-based. Exclusive can be shown with or without the "x" marker. • inclusive gateway decision and merging • complex gateway – complex conditions and situations • parallel gateway – forking and joining
Other elements	• looping ○ activity looping ○ sequence flow looping • multiple instances • process break • transactions • nested/embedded sub-process • off-page connector • compensation association		• looping ○ activity looping ○ sequence flow looping • multiple instances • process break • transactions • nested/embedded sub-process • off-page connector • compensation association • communication (sub communication) • communication link

Appendix VII - Design Roadmap

Design Roadmap (DR) is developed by Park and Cutkosky in (1999). The original purpose is to seek a method to overcome the limitations of process representation discussed above. Park and Cutkosky developed this technique to provide a comprehensive method for the project management.

The most basic elements of DR are the task and feature, and the tasks and feature are unique in the DR process map and is shown in Figure A4. The task is the primary unit of the process, and it represents the elements which are participant in the process. The feature is the input and output of the tasks. Thus every task needs a feature to be the input, and it also needs another feature to represent the output of this task. The arrows are used to represent the process flow and link the tasks and features together. DR also has the complex dependencies. In these dependences, the feedback dependency is most often to be used. The definition given by Park and Cutkosky is “Fi is not needed for executing Tj, but if Fj changes, Ti needs to be revisited” (Park and Cutkosky, 1999). The feedback loop is needed in the manufacturing design process. For example, when the engineering requirements need to be integrated with design requirements, the engineers will need to discuss with design team. A feedback loop needs to be existed between the output of the engineering requirements and the design requirements. If the design requirements are changed, the engineering requirements have to be changed with design requirements.

In Figure A.4, a simple DR model is represented. The Feature A is the input of the Task 1, and the Feature B is the output of the Task1. Normally, the dataset is based on each feature. Similarly, Feature B and C are the input and output of the Task 2. There is a feedback loop existed between Feature C and Task 1, thus if Feature C is changed, the process will go back to the Task 1 and redefine the Feature B. The DR enables to contain the hierarchy of each task and feature. The serial number of sub-tasks is N.1. For example, if Feature B contained a sub-system, the serial number will start from B.1.1.



DR can deal with both simple process and complex process, and it can be simple and complex based on the particular project requirements. The syntax of DR is easy to understand and learn. Thus, organisations do not need to train the particular expertise for producing DR. DR is particular appropriate for manufacturing project, because it is good at representing sequences and feedback loops. DR also does not require a particular system programme to produce it, and Microsoft Excel can produce a perfect DR model.

However, It is not a common method as IDEF as a standard, because DR is a new process technique in process modelling domain. Therefore, many experts are not familiar with DR. To tackle the on-going design process of the system, the companies should follow a simple design roadmap that will guide the reader through the creation of the models and the consequent production of the code that will materialize those models into a working software system. The roadmap consists of several steps or activities, many of which can be accomplished in parallel as follows:

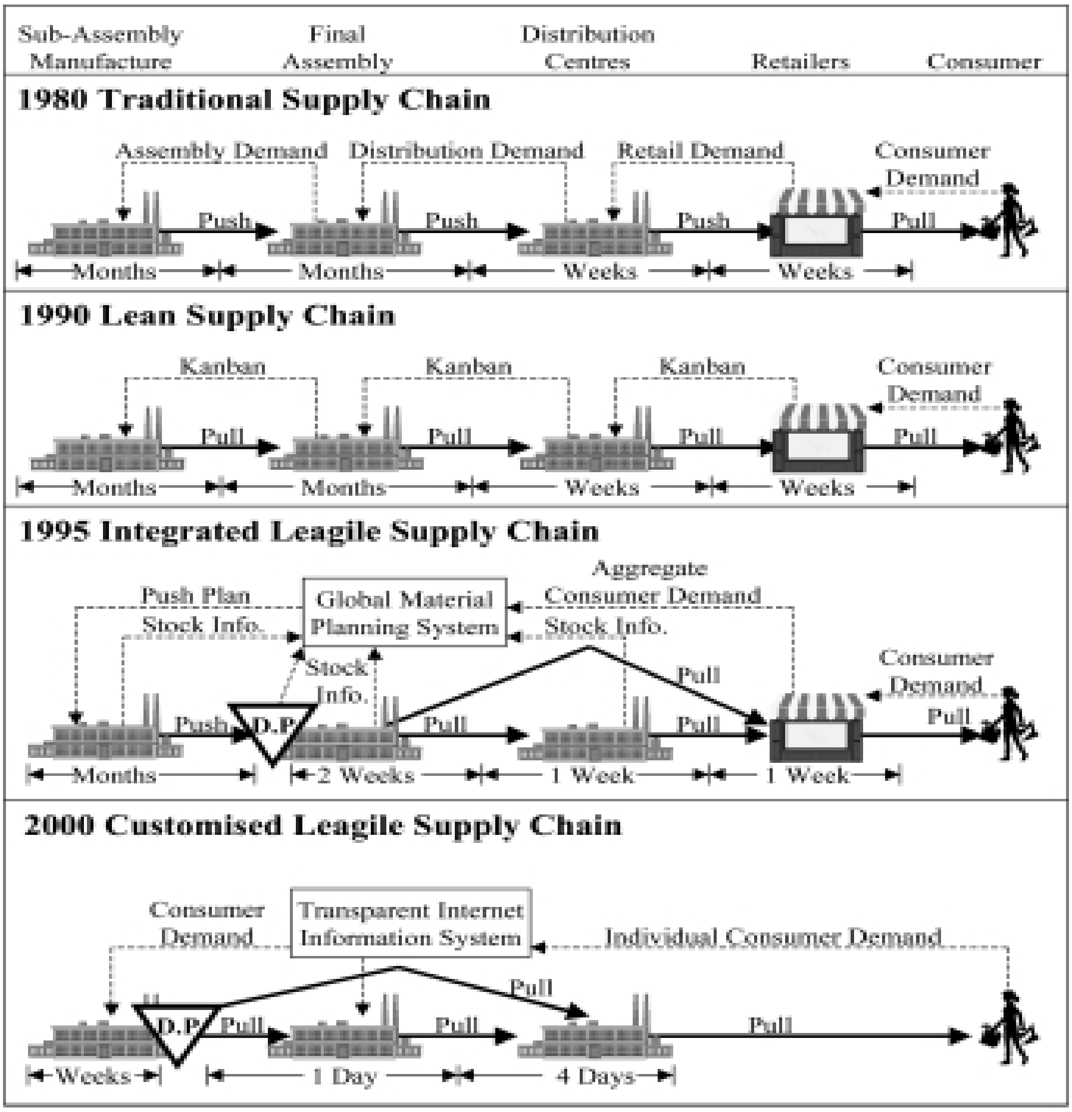
- Creation of an analysis object model (domain model): An understanding of the domain is documented in the form of a static model (class model) that will serve as guidance during the requirements analysis and creation of the design models. This step gives a high-level foundation from which it's easier to see subsystems of related objects and components emerge. A domain model also serves as a way to validate any assumptions or preconceived notions about the domain and solidifies and centralizes the knowledge about the problem domain.
- Requirement analysis: Actors are defined from the analysis and architectural documents. User use cases (a use case that fulfils a specific feature) are created for high-level interactions of the primary actors with the system. User use cases are then decomposed into system-level use cases if necessary. System-level use cases depict actions taken by specific

components in the system to accomplish a task needed for the fulfilment of a user use case. Quick assessment of the reuse of system-level use cases is performed. High- priority use cases are written in detail to curtail major risks (detail doesn't mean implementation-specific details). Analysis of requirements continues iteratively for as long as the project or product is alive.

- Iteration planning: Iterations are planned based on a group of use cases. Integration planning is performed to determine points of integration and modifications, or enhancements to the overall automation of the integration process are made. In this book each chapter is set as an iteration that sets out to fulfil a certain number of use cases.
- Iteration execution: Detail is added to use cases, both user and system use cases. Tests are written for each feature, and integration code or scripts are created or enhanced. Detailed dynamic models are created (detailed enough to be implemented and detailed enough to utilize any forward-engineering features of the CASE tools available to the maximum). Class diagrams for any subsystems created are defined and the overall model diagram is updated to reflect the results of the iteration. Whenever necessary, component diagrams and subsystem diagrams are created, thereby displaying the component interfaces and their relationships to the object models.

Appendix VIII - Supply Chain Evolutions

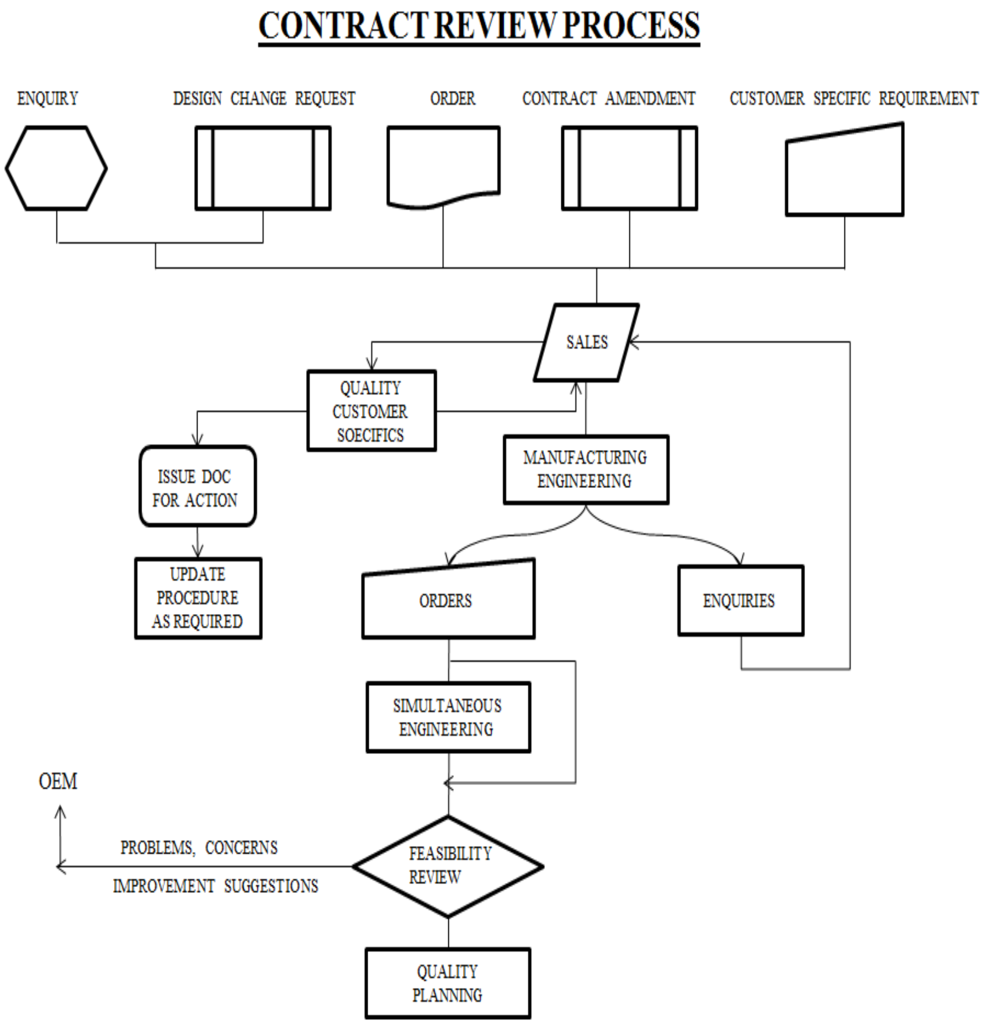
Supply chain evolution starting from 80's, when initially the concept was developed to the latest trend which is in use by industries currently.



(Adapted from Childerhouse and Towill 2000)

Appendix IX – Contract Review Process

In this process, Sales department links with the entire concerned departments for enquiry, design change (if required), purchasing, administration and OEM to check the feasibility of going into the production.



Sales department after consulting the above mentioned departments checked the quality specification requirement of the customer and in the same time links with manufacturing engineering department. Their job is to create the enquiry and orders (If required) to do the feasibility review.

Appendix X - Part Drawing Views

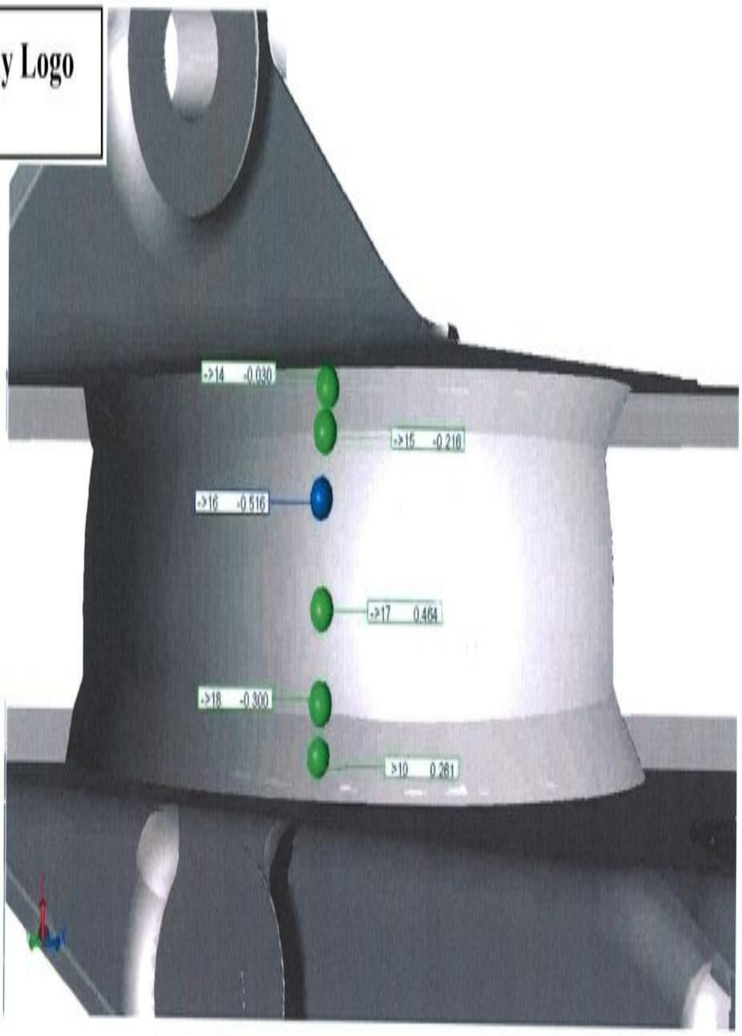
View 2

6S61-3K305-AA

User name

Date

Company Logo



6S61-3K305-AA
Impression 7
view 2

Sheet Thickness	0.000 mm		
Meas. mode surf		Meas. mode edge	
Max. deviation	0.464 mm(17)	Max. Deviation	
Mean deviation	-0.143 mm	Mean Deviation	
Min. deviation	-0.516 mm(16)	Min. Deviation	

Bestfit
Move
Rot.

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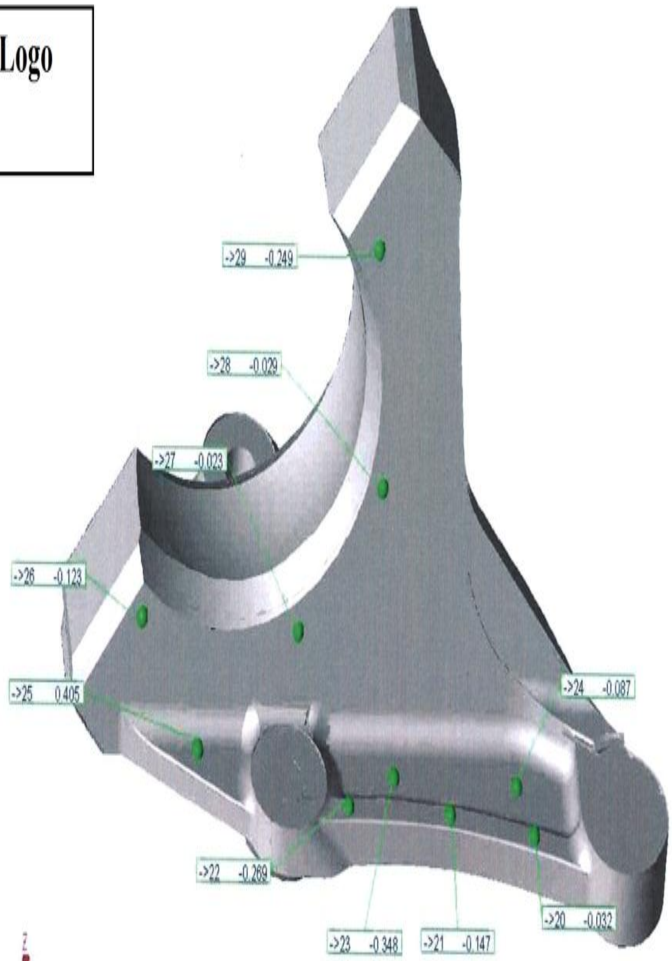
- Page1 -

View 3

6S61-3K305-AA

User name | Date

Company Logo



6S61-3K305-AA
Impression 7
view 3

Sheet Thickness	0.000 mm	
Meas. mode surf		Meas. mode edge
Max. deviation	0.405 mm(25)	Max. Deviation
Mean deviation	-0.090 mm	Mean Deviation
Min. deviation	-0.348 mm(23)	Min. Deviation

Bestfit
Move
Rot.

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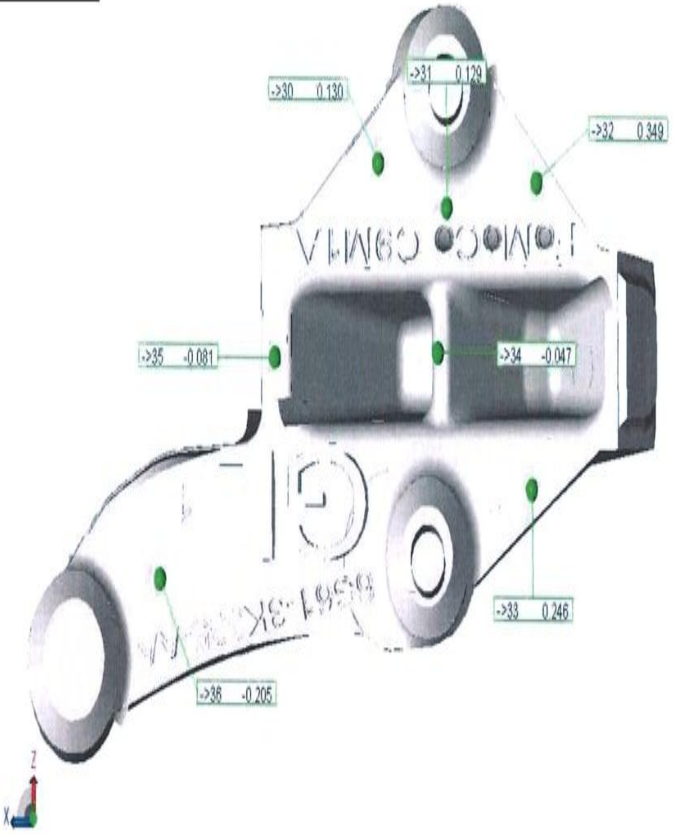
View 4

6S61-3K305-AA

User name		Date	

Company Logo



6S61-3K305-AA
Impression 7
view 4

Sheet Thickness	0.000 mm	
Meas. mode surf		Meas. mode edge
Max. deviation	0.349 mm(32)	Max. Deviation
Mean deviation	0.074 mm	Mean Deviation
Min. deviation	-0.205 mm(36)	Min. Deviation

Bestfit
Move
Rot.

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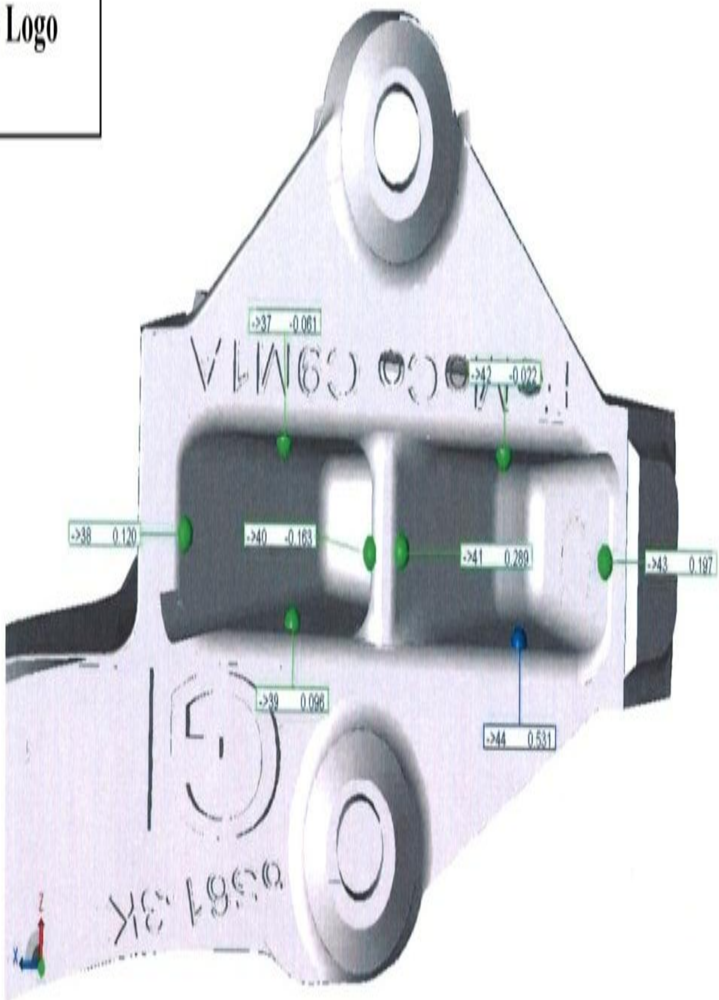
View 5

6S61-3K305-AA

User name | Date

Company Logo



6S61-3K305-AA
Impression 7
view 5

Sheet Thickness	0.000 mm		
Meas. mode surf		Meas. mode edge	
Max. deviation	0.531 mm(44)	Max. Deviation	
Mean deviation	0.124 mm	Mean Deviation	
Min. deviation	-0.163 mm(40)	Min. Deviation	

Bestfit
Move
Rot.

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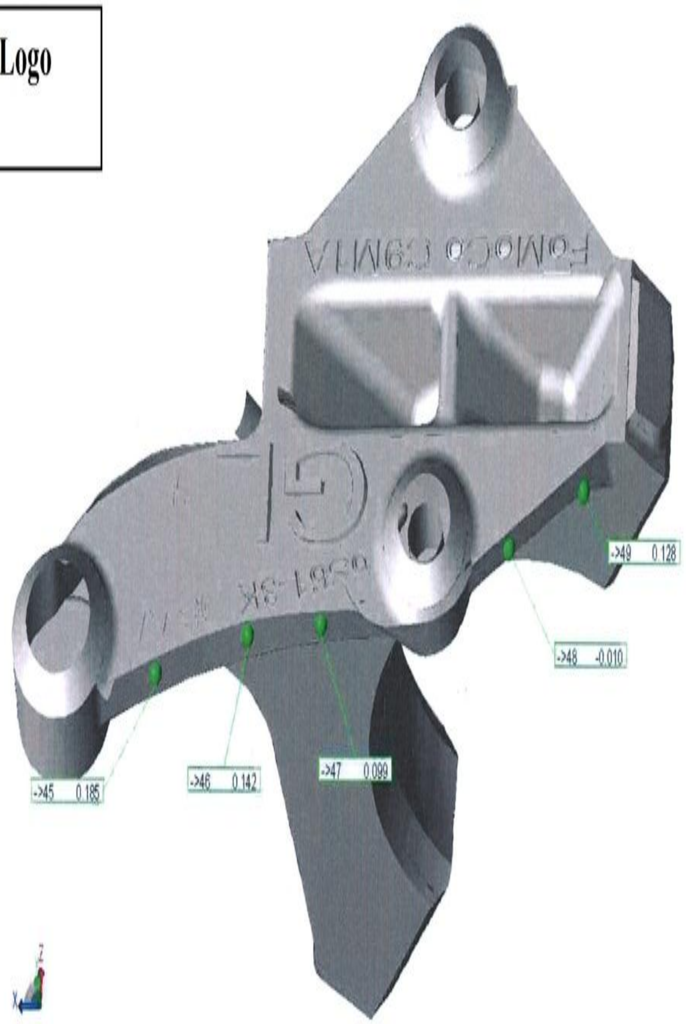
View 6

6S61-3K305-AA

User name | | Date |

Company Logo



6S61-3K305-AA
Impression 7
view 6

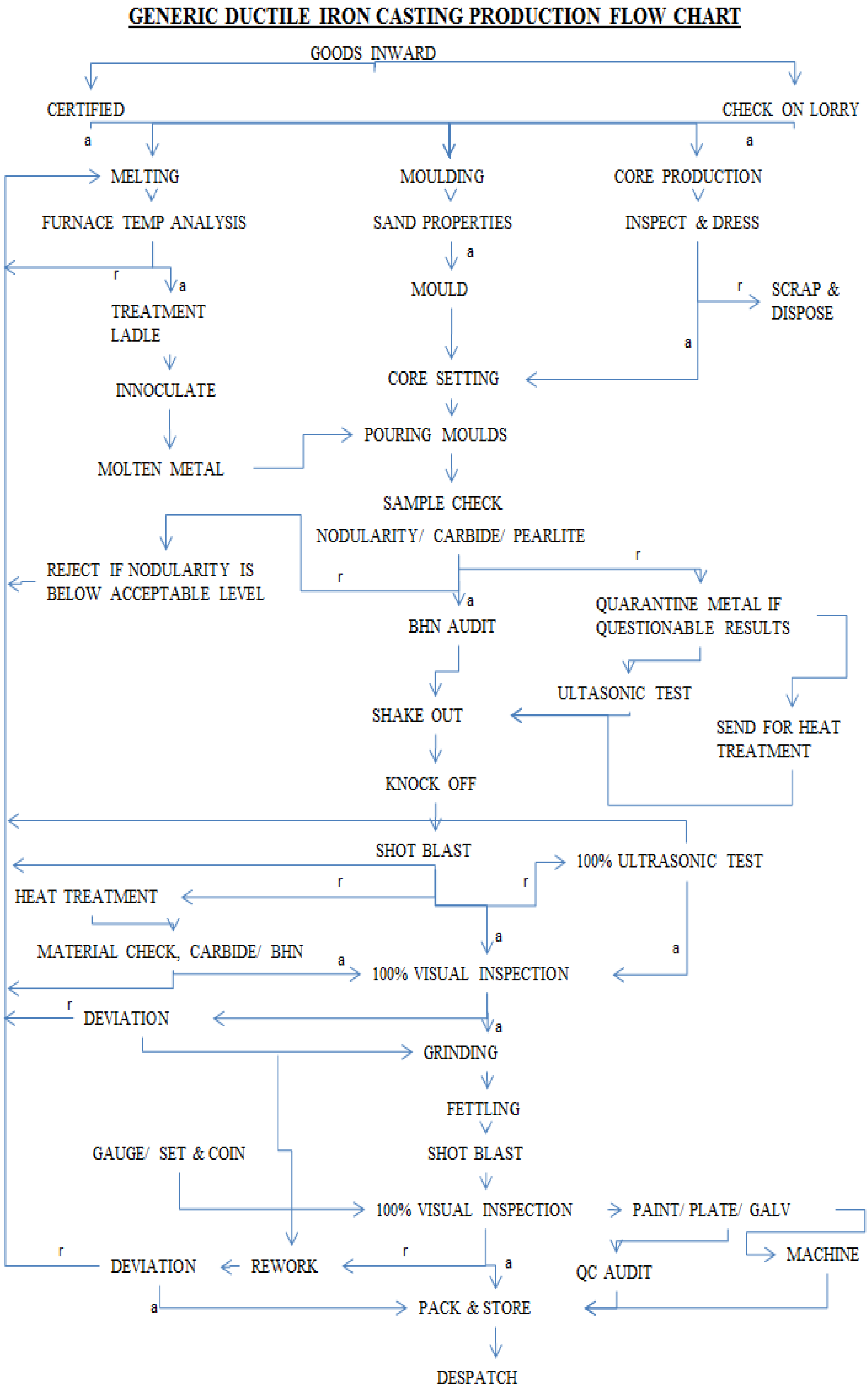
Sheet Thickness	0.000 mm	
Meas. mode surf		Meas. mode edge
Max. deviation	0.185 mm(45)	Max. Deviation
Mean deviation	0.109 mm	Mean Deviation
Min. deviation	-0.010 mm(48)	Min. Deviation

Bestfit
Move
Rot.

CAT1000S v3.0.R11 Edition 10 in MCOSMOS-1 - Page1 -

Appendix XI – Production Flow Chart

The detailed production flow chart, which is use by Tier 2 supplier for casting process, is shown diagrammatically below.



Appendix XII – Quality Control Plan

When the part is being manufactured, it goes through this quality control plan which can be summarised as follows:

QUALITY CONTROL PLAN

Control Plan Number : CP000639

First Created :

INITIAL / VOLUME PRODUCTION

Customer :
Plant :
Customer Part Number :6S61-3K305-AA
Customer Reference :0.975 KG / ON

Customer Drawing Number :6S61-3K305-AA
Customer Drawing Issue :EN01 E11869836 000
Surface Finish :
Production Plan :10056C, 9667C, 9598C

Material :SG IRON
Material Specification :450.10 (EN1563-GJS)

Part Number :6S61-3K305-AA
Description :LINKSHAFT - GOLD
Plan Number :CP000639

Drawing Number :6S61-3K305-AA
Drawing Issue :EN01 E11869836 000
Issue Number : 2

Engineer :
Supervisor :
Latest Issue Date :

Characteristic		Checking Technique or Method					Reaction Plan	
Description of Characteristic	Special Char/Class	Checking Method	Sampling Frequency	Sample Size	Dept/Person Responsible	Trace / Control	Reaction Programme	Dept/Person Responsible
Process No. 1 — Process Name : RAW MATERIAL GOODS INWARDS; Process Description : LABORATORY CONTROL								
STEEL SCRAP CHROMIUM LEVEL REF WI013		"SPECTRA-VIST" SPECTRO-METER	EVERY DELIVERY	REPRESENT-ATIVE SAMPLE	LABORATORY	STEEL SCRAP DELIVERY RECORD DOC 042	REJECT THE LOAD & INFORM THE SUPPLIER	TECHNICAL DIRECTOR
STEEL SCRAP CONTAMINATION IE.SURFACE COATINGS NON-METALLIC INCLUSIONS REF WI013.		VISUAL INSPECTION	EVERY DELIVERY	AS ABOVE	AS ABOVE	AS ABOVE	AS ABOVE	AS ABOVE
PIG IRON CHEMICAL ANALYSIS REF. WI013		CERTIFIED	AS ABOVE	NOT APPLICABLE (DOCUMENTS ONLY TO BE EXAMINED)	LABORATORY	PIG IRON DELIVERY RECORD DOC 174	AS ABOVE	AS ABOVE
FURNACE ADDITIONS & MOULDING MATERIALS CORRECT TO SPECIFICATION REF.WI013		CERTIFIED	EVERY DELIVERY	NOT APPLICABLE (DOCUMENTS ONLY TO BE EXAMINED)	AS ABOVE	SUPPLIER C OF C GENERAL DELIVERY SHEET DOC 073	REJECT THE LOAD & INFORM THE SUPPLIER	TECHNICAL DIRECTOR
Process No. 2 — Process Name : MATERIAL CONTROL I; Process Description : BASE METAL & INNOCULATION CONTROL								
CORRECT BASE METAL ANALYSIS AS SPECIFIED BY THE FOUNDRY METALLURGIST.		SPECTROLAB OPTICAL EMMISSION SPECTRO-METER & LECO CS-200 C & S DETERMIN-	EVERY MELT	CHILL SAMPLE FROM FURNACE	FOUNDRY METALL-URGIST	LABORATORY COMPUTER DATABASE	CORRECT ANALYSIS BEFORE CASTING	FOUNDRY METALL-URGIST
CORRECT TEMPERATURE AS SPECIFIED BY THE FOUNDRY METALLURGIST . AIM 1540 DEG CENT		THERMO-COUPLE WI 551 WI 311	2 CASTINGS PER FURNACE (MINIMUM)		FURNACE	FURNACE SPC SHEET DOC 265	CORRECT TEMPERATURE BEFORE TREATMENT	FURNACE
CORRECT TREATED METAL ANALYSIS AS SPECIFIED BY THE FOUNDRY METALLURGIST		SPECTROLAB OPTICAL EMMISSION SPECTRO-METER & LECO CS-200 C & S DETERMIN-	TWICE PER MELT	CHILL SAMPLE FROM LADLE	FOUNDRY METALL-URGIST	LABORATORY COMPUTER DATABASE	HOLD CASTINGS PENDING MATERIAL CHECKS	FOUNDRY METALL-URGIST

Report : CONTROL PLAN REPORT Printed on : Time : by : Page 1 Authorisation

Part Number :6S61-3K305-AA
Description :LINKSHAFT - GOLD
Plan Number :CP000639

Drawing Number :6S61-3K305-AA
Drawing Issue :EN01 E11869836 000
Issue Number : 2

Engineer :
Supervisor :
Latest Issue Date

Characteristic		Checking Technique or Method					Reaction Plan	
Description of Characteristic	Special Char/Class	Checking Method	Sampling Frequency	Sample Size	Dept/Person Responsible	Trace / Control	Reaction Programme	Dept/Person Responsible
Process No. 3	Process Name : MOULDING CONTROL Process Description : PATTERN & SAND PROPERTY CONTROL							
CORRECT PATTERN FORM		VISUAL INSPECTION	EACH PRODUCTION	PATTERN INSPECTED	FOUNDRY SUPERVISOR	PRODUCTION AUDIT SHEET (DOC 188)	CORRECT THE PATTERN PRIOR TO PRODUCTION	PATTERNSHOP
		CASTINGS SAMPLED PRIOR TO APPROVAL. CORE FORM CHECKED TO DRAWING	INITIAL SAMPLES ONLY	ONE SPRAY MINIMUM	INSPECTION	ISIR	REASON FOR NONCONFORMANCE INVESTIGATED. CORRECTIONS MADE & CASTINGS RE-SAMPLED.	INSPECTION/ PATTERNSHOP
		DIMENSIONAL CHECKS	BEFORE DELIVERY TO CASTINGS PLC.	PATTERN INSPECTED	SUB-CONTRACT PATTERN-MAKER	PATTERN CHECK SHEET	PATTERN NOT ACCEPTED UNLESS CORRECT TO DRAWING.	PATTERNSHOP
DIMENSIONS VERIFIED FOR COMPLIANCE . (REPORTING IN ACCORDANCE WITH PPAP LEVEL III SUBMISSION) . CAP BATCH PRODUCED ON APPROVAL OF INITIAL SAMPLES.		DIMENSIONAL CHECKS	INITIAL SAMPLES	REPRESENT-ATIVE SAMPLE . (ALL IMP. VERIFIED)	INSPECTION	ISIR	CORRECT THE PATTERN PRIOR TO PRODUCTION	INSPECTION/ PATTERNSHOP
		AS ABOVE	CAPABILITY BATCH	CAPABILITY BATCH 400 PCS	FOUNDRY / INSPECTIO	AS ABOVE	AS ABOVE	AS ABOVE
PIN WEAR (DISAMATIC)		GAUGE	MONTHLY (MIN)	ALL PARTS	MAINTENANCE	PLANNED MAINTENANCE RECORDS	CORRECTIONS MADE TO CONFORM TO SPECIFICATION	MAINTENANCE
MOULD DEFECTS		VISUAL INSPECTION	INITIAL SAMPLES ONLY	5 MOULDS INITIALLY, FOLLOWED BY 10 MOULDS BEFORE PATTERN SIGNED OFF & DIMENSIONAL APPROVAL.	FOUNDRY SUPERVISOR	INTERNAL SAMPLE REPORTS DOC 199 . (INCLUDES FROM INTERNAL DEFECTS / POROSITY)	CORRECT THE PATTERN & RE-SAMPLE	FOUNDRY/ PATTERNSHOP
PERMEABILITY		EQUIPMENT IN THE SAND LABORATORY	EVERY HOUR	REPRESENT-ATIVE SAMPLE	SAND TECHNICIAN	SAND CONTROL CHART DOC 110	ADJUSTMENTS MADE TO BRING TOWARDS THE TARGET	SAND TECHNICIAN
MOISTURE		AS ABOVE	AS ABOVE	AS ABOVE	AS ABOVE	AS ABOVE	AS ABOVE	AS ABOVE
GREEN STRENGTH		AS ABOVE REF WI 041	EVERY 15 MINUTES	AS ABOVE	AS ABOVE	AS ABOVE	AS ABOVE	AS ABOVE
COMPACTION		AS ABOVE	AS ABOVE	AS ABOVE	AS ABOVE	AS ABOVE	AS ABOVE	AS ABOVE
TEMPERATURE		THERMO-COUPLE	CONTINUOUS		FOUNDRY METALL-URGIST	RECORDED EVERY 15MIN ON SAND CONTROL CHART DOC 110	AUTOMATIC CONTROL	FOUNDRY METALL-URGIST
LOSS ON IGNITION		LABORATORY PROCEDURE	ONCE PER SHIFT	AS ABOVE	LABORATORY	LABORATORY SAND CHARTS	MONITORED ON AN ONGOING BASIS	FOUNDRY METALL-URGIST
LIVE CLAY		LABORATORY PROCEDURE	ONCE PER SHIFT	REPRESENT-ATIVE SAMPLE	FOUNDRY METALL-URGIST	LABORATORY SAND CHARTS	MONITORED ON AN ONGOING BASIS	FOUNDRY METALL-URGIST
VOLATILE		AS ABOVE	AS ABOVE	AS ABOVE	AS ABOVE	AS ABOVE	AS ABOVE	AS ABOVE
SIEVE ANALYSIS		AS ABOVE	ONCE PER WEEK	AS ABOVE	AS ABOVE	SIEVE ANALYSIS SHEET	AS ABOVE	AS ABOVE

Report : CONTROL PLAN REPORT Printed on : Time : by : Page 2 Authorisation

Part Number :6S61-3K305-AA
Description :LINKSHAFT - GOLD
Plan Number :CP000639

Drawing Number :6S61-3K305-AA
Drawing Issue :EN01 E11869836 000
Issue Number : 2

Engineer :
Supervisor :
Latest Issue Date

Characteristic		Checking Technique or Method					Reaction Plan	
Description of Characteristic	Special Char/Class	Checking Method	Sampling Frequency	Sample Size	Dept/Person Responsible	Trace / Control	Reaction Programme	Dept/Person Responsible
Process No. 3	**Process Name : MOULDING CONTROL Process Description : PATTERN & SAND PROPERTY CONTROL**							
CLAY GRADE		AS ABOVE	ONCE PER WEEK	AS ABOVE	AS ABOVE	AS ABOVE	AS ABOVE	AS ABOVE
Process No. 4	**Process Name : MATERIAL CONTROL II Process Description : MATERIAL MATRIX CHECKS**							
NODULARITY (>80% PASS) REF WI 551 WI 301		MICROSTRUC-TURAL MATERIAL EXAMINATION WI 551 WI 301	EVERY TREATMENT	SAMPLE OF LAST METAL POURED	SAMPLER	SG MATERIAL ASSESSMENT SHEET DOC 179 OR DOC 468	QUARANTINE WORK PENDING SCRAP OR SORTING. WI 325	FOUNDRY METALL-URGIST
GRAPHITE NODULE COUNT REF: WI 551 WI 301		IMAGE ANALYSER	EVERY TREATMENT	AS ABOVE	SAMPLER	AS ABOVE	HOLD CASTINGS PENDING MATERIAL CHECKS	FOUNDRY METALL-URGIST
MATRIX STRUCTURE . PREDOMINANTLY FERRITIC MATRIX		MICROSTRUC-TURAL MATERIAL EXAMINATION	EVERY TREATMENT	AS ABOVE	SAMPLER	AS ABOVE	AS ABOVE / HEAT TREATMENT	FOUNDRY METALL-URGIST
FREE CARBIDE . LESS THAN OR EQUAL TO 1%		AS ABOVE	EVERY TREATMENT	AS ABOVE	SAMPLER	AS ABOVE	AS ABOVE	FOUNDRY METALL-URGIST
Process No. 5	**Process Name : MATERIAL CONTROL III Process Description : MECHANICAL PROPERTY CHECKS**							
BRINELL HARDNESS (HB160 - 210)		BRINELL HARDNESS TEST	2 CASTINGS PER FURNACE (MINIMUM)	RANDOM SAMPLE	FOUNDRY METALL-URGIST	SG MATERIAL ASSESSMENT SHEET DOC 179 OR DOC 468	HOLD CASTINGS PENDING MATERIAL CHECKS	FOUNDRY METALL-URGIST
TENSILE PROPERTIES UTS 450 N/MM2 0.2% 310 N/MM2 ELONG 10% (MINIMUM VALUES)		TENSILE TESTING MACHINE	DAILY (MIN)	TEST BARS CAST DURING PRODUCTION	LABORATORY	MECHANICAL PROPERTY RECORDS IN THE LABORATORY (DOC 300)	AS ABOVE	AS ABOVE
Process No. 6	**Process Name : ULTRASONIC CHECKS Process Description : SORTING SUSPECT MATERIAL**							
ULTRASONIC VELOCITY THROUGH THE MATERIAL		PANAMETRIC OR TELEDICTOR VELOCITY GAUGE	100% WHEN MATERIAL PROBLEMS ARE EXPERIENCED	100% IE.ALL QUARANTINED PARTS	FOUNDRY METALL-URGIST / QUALITY ENG	DAILY PRODUCTION & SCRAP ANALYSIS DOC 054	AFFECTED PARTS SCRAPPED	FOUNDRY METALL-URGIST / QUALITY ENG
Process No. 7	**Process Name : HEAT TREATMENT (RE-WORK ONLY) Process Description : CONTROL OF CASTING HEAT TREATMENT**							
BRINELL HARDNESS (HB160 - 210)		BRINELL HARDNESS TEST	EVERY QUENCH & TEMPER HEAT TREATMENT CYCLE (QT OVENS)	5 CASTINGS FROM EVERY HEAT TREATMENT CYCLE	LABORATORY	SQT RECORD SHEET DOC 034	HOLD CASTINGS PENDING MATERIAL CHECKS	LABORATORY
Process No. 8	**Process Name : SHOT BLASTING Process Description : INITIAL CLEANING OF PART AFTER CASTING PROCESS**							
CASTING FREE FROM RESIDUAL SAND / MOULDING MATERIAL		VISUAL INSPECTION	EACH SHOT BLAST MACHINE LOAD	REPRESENT-ATIVE SAMPLE	OPERATOR	FOUNDRY LABOUR RECORDS	PARTS RETURNED FOR FURTHER SHOT BLAST CYCLE.	OPERATOR

Report : CONTROL PLAN REPORT Printed on : Time : by : Page 3

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Part Number :6S61-3K305-AA
Description :LINKSHAFT - GOLD
Plan Number :CP000639

Drawing Number :6S61-3K305-AA
Drawing Issue :EN01 E11869836 000
Issue Number : 2

Engineer
Supervisor
Latest Issue Date

Characteristic		Checking Technique or Method					Reaction Plan	
Description of Characteristic	Special Char/Class	Checking Method	Sampling Frequency	Sample Size	Dept/Person Responsible	Trace / Control	Reaction Programme	Dept/Person Responsible
Process No. 8 — Process Name : SHOT BLASTING; Process Description : INITIAL CLEANING OF PART AFTER CASTING PROCESS								
		AS ABOVE	REGULARLY	AS ABOVE	FOUNDRY SUPERVISOR	ROUTE CARDS /PRODUCTION AUDITS (DOC 188)	AS ABOVE	FOUNDRY SUPERVISOR
Process No. 9 — Process Name : INSPECTION; Process Description : INITIAL INSPECTION FOR CASTING DEFECTS								
CASTING DEFECTS . INTERNAL DEFECT STANDARDS USED.		VISUAL INSPECTION . REFERENCE VISUAL INSTRUCTION	100%	100% IE. ALL PARTS	FOUNDRY	DAILY PRODUCTION & SCRAP ANALYSIS DOC 054	CASTINGS SEGREGATED PENDING SCRAP OR RECTIFICATION	INSPECTION
		AS ABOVE	REGULARLY	REPRESENT-ATIVE SAMPLE	INSPECTION SUPERVISOR	ROUTE CARDS /PRODUCTION AUDITS (DOC 188)	AS ABOVE	AS ABOVE
Process No. 10 — Process Name : PROCESSING - GRINDING / FETTLING OPERATION; Process Description : FINISHING OPERATION CONTROL								
PROCESSING STANDARDS . (REMOVAL OF CASTING INGATES AND EXCESS MATERIAL AT JOINT-LINE)		VISUAL INSPECTION . REFERENCE VISUAL INSTRUCTION	DAILY	REPRESENT-ATIVE SAMPLE	PROCESSING SUPERVISOR	PRODUCTION AUDIT SHEET (DOC 188)	CASTINGS REWORKED TO CORRECT STANDARD OR REJECTED AS APPLICABLE	PROCESSING SUPERVISOR
		AS ABOVE	100%	100% IE. ALL PARTS	OPERATOR	PROCESS CARDS	AS ABOVE	OPERATOR
Process No. 11 — Process Name : COINING; Process Description : PRESSING CASTING TO REQUIRED DIMENSION								
DRAWING DIMENSION: 2 X BOSS: 9.00mm + 0.5 /- 0 . 1 X BOSS 13.00mm + 0.5 / - 0 . (BOSS SIZE WILL INCLUDE + 2.50mm M/C ALLOWANCE)		ATTRIBUTE GAUGE	SET-UP FOLLOWED BY A MINIMUM OF 1 IN 50	SINGLE PIECE	PRESS OPERATOR	ROUTE CARDS /PRODUCTION AUDITS (DOC 188)	CASTINGS REWORKED TO CORRECT STANDARD OR REJECTED AS APPLICABLE	PRESS OPERATOR
		DIGITAL CALIPER AS ABOVE	REGULARLY	REPRESENT-ATIVE SAMPLE	PROCESSING SUPERVISOR	AS ABOVE	AS ABOVE	PROCESSING SUPERVISOR
DRAWING DIMENSION: PARALLEL TOL = 0.2 TO A (CAST TO CAST FEATURE FINISHED PRODUCT WILL BE CAST TO M/C)		COORDINATE MEASURING MACHINE	INITIAL SAMPLES AND SURVEY OF CAPABILITY BATCH	REPRESENT-ATIVE SAMPLE	INSPECTION	ISIR AND CAP BATCH	CORRECTIONS MADE TO CONFORM TO SPECIFICATION	INSPECTION
Process No. 12 — Process Name : FINAL INSPECTION; Process Description : INSPECTION FOR CASTING AND PROCESSING DEFECTS								
GENERAL CASTING & PROCESSING DEFECTS . (REF: INTERNAL QUALITY STANDARDS)		VISUAL INSPECTION	100%	100% IE. ALL PARTS	FINAL INSPECTION	PROCESS ROUTE CARDS	CASTINGS SEGREGATED PENDING SCRAP OR RECTIFICATION	INSPECTION
		AS ABOVE	REGULARLY	REPRESENT-ATIVE SAMPLE	FINAL INSPECTION SUPERVISOR	ROUTE CARDS /PRODUCTION AUDITS (DOC 188)	AS ABOVE	FINAL INPECTION / QUALITY ENGINEER

Report : CONTROL PLAN REPORT Printed on : Time : by : Page 4 Authorisation

Part Number :6S61-3K305-AA
Description :LINKSHAFT - GOLD
Plan Number :CP000639

Drawing Number :6S61-3K305-AA
Drawing Issue :EN01 E11869836 000
Issue Number : 2

Engineer :
Supervisor :
Latest Issue Date :

Characteristic		Checking Technique or Method					Reaction Plan	
Description of Characteristic	Special Char/Class	Checking Method	Sampling Frequency	Sample Size	Dept/Person Responsible	Trace / Control	Reaction Programme	Dept/Person Responsible
Process No. 13 Process Name : DESPATCH Process Description : DESPATCHING GOODS TO CUSTOMER								
DESPATCHING GOODS TO		CHECKING OF DELIVERY REQUIREMENT . REFERENCE ROUTE CARD	EACH DELIVERY	ALL DOCUMENTS & PACKAGING	DESPATCH SUPERVISOR & TRANSPORT MANAGER	ADVICE NOTE DETAILS ROUTE CARDS /PRODUCTION AUDITS (DOC 188)	GOODS SEGREGATED & AMENDMENTS MADE TO ENSURE GOODS CONFORM TO CUSTOMER REQUIREMENTS	DESPATCH SUPERVISOR & TRANSPORT MANAGER

Report : CONTROL PLAN REPORT Printed on : Time : by : Page 5

Authorisation

Appendix XIII - Laboratory Material Report

Laboratory material report is the document which is in use by Tier 1 supplier to submit it to OEM for their final approval about the quality of the part.

Company Logo

LABORATORY MATERIAL REPORT

CUSTOMER :

Part No.	6S61 - 3K305 - AA	Safety Critical.	-
Drawing No.	6S61-3K305AA Issue ENO1E 11869836000	Description.	LINKSHAFT BRACKET
Order No.	E 41671	Specification.	EN1563:1997 GJS450-10

Cast Code	Type of Test	Specified Results	Test Results
	BRINELL HARDNESS	160 - 210 HB	207 HB 10/3000
	TENSILE STRENGTH	450 N/mm² (Min)	516 N/mm²
	0.2% PROOF STRESS	310 N/mm² (Min)	383 N/mm²
	% ELONGATION	10.00% (Min)	12.40%
	MICROSTRUCTURE	SPHEROIDAL GRAPHITE NODULES IN A FERRITE AND PEARLITE MATRIX	SPHEROIDAL GRAPHITE NODULES IN A PREDOMINANTLY FERRITE MATRIX

These Tests represent the following castings.

	Quantity	Advice Note	Date
Initial Samples	-	-	-
Production Samples	1	-	-

Laboratory Performing Tests

WE HEREBY CERTIFY that the above results to be correct

Signature | *Date*

Doc 062

Appendix XIV - Sample Inspection Reports

Sample inspection file is the document which is in use by Tier 1 supplier to submit the relevant inspection data to OEM for their final approval.

Company Logo

SAMPLE INSPECTION REPORT

CUSTOMER

Part No.		Description BRKT ASY - FRT WHL DRV LNK SHT	Date
New Part ✓	Modified Part	Drawing No.	Issue No.
Initial Sample	Production Sample ✓	No. Samples Sent 6 / Material Spec. GJS 450/10	Safety Critical

Drg. No.	Characteristic Dimension or Specification	Inspection Results						CONFORM / NON CONFORM
	LEFT CENTRE VIEW	7	8	9	10	11	12	
	26.0	26.26	25.87	25.94	26.02	26.09	26.20	✓
	13	12.57	12.94	12.86	12.90	12.79	12.65	✓
	96	95.91	96.19	96.09	96.13	96.16	96.12	✓
	73.5	73.76	73.63	73.83	73.88	73.84	73.77	✓
	51.2	51.82	51.68	51.55	51.52	51.45	51.47	✓
	26.8	26.47	26.17	26.04	25.98	25.86	26.03	✓
	Ø24 BOSS	24.73	24.69	24.71	24.75	24.71	24.68	✓
	2 X Ø21 BOSSES	21.62	21.58	21.58	21.55	21.56	21.51	✓
	91	91.14	91.20	91.19	91.23	91.30	91.25	✓
	12.5	12.51	12.31	12.45	12.45	12.48	12.48	✓
	RIGHT CENTRE VIEW							
	7	6.57	6.56	6.65	6.48	6.40	6.43	✓
	9	8.88	8.75	8.75	8.83	8.76	8.73	✓
	15	15.00	15.00	15.00	15.00	15.00	15.00	✓
	R37.5 ± 0.15	35.14 M/C	35.17 M/C	35.23 M/C	35.08 M/C	35.13 M/C	35.18 M/C	✓
	50°	50.02°	49.88°	49.98°	50.05°	50.06°	50.10°	✓
	61.35	60.96	61.04	61.13	60.86	60.83	60.96	✓
	8	8.00	8.00	8.00	8.00	8.00	8.00	✓
	2	1.75	1.62	1.46	1.56	1.55	1.68	✓
	A	2.04	2.50	2.11	2.51	2.39	2.27	✓
	107.3	107.14	107.39	107.45	107.38	107.31	107.44	✓
	125	125.00	125.00	125.00	125.00	125.00	125.00	✓
	TOP CENTRE VIEW							
	R5	5.50	5.50	5.50	5.50	5.50	5.50	✓

Samples Made on Production Set Up	YES / NO	Additional Hand Work Performed	YES / NO

WE HEREBY CERTIFY the above results to be correct to drawing specification

Signature .... *Title* .... *Date* ....

SAMPLE INSPECTION REPORT

Drg. No.	Characteristic Dimension or Specification	Inspection Results						CONFORM NON CONFORM
	2.6°	2.43°	2.40°	2.62°	2.72°	2.82°	2.55°	✓
	2.3°	2.14°	2.16°	1.94°	1.99°	1.87°	2.01°	✓
	R3.5	3.50	3.50	3.50	3.50	3.50	3.50	✓
	<u>LEFT VIEW</u>							
	132	132.33	132.24	132.32	132.32	132.41	132.27	✓
	(107.28)	107.14	107.39	107.45	107.38	107.45	107.44	✓
	(61.35)	60.96	61.04	61.13	60.86	60.88	60.96	✓
	R30	30.00	30.00	30.00	30.00	30.00	30.00	✓
	<u>LOWER VIEW</u>							
	2 X 9 +0.5,-0	11.31 M/C	11.69 M/C	11.69 M/C	11.76 M/C	11.95 M/C	11.81 M/C	✓
		11.30 M/C	11.68 M/C	11.66 M/C	11.71 M/C	11.92 M/C	11.78 M/C	✓
	13 +0.5,-0	15.04 M/C	15.50 M/C	15.11 M/C	15.51 M/C	15.39 M/C	15.27 M/C	✓
	<u>SECTION A-A</u>							
	20	22.67 M/C	22.71 M/C	22.78 M/C	22.65 M/C	22.63 M/C	22.71 M/C	✓
	R50	50.00	50.00	50.00	50.00	50.00	50.00	✓
	R10	9.00	9.00	9.00	9.00	9.00	9.00	✓
	R46	46.00	46.00	46.00	46.00	46.00	46.00	✓
	15.5	17.79 M/C	17.80 M/C	17.75 M/C	17.71 M/C	17.80 M/C	17.65 M/C	✓
	SPH Ø75	70.22 M/C	70.41 M/C	70.25 M/C	70.05 M/C	70.12 M/C	70.48 M/C	✓
	<u>SECTION B-B</u>							
	SPH Ø75	70.22 M/C	70.41 M/C	70.25 M/C	70.05 M/C	70.12 M/C	70.48 M/C	✓
	<u>RIGHT VIEW</u>							
	FORD PART NUMBER	**6S61-3K305-AA**						✓
	SUPPLIER CODE	C9M1A						✓
	FoMoCo LOGO	FoMoCo						✓
	IMPRESSION No	7	8	9	10	11	12	✓
	DATE CODE	WEEK / YEAR	WEEK / YEAR	WEEK / YEAR	WEEK / YEAR	WEEK / YEAR	WEEK / YEAR	✓
	COLOUR CODE	GL	GL	GL	GL	GL	GL	✓
	WALL THICKNESS 5	5.70 TYP						✓
	RIBS 5	5.70 TYP						✓
	DRAFT ANGLE 2°	AS PER CPLC CHART DOC No 403						✓
	FILLET RADII R3	3.00						✓
	CORNER RADII R2.5	2.50						✓

Appendix XV - Part Submission Warrant File

Part submission warrant is the document which suppliers use when they submit the part to OEM, in order to make sure all the supporting documents are attached.

Part Submission Warrant

Part Name ______ Cust. Part Number ______

Shown on Drawing No. ______ Org. Part Number ______

Engineering Drawing Change Level ______ Dated ______

Additional Engineering Changes ______ Dated ______

Safety and / or Government Regulation ☐ Yes ☑ No Purchase Order N° ______ Weight (kg) 0.975

Checking Aid N° ______ Checking Aid Engineering Change Level ______ Dated ______

ORGANIZATIONAL MANUFACTURING INFORMATION

Supplier Name & Supplier/Vendor Code

Street Address

City Region Postal Code Country

CUSTOMER SUBMITTAL INFORMATION

Customer Name/Division

Buyer/Buyer Code

Application

MATERIALS REPORTING

Has customer-required Substances of Concern information been reported?. ☐ Yes ☑ No ☐ n/a

Submitted by IMDS or other Customer format: ______

Are polymetric parts identified with appropriate ISO marking codes? ☐ Yes ☐ No ☑ n/a

REASON FOR SUBMISSION (Check at least one)

- ☐ Initial submission
- ☐ Engineering Change (s)
- ☑ Tooling : Transfer, Replacement, Refurbishment, or additional
- ☐ Correction of Discrepancy
- ☐ Tooling Inactive > than 1 year
- ☐ Change to Optional Construction or Material
- ☐ Sub-Supplier or Material Source Change
- ☐ Change in Part Processing
- ☐ Parts Produced at Additional Location
- ☐ Other - please specify

REQUESTED SUBMISSION LEVEL (Check one)

- ☐ Level 1 - Warrant only (and for designated appearance items, an Appearance Approval Report) submitted to customer.
- ☐ Level 2 - Warrant with product samples and limited supporting data submitted to customer.
- ☑ Level 3 - Warrant with product samples and complete supporting data submitted to customer.
- ☐ Level 4 - Warrant and other requirements as defined by customer.
- ☐ Level 5 - Warrant with product samples and complete supporting data reviewed at organization's manufacturing location.

SUBMISSION RESULTS

The results for ☑ dimensional measurements ☑ material and functional tests ☐ appearance criteria ☐ statistical process package

These results meet all design record requirements : ☑ Yes ☐ No (If "NO" - Explanation Required)

Mold / Cavity / Production Process ______

DECLARATION

I affirm that the samples represented by this warrant are representative of our parts, which were made by a process that meets all Production Part Approval Process Manuel 4th Edition Requirements. I further affirm that these samples were produced at the production rate of _14400/__8___Hours I also certify that documented evidence of such compliance is on file and available for review.I have noted any deviations from this declaration below.

EXPLANATION/COMMENTS : ______

Is each Customer Tool properly tagged and numbered? ☐ Yes ☐ No ☐ n/a

Organization Authorized Signature ______ Date ______

Print Name ______ Phone No. ______ FAX No. ______

Title ______ E-mail ______

FOR CUSTOMER USE ONLY (IF APPLICABLE)

PPAP Warrant Disposition : ☐ Approved ☐ Rejected ☐ Other ______

Customer Signature ______ Date ______

Print Name ______ Customer Tracking Number (optional) ______