A Knowledge Sharing Framework to Support Rapid Prototyping in Collaborative Automotive 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 Mehdi Tavakoli

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Professor James Gao

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Abstract

In today's global economy, competition is increasingly driven by a high rate of product renewal. In this context, with market demands for the development of high quality products at lower costs, highly customisable and with short life cycles, new technologies have been adopted by the automotive manufacturers in the move away from a local economy towards the global economy. The continuous evolution of this technology often requires the updating and integration of existing systems within new environments, in order to avoid technological obsolescence. To allow companies to compete in the global market, they (the companies) can no longer be seen acting as standalone entities and are having to reconsider their organisational and operational structure. This thesis presents a Knowledge Sharing Framework Design Roadmap to support rapid prototyping in the automotive and collaborative supply chain. IranKhodro Diesel (IKD) is the automotive company and CarGlass Company (Iran) is the supplier and sponsor of this research study. These two companies will be used to develop and test the Knowledge Sharing Framework Design Roadmap (KSFDR) methodology.

An industrially based case study was conducted in IKD and CarGlass to identify key elements in the Knowledge Sharing Framework and provide the focus for this study. The study itself drew on empirical sources of data, including interviews with IKD personnel via an internal company survey. The absence of mechanisms to make information accessible in a multilingual environment and its dissemination to geographically dispersed NPD project team members was identified along with the lack of explicit information about the knowledge used and generated to support first stage rapid prototyping in the product development process with respect to reduction of costs and lead times.

The Knowledge Sharing Framework Design Roadmap was tested between IKD and CarGlass. The business objectives in both IKD and CarGlass are the main drivers of knowledge system development. The main novel point from this research study is that this particular framework can be used to capture and disseminate information and knowledge. This was supported by positive feedback from a series of interviews with NPD practitioners. The Knowledge Sharing Framework Design Roadmap (KSFDR) methodology, however, can also be applied in other manufacturing and business environments. Further testing of the framework is strongly advised to minimise any minor flaws, which remain.

Glossary

(CAPP)	Aided Process Planning
(CEO)	Chief Executive Officer
(CPFR)	Collaborative Planning Forecasting and Replenishment
(CPFR)	Collaborative Planning Process Framework
(CPFR)	Collaborative Planning, Forecasting and Replenishment
(CAE)	Computer Aided Engineering
(CAM)	Computer Aided Manufacturing
(CIM)	Computer Integrated Manufacturing
(CRP)	Continuous Replenishment Program
(DME)	Decision Modelling Environment
(DR)	Design Road Map
(FEA)	Finite Elements Analysis
(ICT)	Information and Communication Technology
(IS)	Information System
(IKD)	IranKhodro Diesel Company
(IDEF)	Integrated Computer Aided Manufacturing (ICAM) Definition
(KM)	Knowledge Management
(KSFDR)	Knowledge Sharing Framework Design Road Map
(KSF)	Knowledge Sharing Framework
(KS)	Knowledge Sharing
(NPD)	New Product Development
(NPDP)	New Product Development Process
(OECD)	Organisation for Economic Co-Operation and Development
(OEM's)	Original Equipment Manufacturers'
(PT)	Problem Taxonomy
(PD)	Product Development
(PDMA)	Product Development & Management Association
(RP)	Rapid Prototyping
(STL)	Stereo Lithography
(CSCMP)	Supply Chain Management Professionals
(SCM)	Supply Chain Management
(VMI)	Vendor Managed Inventory

Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction

This chapter gives a general overview of this research project. Firstly, the industrial background of this project is described. The problems facing current industry practices are identified and discussed. According to the identified problems, the research area and focus are decided. The aim and objectives of the research area are then defined and the available technologies currently being used in the research area are introduced. The research scope is also described. The potential benefits of this research are introduced. Finally, the background of the sponsor collaborating company is introduced.

1.1 Industrial Problem Analysis

In the competitive worldwide market, companies can no longer act as standalone entities, before being forced to reconsider how they are organised. On one hand, some companies tend to divide into smaller subunits, belonging or not to the mother company, each one having a specific business core, focusing on the production of a few specialised ranges of products. On the other hand, some companies tend to share skills and knowledge, networking together to achieve global production. This research project concentrates on the problems of collaboration between companies in the supply chain of the automotive industry.

The sponsor of this project, Car Glass Limited, was used as the main case study for investigation and subsequent testing of the proposed methodologies. Car Glass Limited was established in 1977, in Tehran, Iran. It has a production capacity of 800,000 pieces per year of high specification glass, which is manufactured using the latest technologies. In addition, Car Glass Limited produces a wide range of other items such as laminated glass, bending and flat tempered glass and double-glazed units. The main products for Car Glass Limited are bending and flat tempered glass, which are used in the automotive industry. The main focus for this research project is to design a knowledge framework to support collaboration in rapid prototyping mainly between Car Glass Limited and its customers. One of the major factors in this collaboration supply chain is to ensure the right prototype specification, which will help to design and develop other aspects of automobile development in co-operating companies. As companies are divided into the smaller operating units, there tends to be less collaboration between manufacturers, which can bring with it poor sharing of skills, knowledge and information. Because of poor knowledge sharing, any major issues in new product development have to be forwarded to high-level management for consideration. This makes senior management teams busier with too many issues that should have been resolved by lower level personnel.

From the review of the current practices and the research literature in industry, it is possible to divide costs into two categories. The first category is the controllable cost and the other category uncontrollable cost (Caridi and Cavalieri 2004a). The controllable costs such as labour costs, transportation costs, design costs and capital costs are easy to predict and calculate. The uncontrollable costs are the costs that are hard to predict. These are the risk lead costs, missed collaboration and knowledge sharing costs, which can be, defined as bad co-operation between enterprises, human errors and innovation costs. This research project will help to reduce the uncontrollable costs. Due to the competitive nature of the market, companies do not generally share all commercially sensitive knowledge with each other. It is envisaged that without this kind of knowledge sharing, it would be easier to control the market place or even new product innovation. When an automobile company (the customer) requires glass for a new automobile design, then very little knowledge and information would be provided to Car Glass Limited (the supplier company). This information would normally be the very basic prototype design, or in some special cases, it would be the AutoCAD drawing, which would not satisfy the designers in the glass supply company. Due to poor knowledge sharing between these companies, it becomes highly costly to understand and interpret the requirements of the customer, especially when a lot of changes and re-workings are needed to finalise the glass design to meet the customer's requirements during the whole product development process. These costs can be huge in large manufacturing organisations and this information and knowledge need to be properly managed in new product development within the manufacturer's requirements, in order to gain a competitive advantage in the global market. The uncontrollable costs here can be reduced by using a better knowledge sharing framework and having a better understanding of the relationship for knowledge sharing between the customers and suppliers in the automotive industry.

1.2 Importance of New Ideas and Knowledge Development in Global Competition

It is unquestionable that technological progress has driven the overall improvement in the standard of living across the globe. It is also clear that many manufacturing companies in the automotive and glass industries, in some countries have been excluded from the full benefits of new technology and innovations (McCarthy and Nonokia, 2006). In this context, it is accepted that beyond technology is a "knowledge framework" (ideas from skilled and educated people) that are increasingly important for economic and developing of new products especially to develop automobiles which require different components such as, front windscreens, side screen and windscreen glass. It is envisaged that the framework will be designed with related incentives to reward and stimulate future generation of new ideas and to promote investments in education and training currently only exists in a relatively small part of world.

Ideas are the critical input in the production of valuable human and non-human capital, (Ramesh et al, 1999). While investments in machinery, technological infrastructures and human capital are correlated with economic growth, it is the ideas of what to put those investments into, to develop through education, research, and experimentation that both drives the investments and provides the mechanisms through which economic growth occurs (Freeman, 2001). Factor accumulation alone is not sufficient to support development, which is amply illustrated by the failures of European countries to succeed as Asia's newly industrialising economies (NIEs) thrived over the last several decades (Park and Cutkosky, 1999). Unlike most other countries, which also developed high education levels and many research institutes, the distinguishing features of the NIEs have been their openness to foreign knowledge, their superior capacity to use and improve upon transferred knowledge, and the competitiveness of the markets into which they sold their outputs (Park and Cutkosky, 1999). It is this type of evidence that led Ahmed and Zairi (2000) to conclude that "countries and firms must be open to new ideas, have multiple sources of new ideas, and see that ideas are diffused" if they are to achieve economic development and growth. Acceptance of and competition among new ideas is what allows organisations and their nations to remain on the creating end rather remain than on the destructing end of Swaminathan et al (2000) 'perennial gale of creative destruction', and the widespread diffusion of these ideas is what fosters the development of what Andrew et al (2001) "call know why" (system understanding and trained intuition) instead of only "know what" (cognitive knowledge) and "know how" (advanced skills). At the same time, however, pursuit of new ideas does not come without costs, as organisations encounter "knowledge search" (Strauss, and Corbin, 1990) and knowledge exchange (Harrison, 1992), costs and limitations, as well as running risks of being distracted from using or progressing local knowledge that could benefit them in the longer run (Ancona and Caldwell, 1992). Thus, those charged with overseeing an enterprise's knowledge management functions must balance the costs and the benefits inherent in knowledge sharing activities. The automotive supplier in developing countries should also continue to develop and adopt new ideas such as the ideas proposed in this research project.

1.3 Knowledge and Collaboration in Product Development

In the information age, knowledge is becoming a critical component of competitive success of firms (Dudek, 2004). Nonaka and Takeuchi (2000) observed that, as markets shift, technologies proliferate, competitors multiply and products become obsolete, successful companies are characterised by their ability to consistently create new knowledge, quickly disseminate it, and embody it in new products and services. In the post industrial era, Nonaka and Takeuchi (2000) also maintain that the success of a corporation lies more deeply embedded in its intellectual systems, as knowledge based activities of developing new products and processes are becoming the primary internal functions of firms attempting to create the greatest potential for a competitive advantage. However, the consumer's needs are that products should satisfy, and technologies used in the development of a product or products can change radically, even as they are under development (Nonaka and Takeuchi 2000). This has necessitated a flexible product development process where designers can continue to change and shape products even after their implementation have been initiated. The impact of the aforementioned forces is witnessed most prominently in high technology environments, where according to a survey by National Research Council, the cost of development can account for up to 85% of the total cost of the product. However, by providing effective decision support by making knowledge about past and current development efforts readily available and accessible has been a significant contribution towards better process. Nonaka and Takeuchi suggested that as firms shift from a product centric form to a knowledge centric form, support that enables a continuous flow of information about stakeholder needs and evolving technologies could reduce both the costs and time required for development. The process of design is characterised by complex deliberations about a series of interdependent decisions that lead to design solutions. Based on a study of concurrent product development activities, Ramesh et al (1999) also observed that knowledge about these deliberations is typically lost, as it is never recorded. Donnellan et al (2004) suggested that better knowledge of past, similar product development processes can lead to assessable efficiencies in product development and its consequent production. Such knowledge utilisation is innately a collaborative process. Here, collaboration refers to informal cooperative relationships that build a shared vision and understanding. Neither within nor cross firm utilisation and transfer of knowledge can succeed without effectively supporting collaboration (Nonokia and Takeuchi 2000).

In today's networked world, different types of networks, joint ventures, alliances, outsourcing, and mergers are driving advancement in new product development processes. These network business trends have resulted in complex highly technical organisations and development projects that cross location, company, country and cultural boundaries. In such networks, each activity within the new product development process tends to be carried out by separate functions within or across the company boundaries. Once an activity is completed, the output is sent to the next function in the process, so those responsible can contribute their specialised knowledge and skills to develop the product (Park and Cutkosky, 1999). In such projects, the new product development process often suffers from a lack of coordination and communication. Delays and overspending on these projects are not uncommon (Hansen et al, 1997). The key to success is no longer about integrating a company's units and activities, but integrating the new product development process across a network of strategic partners (Chesbrough, 2003). However, in today's automobile and glass industries, minimum cost is the goal, which these industries are seeking within the stagnant technology of improving performance. Usually, many manufacturing companies have to direct costs, such as material, prototyping, labour, risks or mistakes in the product or design process and some integral factors like plant and transportation. Some of these factors cannot be avoided, but some can be kept relatively low or close to zero. One of the aims of this research study is to improve and develop the current knowledge sharing and collaboration processes between the automotive supplier and customers to develop appropriate rapid prototyping in new product development. The aim is also to increase performance for manufacturing industries and to minimise uncontrollable costs and manufacturing lead times and improve processes to develop new products for a global market, which is always the preferred solution for competitors in the supply chain, especially in the automotive and glass industries.

1.4 Overview of Knowledge Sharing in Product Development

Knowledge sharing, defined by Yang (2004) as the dissemination of information and knowledge within a community, is considered to play a crucial role in knowledge management ventures within an organisation (Liebowitz, 1999 and Riege, 2005). Effective knowledge sharing drives organisational and individual learning, which in turn, speeds up and improves the quality of product innovation (Riege, 2005).

As already alluded to, new products have become a focus of competition for many manufacturers, and the product development process has become increasingly important to these businesses. The product development process is comprised of 'a sequence of steps or activities which an enterprise employs to conceive, design, and commercialise a product' (Ulrich and Eppinger, 2003). These activities are linked by an exchange of information (Browning and Eppinger, 2002). Indeed, Eppinger (2001) urged that this exchange of information is the lifeblood of product development'.

Manufacturers are seeking to compete on issues like product quality and the time taken to introduce new products to the market. It has been argued by, Gieskes and Langenberg (2001), and Ramesh et al (1999), that such pressures have made the effective sharing of knowledge in the NPD process into a means of achieving a competitive advantage. Consequently, great attention has been focused in recent years on the application of knowledge management to new product development, a point emphasised by Zahay et al. (2004). Nonetheless, Hong et al. (2004) stressed that relatively little heed has been paid to knowledge sharing in the NPD domain.

However, the sharing of knowledge among individuals in an organisation is confounded by an abundance of obstacles. Obstacles to knowledge sharing common to large enterprises, or more specifically, large multinational companies, may concern the individuals working in the organisation or the environment in which these individuals function. Such obstacles have been shown to be detrimental to product development performance. Hoopes and Postrel (1999) put forward evidence that gaps in shared knowledge could be directly responsible for costly mistakes made in the course of the product development process. Hong et al. (2004) conducted an empirical study into the efficacy of knowledge sharing in new product development. They found that 'project teams working with high levels of shared knowledge in customers, suppliers and internal capabilities were significantly higher in their process performance outcomes than those teams with low levels of shared knowledge' (Hong et al., 2004). It is asserted then, that it is desirable to eliminate or reduce the impact of obstacles to knowledge sharing in a product development environment.

1.5 Research Question

This research will investigate the organisational frameworks, which lead companies to their new product development projects with integrated process elements with external partners, and subsequent effects on performance. The integrated process in this research project focuses on the communication and co-ordination between two independent companies, one is a supplier and the other is its customer, i.e., the sponsoring company of this project and its main automotive customer.

This project will propose a new knowledge framework to support the rapid prototyping process in the collaborative process between automotive and supply chain, to reduce product development lead times, costs and also improve quality and relations with suppliers. The main research question is:

Whether and how a knowledge framework will lead to the organisation bringing in a higher level of collaboration in automotive supply chain to support the rapid prototyping process in new product development?

Due to the nature of the research question, this project will focus on the prototyping process elements and knowledge management to bring stronger collaboration between the new product development project team and the project‘s strategic partners.

1.6 Research Aim and Objectives

The main aim of the research is to develop a Knowledge Sharing Framework Design Roadmap (KSFDR) to support rapid prototyping in the automotive supply chain in order to reduce the product development lead time, cost and improve quality and customer supplier relationship.

The objectives of this project are to:

a) Investigate industrial problems and requirements for the critical rapid prototyping stage of product lifecycle in the collaborative supply chain,

b) Investigate state-of-the-art technologies commercially available and methodologies developed by international researchers used in the new product development (NPD) process,

c) Propose a knowledge sharing framework to support rapid prototyping in the collaborative supply chain, including methods for product and process modelling, knowledge sharing and communication management,

d) Develop the above knowledge sharing roadmap framework and methods into a prototype system with the industrial sponsor in the automotive industry, and

e) Evaluate and validate the roadmap framework using a case study to determine whether the framework can bring benefits to industry.

1.7 Research Approach

The function of research is to either create or test a theory. Research is the instrument used to test whether a theory is valid. It is the process by which data is gathered to generate a theory or used to test a theory. In other words, research is about a systematic search for solutions to problems and also about helping to evaluate the research of others. The word research has got several different meanings. Research is a systematic formal rigorous and precise process employed to gain solutions to problems and or to discover and interpret new facts and relationships (Waltz and Bausell 1981). Payton (1979) believed that research was the process of looking for a specific answer to a specific question in an organised, objective and reliable way. Research is the systematic, controlled, empirical and critical investigation of hypothetical propositions about the presumed relations among natural phenomena (Kerlinger, 1973).

When a research problem has been identified, the aims and objectives are then defined. Then it is necessary to indicate how the research objectives will be achieved (Walliman, 2001). According to Zikmund (2000), it is over simplification to state that every research programme follows the same path and the phases of research process in a cyclic manner. On the other hand, most research projects follow roughly a general process as shown in Figure 1.1.

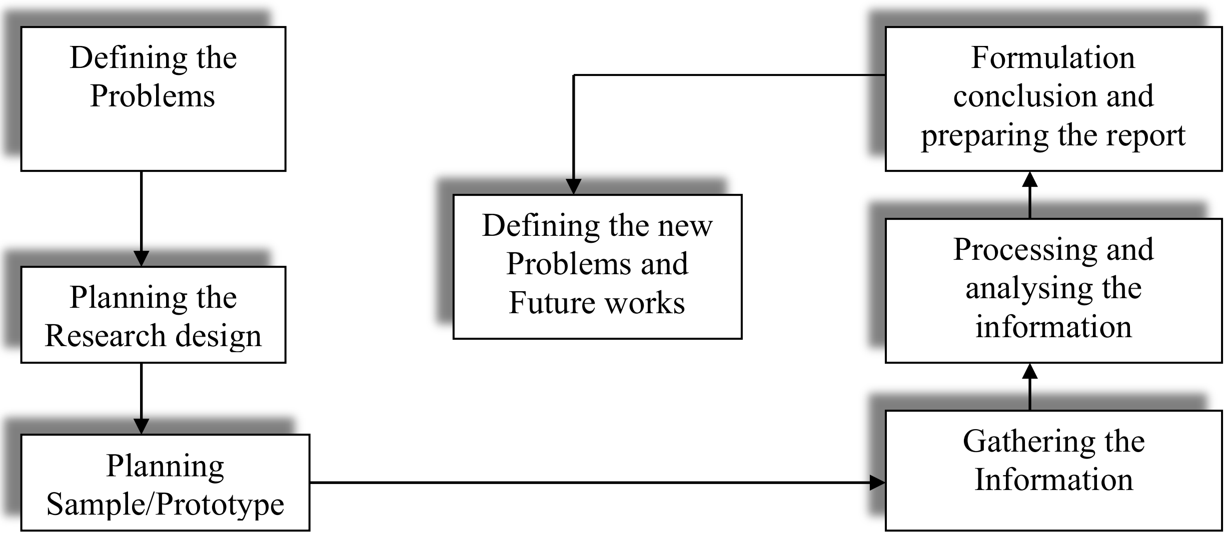

Figure 1.1 - Phases of several research process, Zikmund (2000)

There are many ways to carry out research. Most types of research can be classified according to how much the researcher knows about the problems before starting the investigation (Yin 1994). According to Reynolds (1971), Patel and Tebelius (1987), Aaker and Day (1990), Yin (1994), Zikmund (2000), Wiedershwim and Eriksson (1999), there are three classifications of research available when dealing with research problems: exploratory, descriptive and explanatory, which are summarised below.

Exploratory research should be designed by stating a purpose and stating the criteria to judge the exploration a success (Yin 1994). Zikmund (2000) states this type of research is conducted when the research is very uncertain about the nature of the problem.

Descriptive research is carried out to make complicated systems more understandable by reducing them into their component parts (Bernard, as referred by Miles and Huberman, 1994). Zikmund (2000) elucidates descriptive research as, when research problems are known but the researcher is not fully aware of the situation.

Explanatory research is an approach, which could also be used when the study aims to explain certain phenomena from different perspectives or situations with a given set of events. Trying to explain or analyse a strategy that resulted in particular action would classify a study as an analytical or explanatory study (Ying 1994). Zikmund (2000), states that this type of research requires sharply defined problems, even though uncertainly about the future outcomes exists.

There is little detailed knowledge available on the impact of the collaboration to determine a company's organisational design of integration across a network of strategic partners. At the present time, the existing knowledge base is limited, and the available literature does not provide conceptual frameworks or notable hypotheses. Such a knowledge base does not lend itself to the development of good theoretical and practical statements, and any new empirical study is likely to be characterised as an exploratory study.

This research adopts an exploratory study approach in the first stage (capturing industrial problems and requirements), followed by descriptive research (modelling the collaboration process and knowledge), and explanative research (analysing root cause of problems and developing solutions and future work) in the final stage. Case studies will be extensively used in this project. Case study research is an appropriate method of data collection for such a complex subject. A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, where the boundaries between phenomenon and context are not clearly evident, and in which multiple sources of evidence are used (Yin, 1989). An analytical strategy should guide data collection (Yin, 2003). In this research project, the author will try to develop and improve a genetic Knowledge Sharing Framework (KSF), and practise based preliminary model designed to guide the collection of data for case studies. Reliance on theoretical and practical concepts remains one of the most important strategies for completing successful case studies. Such theoretical concepts can be useful in conducting exploratory, descriptive, or explanatory case studies (Yin, 2003). In developing the framework, the author will use two streams of research: (1) collaboration process and knowledge sharing; and (2) rapid prototyping function.

1.7 Research Scope

The main purpose of this project is to develop a Knowledge Sharing Framework to support the decision making process to meet the customer requirements in the prototyping process of new product development in the global supply chain context between automotive and glass industries. The framework will enable improvements in both the efficiency and the capability of product development through the application of advanced knowledge management and knowledge sharing technologies. The framework can help reduce the costs and lead times which are necessary to bring suppliers' new products move quickly and in line with the original equipment manufacturers' (OEM's) product development. This framework would focus on developing a new product in CarGlass process development that would significantly benefit from knowledge and information sharing techniques to improve collaboration within the supply chain such as car manufacturing. The communicative process between them in rapid prototyping of the car glass will be modelled and changes will be modified and improved by both academics and the sponsoring company.

1.8 Thesis Structure

Chapter 1- Introduction: this chapter gives the introduction to the research domain and states the aim, objectives, scope and questions of the research project.

Chapter 2 - This chapter reviews the available research methods and techniques and describes the research methodology to fulfil the research aim and objectives.

Chapter 3 - Literature review: this chapter reviews the published literature relevant to knowledge sharing, knowledge management, knowledge tools, prototype concepts, prototype functions; collaboration, supply chain management and relevant area for further research are also identified.

Chapter 4 - Investigation of Industrial Problems: This chapter will describe the procedure, methods and results of data collection in the automotive and collaborating company such as CarGlass.

Chapter 5 - The Proposed Knowledge Sharing Framework to Support Rapid Response in Automotive Industry: This chapter describes the work conducted to support the knowledge sharing framework to support the rapid response to design and develop rapid prototype facilitate in the new product development (NPD) process in automotive and supplier company.

Chapter 6 - Implementation Knowledge Sharing Framework: Implementation involved demonstrating the functionality of the knowledge sharing framework Design Roadmap (DR), and providing a test of the knowledge sharing content classification used in the framework.

Chapter 7 - Evaluation and Discussion of Knowledge sharing Framework: This chapter discusses the findings of the research presented in the previous chapters of this thesis document

Chapter 8 - Conclusions and Further Research: This chapter presents the conclusions of the research project and identifies areas for further research.

Chapter 2

Research Methodology

According to the literature survey and industrial investigation that will be described in chapter three and four; there is a strong requirement for better understanding and management of knowledge sharing in current industrial practice. There is a lack of formal methodologies for designing and developing information systems and knowledge sharing systems in the both automotive and collaborative. The purpose of this chapter is to define and select a suitable methodology for addressing the research problem. This chapter discusses the different research approaches available for research enquiry and presents the research methodology designed and used in this research investigation.

2.1 Definition of Research

Leedy and Ormrod, (2005) described research as a procedure by which one attempts ‘to find systematically, and with the support of demonstrable fact, the answer to a question or the resolution of a problem’.

Miller (1991) proffered the notion that organisational research focuses enquiries in three directions known as basic or pure, applied, and evaluation. As Miller would have it, investigators practicing pure research seek to ‘advance knowledge sharing’ without concern for its short term utility. Their mission is ‘to describe the world as it is, not to change it’. For applied researchers, on the other hand, the aim is ‘to create knowledge sharing that can be used to solve pressing social and organisational problems’. Similarly, Patton (1990) stated that the purpose of applied research is ‘to contribute knowledge sharing that will help people understand the nature of a problem so that human beings can more effectively control their environment’. Easterby-Smith et al. (2002) asserted that applied research should result in a solution to specific problems identified by a client. Lastly, evaluation research attempts to assess the outcomes of the treatment applied to given social problem or to assess the result of a current practice (Miller 1991). This investigation is concerned with providing solutions to problems in knowledge sharing framework between automotive and collaborative industries to support the rapid prototyping with respect to reduction of cost and production lead time and better product quality.

2.2 Research Design and Method

The research design is the logical sequence linking the empirical data to the study’s initial research questions and, ultimately, to its conclusions (Yin, 1994). In research design, choices have to be made as to the way in which data will be collected (research method and means of empirical data collection), the aspects on which data will be collected, and the practical environment in which data will be collected (research domain).

Research is a systematic process of enquiry that focuses on a defined subject area that involves collecting, analysing and interpreting information in order to achieve greater understanding of a phenomenon (Leedy and Ormrod, 2005). Research in academic disciplines is often categorised into two distinct types, pure and applied research. Pure research is usually theoretical work undertaken to acquire new information and contributes to advancement of knowledge. Whilst applied research is work undertaken primarily to apply it's finding to solve a specific problem. Blaikie (2000) stated that research is often a blend of both pure and applied types.

There are many research design options available to a researcher for conducting a research inquiry in a defined domain. As a result, there is often no one right or set way of conducting a piece of research. Therefore, the researcher is faced with the challenge of choosing the most appropriate methodology to suit the research enquiry and questions. Many of the choices available to a researcher are attributed to a particular philosophical position.

When designing a research enquiry it is important to understand the theoretical paradigms that establish the general approach to the research. The term paradigm refers to the scientific practise based on a researcher's particular philosophy and assumptions about the world and how research should be conducted. In order to design a methodology to best suit this research investigation the following three theoretical concepts were considered and discussed in details in the following sections:

- Research Philosophy
- Research Purpose
- Research Strategy

2.2.1 Research Philosophy

Research philosophy relates to knowledge and its development in a particular academic field or discipline. Easterby-Smith et al., (2002) states that a philosophical perspective is useful in clarifying decisions about research designs by considering the kind of evidence that might be required, how to gather and interpret it in a way that provides answers to the questions being investigated in the research study. This further emphasised its importance by stating that philosophical paradigms are fundamental to research design and failure to consider them can seriously affect the quality of the research. A number of authors argue that the research philosophy adopted by a researcher contains assumptions about the researchers world-view (Easterby-Smith et al., 2002; Yin, 1994; Saunders et al., 2007). Therefore it is important to understand the research paradigms, as they will have an impact on the overall research design. There are two main contrasting paradigms upon which research methods are based; they are positivist and phenomenological paradigm. The positivist paradigm relates to observing social reality that can be measured using a scientific approach using objective methods, which involves thorough testing, and observation rather than being inferred subjectively through experience or intuition. Under a positivist paradigm, theory is deduced through explanation that seeks to establish causal relationships between variables (Hussey and Hussey, 1997). Positivists tend to adopt a deductive and quantitative approach to a research investigation.

In contrast, phenomenological paradigm refers to the way in which researchers make sense of the world around them. Reality from a phenomenological perspective is socially constructed, subjective and difficult to measure. Here the focus is on understanding what is happening and why, appreciating the different constructions and meanings people give to their experience rather than measurement of social phenomenon. In this paradigm an inductive approach is used for developing theories and seeks to describe and explore research investigation from a qualitative perspective.

2.2.1.1 Deductive and Inductive

In deductive research, a hypothesis is necessary. It is based on the findings of previous research from the review of literature or from the researcher's previous experience with the subject. The ultimate objective of deductive research is to decide whether to accept or reject the hypothesis as stated. Inductive research goes from the specific to the general whilst deductive research goes from the general to the specific. Due to the nature of inductive and deductive research, it is argued that it is not feasible to undertake both types concurrently Donnellan et al (2004). Both deductive and inductively approach are characterised into four main stages. Inductive strategy can be used to pursue an exploratory objective to answer 'what' questions. This would allow the research to describe phenomena and establish regularities.

2.2.1.2 Quantitative and Qualitative Research

Research methodologies are often classified into two different type's quantitative and qualitative approach. Both groups of research methods, rather than being methods in there own right. Any specified method of doing research would belong to one or the other. Quantitative research answers questions about relationships among measured variables with the purpose of explaining, predicting and controlling the phenomena. In contrast, qualitative research answers questions about complex nature of phenomena, with the purpose of describing and understanding the phenomena from the participant's point of view (Leedy and Ormrod, 2005). Although quantitative research methods (descendant of a positivist philosophy) and qualitative methods (descendant of a phenomenologist philosophy) are often seen as opposing views, they are frequently used in conjunction. The purpose of qualitative research is to facilitate taking action in the real world in order to bring about change. In contrast the purpose of the quantitative approach is to develop causal laws, where data are derived from the use of strict rules and procedures (Robson, 2002). The quantitative approach is deemed as the so-called 'scientific' approach (Robson, 2002) and is characterised by analytical approach to data that normally involves the numerical analysis of data often generated through questionnaire survey instruments. The distinctions between quantitative and qualitative data collection techniques are sometimes ambiguous. Although some researchers perceive qualitative and quantitative approaches as incompatible, Patton (1990) believe that the skilled researcher can successfully combine approaches. Strauss and Corbin, (1990) and Easterby-Smith et al., (2002) suggested the use of techniques from the same paradigm whenever possible and also to traverse paradigms, but this must be done with care. Partington (2002) argued that quantitative and qualitative approaches should be viewed as two ends of a continuum instead of viewing them as a discrete either or options. Therefore the approaches can be used to complement each other.

2.2.1.3 Research Philosophy and Methodology Adopted

This section presents a justification for the philosophical and methodological approach adopted in this thesis that is based on their key attributes, strengths, collaboration and weaknesses and the nature of research problem. This research to a great extent adopted a phenomenological perspective, as it enables a deeper understanding of knowledge sharing framework (KSF) process operations in automotive and collaborative industries to support rapid prototyping in NPD. According to Miles and Huberman (1994) phenomenology explicate the ways people understand, justify, take action and manage their daily situations, these sets of characteristics suggests the suitability of the paradigm for this research, as it attempts to understand the current knowledge sharing framework (KSF) process to support rapid prototype, and identify ways of effectively managing the process with respect to reduction of cost and production lead-time and quality improvement. As this research does not commence with a predetermined theory, it is not deductive. An inductive approach was adopted and further supported by both qualitative and quantitative approach to elicit further knowledge sharing process. The dearth of research on knowledge sharing framework in RP process required a need for conducting an in-depth exploratory review of the subject domain. This can be achieved by observing raw data in order to identify patterns and key themes emerging from the data collected which can that be further explored to develop theories.

2.2.2 Research Strategy

Irani et al. (1999) emphasised the important role of the research strategy in developing a research methodology: ‘the underlying construct upon which any robust methodology is built is the research strategy. There are numerous strategies available to guide researchers around the phenomenon of interest.’ Drawing on definitions from Galliers (1992) and Weick (1984), Irani et al. (1999) offered the following definition: ‘A research strategy is considered to be a way of going about one's research, embodying a particular style and employing different research methods’. It is distinct from a research method, which ‘is a way of collecting evidence that indicates the tools and techniques used during data collection’. Pursuing the same theme, Remenyi et al. (1998) highlighted the importance of outlining the philosophical approach adopted as the basis of the research programme, since it is this approach that determines the research strategy.

Remenyi (1998) advanced a taxonomy containing two classes of research. These classes are theoretical research and empirical research. Theoretical research involves the study of academic literature and learned discourse of a subject, while generally refraining from observation of behaviour in the real world. Based on these studies, the research theorist will build a new view of this subject of interest, which might emerge as a theory, accompanied by conclusions that serve as a contribution to knowledge. Empirical research in contrast, involves studying observations made in the real world and the gathering of evidence. Conclusions are made based on this evidence and the potential contribution to knowledge. It is suggested that theoretical research demands the rigorous scrutiny of text-based sources, whereas empirical research will feature contact with people.

Empiricism is the underlying philosophy for positivist and phenomenological research. Some of main assumptions of positivism summarised by Robson (2002) are that objective knowledge can be collected from observation, science is predominantly based on quantitative data and the methods of natural science can be transferred to social science e.g. applied research. Phenomenology, in contrast rejects the notion of objective knowledge. It attempts to ‘capture people’s experience of the world’ and how they interpret it (Patton, 1990). In this way it takes a more subjective, qualitative stance. Remenyi et al. (1998) claimed that phenomenology is the prevailing philosophy in management settings. This is because it takes a holistic, subjective approach that is better suited to a complex social environment than the reductionist stance of positivism.

Walsh (2001) defined research strategy as methodologies of enquiry that define the methods that researchers use to collect data. Research strategies seek to achieve the best procedure for dealing with a research, in particular, for answering the research questions. Saunders (2007) stated that a researcher’s choice of strategy is guided by the research question(s) and objectives, and the extent of the existing knowledge and resources available as well as the researcher’s philosophical perspectives.

Robson (2002) identified the following five research strategies for conducting so called ‘real world’ research; experiment, non-experiment, case study, action research and grounded theory. Whilst other research strategies exist (Gill and Johnson, 2002), this research primarily adopts a case study strategy that deploys interviews and questionnaire survey research methods.

Case Study is defined as an empirical inquiry that investigates a contemporary phenomenon within its real life context (Yin, 2003). It focuses on understanding the dynamics present within single settings (Hussey and Hussey, 1997). According to Peshkin (1993), by using a case study the research serves to reveal the nature of certain situations, processes, relationships, systems or people, gain insights about the nature of a particular phenomenon, develop new concepts about the phenomenon and discover existing problems within the phenomenon.

Also the research serves to test the validity of certain assumptions, claims, and theories within real-world context; and finally provide a means through which researchers can judge the effectiveness of particular practises. This was augmented by a survey strategy that involved the collection of information from a large population in order to understand the population. The survey method usually employs the use of a standardised questionnaire and or a structured interview, with standard questions (Robson, 1993).

2.3 Overview of Research Approaches

Literature discussing research methodology indicates that there are at least two routes to the selection of a research methodology or approach. One is a data driven approach, as advocated by Leedy and Ormrod, (2005) and also found in Robson (2002), while the other is determined by the stated research problems or questions, as put forward by Yin (1994) and Remenyi et al. (1998).

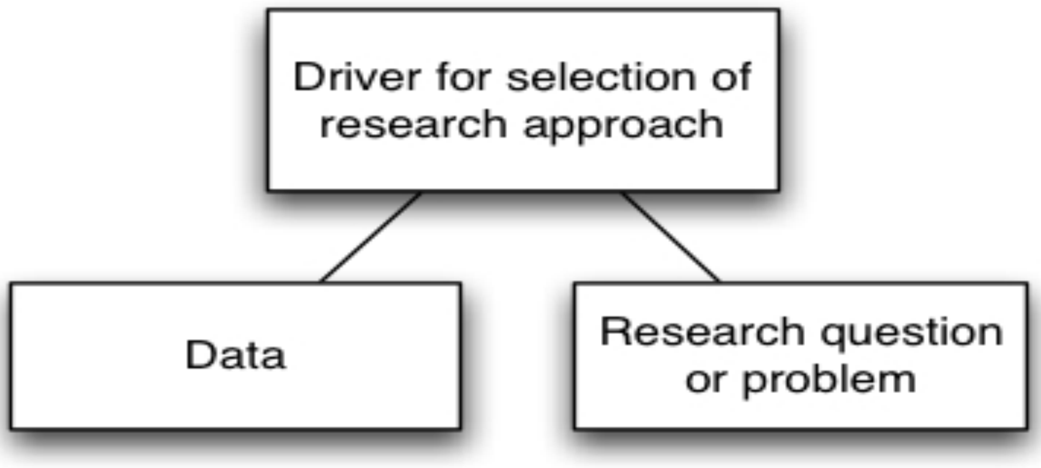

Figure 2-1- Drivers for the Selection of a Research Approach.

2.3.1 Action Research

The purpose of action research is ‘to influence or change some aspect of whatever is the focus of the research’ (Robson, 2002). In this approach, the researcher will intervene in the environment or scenario being studied. Robson (2002) ventured that this intervention has three aims: to achieve an improvement in a practice, to gain an improved understanding of that practice by its practitioners, and to accomplish an improvement in the situation in which the practice is taking place. Remenyi et al. (1998) identified three main weaknesses to this approach. The first problem is that action research often requires long periods of time to observe the impact of an intervention. The second and more relevant problem is that the personal involvement of the researcher in the scenario being observed puts them at risk of compromising their ‘intellectual independence’. Of equal concern is the third problem, that of a perceived lack of research rigour in the approach. It is therefore cautioned that any use of this approach in a PhD research project must be conducted with great attention to rigour.

2.3.2 Research Purpose

There is a dearth of academic literature concerning how feedback from knowledge sharing tends to support rapid prototyping in new product improvement. In this research project being a 'what' question requires an inductive strategy. 'What' questions enables the researcher to make appropriate observations or measurements. Therefore, the primary purpose of this study was to further explore this phenomenon and so an exploratory approach was adopted, to derive new insight and understand current practise and develop theory inductively from the data collected. The flexibility offered by exploratory research allows the focus of the research to be broad initially and then progressively narrows as the research ensues, allowing for greater adaptability. There is also a descriptive element in the research design that provides accurate descriptions of situations and events as well as further evaluations and conclusions from the data gathered.

A descriptive method is used because the research portrays an accurate report of persons, process and situations. As a result, this research has deployed a multiple research purpose. In addition a combination of case study and survey strategy is adopted for this research project. Both strategies would be useful in establishing different views of phenomena. The rationales for selecting a survey strategy is that the statistical data produced from the survey would enable the researcher to make data more visible and understandable to readers.

Yin (2003) asserted that case studies are considered as the ideal method for answering 'how' and 'why' questions, and especially when the researcher has little control over events, and when the focus is on a contemporary phenomenon within some real-life context. As this set of conditions applies to this research, the case study is chosen as the most appropriate strategy for this research. According to (Gummesson, 1991), case study provides the opportunity for a holistic view of a process.

2.3.3 Case Study and Survey Strategy

Gill and Johnson (1997) asserted that case study strategy is highly relevant if there is a need to combine research with practise in the real world. In addition Voss (2002) states that case study strategy is good not only at investigating 'how and why' questions, but also particularly suitable for developing, testing and refining theory.

To enable the researcher to gain an in-depth understanding of the knowledge sharing framework process in automotive supply chain in order to support the rapid prototyping in new product improvement, a case study approaches has been adopted. A case study would be considered IKD as an automotive company and CarGlass Company as the sponsor and collaborative industry of this research project. However multiple unit of analysis was embedded into the case studies. According to Yin (2003) it is possible to embed more than one unit of analysis within a case study. The use of multiple sources of evidence within this case study would allow triangulation of data sources and reduce the effect of bias in the findings (Robson, 2002; Yin, 2003). The case study approach is used because of the lack of information on the knowledge sharing framework process. It would enable the investigation into the “how and why” of the knowledge sharing process operation and its lack of effectiveness. By using a case study strategy, this research serves to describe the current knowledge sharing process, its limitations and the need for improvements, and thereby further develop theory from its findings. A case study provides a better understanding of individual cases by seeing events within the context of the whole.

The rationale for adopting a case study approach is its ability to support research questions through variety of evidence. It is also useful for understanding and exploring emerging processes and building theory (Easterby-Smith, 2002, Yin, 2003, Gill and Johnson, 1991).

Yin (2003) suggests that a case study can help reduce bias by not being restricted to one source of data and consists of a variety of sources such as interviews, observation, documents, artefacts and archival records attaining for triangulation. Other reasons for selecting a case study strategy include its strong academic credibility and thoroughness for use in research investigations of this type published in international and peer review literatures. As a result of all these reasons, a case study approach will be used in the empirical investigation and the validation of the proposed conceptual framework.

Surveys entail gathering information from a segment of the larger population to understand something about that population. Robson (2002) offers three main methods for collecting survey data: self-completion questionnaire, face-to-face interview and telephone interview. This method usually employs the use of a standardised questionnaire or and a structured interview, with standard questions (Robson, 1993).

2.3.4 Field Experiments

Field experimentalists seek to conduct experiments in a real world setting, rather than a laboratory, and field research has been employed in the business and management domain. Field experiments have been subject to considerable criticism, in part due to the effect that the knowledge that the experiment is taking place can have on the behaviour of the parties being investigated (Robson, 2002). Robson (2002) cautioned that the real world is not an environment where variables that may influence the outcome of the experiment can be readily controlled by the field researcher in the same way that they can be by the experimentalist in the laboratory. Remenyi (1998) warned of three further problems. From a methodological point of view, field experiments are considered to be too artificial in the businesses domain. As a result, PhD researchers do not usually adopt this approach. Furthermore, it may prove difficult to convince a business to spend significant time and money implementing a change for the sake of allowing a researcher to study its impact. If it is not possible to persuade an organisation to initiate this change in a timetable suitable for the researcher, the researcher will have to wait for the desired scenario to present itself in the natural course of events. This may not be practical within the timeframe of a PhD project. Together, these issues suggest that the field experiment approach is inappropriate for this investigation.

2.3.5 Focus Groups

A focus group is a homogeneous group of selected well informed or highly specialised individuals (Remenyi, 1998, Patton, 1990). Groups usually consist of five to eight people. Evidence is collected from these groups using open interviews, which focus on carefully targeted subject areas (Remenyi, 1998, Patton, 1990). Patton (1990) commented that an interview session might last from half an hour to two hours. Remenyi (1998) noted that the focus group approach is typically employed in business and management research as one of many evidence collection techniques in a single project in doctoral research. It is, however, not included in the list of research approaches applicable to information systems research provided by Galliers (1992). Furthermore, it is posited that the focus group approach may be used at the start and end of a research project in order to support research questions derived from a literature review or support findings respectively.

2.3.6 In-Depth Surveys

An in-depth survey approach seeks to elicit data from a small number of people by means of interviews (Remenyi, 1998). Interviews may be facilitated with an interview schedule or an interview protocol. Evidence is collected in the form of detailed notes or the interview is recorded and a transcript produced. The interview notes or transcript may be interpreted in a quantitative or qualitative fashion. For the former interpretation type, content analysis techniques may be applied to count the number of times an issue occurs. The frequency with which the issue appears is linked to the importance of that issue. For the latter interpretation type, the relevance attached to issues is based on the interpretation of the researcher, a technique known as grounded analysis. Given the subjective nature of this method, grounded analysis demands that the researcher ensures that the data collected is made available for analysis by other interested parties (Easterby-Smith, 2002). Remenyi (1998) mentioned that the in-depth survey approach has been employed in new product development research.

2.4 The Research Process of This Project

The term methodology, in its broader sense, refers to the complete research process and describes the detailed approach to data collection and its analysis. According to Leedy & Ormrod (2005), the research methodology directs the research study, dictates how data are acquired, arranges it in logical relationships, sets up an approach for refining and synthesizing the raw data, and contrives an approach so that the meanings in the data become clear and conclusions can be derived to contribute to knowledge sharing processes in production. Research process is often presented in literature as a multi-stage process that is undertaken by a researcher in order to complete a research study. Example of such stages includes formulating and clarifying a topic, establishing research questions, aim and objectives, reviewing the literature, research design, data collection, data analysis, and interpretation write up. Saunders, (2007) argues that the research process is often portrayed as being rational and straightforward yet in reality it is an iterative process which often requires revisiting each stage and refining one's ideas about research design and implementation. Each of the research objectives are accomplished in the different phases of the research programme and presented as separate chapters in this thesis structure.

The focus of the first phase of the research is to carry out an investigation on existing research on knowledge sharing framework in supporting rapid prototyping in product development process in particular the design function for facilitating product quality and reliability improvement. This phase led to the identification of gaps in existing research as presented in the literature review chapter.

The emerged themes as well as the identified weaknesses in existing literature is then used for designing interview questionnaires for exploring the actual knowledge sharing framework process operation in practise within the sponsoring company in the second phase. The second phase involved conducting an empirical investigation using a single in-depth case study to explore knowledge sharing roadmap framework process operation in practise within an industrial setting, in other to acquire the requirements for an effective field knowledge sharing framework process.

The emerged theoretical concepts were developed through a series of inductive iterations based on both literature reviews and empirical case study. The research extensively used questionnaires, company documentations, interviews reports, qualitative and quantitative data to identify converging lines of investigation and ethnographic methods to enhance the validity and reliability of the research outcomes.

2.4.1 Selection of Unit of Analysis

The units of analysis used for the empirical study were selected because they are the key stakeholders of the knowledge sharing framework process. The unit of analysis used in this research investigation was selected based on the following criteria:

- A function within knowledge sharing framework roadmap process.
- A function of using rapid prototyping in new product development.
- A function of collaboration procedure in automotive industries.
- The feedback process is key to its functional activities
- Contributes to different aspects of the Knowledge Sharing Framework process.

2.4.2 Data Collection and Analysis

As part of this case study research investigation, it was important to consider data sources that are most appropriate to address the research questions in order to achieve the research objectives. Yin (1994) identified six main sources, which are documents, archival records, interviews, direct observations, participant observation and physical artefacts. See Table 2.1 below, for the strengths and weaknesses of the various data collection techniques.

Methods	Strengths	Weaknesses
Documentation	• Stable- it can be reviewed repeatedly. • Contains exact details of an event • Multiple source can facilitate data triangulation • Data can be tracked over a long period of time	• Irretrievability can be low • Biased selectivity, if collection is incomplete • Access may be deliberately blocked • Reporting bias reflects bias of author
Interviews	• Targeted-focuses directly on case topic • Insightful-provides perceived causal inferences	• Bias due to poorly constructed questions • Response bias • Inaccuracies due to poor recall • Interviewee says what interviewer wants to hear
Questionnaire	• Respondent can be quantified for the case analysis • Time efficient for researcher and respondents	• No opportunity for clarification and deeper questions • Data collection depends on respondents goodwill • Quantity of data collected is limited
Direct Observation	• Covers event in real time • Covers context of event	• Time consuming • Event may proceed differently because it is being observed
Archival records	• Precise and quantitative	• Accessibility due to privacy reasons

Table 2.1 - Strength and Weakness of the Data Collection Techniques (Yin 2003)

The literature review is the secondary data collection technique used in this research and the primary sources of data collection for this study are interviews and questionnaire survey instruments. Where possible other techniques such as observation and company documentation were used to triangulate with the objective of overcoming potential bias and validating the quality and reliability of the data and data sources.

2.4.3 Literature Review

The literature review is often the starting point of a research inquiry. It is a critical and evaluative report on what has been published on a chosen research topic. Its purpose is to summarise, synthesise and analyse the arguments of others. The researcher can describe and analyse the knowledge that exists, gaps that occur in research related to the research study in order to reveal similarities and differences. The purpose of conducting literature review in this research is to gather information on the area under investigation so that researcher can gain knowledge about the subject area. As suggested by Strauss and Corbin (1990), Literature review was conducted (see chapter three) because of the following reasons:

- To stimulate theoretical sensitivity: by providing concepts and relationships that can be compared to the actual data collected.
- To provide secondary sources of data: to be used perhaps as initial hypotheses testing of the researchers' concepts and ideas.
- To stimulate questions during data gathering and data analysis.
- To direct theoretical sampling: to guide the researcher on how to discover phenomena that are important for theory development.
- To be used as supplementary validation – to justify findings and present augment on it supports or differ from the existing literature.

2.4.4 Interview Survey

In conducting a qualitative research, the interview technique can yield a great deal of rich data. The need to gain insights into the management of knowledge sharing framework process requires the use of an interview because it allows the researcher to obtain facts and opinions about events from first hand sources (Yin, 2003). There are different types of interviews such as; face-to-face, structured, semi-structured, telephone and focused interview.

Interviews are essentially conversations between the researcher or interviewer and their interviewee (research participants) and assume that the participants' perspectives are meaningful and knowledgeable. According to Patton (1990) the quality of information obtained is largely dependent on the interviewer's skills and personality. Easterby-Smith (2002) asserted that interviews are an opportunity for the researcher to probe deeply to uncover new clues, open up new dimensions of a problem and to capture clearly and accurately a problem situation based on personal experience. The objectives of the interviews were:

- To understand the knowledge sharing process functions in automotive industry.
- To identify current knowledge sharing framework to support rapid prototyping process in automotive and collaborative industry.
- To explore how the knowledge data is collected, analysed and utilised.
- To understand the current methodology to support new product development
- To identify current collaboration procedure in automotive and other industries.

The literature review identified a number of gaps in the existing body of knowledge. The main issues identified from the literature are the limited research foci on knowledge sharing framework process management and the problems with quality of data captured in the field. The literature influenced the areas to focus on in the research and no existing model of questions from the literature was adopted to formulate questions. The interview questions were formulated by the researcher to relate to the emerged gaps identified from the literature as well as the research problems and objectives it aims to fulfil. The interview questions were developed using the "what" and "how" context which shows the exploratory nature of the questions in the subject area. The questions "how" were used with various adjectives to ask detailed information about the subject that is examined. The first criteria considered for creating the questions are relevance, which meant that the questions must be related to the purpose of study and capable of eliciting the data desired by the researcher. The second criteria was to consider the respondent of the interview by ensuring the question is worded in a language or terminology that is understandable by the interview participants and finally the ease of response is equally important, which meant that questions must be relatively easy to answer by the interviewees.

2.5 Limitations to Approach

It has been acknowledged that the resolution of research methodology in appropriate research problems falls within the temporal and financial constraints of the doctoral research project. However, it must be acknowledged that there are a number of weaknesses in the methodology adopted. Some of these weaknesses concern the research strategy and others are inherent to the research methods employed. A discussion of these weaknesses follows.

A major criticism of the methodology may be levelled at the choice of a single case study approach. It is argued that the selected case possesses important features that make it relatable to companies in similar circumstances. These features are the use of a Stage Gate product development process that closely matches the generic models presented in the literature. Furthermore, the product development teams possess many of the traits attributed to global product development teams in the literature, as highlighted in next chapter. Additionally, the focus on a single organisation for the entire duration of the research project allowed a level of trust to be established which meant that useful and confidential data could be obtained.

Another criticism is that the knowledge sharing classification employed in the ontology was only tested using knowledge associated with the conception phase of the new product development process to support rapid prototyping with respect to aims and objectives of this research project. Nonetheless, work by Zahay et al. (2004) has emphasised the diversity of knowledge used in this phase, and Ulrich and Eppinger (2003) stressed the importance of knowledge sharing in this stage of the product development process.

2.6 Summary

This chapter has reviewed approaches available for conducting research and described the research design chosen for this investigation. Based on this review, suitable methodologies were defined and selected for addressing the research problems. Interviews and questionnaire survey instruments were deployed in conducting the research investigation so as to fulfil the objectives set in chapter one of this thesis. Data collected was analysed using data analysis method by Miles and Huberman (1994). In addition, it presented the approaches taken to assure the quality and validity of the research enquiry.

Chapter 3

Literature Survey

Based on the research aims, and under the auspices of the sponsor company, a review of the literature was carried out to examine issues related in knowledge sharing to support rapid prototyping in new product development in industry. This chapter presents the research background, and describes the nature of knowledge management domain, the types and content of knowledge used to develop rapid prototyping and knowledge content to the collaborative supply chain.

The literature review is an integral part of this thesis as it informs the direction of this research and acts as a foundation of the project and gives the author an idea of the current state of the art in this particular field. The review is broadly divided into three areas, the first area discusses the current understanding of the concepts of knowledge in the knowledge management domain, the type and content of knowledge used in new product development (NPD), examines models for knowledge sharing. The second area reviews the current understanding of rapid prototyping that has been used in many industries to reduce manufacturing lead time. Finally, the third area concentrates on the collaborative aspects between automotive supply chains.

The literature review for this research project will consider the new product design process and development issue, knowledge framework of rapid prototyping, knowledge management (KM) and knowledge sharing (KS) issues to collaboration between industries, engineering management, supply chain management cost modelling, estimation, information framework techniques and process modelling techniques.

3.1 Innovation and Knowledge Management

3.1.1 Innovation

Schumpeter (1939) provided a general definition of innovation: the commercial or industrial application of something new, a new product, process or method of production; a new market or source of supply; a new form of commercial, business or financial organisation. A review of the literature reveals that the Organisation for Economic Co-operation and Development (OECD) Schumpeter (1969) study on technological innovations best captures the essence of innovations from an overall perspective: Innovation is an iterative process initiated by the perception of a new market and or new service opportunity for a technology based invention which leads to development, production and marketing tasks striving for the commercial success of the invention. This definition addresses two important distinctions. Firstly, the innovation process comprises the technological development of an invention combined with the market introduction of that invention to end users through adoption and diffusion, and secondly, the innovation process is iterative in nature and, thus, automatically includes the first introduction of a new innovation and the reintroduction of an improved innovation. This iterative process implies varying degrees of innovativeness, thereby necessitating a typology to describe different types of innovations. As pointed out by some reviewers, the OECD definition also references technology-based inventions. Technological innovations are those innovations, which embody inventions from the industrial arts, engineering, applied, and pure sciences. Examples include innovations from the electronics, aerospace, pharmaceutical, and information systems industries. Innovation in this research project seeks to propose and develop a new way to better collaboration relationships with supporting rapid prototyping in new product development with better production lead times, less costs and better quality in automotive industries.

3.1.2 Data, Information and Knowledge

Data, information and knowledge are words that are often interchangeable used. It is important to understand the difference between these terms, as they are relative within their context of use. According to (Groff et al, 2003), data is raw in nature and it is without context. It has no meaning beyond its existence. Maier et al, (2005) described data as a "symbol that is ordered to an elementary description of a person, thing, event, activity or transaction in the perceived reality or imagination of a person". Data can be recorded, categorised and stored without conveying any specific meaning. Information on the other hand results from adding some meaningful context to the data, often in the form of a message. Therefore, Information is data that has been given meaning by way of context. The term knowledge is often used vaguely within organisation and within the subject of knowledge management. Knowledge is the combination of data and information that guides the action of a person. According to (Schreiber et al*,* 2000) knowledge is used by a person to carry out tasks and create new information. This statement supports Davenport's definition of knowledge as "information that has been combined with experience, context, interpretation, and reflection" (Davenport and Prusak 1998).

3.1.3 Knowledge Management

It is useful to distinguish between raw information and knowledge (Edwards, 1994). Raw information may be widely available to a number of agencies, but only some organisations will be able to convert the information into relevant knowledge and use this knowledge to achieve their aims. The processes by which they do this are known as knowledge management strategies. Challenges and advantages of knowledge management are naturally related to challenges and advantages of organisational learning, and in the international development field, these two sets of issues are often examined together. As with the two generations of knowledge management strategies, an organisation's ability to learn from past experiences can also be divided into first and second order strategies (Argyris, 1992). First order strategies concern 'single loop learning', aimed at correcting and modifying practices in order to fit in with an established policy. Second order strategies are those of 'double loop learning', which in parallel with second generation knowledge management strategies aims to increase an organisation's capacity to think creatively and act innovatively. Accenture (2002) emphasised that knowledge management must be tailored to the circumstances of each particular firm and the work of that firm. Work settings differ along two axes, the level of interdependence required and the complexity of the work itself as illustrated in Figure 3.1. Each work setting operates with different types of knowledge. A very large proportion of the literature on knowledge management and organisational learning is developed by, and aimed at, commercial businesses and firms. Many organisations in the corporate sector look to knowledge management as a solution to the new challenges of the information age. Knowledge and information are becoming crucial core assets for businesses, who have to learn to handle their assets in new ways. Traditional accounting and monitoring systems designed to deal with tangible inputs and outputs are no longer adequate.

Local ⟷ Global

Collaboration ↕ Individuals

Process model	**Network model**
• Systematic, repeatable work • Highly reliant on formal processes, Methodologies or standards • Dependent on tight integration across Functional boundaries **KM: Methodologies, standardisation**	• Improvisational work • Highly reliant on deep expertise Across multiple functions • Dependent on fluid deployment of Flexible teams **KM: Alliances, expert teams**
Systems model • Routine work • Highly reliant on formal procedures And training • Dependent on individual workers and Enforcement of strict rules **KM: Automotive, training**	**Competence model** • Judgement-oriented work • Highly reliant on individual expertise And experience • Dependent on star performers **KM: Apprenticeships, recruit Individual experts**

Figure 3.1 - Knowledge Management strategy (Accenture, 2002)

Instead, organisations now find that they have to share information internally more efficiently and learn to adapt more quickly to external circumstances in order to retain their competitive advantage. In response to this situation, the 'first generation' of knowledge management strategies aimed at improving knowledge sharing within organisations (McElroy and Zaheer, 2000), was very focused on information technology and systems; technical tools were used to collect existing knowledge in order to make the organisation run more smoothly. A 'second generation' of knowledge management strategies has now emerged. This focuses more on organisational processes and the creation of new knowledge in order to keep the organisation one step ahead of the competition. For example, the most successful organisations are shifting from strategies based on prediction to strategies based on anticipation of surprises (Savage, 2000). They are shifting from management based on compliance to management based on self-control and self-organisation. They are also shifting from the utilisation of already known knowledge to the creation of new knowledge, from pure 'technology' knowledge management applications to include 'process' applications (Binney, 2001). When and how these shifts should be undertaken depends on the type of organisation in question. Accenture's (2002) presentation of a typology of work settings distinguishes between four different types of processes in organisations, systems, network and competence which are based on the different levels of interdependence and complexity that are required in different work situations. For example, the competence model describes a workplace that is highly reliant on individual expertise (low level of interdependence) in order to carry out evaluation and judgement-oriented work (high level of interpretation). The network model denotes a workplace that depends on fluid deployment of flexible teams (high level of interdependence) in order to improvise and meet new challenges as they arise (high level of interpretation). Different work settings require different ways of handling and processing information to create the necessary knowledge. However, in this particular research study, knowledge management can be used as a tool to allow industries to have a better understanding of new product development and improve their ability to have better collaborative procedures with other industries to future develop rapid prototyping in new product development.

3.1.4 Knowledge Management in Manufacturing

During the early 1990s, many researchers studied concurrent engineering to reduce manufacturing lead time (Studer et al, 1998). To shorten the duration of product development, a systematic management of product knowledge is required. Engineers spend more than 70% of their working time in searching and handling recently updated knowledge. This is an unnecessarily time consuming activity and decreases the productivity of engineers (Stauffer and Ullman 1991). Stauffer et al studied why engineers take too much time to utilize knowledge of past projects. The problem is that past knowledge is not well organised. One of the reasons that this is a problem becomes is engineers do not have enough time to arrange information and knowledge which they already have. Another reason is that companies do not necessarily regard knowledge as an asset that they own and lack budgets for knowledge management. According to the result of Court's (1998), engineers use about 30% of their personal knowledge during product development. They use between 50% and 70% of their personal knowledge in some cases. Therefore, increasing the utilisation of engineers' private knowledge and knowledge framework sharing through knowledge management is a critical advantage in product development.

Many researches adopt different knowledge management frameworks for their systems. One of the most popular knowledge frameworks managements for pervious researches is ontology. In this form, knowledge is categorised and structured for comprehensive, unambiguous and homogeneous knowledge management. For this, knowledge representation is based on ontology (Bozsak et al, 2002). In addition, typical types of knowledge such as engineering functions, expert rules, and data analysis based knowledge are specified and accommodated with the framework. However, Bozsak et al, define an ontology structure in six categories; concepts, relations, concept hierarchies, relation hierarchies, functions, and axioms. These ontology components can be used for a base of knowledge framework. The concepts and relations generally represent the basic structure of domain knowledge. Thus, common domain knowledge can be represented with concepts and relations including concept hierarchies, relation hierarchies and functions. On other hand, axioms specify the semantics of concepts and relations so that the semantics of knowledge can be represented with axioms. In addition, the task-specific knowledge can also be defined with ontology because it specifies the quantified relationship between concepts of ontology, which is the relation between their instances. Thus, the three levels of knowledge are precisely organised with an ontology structure (Bellanet, 2000).

Manufacturing industries are typically identified with the production of discrete items that can be individually recognised, counted and defined in form, weight and features. This is case in the production of automobiles, glass, computers, and process industries, which are typically identified with the production of goods involving constant and continuous production processes. At the production level, the production process of a manufacturing industry can be modelled by considering a platform that comprises of machinery, tools, knowledge and human labour, as illustrated in Figure 3.2. Nowadays, knowledge framework is a prominent production factor, together with traditional production factors, such as capital, labour and raw materials. The production processes have inputs such as raw materials, information and energy. The guidelines that support the decisions of production are the organisational strategies, product demands and external disturbances (Kamara and Mahnke 2000). The organisational strategies define the guidelines of production, such as the production type and the medium to long-term production plan. During transformation processes, which are, subjected to environmental effects, quality and safety constraints waste is generated due to material transformation processes, failures in machinery and quality control rejections. The variation in product demand and external disturbances requires the introduction of corrective actions in the planning and control system to maintain the production stage strategic guidance.

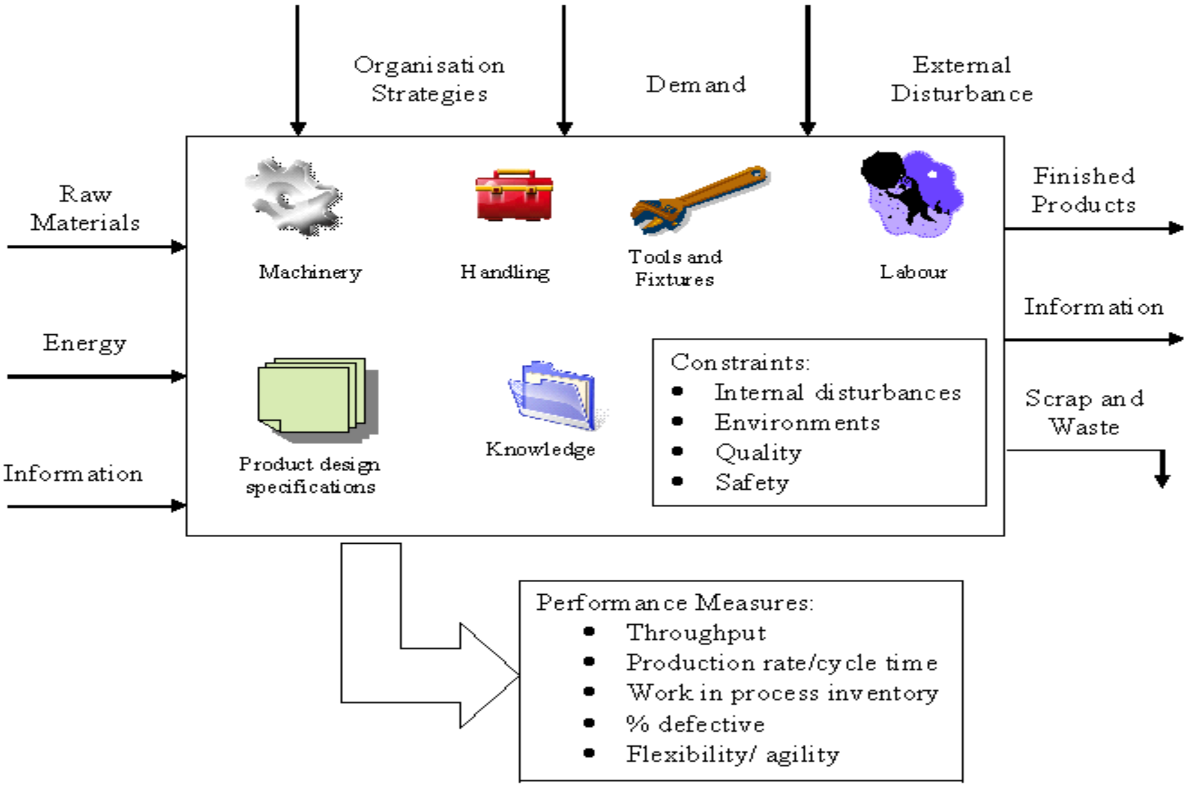

Figure 3.2- Abstract Model of a Manufacturing System (Kamara and Mahnke, 2000)

3.2 Knowledge Sharing

Teece (2004) and Argote and Huber (2004) stated that knowledge management involves panoply of procedures and techniques, which are used to get the most from an organisation's tacit and codified know-how. While defined in many different ways, knowledge management generally refers to how organisations create, retain, and share knowledge. It is obvious that knowledge sharing is a means by which an organisation obtains access to its own knowledge and other organisations knowledge. Knowledge sharing has emerged as a key area for research from a broad and deep field of study on technology transfer and innovation, and more recently from the field of strategic management (Nelson and Rosenberg, 1993). In simple terms, knowledge sharing refers to the transfer of knowledge between a knowledge source, or owner and knowledge recipient, or reconstruction (Hendriks and Polanyi 2007). Nelson and Rosenberg (1993) noted that this process is also called knowledge dissemination or knowledge transfer. It is emphasised that knowledge sharing is similar but distinct from both the communication and the distribution of information. In Figure 3.3 identifies five primary contexts that can affect such successful knowledge sharing implementations, including the relationship between the source and the recipient, the form and location of the knowledge, the recipient's learning predisposition, the source's knowledge sharing capability, and the broader environment in which the sharing occurs.

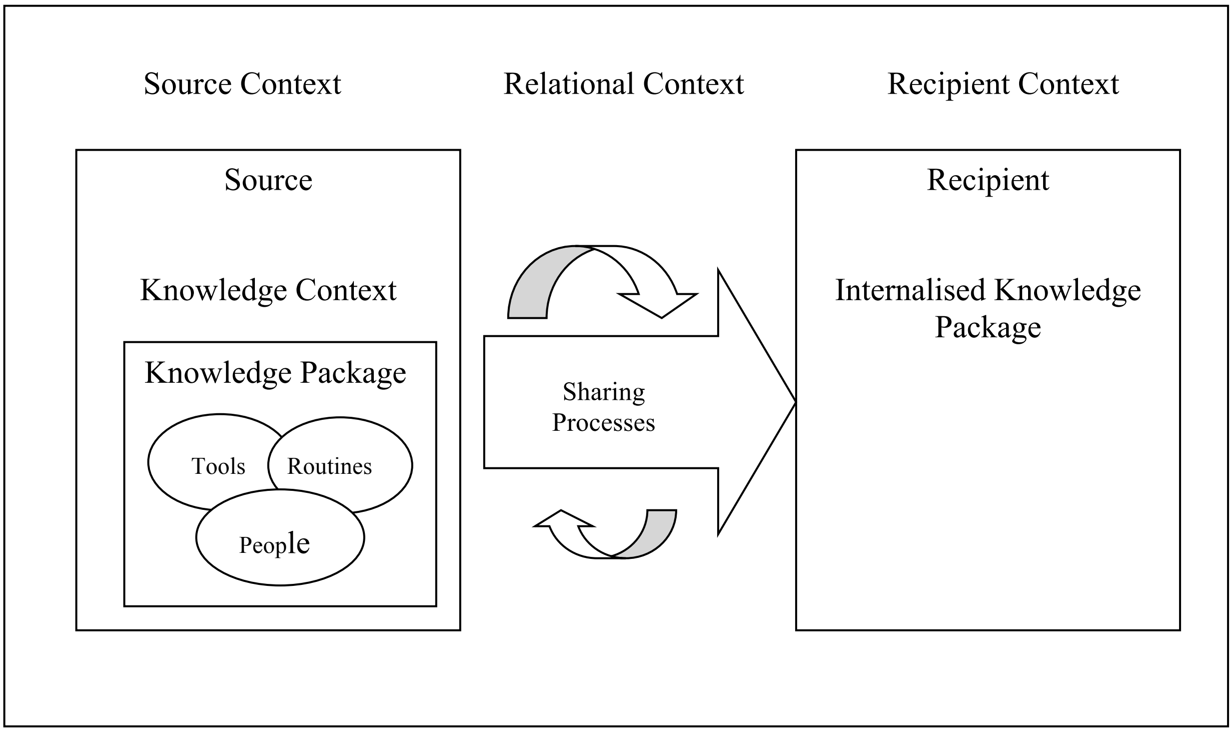

Figure 3.3 - Five Contexts of Knowledge Sharing (Nelson and Rosenberg, 1993)

Knowledge sharing has also become an important focus in the strategic management field, where knowledge is seen as "the most strategically important resource which organisations possess," (Grant, 1996) and a principal source of value creation, (Nonaka, 1991; Spender and Grant, 1996; Teece, 1997). Indeed, in many industries, the importance of developing abilities to better utilise the knowledge contained within a firm's network has become apparent. Bellanet (2000) has demonstrated the potential benefits of best practices transfer. Instances of failure in downsizing, on the other hand, have revealed the costs of losing knowledge. Empowerment and globalisation have created local knowledge with potential for utilisation elsewhere, and information technology has given individuals increasingly differentiated knowledge, unknown to the head office," (Bresman et al, 1999). Moreover, in automotive and collaborative industries, these activities are the basic concept of sharing of knowledge between and with outside partners and clients.

As with the technology transfer and innovation research, strategic management scholars have also identified a number of variables that can affect knowledge sharing, notably the nature of the knowledge being shared in terms of its tastiness and embedding's (Zander, 1991; Szulanski 1996; Dinur 1998 and Dixon, 2000), the strength of relationship ties between the parties (Hansen, 1999), the learning mind set and capability of the recipient (Yeung et al, 1999), and the transfer activities which should have been undertaken (Dinur, et al., 1998; Davenport and Prusak, 1998). Sharing knowledge requires effort on the part of the individual who is sharing the knowledge with other parties. Davenport and Prusak (1998) identified four mechanisms for the sharing of individual knowledge within organisations: (1) contributing knowledge to organisational database, (2) sharing knowledge in formal interactions within or across teams or work units, (3) sharing knowledge in informal interactions, and (4) sharing knowledge within practice communities. According Kim and Nelson (2000), knowledge sharing also occurs as a dynamic learning process involving organisational interactions with customers and supplier, resulting in innovation or creative imitation. Because of advancement in information this process often entails increasingly differentiated knowledge that is shared between units and with outside partners and clients.

Epple et al (1999) also discussed that there is an increasing emphasis on the importance of knowledge sharing for organisational performance and effectiveness in both the private sector and the public sector. Knowledge sharing activities create opportunities for organisations to maximise their ability to meet customer's changing needs and to generate solutions to a gain competitive advantage. Nonaka (2001) also noted that the diversity of knowledge used by different function is detrimental to knowledge sharing. This is because each function may have different vocabularies, targets and ways of addressing problems that can sometimes make it difficult to achieve a shared understanding.

Nonaka, et al (2000) concludes that a successful knowledge sharing effort requires a focus on more than simply the transfer of the specific knowledge. Instead, many of the activities to be undertaken need to focus on structuring and implementing the arrangement in a way that bridges both existing and potential relationship issues, examining the form and location of the knowledge to ensure its complete transfer. In other words, while the activities used to share knowledge, such as document exchanges, presentations, job rotations, are important, overcoming the factors that can impede, complicate and even harm knowledge internalisation are equally important in determining the ultimate results of a knowledge sharing effort in industries. Accordingly, any evaluations of the knowledge sharing efforts need to incorporate assessments of its use of activities related to understanding the form and embedding's of the knowledge, establishing and managing appropriate administrative structures, and facilitating the transfer of the knowledge.

3.2.1 Knowledge Sharing Success

Argote and Ingram (2000) stated that one approach to defining knowledge sharing success focuses on the degree to which the knowledge is recreated in industries. Consistent with the innovation literature but on more basic level, knowledge can be seen as knowledge packages embedded in different structural elements of an organisation, such as in the people, skills, technical tools, routines and systems used by the organisation, as well as in the collaboration networks formed between and among these elements (Argote and Ingram, 2000 and Barton, 1992). From this perspective, knowledge transfer involves the recreation of a source's knowledge related elements in knowledge package in NPD to the industries (Winter, 1995). In addition to the fact that it is often difficult to know what aspects of knowledge are important (Sowell, 1980), or which elements need to be transferred (Spender and Grant, 1996), there is significant evidence that effective recreation also requires that the knowledge package is made accessible to the industries so that 'the local doers of development' can convert and adapt it or reconfigure it to their localised needs (Dixon, 1994; Nonaka, 1994; Barton, 1988; Moreland et al, 1996). Yeung et al (1999) also suggests that a source's learning knowledge is also an important factor affecting knowledge transfer success. This is because a capable source is able to manage knowledge sharing activities in such a way that it improves an industry learning of the specific knowledge, much as a university lecturer structures lectures, readings and assignments to best facilitate their students' learning.

3.3 New Product Development

Understanding the context of new product development requires a definition of the subject matter in order to provide a basis for further literature review. The Product Development and Management Association (PDMA) handbook of product development provided the following definitions of a new product and the product development process: A product is a system comprising several elements, which can be broken down into a hierarchy of levels. Blischke and Murthy (2000) classified product into seven levels of hierarchy with 'system' at the highest level and 'parts' at the lowest level. The diagram in Figure 3.4 illustrates the hierarchy of a product.

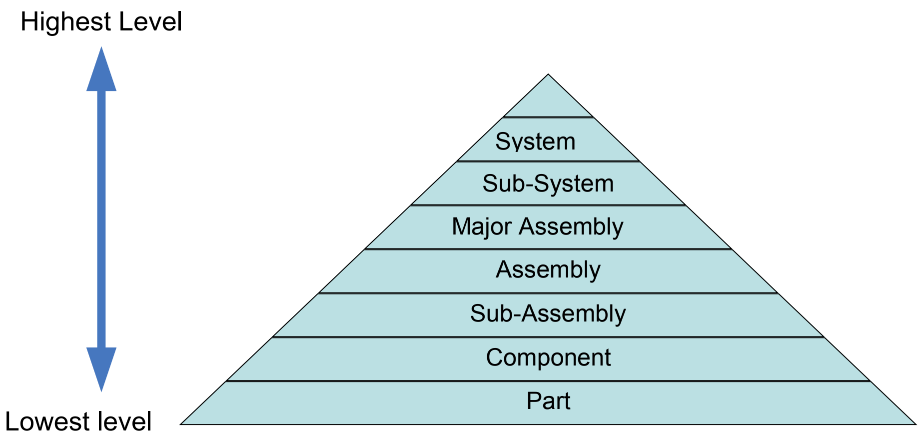

Figure 3.4 - Hierarchy of a Product (Blischke and Murthy, 2000)

New product development (NPD) is "the overall process of strategy, organisation, concept generation, product and marketing plan creation and evaluation, and commercialisation of a new product. Also frequently referred to as ‘‘product development" (PDMA, 2003)

New product development process is defined as "A disciplined and defined set of tasks and steps that describe the normal means by which a company repetitively converts emergent ideas into viable products or services" (PDMA 2003).

3.3.1 Main Issues of New Product Development

New product development (NPD) becomes one of main efforts in most manufacturing organisations. Usually, a successful product development is determined by 5 factors: good product quality, low product cost, short development time, low development cost, and effective development capability (Kidder, 1981). Therefore, these 5 factors become the objectives in manufacturing business. NPD involves most departments in manufacturing companies. Some departments play main roles in NPD, whilst some others are in supporting roles, such as finance department. In common practice, three departments must be involved (Katzenbach and Douglas, 1993): (i) Marketing department which connects enterprises with customers and captures useful knowledge consisting of customer requirements, market segmentation and product opportunities; (ii) Design department which defines product concepts and designs the final products to meet customer needs; and (iii) Manufacturing department which defines the production planning, scheduling and manufacturing methods, as well as purchasing, distribution, and supply chain management.

In current manufacturing practices, most products are developed as an independent project. Many people cooperate with each other to define the product. Ulrich and Eppinger (2011) described a structure of a product development team for an electromechanical product. The team consists 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 identify all the concepts of the product. The extended team includes suppliers to support the core team with the relevant knowledge and materials. Ulrich and Eppinger (2011) defined a generic new product development process, which contains six phases (as shown in Figure 3.5).

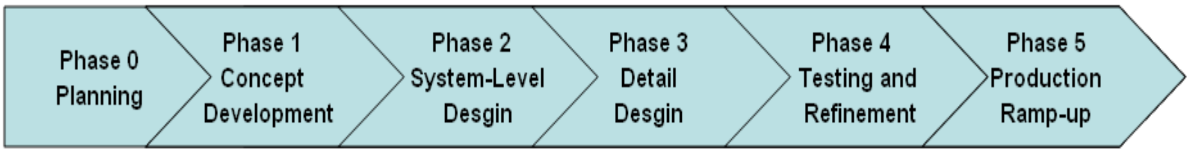

Figure 3.5 – A Generic New Product Development Process (Ulrich and Eppinger, 2011)

Phase 0 is planning, and the purpose of this stage is to identify market objectives and assess the current technologies. The output of this stage is a strategic statement including business goals, missions, key assumptions and constraints. Phase 1 is concept development, which is one of most important stages in the process. Product concepts are identified, tested and evaluated in this phase based on customer needs. Phase 2 is system-level design. This phase contains the definition of product architecture and breakdown of the product into subsystems and individual components. The detail design phase (phase 3) contains the complete product specifications, such as geometry, tolerances and materials. In this phase, constraints of the product in implementation are identified, in order to control the risks and failures in actual implementation. Phase 4 is product test. A prototype of the intended product is produced under the constraints and controls. Phase 5 is the production ramp-up. During certain point of this phase, the product will be launched.

This generic product development process is commonly accepted, although there are variations in different manufacturing companies, including the collaborating company of this project. It is noted that the generic process provides a sequential process rather than a iterative process showing feedback or changes.

When a product is developed, it is managed as an individual project, and a project manager is assigned. Meredith and Mantel (2006) defined three objectives of project management, i.e., performance, cost and time. To identify the maximum performance in a limited time period with reliable cost estimation is critical to design management in the manufacturing business. Project management should integrate all aspects in the product development process (Project Management Institute, 1996). Therefore, project management can be used as the basis or starting point for this project to integrate all the stages of new product development within the framework to be developed. Project managers have three main responsibilities: plan, organisation and control. In other words, project managers are required to plan, organise and control design projects to finish in time and satisfy all customer requirements (Gido and Clements, 2004). A successful project manager should have many skills, and should be trusted by customers and can motivate members in the project team.

Understanding customer requirements is the starting point in project management. Customer requirements need to be transferred to product design requirements and engineering requirements. Baxter and Gao (2005) reported a methodology to transfer customer requirements to design and engineering requirements. Johnson et al (2001) developed a methodology to integrate customer requirements with requirements of other stakeholders.

Another factor that can directly influence the success of projects is communication. Good communication can also satisfy the KM requirements in new product development. Shiffler provided a three ways: Communication, Communication (Project Management Institute, 1998). The formats of communication in project management are multiple, such as oral communication, meetings, telephone calls, emails, letters and Internet meetings. The abundant communication provides a good condition of sharing knowledge in new product development. As previous discussed, excellent knowledge sharing is a basic factor of any successful new project development. Therefore, the combination of project management and knowledge management can assure the success of new product development.

There is a common problem with project based product development, i.e., each product development project is carried out independently. The collaboration between projects is limited. This may lead to the continuous product development between generations becoming separated individual projects. This situation could lead to high cost and time wasted in the development of similar products. This problem can be improved using the methodologies developed in this research project.

3.3.2 New Product Development Process (NPDP)

New product development is part of the innovation process (Roozenburg and Eekels, 1995) and is critical to the growth and success of many organisations. A number of researchers have focused on the success and failure of a new product (Ulrich and Eppinger, 1994). Cooper (2001) identified factors that are fundamental to new product success. There are different types of new products (Cooper, 2001), for example, new to the world, new product lines, additions to existing product lines, improvements and revisions to existing products, repositioning and cost reductions (BoozAllen and Hamilton, 1982 and Trott, 2005). Whatever the case, the underlying motive of product development is to gain the competitive edge. Over the years this has become the dominant driver of competition in many industries. As a result of the intense global competition, constant changes in technology and increasingly demanding customer needs and expectations, the product development process is becoming more complex and the outcome of the process is less certain (Trott, 2005).

According to Ulrich and Eppinger (2003) new product development process involves a set of activities beginning with the perception of a market opportunity and ending in the production, sale and delivery of a product. Nanda and Vivek (2005) described NPD as a gradual process of transformation of specified product requirements into a finished product. Cooper (2001) argued that it is a process by which an organisation uses its resources and capabilities to create a new product or improve an existing one. Based on the various definition of product development process, it can be concluded that in general it is a process that transforms an idea and opportunity into a real product.

3.3.3 Stages of New Product Development

NPD is presented in various literatures as consisting of a varying number of steps, stages and activities (Cooper, 2001; Ulrich and Eppinger, 1994). Page (1993), argued that the variety of conceptions and compositions, together with the differences in terminology present difficulties when researching the NPD process. There are two approaches to the NPD process as identified by Nonaka and Takeuchi (2000). The traditional approach involves a sequential method where one phase of the process would have to be complete before the next phase can begin. The second approach is the overlapping approach, which has no structured approach to the development process. Instead it involves a multidisciplinary team who work together through the product development lifecycle. Tasks in different phases can be worked on in parallel. For example, tasks in phase three can be started before tasks in phase two are completed (Nonaka and Takeuchi, 2000).

Traditionally NPD processes are managed through milestones and deliverables (Minderhoud, 1999). It involves parallel as well as sequential product development projects (Gieskes and Langenberg, 2001). The sequential NPD model is performed in various time-based stages. The commonly used stage-gate approach splits the NPD process into a series of sequential phases. Each gate, also known as a milestone, must be completed before proceeding to the next phase. Milestones are used to achieve a certain level of quality in the NPD project. Although product development models have similar goals they have different stages (Cooper, 2001; Ulrich and Eppinger, 2003; Wheelwright and Clark, 1992). Rudder et al, (2001) implied that an organization should not be attached to one particular product development model but consider the basic fundamentals of a model, adapt and amend it to their particular circumstances.

However, a stage gate approach to product development is widely implemented in many organisations for conducting a product development project. It is a conceptual and effective roadmap for moving a new product project from idea to launch, Cooper (2001). The stage gate approach is effective under certain conditions such as, when innovation time is shorter than the rate of change in business environment and also for controlling quality and reliability (Meyer, 1998). Stage Gate divides the product development process into distinct stages separated by management decision gates. The purpose of the go/no go decision between each stage is to identify and reduce the risks. Figure 3.6 illustrates the Stage Gate process model. The shaded stages are commonly used in product development models. The stages are Idea/Concept Generation, Idea/Concept Screening, Concept Development and Testing, Product Development and Testing; see Ulrich and Eppinger, (1994) for details. All of the stages are important for a successful product development project. The product development process is performed as an interdisciplinary activity requiring contributions from all functions within an organisation. Traditionally, the NPD process has been characterised by functional division, particularly between Marketing, Research and Development and Production. Nowadays, NPD is seen as a vital cross-functional business process, which also involves external suppliers or partners collaborating together to achieve a successful product development (Molenaar et al, 2002).

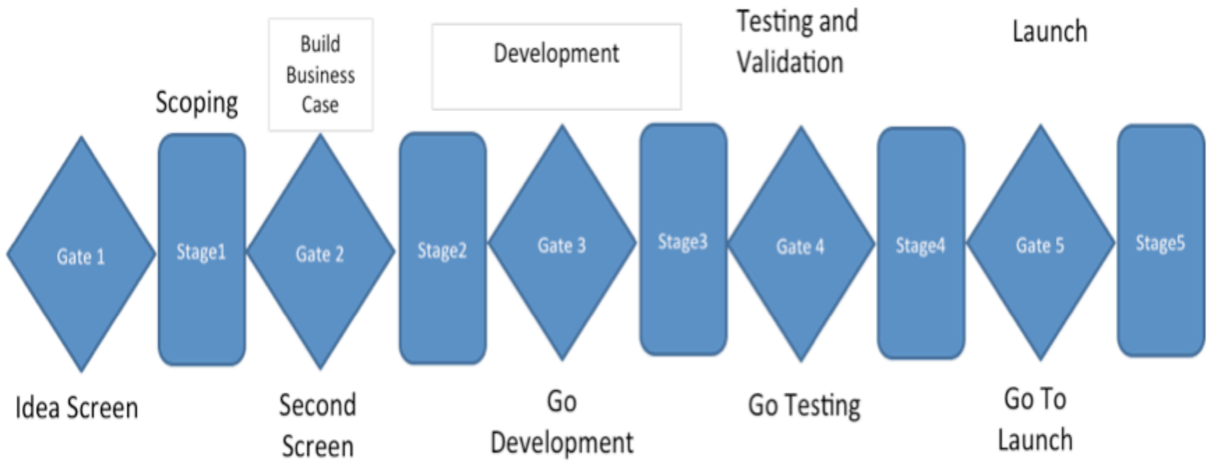

Figure 3.6 - The Stage-Gate Process Model (Meyer, 1998)

Using a cross functional team in new product development ensures diversity in knowledge ideas and a variety of information sources. Schilling et al (1998) asserted that the effective use of a cross-functional team in new product development lowers costs and reduces product defects. Fredericks (2005) stated that cross-functional input to product development is dependent on having a shared understanding of the tasks required at different phases of the NPD process. Team diversity in product development project provides people with different training, experience, perspectives and personalities which, when combined, is used to develop a creative product that satisfies customer needs (Ulrich and Eppinger, 1994). However, Berndes et al, (1996) argues that product development organisation needs to think in a process-oriented way, in order to establish a holistic view of the process, instead of thinking in a functional and departmental oriented way. Improvements to a product are made during the design process. This thesis examines the role of design in product development, which is discussed in the next section.

3.3.4 Challenges in New Product Development

Organisations are faced with a number of challenges when performing new product development process, and many of these challenges have been focused upon in product development literature. Some of the dominant driving forces of today's competitive business environment are technological advances and increasing customer expectations. As a result, products are becoming more complex whilst product life cycles are getting shorter. Existing literature in about NPD suggests that the combination of technological innovation, pressure on time to market and increasing customer demands urges manufacturing companies to shorten their product development process (Molenaar et al, 2002). McDonough et al, (1999) asserted that organisations involved with NPD process face pressure to reduce their development cycle time and costs, without sacrificing innovation. Barton (1992) stated that time to market have become critical in the highly competitive global environment and driving the need to respond quickly to customers need. Another challenge in NPD is how to acquire knowledge and manage sources of uncertainty in order to reduce the risk of failure of either the project or the ensuing product, (Cooper, 2001). Increasing product complexity increases the risk of product failure. However, despite the extensive testing of products, it is impossible for failures to be totally eliminated from a product. Therefore, when developing new products, the challenge is to reduce the chances of product failures. There is a need for a continuous improvement in product development process, which acts as a proactive strategy for preventing failures from occurring and at the same time maintains product quality and reliability. Research conducted by Barclay (1992) indicated that product development process needs on-going improvement activities. Bessant and Caffyn (1997) define continuous improvement as "an organisation wide process of focused and sustained incremental innovation". It involves set of activities that enables an organisation to improve its performance (Bessant et al, 2001). One such activity is learning from experiences, for example capturing and using field failure data.

To survive in the competitive global and dynamic environment, products brought to the market must be better, faster and cheaper. This requires the product development process to be managed efficiently. Regardless of the type of product being developed, it is subject to various risks, which can lead to reliability problems. The next section describes quality and reliability improvement in the product development process.

3.3.5 Integrated Product Development

The Product Development and Management Association PDMA Hand Book (2003) defines product development (PD) as the overall process of strategy, organisation, concepts generation, product and marketing plan creation and evaluation and commercialisation of a new product. The MIT Centre for Innovation in Product Development defines product development as the process by which a product comes to market. Others (Clark and Wheelwright, 1993) define product development as the flow of activities and decisions from identification of market needs to production and use of products. From a management perspective, the product development process is a disciplined and defined set of tasks, steps, and phases that describe the normal means by which a company repetitively converts embryonic ideas into scalable products (PDMA, 2003). The main objective of any product development process is the design, development and manufacture of the right product and its supply to right customer at the right time.

Lawrence and Lorsch (1986) define integration as the process of achieving unity of effort among the various subsystems in the accomplishment of an organisation's task. According to Harmancioglu (2007), it has been stated that integration facilitates reciprocal information flow among functions responsible for the development, design, and implementation of the innovations. The Product Development Management Associated (2003) defines integrated product development as a methodology that systematically employs an integrated team effort from multiple functional disciplines to develop, effectively and efficiently, new products that satisfy customer needs. According to Thompson (1967), integration may be achieved through standardisation, by plans or by mutual adjustment. The author concludes that standardisation is most suitable when the interdependence between organisational units is of a pooled nature, coordination by plans is a function of sequential inter-dependency, and mutual adjustment is called for when the inter-dependency is reciprocated. Moreover, the burden of the mechanism on decisions, communication, and resources increases from standardisation plans to mutual adjustment.

Galbraith (1973) suggests seven lateral processes to integrate the work of different functional specialties: direct contact, liaison roles, task force, teams, integrating role, managerial linking role and matrix form. Direct contact between managers shifts the decision making to a lower level of the hierarchy, thereby improving the quality of the decision-making. Liaison roles are designed to enhance the lateral communication between two interdependent departments. Task forces are used when the problem involves several interdependent departments. Teams are used when group problem solving is to be used on a more permanent basis, typically around frequently occurring problems. The integrator is a general manager with responsibility for a particular decision process. The integrators do not participate in the work itself, but rather coordinate the decision making process. In the managerial linking role the authority of a formal position is added to the expert power of the integrating role. The matrix organisation creates a formal dual reporting relationship to guarantee the efficient use of resources and to maintain the level of technical specialisation. Van de Ven (1976) divides the coordination modes within organisations into two general types, by programming. The coordination by programming is further divided into a personal and a group mode. More recent research has studied the cross-functional integration mechanisms in NPD. New product development is inherently paradoxical in nature (Donnellon, 1993). It requires both specialisation and integration. Clark and Fuijimoto (1991) divide NPD into two main problems: (i) problem differentiation, how to get a product's parts and subsystems designed, built, and tested so that each element achieves a high level of functionality; and (ii) problem integration, how to achieve product integrity. From an organisational standpoint, the former requires functional specialisation by component, subsystem, or functional task or any combination of these. On the other hand, the latter requires an integrated development process, which can be further divided into internal integrity and integration within the project team; and external integrity and integration with the customer (Clark and Fuijimoto, 1991). In this research project, the focus will be on the integration with the external partners and collaboration between two partners or organisations (such as automotive and glass industries), which, for purposes of this research are principally the collaboration and sharing of the knowledge information and technology to support rapid prototyping in develop new products with lower lead times, costs and quality. According to Clark and Fuijimoto (1991), if the product's performance is heavily dependent on the component's ability to work together, the integration aspect should be emphasized. Although NPD process integration has been an important formal concern of companies for well over 40 years and continues to be, there is still much to be understood about the process as companies continue to have spectacular new product failures. Only one NPD project in four becomes a winner (Cooper and Robert, 1975).

3.4 Rapid Prototyping

3.4.1 Introduction

Companies are closing the loop on integrated product development through the use of rapid prototyping. Rapid prototyping (RP) is relatively a new tool that can help industrial engineers to effectively wage the time compression war (Miles and Huberman, 1994). In general terms, rapid prototyping is a design approach, which is especially useful for the development of products in large-scale projects. In the early stages of a project, a small-scale prototype would be built to exhibit the key features of the planned system. This prototype is then extensively tested to achieve a better understanding on the requirements and challenges of the large-scale system. The prototype may or may not evolve into the final product at a later stage. The benefit of the rapid prototyping approach is that it allows exploration of key concepts at an early stage when costs are relatively small and any design changes easily conducted (Wilson et al, 1993).

The need for product innovation has never been greater. Product life cycles are now shorter and hence any new products will make older versions obsolete more quickly (Harmancioglu 2007). New product development is considered to be one of the riskiest and most important activities of modern corporations and is essential for the continued success of companies. However, in the early stages of prototyping, it is often difficult to follow the ever-changing customer requirements, in addition to improving the performance and capabilities of the new product development and services that satisfies consumers better than the competing alternatives. Rapid prototyping is a product development process in manufacturing technology that involves a group of manufacturing techniques that is based on layer by layer material deposition rather than on material removal or deformation (Masood, 2005). The framework of rapid prototyping enables engineers to improve the efficiency and capability of products through the application of distributed "black board control" technology. Such a framework facilitates companies to make models and prototypes for focus group evaluation, testing and downstream moulding and casting processes. However, rapid prototyping can also reduce costs and lead times, which are necessary to bring new products to the market quicker. In rapid prototyping systems, the parts are built on fixtures, which are created either during the CAD modelling stage or are generated by the rapid prototyping software during a pre-processing stage. The fixtures are physically removed from each part after that parts building stage is finished. The creation, selection and removal of fixtures also affect the quality and costs of the parts, which are built. According to Masood (2005), it has been stated that fused deposition modelling is a rapid prototyping technology by which physical objects are created directly from a CAD model using layer-by-layer deposition of extruded material. This technology offers the potential of producing parts accurately in a wide range of materials safely and quickly. In using this technology, designers are often confronted with a host of conflicting options such as desired accuracy, optimum building time and cost and fulfilment of the functionality requirements. In figure 3.7, Masood presents a methodology for resolving these problems through the development of an intelligent rapid prototyping system integrated with distributed blackboard technologies with different knowledge based systems and feature based design technologies.

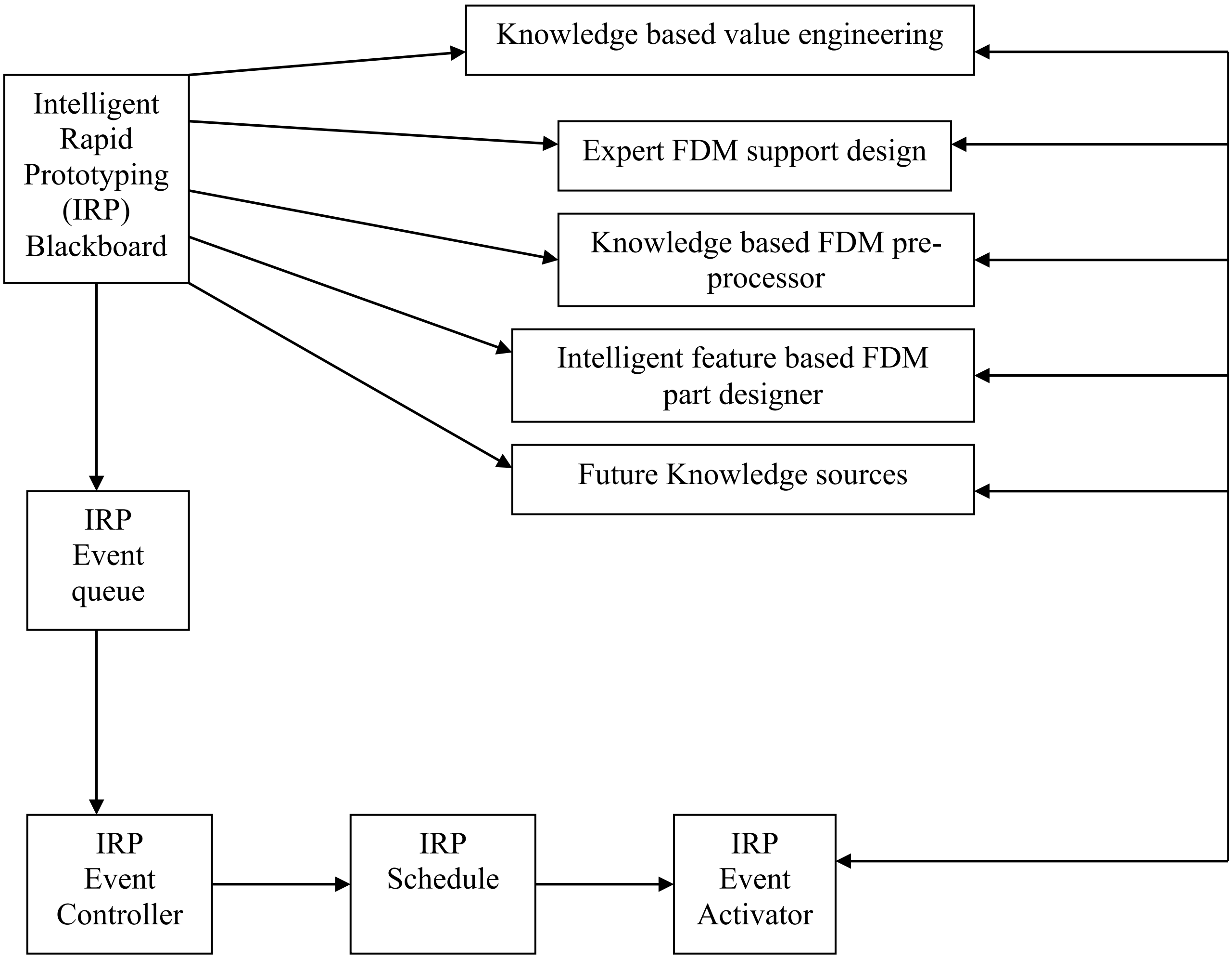

Figure 3.7 - Configuration of an Intelligent Rapid Prototyping System (Masood 2005)

The term rapid prototyping (RP) refers to a system, which can automatically construct physical models from Computer Aided Design (CAD) data. Three-dimensional printers allow designers to quickly create tangible prototypes of their designs, rather than just two-dimensional pictures. Such models have numerous uses. They make excellent visual aids for communicating ideas with co-workers and customers. In addition, prototypes can be used for design testing. For example, an aerospace engineer might mount a model aerofoil in a wind tunnel to measure lift and drag forces. Designers have always utilised prototypes; rapid prototyping allows them to be made faster and less expensively (Griffith and Lamancusa, 1998). In addition to the creations of prototypes, rapid prototyping techniques can also be used for tooling (referred to as rapid tooling) and even for the production of high quality parts (rapid manufacturing). For small production runs and complicated objects, rapid prototyping is often the best manufacturing process available. The term, "rapid" is relative. Most prototypes require between three hours and seventy-two hours to be built, depending on the size and complexity of the components. This may seem slow, but it is much faster than the weeks or months which are sometimes required to make a prototype by traditional machining processes. This dramatic time saving, allows manufacturers to bring products to the market faster and more cheaply. In 1998, Fine et al, achieved an order of magnitude cost in reduction and timesaving's between 70 and 90 percept by incorporating rapid prototyping into their investment casting process.

3.4.2 Rapid Prototyping Process

Lee and Weiss (1997) mentioned that at least six different rapid prototyping techniques are commercially available, each with unique strengths. Because rapid prototyping technologies are being increasingly used in non-prototyping applications, the techniques are often collectively referred to as solid free form fabrication and computer automated manufacturing, or layered manufacturing. The latter term is particularly descriptive of the manufacturing process used by all commercial techniques. A software package "slices" the CAD model into a number of thin (~0.1 mm) layers, which are then built up one on top another. Rapid prototyping is an additive process, combining layers of paper, wax, or plastic to create a solid object. In contrast, most machining processes such as milling, drilling and grinding, are "subtractive" processes that removes material from a solid block. The rapid prototyping additive nature allows the creation of objects with complicated internal features that cannot be manufactured by other means.

Machining is a subtractive process, beginning with a solid piece of stock material. A machinist must carefully remove material until the desired geometry is achieved. For parts with complex geometries, this is an exhaustive, time consuming and expensive process. Some parts are even too complex to be machined. Rapid Prototyping is a method in which the part is created by a layer-additive process (Wohler, 2002). Using specialised software, a 3D CAD model is cut into very thin layers or cross-sections. Then, depending on the specific method used, the RP machine constructs the part layer by layer until a solid replica of the CAD model is generated. Material selection is also method specific. Wohler (2002) stated that although several rapid prototyping techniques exist all involve a five-step process.

- Creation on of a CAD model of the design
- Conversion of the CAD model into STL format
- Slicing the STL file into thin cross-sectional layers
- Construction of the model layer by layer
- Cleaning and finishing the model

CAD Model Creation: First, the object to be built is modelled using a Computer-Aided Design (CAD) software package. Solid modellers, such as Pro/ENGINEER, tend to represent 3D objects more accurately than wire frame modellers such as AutoCAD, and will therefore yield better results. The designer can use a pre-existing CAD file or may wish to create one expressly for prototyping purposes. This process is identical for all of the rapid prototyping techniques.

Conversion to STL Format: The various CAD packages use a number of different algorithms to represent solid objects. To establish consistency, the STL (stereo lithography, the first RP technique) format has been adopted as the industry standard in rapid prototyping. The second step, therefore, is to convert the CAD file into STL format. This format represents a three-dimensional surface as an assembly of planar triangles, like the facets of a cut jewel. The file contains the coordinates of the vertices and the direction of the outward normal of each triangle. Because STL files use planar elements, they cannot represent curved surfaces exactly. Increasing the number of triangles improves the approximation, but at the cost of bigger files size. Large, complicated files require more time to pre-process and build, so the designer must balance accuracy with manageability to produce a useful STL file. Since the STL format is universal, this process is identical for all of the rapid prototyping build techniques.

Slice the STL File: In the third step, a pre-processing program prepares the STL file to be built. Several programs are available, and most allow the user to adjust the size, location and orientation of the model. Build orientation is important for several reasons. First, properties of rapid prototypes vary from one co-ordinate direction to another. For example, prototypes are usually weaker and less accurate in the Z (vertical) direction than in the X-Y plane. In addition, part orientation partially determines the amount of time required to build the model. Placing the shortest dimension in the Z direction reduces the number of layers, thereby shortening build time. The pre-processing software slices the STL model into a number of layers from 0.01 mm to 0.7 mm in thickness, depending on the build technique. The program may also generate an auxiliary structure to support the model during the build. Supports are useful for delicate features such as overhangs, internal cavities, and thin-walled sections.

Layer-by-Layer Construction: The fourth step is the actual construction of the part. Using one of several techniques (described in the next section) rapid prototyping machines build one layer at a time from polymers, paper, or powdered metal. Most machines are fairly autonomous, needing little human intervention.

Clean and Finish: The final step is post-processing stage. This stage involves removing the prototype from the machine and detaching any supports. Some photosensitive materials need to be fully cured before use. Prototypes may also require minor cleaning and surface treatment. Sanding, sealing, or painting the model will improve its appearance and durability.

3.4.3 The Rapid Prototyping (RP) in Automotive Industries

In the automotive industry the rapid prototyping approach is used when concept cars are developed for testing and demonstrating new concepts and technologies like steer by- wire or brake-by-wire with respect of tolerance of 0.02 millimetres. Rapid prototyping also allows the building of concept cars in an efficient and fast way and also supports a smooth transfer of the developed concepts into production. To make efficient use of the rapid prototyping design approach, when developing by-wire systems, a complete development environment is essential to allow rapid construction and modification of the by-wire prototype. This development environment needs to contain both software tools for supporting the software development in its different steps such as, design, implementation and testing. Because a failure of a "by-wire" function like steering or braking may be very hazardous, the design of the safety concept is a very important aspect in the development of a by-wire prototype. Therefore the development environment should support design of fault-tolerance strategies and the simulation of effects induced by faults. Nevertheless, rapid prototyping is a design approach to guide a product from concept to market quickly and inexpensively. For efficient rapid prototyping, the user needs to complete the tool chain as effectively as possible to simulate the system. The tools should also allow the customer to generate code out of this system model. Matlab and Simulink are well known and widely used products in this area. The time triggered protocol tool chain has an interface with Matlab and Simulink.

3.4.4 Modular Rapid Prototyping System for Rigid and Flexible Models

Rapid prototyping techniques are an important tool for fast and efficient new product development. Different rapid prototyping techniques are on the market, but the threshold to use it is still very high since high, quality technology is not available at a reasonable price. Also, the technique has not gained wide spread acceptance yet. Since, rapid prototype cannot be used in an office environment, special skills are required for the high end of rapid prototyping techniques. It has also been suggested that the availability of a flexible rapid prototyping technology, which is easy to use and gives high quality models for a low price with the possibility to have different types of materials would help it to breakthrough into the rapid prototyping market. Although many types of machines are available, object technology is best suited as a starting point for the development of such a technology. The technology demands very specific resins. The resin formulations have to comply with the proprietary ink jet technology that jets resin at high temperature. The final mechanical properties must be such that material is comparable with the properties of current engineering polymers. At the same time, the support material removal method should also develop by which the support can be removed easily so that the building of an RP model can take place in an office environment. The object technology in principle should be able to allow the use of more than one model material. To explore this possibility an experimental apparatus will be built with the possibility to print two model materials and a support material. This kind of technology is also a first step in the direction of rapid manufacturing technology. The potential applications of this technology will be investigated via case studies in the foundry applications, automotive, toy and shoe industries. Training programs will be prepared to allow the easy introduction of the technology in the shoe and toy industry.

3.5 Computer Integrated Manufacturing

Computer integrated manufacturing (CIM) is one of the most popular techniques used by many manufacturing companies to develop prototypes. The automation of the production activities to solve partial and specific problems, in a stand-alone way, creates automation islands, which leads to information redundancy and to a non-optimisation of resources. The solution to this problem requires integration of automation islands (Rembold et al., 1993). The computer integrated manufacturing (CIM) paradigm, popular in the eighties, consists of the integration of the enterprise activities, related with the production, through the use of information technologies, such as databases and networks, which allows the exchange and sharing of data (Rembold et al, 1993).

Initially, integration only dealt with the engineering and production activities. But to support all activities related with the production, the final step was to integrate enterprise systems with supplier and customer's systems. Rembold et al, (1993) stated the advantages of the CIM paradigm as following:

- **Increase of productivity**: the elimination of information redundancy leads to a better management and control of the resources, with improvements in productivity of between 40% and 70%.
- **Increase of flexibility**: due to information sharing, it is possible to decentralise control leading to a faster response to external and internal disturbances.
- **Increase of quality**: the integration of automatic systems allows a reduction in the number of failures due to the guarantee of no duplication of information. The integrated management allows the execution of quality control, retaining immediately the products with defects. With CIM systems it is possible to increase between 2 to 5 times the qualities.
- **Reduction of design time**: sharing the information between several teams responsible for the product design allows a reduction between 15% and 30% in the design time.
- **Reduction of the work in progress (WIP)**: an optimised management system using the information integration allows a reduction of between 30% and 60% of the work in progress.

The computer integrated manufacturing paradigm also aims to integrate several computer aided technologies that support production systems, such as Computer Aided Design (CAD), Computer Aided Engineering (CAE), Computer Aided Manufacturing (CAM) and Computer Aided Process Planning (CAPP). These CAD technologies use computational resources to aid the design activity, using specialised graphical systems, to create, update and document a design project in terms of engineering. The usage of CAD tools allows an increase of project design productivity, easy visualisation of the projects and their components (for example the project drawings), a reduction of the development time, an increase in the design quality, and a re-use of old developed projects. Using Computer Aided Engineering (CAE) technologies, such as Finite Elements Analysis (FEA) tools, the analysis and evaluation of the mathematic models created during the design, make possible to verify if the product withstands the mechanical and structural demand characteristics (Bengtsson, 1992).

The process planning acts as interface between the project and manufacturing phases, through the specification of manufacturing process details. The CAPP technologies support the definition of the sequence of operations (e.g. processing, assembly and inspection), necessary to produce the product. The main steps in the elaboration of the process plan are: raw material selection, determination of the operations sequence, selection of the type of machines that will execute the operations, selection of tools, fixtures and inspection equipment, determination of machining parameters (such as cutting speed, feed rate and cutting depth), and determination of manufacturing times (setup times, processing times, manufacturing time).

The manual elaboration of machining programs is a very time consuming task and is susceptible to human error. The Computer Aided Manufacturing (CAM) technologies allow the automatic generation of machining programs, using a post-processor previously configured for each machine. The use of these tools allows the faster development of machining programs and the reduction of design errors. The concurrent engineering concept aims to reduce the time to produce a product respecting the quality and due date specifications. This concept requires a parallel and cooperative approach to the design of the product and processes. It uses computer-aided tools, counter to traditional design practices, which are sequential (Rembold et al, 1993). Concurrent engineering presents several benefits, an important benefit being the reduction of the manufacturing costs and lead times that can reach 50%. As an example, Rolls Royce used concurrent engineering to reduce the time to develop its engines by 30% and reduced the weight in some instances by 25%. The CIM paradigm is not the sum of these components but the integration of them into an operating system that satisfies the enterprise business strategies and objectives. In spite of its objectives and described advantages, the implementation of the CIM concept has not achieved good results, due mainly to the technological, heterogeneity, social and economic problems (Rembold et al, 1993).

The technological problems are related to the complexity of automation and integration of some processes. The heterogeneous problems are due to the proprietary protocols from supplier equipment and technology, making the integration of different systems more complex. The implementation of the CIM concept is very expensive bringing its own economic problems (Rembold et al, 1993). The social problems appear because the introduction of automation causes or seems to cause an increase in unemployment, but generates new jobs that cannot necessarily be taken by workers who have just been made redundant. Additionally, due to the CIM centralised approach it is difficult to expand and reconfigure a process for new products (Rembold et al, 1993).

3.6 Collaboration

Collaboration is a structured recursive process where two or more people work together toward a common goal. It is typically an intellectual endeavour that is creative in nature by sharing knowledge, learning and building consensus. Collaboration does not require leadership and can even bring better results through decentralisation and egalitarianism. In particular, teams that work collaboratively can obtain greater resources, recognition and reward when facing competition for finite resources. Structured methods of collaboration encourage introspection of behaviour and communication. These methods specifically aim to increase the success of teams as they engage in collaborative problem solving.

3.6.1 Collaborative Planning

Collaborative planning spans multiple planning domains. The background idea is to directly connect planning processes that are local to their planning domain in order to exchange the relevant data between the planning domains to improve the local plans (Fleischmann et al, 2002) and the collaboration in the planning process occurs both within and between organisations. Manufacturing companies, which develop new production planners, collaborate with staff and sales planners about capacities, workloads and demand. Within some organisations, a final form of congruent goal orientation exists, whereas in a collaborative planning situation, spanning multiple different organisations, such common focus is often absent. The 'content' of a collaborative planning process can be viewed as a set of group and individual tasks. The goal of groups' tasks is to achieve the group goals through collaboration, whereas an individual's tasks, derived from both the group and the individual's goals, are undertaken from the planner's own domain (Fleischmann et al, 2002).

Several authors emphasize the necessity of common goals, clear performance metrics, and a culture that stimulates collaboration. Fleischmann et al (2002) stated that collaborative planning requires a collaborative relationship with the intent of establishing a mid-term relationship to enable planning activities and the exchange of expertise based on partner information to create additional value. Barratt (2004a) lists a number of critical aspects for collaboration in a supply chain, dividing them in three groups: cultural and strategic elements and aspects of the collaboration itself. A collaborative culture of external and internal trust must exist, mutuality, information exchange, openness and communication. Mutuality is the sharing of profits and risks of collaborative work. Strategic elements include resources, commitment, and a corporate focus on the collaboration, intra-organisational support and supporting technology. Finally, regarding the collaboration itself the management of change is emphasised. Thus, this collaboration means flexibility, alignment of activities and processes, joint decision-making and the sharing of performance metrics. Barratt (2004b) presents the results of a case study revealing a significant number of enablers and inhibitors relating to collaborative planning. The enablers and inhibitors are classified into the level of occurrence: strategic, tactical or operational. All aspects, except for the strategic board-to-board dialogue, are relevant for operational planning. This suggests that operational planning processes is, but also can be influenced in many ways.

A well known framework for collaborative planning has been developed during the 1980s and 1990s in the US retail industry and is called collaborative planning, forecasting and replenishment (CPFR). Collaborative planning, forecasting and replenishment are business practices that combine the intelligence of multiple trading partners in the planning and fulfilment of customer demands (Voss, 2002). The collaborative planning, forecasting and replenishment framework includes activities on the strategic level, tactical level demand, as well as order and shipment requirements over the planning horizon and operational level or order plans. It also includes the operational control of the production and distribution of products and the monitoring of planning and execution activities. The framework is explicitly focused on and mainly implemented in the automotive industry. Another limitation of the framework is its tacit premise of strong alignment and integration of business processes. Moyaux (2007) uses one definition for both collaborative planning, forecasting and replenishment and collaborative relationships: ‘collaboration where two or more parties in the supply chain jointly plan a number of promotional activities and work out synchronised forecasts, on the basis of which the production and replenishment processes are determined’. Various forms of collaboration planning, try to explain these frameworks with the help of different theoretical perspectives. The distinction between the different forms lies in the scope and depth that can be defined in a number of dimensions:

- Amount of shared information (only sales orders, or also production and promotion data)
- Degree of discussion (from no discussion to frequently discussion)
- Goal of the collaboration (cost reduction, improved client service or joint product development)

- Level of coordination and synchronization
- Presence of evaluation, feedback and competence management.

This results in three collaborative planning, forecasting and replenishment forms ranging from low to high scope and depth of collaboration: basic, developed and advanced collaborative planning, forecasting and replenishment with three types of relationship: transactional, information sharing and mutual learning. Different theoretical perspectives like the transaction cost economics (little collaboration, a few common goals, partners in collaboration focused on own profits) and a strategic relationship management or network approach (coordination of all almost all business processes, common goals, focus on collaborative performance) are advised to be used to better understand collaborative planning (Moyaux, 2007).

3.6.2 Collaborative Planning Process Framework

To develop the framework, a requirement for collaborative work between human planners in a supply chain-planning situation must be in presenting a preliminary framework for collaborative planning process analysis (Barratt 2004b). The framework consists of six steps, indicating the research activities that have to be explored. The framework aims at supporting the search for guidelines and general rules to organise and structure collaborative planning processes at the operational level (Barratt, 2004a). It complements other diagnoses and implementation tools like CPFR that are more oriented on the tactical and strategic levels of planning and collaboration. Barratt 2004b. stated that collaborative planning process could be concentrated through operational gaming. An instance of a process, i.e., one case, is analysed, modelled and simulated (steps 1, 2 and 3 respectively). These steps have to be repeated for each different business situation (indicated with the layered boxes). The research starts with an exhaustive analysis of the tasks and activities the planners currently execute. Obviously, both sides of the relationship should be taken into account; all planning activities performed by the collaborating entities have to be modelled. The division of tasks over different personnel in the organisation is important, as is the division of roles: which actor plays which role. Roles indicate what type of performance a certain engineer is able to perform. Special attention has to be paid to the collaborative tasks, because they have a need for communication, collaboration and negotiation. Next to the activities, the aspects mentioned in the middle of the framework should be captured in the models. Based on the models a simple version of an agent-based simulation can be developed. Very simple, 'silly' software agents can be programmed to interact. However, their exact activities should be programmed after observation of the planners' behaviour during the operational gaming sessions. Therefore, steps three and step four are closely related and the simulation is built and used simultaneously. The fourth step includes the simulation of different collaboration strategies. The best outcome after a comparison of the simulation results can be implemented (step 5) in the business environment (possibly, including the implementation of an agent-based support system as discussed in the previous section). Each of the steps in the framework contributes to the analysis and better understanding of collaborative work in operational planning processes. Theoretical development about collaborative strategies for operational planning will result from a deeper analysis of several case implementations. In other words, several rounds of the steps 1 through 5 have to be carried out, after which general conclusions and guidelines can be formulated (step 6). Clearly, the framework needs further refinement. Variables that can be manipulated during the simulation runs should be made more explicit. Nevertheless, the framework gives a first impression of a method for collaborative planning process analysis for supply chain improvement.

3.6.3. Design Roadmap

Park and Cutkosky (1999) developed Design Roadmap (DR). The original purpose was to seek a method to overcome the limitations of process representations discussed above. Park and Cutkosky developed this technique to provide a comprehensive method for project management. The basic elements of a DR model are Tasks and Features. Tasks are the primary elements of the process model. Features are the input and output of Tasks. Thus every Task has a Feature as its input, and another Feature as its output. The arrowed lines are used to represent the process flow and links between the Tasks and Features.

A DR model also has complex dependencies. In these dependences, the feedback dependency is most often used. The feedback loop is needed in the design process. For example, when the engineering requirements need to be integrated with customer requirements, the engineers will need to discuss with the sales and marketing people to see whether customer requirements can be modified. A feedback loop is needed between the output of the engineering requirements and the customer requirements.

Figure 3.8 shows a simple DR model. Feature A is the input of Task 1, and Feature B is the output of Task1. Similarly, Feature B and C are the input and output of Task 2 respectively.

There is a feedback loop between Feature C and Task 1, i.e., the result of Task 2 (Feature C) is considered by Task 1, which may result in changes in Feature B. The DR model enables sub-systems (i.e., sub-models) to be contained in Tasks and Features.

DR models can deal with both simple processes and complex processes. The syntax of DR is easy to understand and build. DR is particular appropriate for manufacturing projects, because it is good at representing sequences and feedback loops. DR normally does not require a particular system programme to produce it, and Microsoft Excel can produce a perfect DR model. However, DR is a not yet a commonly used method such as Integrated Computer Aided Manufacturing (ICAM) Definition (IDEF) which is regarded as an international standard.

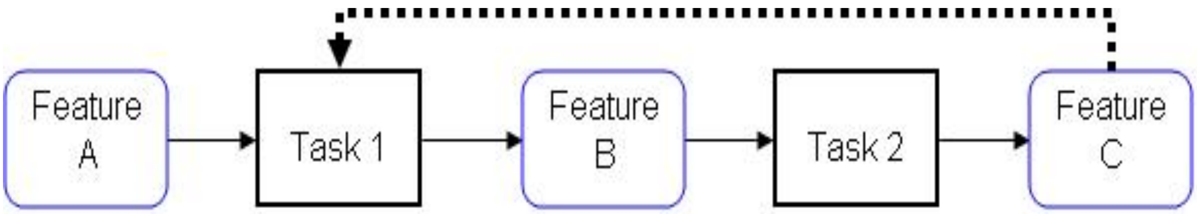

Figure 3.8 – An Example Design Roadmap Model (Park and Cutkosky (1999)

3.7 Supply Chain

In recent years, manufacturing firms have realised that a new, higher level of global competition forces them to compete simultaneously on multiple manufacturing fronts, such as quality, delivery, cost, and flexibility. In response to this realisation, there has been considerable research focusing on the relationship of manufacturing improvement programs to manufacturing goals (Ngai, 2004). Currently, there is a dramatic increase in international manufacturing competition, driving organisations to re-evaluate their operations. With the increase in global competition, there is a commitment to design, build, and operate manufacturing facilities at higher levels of efficiency, with higher quality, more reliable delivery, and a wider variety of products to retain a competitive advantage. The author also believes that there are important clues indicating how manufacturing programs affect the control of manufacturing systems for achieving their manufacturing goals. These clues are described as three sources: firstly, theoretical analysis, secondly, empirical analysis, and finally, pragmatic analysis. One recurring factor is manufacturing lead time (throughput time) and its relationship with the manufacturing goals of productivity and quality. Many firms focus their manufacturing system by removing products with long setup times and putting them in another facility or location (Ngai, 2004). The removal of these high setup time products means there are two systems in play: one focused on making products that are cost competitive, and one focused on all the remaining products. Since the first system is focused on reducing setup times, the products made in the cost-focused facility have lower setup time variance than the original system. Because of the lower setup time variance, these products are more cost competitive than before the system was focused. The remaining set of products has longer setup time variances than the first focused system (Gunasekaran and Ngai, 2005). Adding value to goods and services as they move through the supply chain requires the effective transfer of information among both suppliers and customers. Without such information sharing, supply chain management efforts employed to improve time to market, lower costs, effectively manage existing resources and accurately forecast future demand will be erratic (Corbett et al, 1999). A supply chain perspective entails looking at the supply chain partners. Here it is important to have a trusting relationship between the parties, where each party has mutual confidence in the other members' capabilities and actions (Handfield, Nichols, 1999). Also close collaboration among supply chain partners can be to align the partners depending upon the organisations prospective role in the supply chain. Collaborating with suppliers, manufacturers will derive benefits in such key activities as new product development, order fulfilment, and capacity planning (Harland, 1996). Collaborative product development enabled by sharing and modifying design documents will help manufacturers to develop products better and faster. Similarly, co-ordinating all tier supplier production schedules will help ensures that future new product developments are satisfied (Fall et al, 2001).

3.7.1 Supply Chain Management

Attributed to Moyaux (2007), the Supply Chain Management (SCM) term has been used with several different meanings since its introduction in the early eighties from clear cut definitions based on the idea of system level optimisation (Sepehri, 2006), to broader definitions that use the terms of Supply Chain Management and Value Chain Management interchangeably (Moyaux, 2007). Moyaux (2007) stated that supply chain management (SCM) is the oversight of materials, information and finances as they move in a process from supplier to manufacturer to wholesaler to retailer to consumer. Supply Chain Management involves coordinating and integrating these flows both within and among companies. It is said that the ultimate goal of any effective Supply Chain (SC) system is to reduce inventory with the assumption that products are available when needed. Moyaux (2007) also suggests that there is not a single supply chain, but three essentially different supply chains interleaved, namely product and service fulfilment, product development and capability development. From this standpoint, an open question is how these three chains interleave and how the different chains interface, and how they match their different relative speeds. From the perspective of the corporate architect, one would be interested in knowing whether is it possible to handle classic concerns of one supply chain such as demand volatility in the product fulfilment supply chain by strategic redesign of the other supply chains such as altering the pace of the product development chain.

The understanding of current supply chain management challenges firstly requires an understanding of how the practice of supply chain management has evolved historically. The concerns of the past, the methods used to address them, and how both concerns and methods have changed with time. These changes can be observed just by studying the evolution of supply chain management related professional organisations. Supply chain is the process of planning, implementing and controlling the efficient, cost effective flow and storage of raw materials, in process inventory, finished products, and related information from point of origin to point of consumption for the purpose of conforming to customer requirements (Council of Supply Chain Management Professionals 2005).

The Council of Supply Chain Management Professionals (CSCMP) stated that supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion and all logistics management activities. Importantly, it also includes coordination and collaboration with partners, which can be suppliers, intermediaries, third party service providers and customers. In essence, supply chain management integrates supply and demand management within and across companies. The Council of Supply Chain Management Professionals (CSCMP) also stated that, supply chain management is an integration function with primary responsibility for linking major business functions and business processes within and across companies into a cohesive and high performing business model. This includes all of the logistics management activities, as well as the manufacturing operations marketing, sales, product design, finance and information technology.

From this, it is possible to see that two definitions of supply chain management by the Council of Supply Chain Management Professionals (CSCMP) are substantially different. The first one is very specific and places special emphasis in cost and efficiency. It shows that supply chain management is no longer just about the physical flow and transformation of raw materials into finished products, but also about market mediation, supply and demand. It also conveys the idea that supply chain management is not only the physical flows of products and materials but could also be applied to information flows. In contrast, the second definition is less precise and opens supply chain management to a wider range of possibilities. It no longer talks about cost and efficiency, but about a high performing business model. The main concern now is about collaboration and co-ordination inside the industry and among multiple players in the chain, whereas the first definition implicitly focuses on a single industry. It is longer and less rounded, probably an indication that the definition still evolving.

3.7.2 Information System in Supply Chain Management

One of the main aspects in supply chain management is the information system (IS), which is designed to support activities, and processes that are necessary to carry out the management of supply chain (SC) system. In supply chain management (SCM), the information system design is viewed as the development of information models to facilitate and process problem solving, to eliminate or alleviate the bullwhip effect. Supply chain management information system requirements can be formulated as the necessity of knowledge modules that carry information about problems. Problem taxonomy (PT) aims to serve as the methodology for creating, accessing, and utilizing problem specific knowledge. Problem taxonomy is a synergy of two initiatives: system taxonomy and ontology driven knowledge design.

3.7.3 The Bullwhip Effect Analysis in Supply Chain Information

A supply chain's management information system needs can be analysed based on what problems are going to be solved. When the problems are identified, required information can be defined to facilitate problem solving. Many supply chain related problems can be attributed to the lack of information sharing between supply chain members. One important observation in supply chain management, prominently known as the bullwhip effect, suggests that demand variability is magnified, the further upstream in the supply chain. It is the bullwhip effect that is an important concern in supply chain management for a few reasons. First of all, the increased order variability requires each supply chain member to hold excessively high inventory levels in order to meet a fluctuating demand pattern. Secondly, despite the overall overstocking throughout the supply chain, the lack of synchronisation between supply and demand could lead to complete stock out at certain times. Finally, the bullwhip effect increases not only the physical inventories but also the operating costs. Lack of information or distorted information in supply chain may lead to inefficiencies, excessive inventory investment, poor customer service, lost revenues; misguided capacity plans, inactive transportation, and missed production schedules. The phenomenon of information distortion in supply chain results in the bullwhip effect, and is one of the fundamental problems. To solve the bullwhip effect problem, supply chain management decision-making tools need to be designed to investigate its possible causes and effects and utilise methods for reducing its impact.

Problem identification that contributes to supply chain bullwhip effect highlights various information sharing strategies that can be applied for providing integration along the supply chain. Li et al (2001) have specified four types of strategies as: order information sharing, demand information sharing, inventory information sharing, and shipment information sharing. In order information sharing, each stage of the supply chain does not know the status of its downstream stages and forecasts are based only on the orders from its immediate downstream stage. Demand information sharing assumes total real demand visibility. Real time demand information is transmitted from the end consumer back through every stage in the supply chain. This means that any real change in demand can be known at all points in the supply chain. Direct sales model, sharing of point of sale (POS) data, and collaborative planning and optimisation belong to this type of information sharing. In inventory information sharing, each stage contracts to share its information with only the next supplier up the chain, thus representing a compromise between the two extremes. Here, each stage of the supply chain shares information about its inventory and actual demand with its supplier. This strategy is currently common in the grocery and fashion retailing industry. Vendor managed inventory (VMI), schedule-sharing window, and continuous replenishment belong to this type of information sharing. Shipment information sharing assumes that each stage knows its downstream customer’s shipment data (Li et al, 2001).

3.7.4 Ontology Based Problem Solving in Supply Chain Management

According to the Chandra (2004), ontology consists of three parts, characteristics, and rules describing relationships among those characteristics and their constraints, and algorithms for solving the problem for which the ontology is designed. Supply chain information system requirements analysis is nothing more, but the identification of these three components for each problem. Analysing the problem oriented nature of activities and processes in supply chain and information system requirements can be formulated as necessity of knowledge modules that carry information about problems. Problem taxonomy (PT) aims to serve as the methodology for systematic representation of problems and tasks by applying classification taxonomic schemes, and formulation of problem specific knowledge in the form of objects. Knowledge objects delivered to decision-making tools can be used directly by software applications. These objects encapsulate knowledge about a particular problem. Evaluating each problem in isolation of other issues, may lead to the wrong solution.

However, SC domain is represented as system taxonomy, which defines the structure and vocabulary of system characteristics. Variables taxonomy carries information about each variable used in decision modelling environment (DME). These are input, output, factors, and constraints for the decision model related to a domain problem. Problem classification is the hierarchy of SC problems. Problem methodology classification is the taxonomy of problem-solving policies. Various policies can be applied for solving each problem. By implementing these policies, methodologies define the algorithm according to which the problem can be handled and solved. Problem model development is information modelling, which is concerned with ontology development.

3.7.5 Supply Chain Management and Multivalent Systems

The term collaboration is confusing because it has taken on several interpretations when used in the context of supply chain management (Moyaux 2007). For example, various levels of collaborative techniques based on information sharing were set up in real supply chains. In this section three different types of collaboration planning in supply chains are discussed. Firstly there is information centralisation. This is the most basic technique of information sharing in which retailers broadcast the market consumption to the rest of the supply chain. To refer to information centralisation, it is necessary to clarify information sharing in multi-casting, which is the real-time and instant sharing of demand information between companies, tenuously of the market consumption information. Moreover, several kinds of information may be shared, such as available production capacity, inventory level, and from this viewpoint, information sharing includes information centralisation. Secondly, there is Vendor Managed Inventory (VMI) and Continuous Replenishment Program (CRP) (Moyaux 2007).

These two collaborative techniques are very similar, but are used in different industries. The idea is that retailers do not need to place orders because wholesalers use information centralisation to decide when to replenish them. Although these techniques could be extended to a whole supply chain, current implementations only work between two business partners. In fact, many customers are attracted to these techniques, because they mitigate the uncertainty of demand, a consequence of the bullwhip effect. Thirdly, there is Collaborative Planning Forecasting and Replenishment (CPFR): This technique was developed by the Industry Commerce Standards association which enhances vendor-managed inventory and collaborative planning forecasting and replenishment by incorporating joint forecasting. Like vendor managed inventory and collaborative planning forecasting and replenishment, current implementations of collaborative planning forecasting and replenishment only includes two levels of a supply chain, i.e., retailers and their wholesalers. With collaborative planning forecasting and replenishment, companies electronically exchange a series of written comments and supporting data, which include past sales trends, scheduled promotions, and forecasts. Conversely to the previous two techniques, collaborative planning forecasting and replenishment shares more information than only the demand information. This allows the participants to coordinate joint forecasts by focussing on differences in forecasts.

3.8 Summary

This Chapter reviewed previous work undertaken in the field of knowledge management, new product development, knowledge sharing, rapid prototyping, prototype collaboration and supply chain and collaboration in supply chain has been reviewed.

During the literature survey, it has been identified that there is a lack of understanding in the current industrial practice in the proposed research area. There are various technologies being used in current industries, which manage knowledge transfer to support the rapid prototype development in collaboration environment. However, from the literature surveyed, there is still scope for further improving collaboration in the automotive supply chain through knowledge sharing, especially in developing countries. In the knowledge sharing aspect between business partners, there are some commercially available tools and ICT systems, but these are not sufficient to support all knowledge and key decision making in real life product development, especially in the context that this research is concerned. Also, the literature does not present how knowledge can be shared between automotive and glass suppliers and what methodology does automotive requires supporting and developing the rapid prototyping in respect of quickest production lead time and at least production cost.

Chapter 4

Industrial Investigation

Behind any successful manufacturing company, there is support from research and development. It is the support and knowledge, which allow them to improve the manufacturing collaboration and bring products to the highest level in the marketplace with lower costs and better quality. The main aim of collaboration between the automotive and glass industries is to collate information and knowledge in production with the latest technology, which would evaluate and verify the outcome of research in these industries. In an age when consumers demand high quality, low prices and bespoke products, the competition among firms has ceased to be strictly a price competition but is now a competition in product variety and speed to market (Irani et al, 1999). The current philosophy is to replace old products constantly with either an improved product development or a new variation of the product. Differentiation in product variety, i.e. customisation, assumes ever-increasing importance as a production instrument. The duration of a product's life depends on its acceptance by the consumers; a "failed" product could be out of the market in a matter of months. A short product development cycle is crucial to the survival of the company as it enables the company to deliver new products to the market quickly. On the other hand, pursuing variety and quick response would not compromise the economy of scale, an advantage characterised by mass production. The balance between the economy of scale and scope is often difficult as manufacturers pursue a "dynamic stability" (Irani et al, 1999). This Chapter describes the industrial investigation carried out to capture knowledge and data of the collaboration procedures and also to understanding the method and processes in the collaboration strategy.

4.1 The Planning of the Industrial Investigation

Industrial investigation is very important and becomes a necessary part in every manufacturing related research. Usually, the main aim of industrial investigation is collecting data from companies, and then verifying and evaluating the developed methodology, theory or technologies with real industrial examples. Before planning the industrial investigation, the researcher studied various methods used in industrial investigation from books such as Robson (2006), PhD theses such as Bradfield (2007) and the lecture notes of the Research Methodology course taught by Professor Gao (2008). The investigation is then planned as several stages in an iterative approach, taking advice from the project supervisors, and in consultation with other researchers in the Centre for Innovative Product Development of School of Engineering, University of Greenwich, where the researcher is based.

The initial stage is primarily a learning exercise, i.e., as a new PhD student, the researcher will visit the company for a certain of times to observe the business processes and discuss with various managers, engineers and support people to get an understanding of the real life situation and their requirements for intended research project. The focus is on the top management and the design, manufacturing and sales and marketing departments. General information about the company, main problems and requirements will be discussed informally.

The selected methodology in industrial investigation focussed on whole product development activities. The organisational structure (as shown in Figure 4.1) represents an affiliation with a parent and child relationship like a family tree with three “generations” (levels). The first level is the enterprise level, i.e., the product development enterprise. The second level is the department level that includes five departments involved in different stages of the product development process. The first department is the Strategic Development Department that mainly analyses the product perspective and gathers the knowledge needed for product development. It consists of three groups: the Strategy Planning Group, the Product Analysis Group and the Product Knowledge Management Group. The second department is the Product Management Department, which carries out product planning. It has two groups: the Product Concept Development Group and the Product Planning Group. The third department is the Product Design Department, which carries out the main design tasks. It has two groups: the Main Design Group and the Design Support Group. The Main Design Group is responsible for car body framework design and engine design.

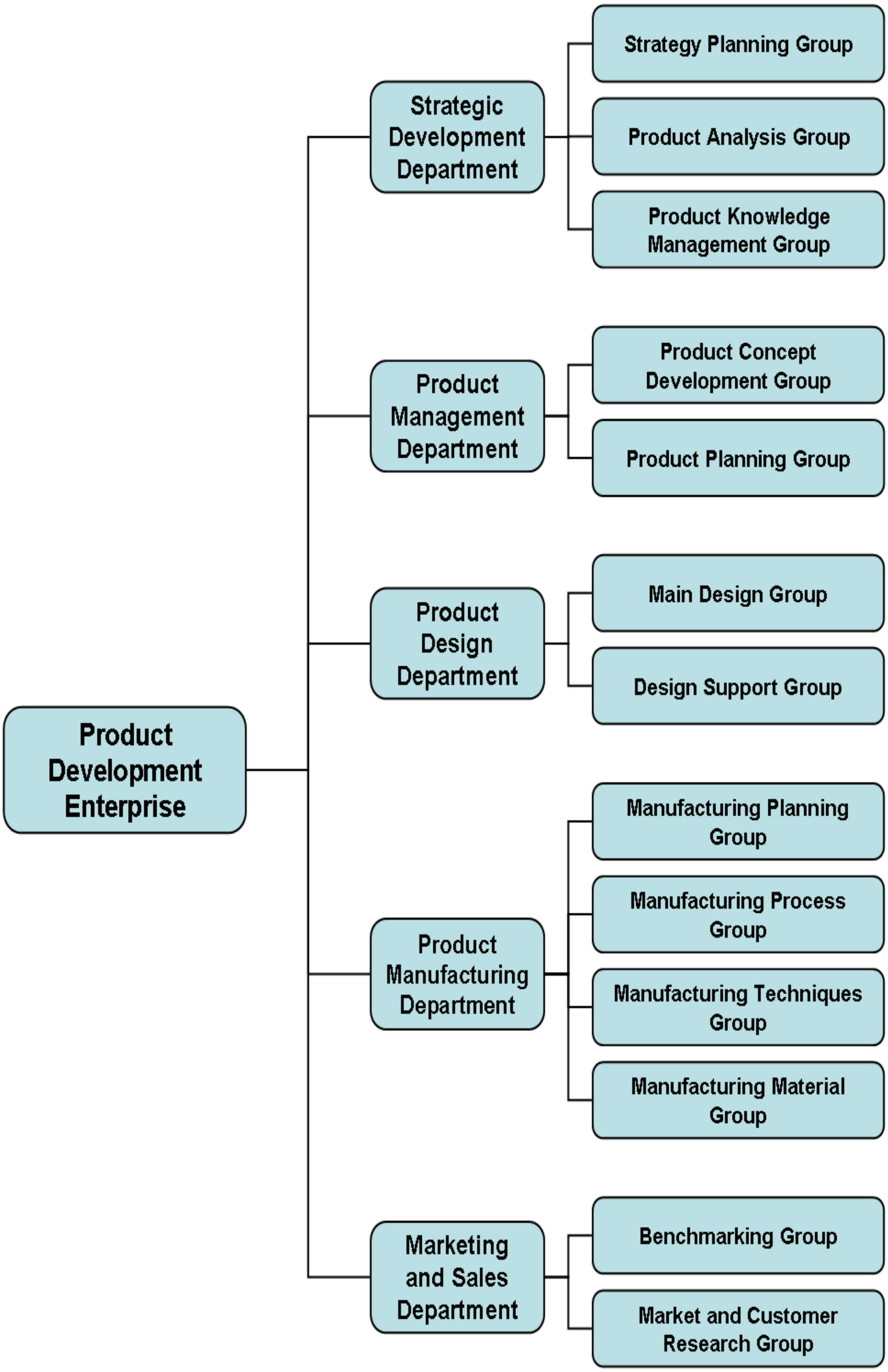

Figure 4.1 – Organisation Structure of the Automotive Company

The Design Support Group communicates with others departments and groups to find the correct resource to support the Main Design Group. The fourth department is the Product Manufacturing Department, which manages the whole manufacturing processes. This department carries out product manufacturing, planning, testing, refinement and production ramp-up. It consists of four groups: the Manufacturing Planning Group, the Manufacturing Process Group, the Manufacturing Techniques Group and the Manufacturing Material Group. The fifth department is the Marketing and Sales Department. Its main function is to gather feedback from existing customers, investigate the potential market information, and benchmark the product with main competitors. It has two groups: the Benchmarking Group, and the Market and Customer Research Group.

After the initial stage, the researcher checks with the literature survey results and revise the gaps and objectives initially defined, and then designs questionnaires for the formal data collection in the next stage of the industrial investigation. The general manager or Chief Executive Officer (CEO) and key members of his/her office will be interviewed, in order to capture the information about the overall company. Then the heads of the design department, manufacturing department and the sales/marketing department and their key members will be interviewed respectively. Face-to-face semi-structured interviewing approach will be taken based on pre-prepared questionnaires. Details of the questionnaires are discussed in the following section.

After the formal data collection stage, the answers and data obtained will be analysed, and then the aims and objectives of the research objectives will be further revised and/or confirmed. The feasibility of the proposed methodology will be tested using the information collected. Then a pilot prototype system will be planned and the examples to be used will be decided.

The next stage of the industrial investigation is to capture the information about the specific examples to be used for the implementation of the pilot prototype system based on the proposed methodology. Some information may have already been captured in the previous stages.

This stage of data collection is less formal, i.e., the researcher goes directly to the relevant people to get the detailed information about the specific examples selected for implementation. From the research methodology point of view, the approach used in this stage is 'un-structured interviews' with pre-prepared questionnaires as reference during the interview. Several visits may be needed in this stage of investigation depending upon the need for the data in the implementation of the methodology.

After the pilot prototype system is developed and tested at the University, the researcher will go to the company to demonstrate the prototype system with the selected examples. Opinions and suggestions of the managers and engineers will be collected and the prototype system will be further improved to address their opinions and suggestions. The company in terms of technological advances, usefulness, and potential benefits to industry will then evaluate the improved system. Further work and/or commercial applications will be recommended.

4.3 Overview of Knowledge Sharing Problem Between the Glass Supplier and Automotive Customer

Automotive companies face a variety of challenges from the rapid introduction of new products and technologies to lean manufacturing, globalisation and regulatory compliance. The automotive industry is driven by the adoption of fundamental business processes and knowledge management that enable real time and global collaboration. Implementing such solutions may result in system wide cost reductions of up to 20 % as the industry adopts a new business collaboration model. This was a statement by Dr. Mohammadi, General Manager of IRANKHODRO DIESEL (IKD), in Iran (www.ikd-co.com). In fact, the new business collaboration methodology to industries should bring the better collaboration in new product development with reduction of the production costs, lead time and importantly, improving the marketplace for products. The research investigation will focus on current collaboration between glass manufacturing company (CARGLASS) and an automotive company. IranKhodro, Sipa, MAN and Volvo. The typical products developed by CarGlass and automotive companies are illustrated in Figure 4.2

The automotive industry may be ahead of other industries in both the conversion of knowledge management and knowledge sharing to develop new products, but it is the way that data is managed within the companies and across the vast supply chains that is important. This is an industry where change is constant, as competitors vie for global markets against intense competition. Without high levels of collaborative product design and manufacturing, companies have less chance to succeed. This research study requires the development of a knowledge framework and a new methodology of collaboration, which would enable an industry to develop a flexibility of the new product development in the near term of future. This project started with an in-depth investigation into the specific problems in the collaboration between the sponsoring company, i.e., CarGlass (supplier) and its main automotive customer.

Figure 4.2 - Products Developed by the Collaborative Companies

4.4 The Designing of the Questionnaires

The design of the questionnaires for the formal data collection are based on the literature survey carried out, proposed project areas, aims and objectives, keeping in mind that the 'semi-structured' approach will be taken for the face-to-face interviews with managers and engineers in the collaborating company. Methods and good practices recommended in references (Gao 2008 and Robson 2006), and example questionnaires in reference (Bradfield 2007) are considered during the design of the questionnaires and have been approved by research project supervisor. The following sub-sections present the actual questionnaires including the information that may be used for the initial feasibility test of the proposed methodology.

The questionnaires used for the informal data collection for the specific examples used for the pilot prototype system implementation will not be presented here. Because the questionnaires are only used as reference during the 'un-structured' interviews and the data to be collected are mainly details such as drawings, parameters, materials with properties and costs. The following are the questions and information collected towards each question.

The interview questions were developed in an open-ended format in order to elicit the kind of information required by the researcher. The interview questions consist of seven parts: a) General information about the participant role and relationship feedback process. b) Feedback process operation c) Knowledge sharing technique d) Rapid prototype in new product development e) Collaborating process feedback f) Design and development process g) Marketing and customer requirements. The interview questions were designed for both automotive and collaborative industries (CarGlass Company sponsor) for all department and production managers. However, feedback from the piloted questions was used to modify the interview questions. A final version of the interview questions were accompanied by a covering letter, which is available in appendix A, was sent to each research participant in advance of the face-to-face interview. The covering letter explained the purpose of the interview, provided the interview questions, what the researcher aimed to achieve from it, assured confidentiality and anonymity, stated the amount of time required for the meeting and encouraged the participant to bring any supporting company documents or other artefacts to aid their responses during the interview process. In conducting this research investigation, data triangulation and investigator triangulation strategies have been exploited to address bias in the data collection and interpretation.

4.4.1 Interview Participant Selection

The research presented findings from the literature with the automotive and glass industrial managers and discussed plans for the interviews to be conducted. Together with managers the researcher created criteria for participant in the interview that is:

- Participant must be from the knowledge sharing process, methods of product development and design function, customer relation and place of rapid prototyping in NPD.

- Must be actively involved in the feedback process either as a contributor to the process or the user of the information produced by the process.

- Participant must have some understanding of the knowledge sharing process.

- Able to communicate reasonably both verbally and orally in English as most of the participants are based in the company headquarter in Iran where the official language within the company is Persian.

Once these criteria were set the industrial managers helped the researcher in selecting appropriate interviewees that meets all the set requirements. Figure 4.3, illustrate shows a list of job roles of the interviewees.

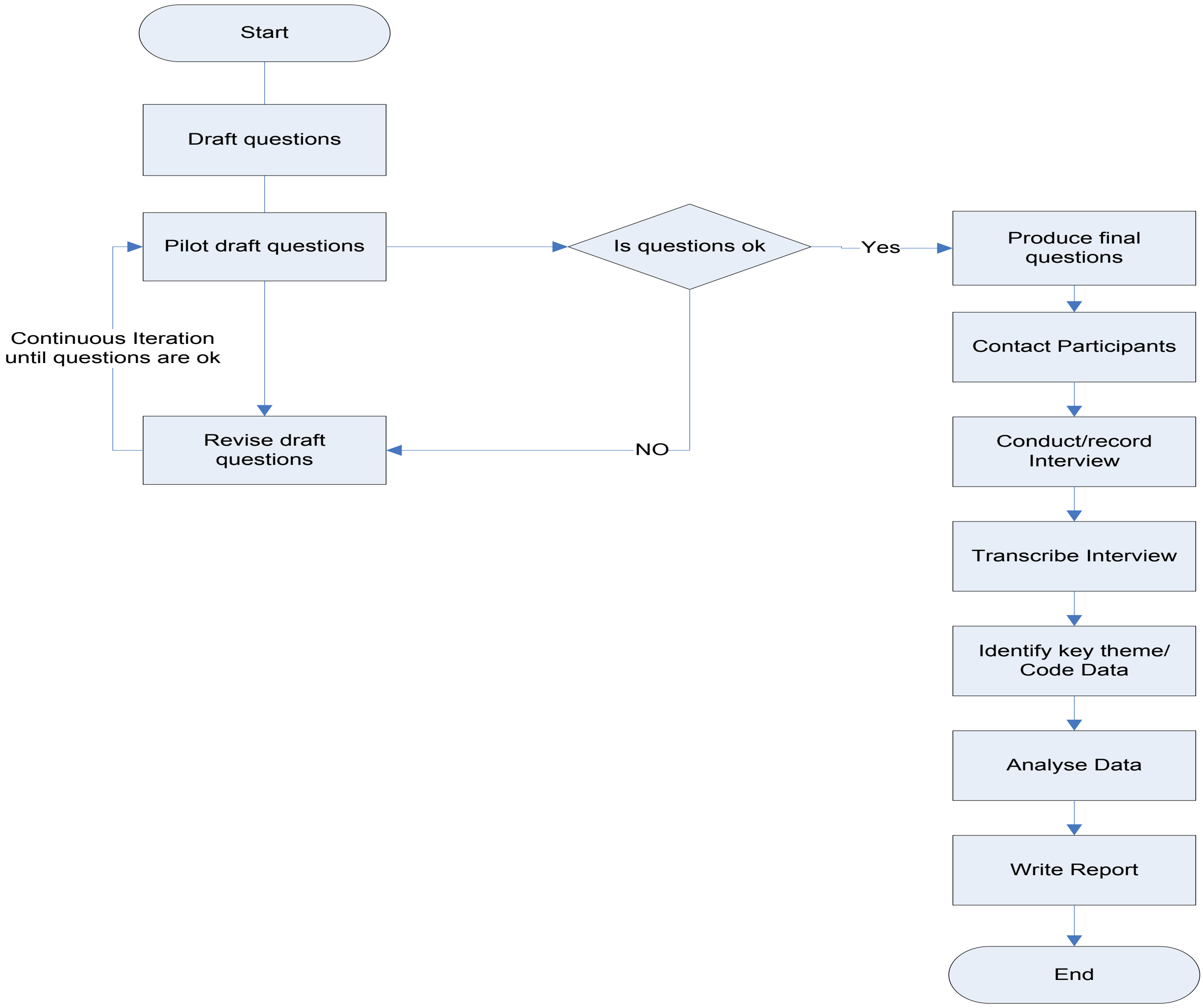

Figure 4.3 - Research Interview Survey Approach

4.4.2 Interview Implementation

The interview process began with a brief introduction, whereby the interviewer introduced and the purpose of the interview, assured confidentiality, asked for permission to audio tape record and make detailed notes. The interview commenced and the participants were asked to describe their role within the company; this was to establish a good rapport at the outset of the interview. A face-to-face interview was conducted as this provided a higher richness of communication than telephone interview (Gillham, 2001a) however, face to face interview can be very expensive, as it required a lot of travelling to a clients' site.

A semi-structured interview was conducted which allowed the interviewer to use probing techniques to obtain further response from the participants. A semi-structured interview method was adopted because it allows the flexibility to ask questions about emerging issues during the investigation, whilst keeping the researcher focused with the research boundary. Easterby-Smith (2002) argues that interviews are appropriate methods for understanding the constructs an interviewee uses as a basis for his or her opinions and beliefs about a particular situation, when the researcher wishes to develop an understanding of the respondent's 'world' so that he could influence it.

The main role the research during the interviews, apart from keeping the process in control and guiding it to productive areas, was to listen, take note and make sure that each of the interviewees had an opportunity to express themself. Patton (1990) argues that the fundamental principle of qualitative interviewing is to provide a framework within which respondents can express their own understandings in their own terms. Table 4-1 illustrates the number of interviews conducted, the number of hours taken and the number of transcript pages generated. Interviews were conducted with general mangers, design and develop engineers, production line managers, however it was difficult to gain access to all department managers, in total only four personnel were interviewed. This a relatively small sample when compared to the number of personnel interviewed from the design and development function. At the initial stage of the empirical study, interviews were used and as the research progressed into the in-depth case study; both interviews and a questionnaire survey were conducted in parallel. This facilitated the triangulation of data collected.

Simultaneously, company documentation was surveyed in order to triangulate, and thus substantiate the interview data. The questionnaire questions were similar but did not duplicate the interview questions. Overall the interview normally took 60 minutes on average. Data from the interviews were triangulated through multiple sources, in order to improve the research validity. Furthermore, data triangulation helps to present an accurate picture of events. The researcher believes that each interview conducted could bring diverse perspectives on the same questions. All the interviews were fully transcribed and also have translated from Persian to English by author.

Role	No of interviewees	Department	Location
Innovation engineer construction/Design-condensing automobile	2	Design	Iran
Innovation engineer construction/Design and development of automobile and glass	2	Design	Iran
Project leader Continuous Product Improvement	2	Quality	Iran
Innovation new product development and knowledge sharing feedback	3	Management	Iran
Project leader Innovation Thermal	2	Design	Iran
Team manager Test department	2	Design	Iran
NPD Innovation development	2	Design	Iran
Innovation engineer rapid prototyping in automobile development	2	Design	Iran
R& D Quality Planning	3	Quality	Iran
Knowledge sharing processes	3	Management	Iran
Marketing and customer requirement	1	Marketing	Iran

Table 4.1- Illustrating the Broad Range of Experts Interviewed

No of Interviews	No of Hours	No of Transcript pages
19	38	150

Table 4.2 - Statistical Figures of Interviews Conducted

4.4.3 Data Analysis of Interview Data

The data analysis strategy adopted for this research study is based on the qualitative methods of Miles and Huberman (1994). An in-depth analysis of the interviews involved transcribing the tape-recorded qualitative data, identifying emerging themes and assigning analysis codes to assist in the interpretation and detailed analysis of the data. Strauss & Corbin (1998) stated that all field notes, transcripts and other material should be coded and the coding system should be refined as the data collection proceeds. The codes are then integrated comparatively to identify differences and interrelationships. Easterby-Smith (2002) suggested seven stages to analysis which include 1) Familiarisation 2) Reflection, 3) Conceptualisation, 4) Cataloguing concepts, 5) Coding, 6) Linking, and 7) Re-evaluation. However, the central process highlighted in the analysis phase is coding (Strauss and Corbin, 1990). Coding represents the process where data is broken-down, conceptualised and put back together in new ways.

4.4.4 Questionnaire Survey

Questionnaires are usually considered to be one of the most efficient data collection techniques and widely used to compliment other methods in particular interviews. A questionnaire survey is a means of gathering information about a particular population by sampling some of its members, usually through a system of standardized questions. Mail, telephone, personal interview, or Internet can conduct surveys. They can be administered either to individuals or groups. The primary purpose of a survey is to elicit information that, after evaluation, results in a profile or statistical characterization of the population sampled. Robson, (2002) suggested eight steps to be taken as a data collection method, they are:

- Development of research questions
- Study design and initial draft of questionnaire
- Informal testing of draft questionnaire
- Revise draft questionnaire
- Pre-test revised draft using interviews
- Re-correct questionnaire
- Distribute questionnaire and collect answers
- Analyse data

4.4.5 Questionnaire Survey Design

A structured questionnaire was designed as a survey instrument to collect data from a sample of design, quality and service engineers. The use of the survey method complimented the interviews and provided the researcher with a broader and deeper spectrum of understanding of a range of issues. The literature review indicated that knowledge sharing to support rapid prototyping is important for making product quality and reliability improvement at the design stage of product development. Hence there is a need to manage this knowledge sharing framework process to support rapid prototyping improvement. The aim of the survey questionnaire was to identify problems with the existing knowledge sharing process.

The contact persons within organisation were approached to discuss the intention of conducting a questionnaire survey. The researcher discussed the type of participant required and the need for contact names, email or telephone number of personnel within the specified functions. The production manager (main contact from R&D) organised a list of participant from both the quality and design functions that best suit the set criteria, whilst the production manager informed the methodology administrator to prune a list of engineers' addresses so that the questionnaire can be posted to them.

The questionnaire survey was ideal for eliciting information from the automotive and collaborative industry. The questionnaire survey provides an efficient and cost effective way for obtaining answers to the research question based on new product development in respect with knowledge sharing to support rapid prototyping perspective. The use of questionnaire would also provide a more representative sample size of information obtained from industries. Due to time constraints, it would be challenging for the researcher to conduct a face-to-face interview with a significant number of participant from the industry managers.

A good questionnaire should provide a valid measure of the research enquiry, obtain the co-operation of respondents and elicit accurate information. The design process for the questionnaire survey ensured respondents could easily understand the questions and were able to interpret the questions as intended by the researcher. Therefore questions were worded using familiar terminologies in a simple and precise manner, to reduce the potential for misinterpretation. The researcher adopted the proven technique of Liker scaling, which consists, strongly agree, agree, neutral, disagree, and strongly disagree response options. The questionnaire survey was used to obtain the respondents general views, experiences and attitudes towards the field knowledge sharing framework process. Figure 4.4 illustrates the questionnaire design approach taken.

In designing the questionnaire survey, questions were drafted to relate to the research questions and the underpinning literature. According to Frazer and Lawley (2000) the process of questionnaire design requires determining the information, which is to be collected. The questions required in this research is the limitations of existing knowledge sharing process to support rapid prototyping and the key factors for managing new product development feedback in automotive and collaborative industries such as CarGlass company in this research project, Draft questions were then piloted and refined in collaboration with the Greenwich CIPD faculty and PhD community, who had knowledge of the research subject area, in order to obtain their view on the structure of the questions. This pilot test allowed the researcher to sanitise the survey items and rectify any potential deficiency. Minor adjustments were made on the basis of specific suggestions. The final questionnaire addressed common themes with some sets of questions being specific to knowledge sharing and rapid prototyping respectively in NPD. The example of questioners will be available in appendix for further concerns.

4.5 Company Documentation

Supporting company documentation that was used in this research investigation included:

- Presentation slides on NPD processes.
- Complete product development process documentation, which included process flow charts, web materials such as the digital web version of the product development processes.
- Excel documentation on knowledge sharing process, cost and lead-time records.
- NPD electronic design in CAD system to develop and transfer the knowledge to the production line and collaborative industries.

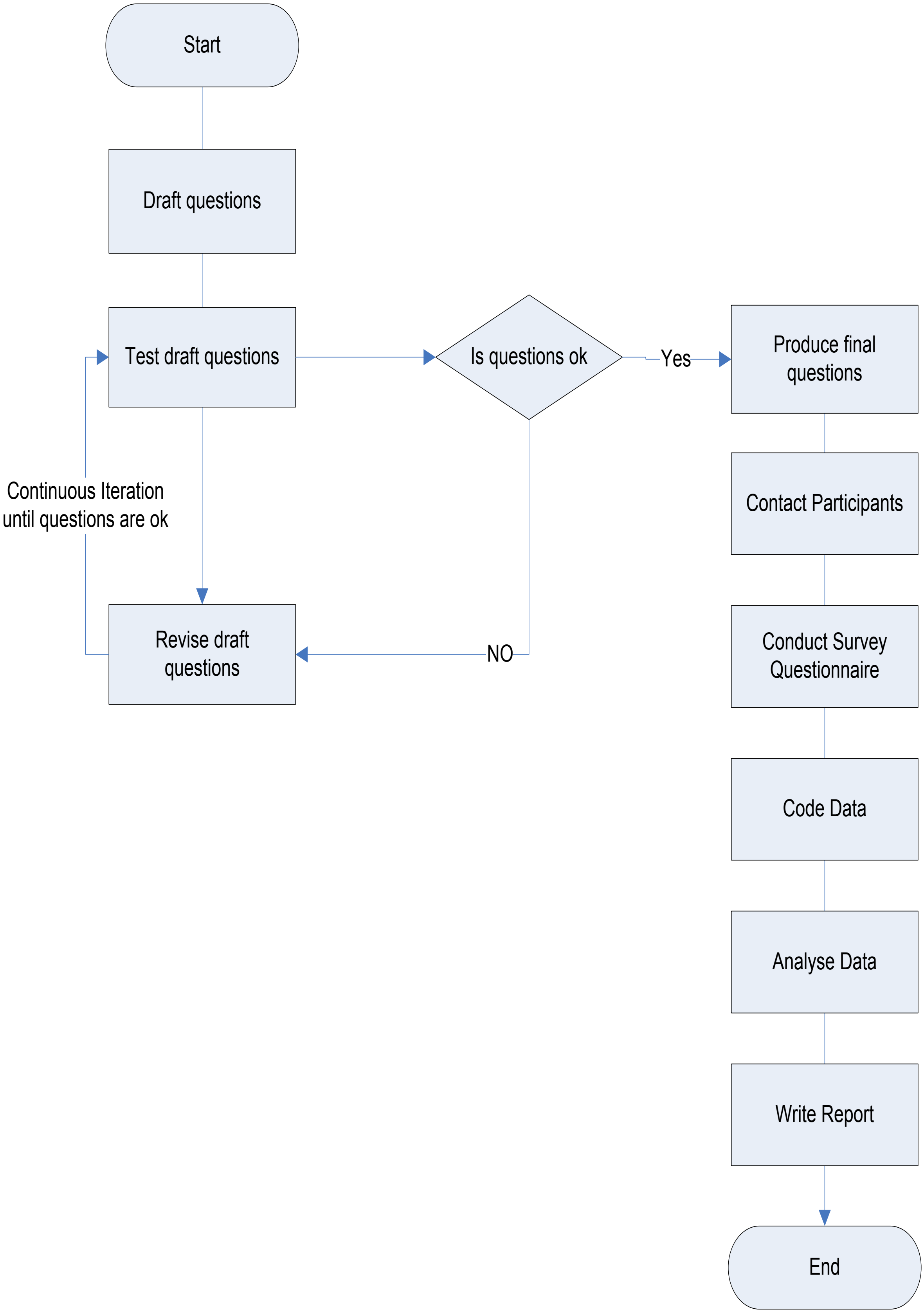

Figure 4.4 - Survey Questionnaire Design Approach

4.6 Case Study Quality and Validity

As part of the research process, a focus was made on assessing the reliability and validity of the research findings to improve data accuracy by reducing the production cost and leadtime with better collaboration process, Robson (2002). Hussey and Hussey (1997) defined validity as the extent to which the research finding accurately represents what is happening in a situation, showing the true picture of what is being studied from the data collected. In this investigation, data triangulation and observer triangulation strategies have been exploited to tackle bias in the data collection and interpretation. Triangulation of data sources was used in the investigation to identify knowledge sharing framework (KSF) process, and in the study to identify knowledge in the NPD process in automotive and collaborative industries, which relied on evidence taken from interviews and company documentation. Triangulating the questionnaire responses with other sources such as the interview responses and company documentation addressed bias and threats to validity of information. Patton (1990) argues that documentation of this kind provides a rich source of information.

It is worth noting that the knowledge audit and knowledge sharing investigation were conducted a year apart and with a largely different group of respondents. Triangulation of methods was not employed in the testing of the prototype knowledge sharing framework tools. Interviews were used to collect the opinions of target tool users on the perceived usefulness of the meta-knowledge concept and the tool, providing a highly subjective, qualitative response. One final kind of triangulation used was observer triangulation, also found in Robson (2002).

Yin (1994) identifies three types of validity applicable to exploratory research; they are construct validity, external validity and reliability. Construct validity is described as the degree of certainty one has that the phenomenon has been appropriately measured and studied. External validity is concerned with the extent of confidence one has that the findings can be generalised beyond the immediate case. Reliability concerns the researcher's conviction that the research and its findings are repeatable. According to Silverman (2000) a researcher's ability to show that the methods used were reliable and that the conclusions made are valid are crucial to any social inquiry. With suggestions to the arguments presented above the following measures were utilised to assure quality and reliability of the research:

- Multiple data sources such as interviews, questionnaire survey literature, company documentation and observation were used for triangulation.
- Perspectives of industrial experts on the research findings and framework developed were obtained. Experts include quality, design and managements.
- Research results were disseminated in academic peer review journals and conferences.
- Both interview and questionnaire questions were documented. Interviews conducted where recorded, transcribed and analysed using consistent data analysis coding.

4.7 Summary of Answers to the Questionnaires

Some of the answers to these questions are presented in this section and rest will be included in Appendix A.1. The summary and analysis of the answers are given here. IranKhodro Diesel Company (IKD) was founded in 1962, with the name of Iran National. Over the years, IKD has developed its capabilities and become the biggest industrial group in MENA region that performs industrial and service activities in the automotive sector in both passenger cars and commercial vehicles with 1,000,000 units of production capacity. Since the policy of vehicle manufacturing companies changed from importing parts from foreign sources to supplying vehicle parts from internal manufacturers, the supplying and engineering companies came into existence. All this process happened during 15 years. Around 180 people in engineering, supplying and purchasing department, and 4000 people in other functions in the main plant, both of them are located in Tehran. IKD has also been appointed by ISO 9001-2 and TS and all other relevant quality and managements certificates which are all available at IKD website as www.ikd-co.com.

IKD as main engineering plant, supplying and purchasing department (EPCO) in Tehran, seven related plants that supply the diesel engine (IDEM) in Tabriz with Associated of Benz in Germany, gear box (Chaekhgar) also in Tabriz, axel (VAMCO) in Qazvin and propeller shaft (Kppco) in Mashhad. CarGlass supply all types of glasses (Such as glass for trucks, buses, vans, trailers and also specific glasses) in Tehran. There are different types of customers for internal market and international. IKD exported a number of our products to countries such as Turkey, Iraq, Kuwait, Central and North of Africa, UAE, Cyprus, Qatar, Syria and some other countries. The products that exported are cars, trucks, and buses, which could be used in both construction and private and public transport and a number of the parts for after sales. The after sales parts are: engines, glasses, car body parts, etc. Top management is appointed from the Board of directors of IKD and totally implements the rules dictated.

4.7.1 General Background about Business

Questionnaire A-1: General Background about the Business:

- What are the main challenges globally and nationally? Answers and data collected are as below:
    - Nationally the competitive market and competing with other companies. Globally the economic sanctions.
- What are the main difficulties/issues in the relationship with customers? Answers and data collected are as below:
    - Old design of our products. Poor collaboration, less knowledge sharing. As there is huge competition in automotive industries, normally automotive company for they own safety of the design they do not wish to share all knowledge with supplier which it cause problems such increase the production lead time and almost our total cost.
    - Poor quality of products. Because of international sanction we are not always able to get good quality of automobile parts.
- What are the main customer requirements changes that concern top level management? Answers and data collected are as below:
    - Newly designed products with more quality. As our products used in public transport it requires high level of quality standards.
- What are your business objectives in the next two years and beyond? Answers and data collected are as below:
    - Totally dependent on economic situation and it may vary. We planned to have joint venture with chine's manufacture and have new production line under their licenses.
- Is information and communication technology (ICT) important to your business and in what way? Answers and data collected are as below:
    - Yes, it could help improve lead times, total costs and quality of products. They would improve their market place in the competitive business.

Questionnaire A-2: The Organisational Structure of Design Department:

The preparing the technical information such as drawings and test plans for parts. Design team tries to bring more closed relation with our supplier to improve our products. Also the new method of software has been introduced to our system based on Autodesk top engineering, which gave us ability of 3D view (see organisation chart in Figure 4.5).

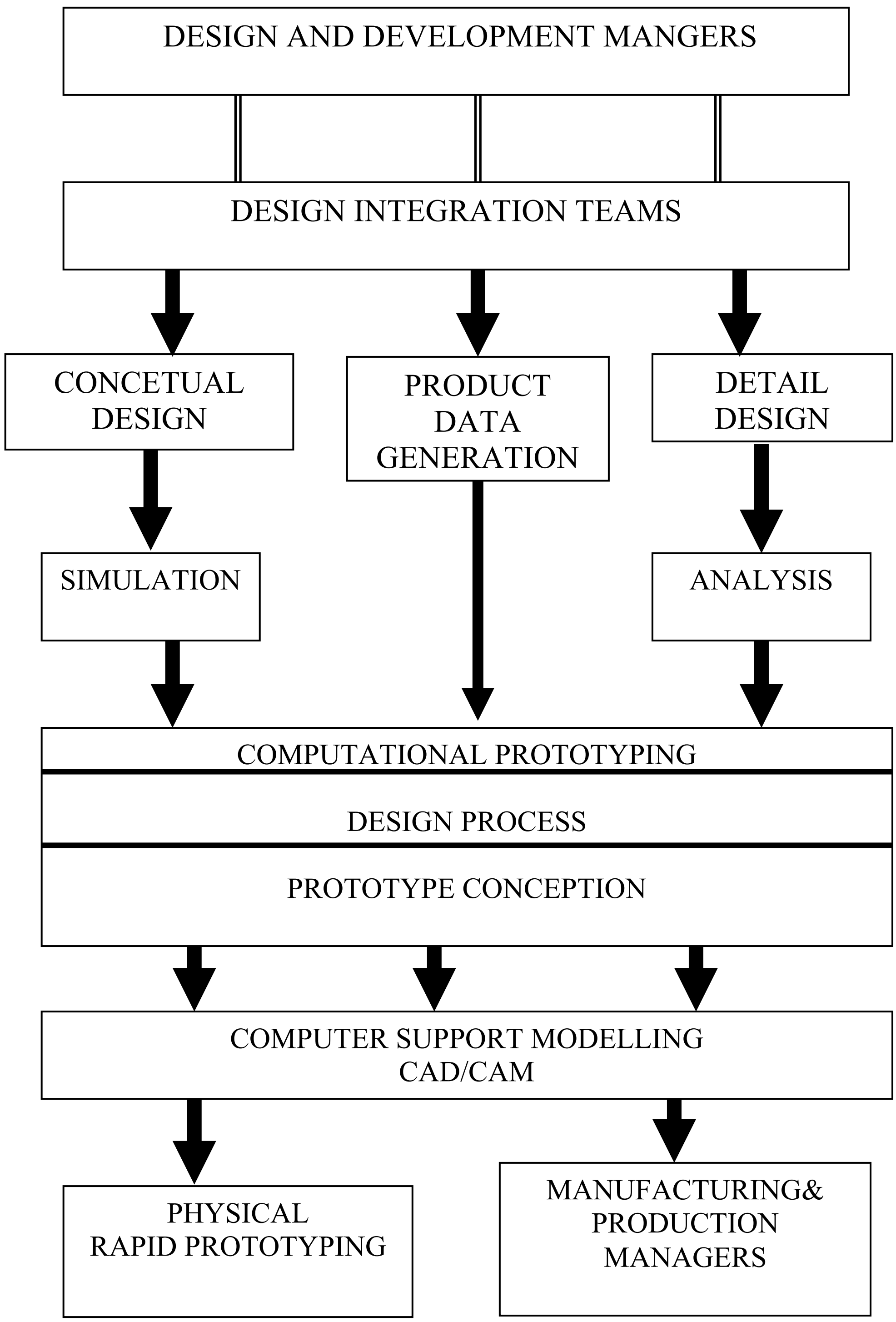

Figure 4.5 - Structure of the Design Department of IKD

4.7.2 Product and Design Department

Questionnaire B-1: The Information About the Product:

- What are the main types of your products? The answers and data collected are as below.
  - As head of the supply chain, IKD provide the main factory with lots of materials and vehicle parts in 4 main categories 1- Raw material and standard parts such as bolts and nuts. 2- Electrical parts 3- Plastic and composite parts 4- Assembled pats.
- What are the geometric parameters of your products? The answers and data collected are as below.
  - Because of wide variety of parts supply to the IKD, lots of geometrical parameters and test equipment's must be taken into consideration and it
- What are the materials, suppliers and costs? The answers and data collected are as below.
  - Raw material such as steel sheets and coils, steel profiles.
  - Standard parts such as bolts and nuts.
  - Electrical, composites and assembled parts.
  - The final cost may vary because of inflation, global change of raw material price and labour cost.
- What are the mechanical properties (weight, strength, etc)? The answers and data collected are as below.
  - It varies for every single part. There are wide varieties of properties.

Questionnaire B-2: The Customer Requirements About Product:

- What are the customer requirements (in a document)? The answers and data collected are as below.
  - Newly designed products with more conformability and quality.
  - Genuine spare parts.
  - Better after sales service.

Questionnaire B-3: Process of Managing Changes:

- What are the main changes in customer requirements? The answers and data collected are as below.
    - Proper price and reliability of products.
- What are the main design changes to respond to the above? The answers and data collected are as below.
    - For designing new products we are not self-sufficient.
- What is the way IKD work with customers? The answers and data collected are as below.
    - There is a one-way relationship between IKD and customers because they have no better choice in Iran.
- What is the way you work with suppliers? The answers and data collected are as below.
    - For every purchase from a supplier a contract is made and all the circumstances is written and signed by top management. The suppliers must guarantee their sold parts for 2 years.
- What is the procedure in dealing with changes in customer requirements? The answers and data collected are as below.
    - Every change that the customer sent to our company is assessed in design and manufacturing departments and if applicable, will be implemented.

Questionnaire B-4: Relationship With Other Departments:

- How does IKD interact with manufacturing department? The answers and data collected are as below.
    - As a quality control representative all the Customer complaints in assembly line and after sales also non-conformity of parts will be assessed accompanied with manufacturing dep.
- How does IKD interact with purchase department? The answers and data collected are as below.
    - Purchasing is the main duty of manufacturing dep. actually nothing is made here. IKD buy and sell parts in the middle of supply chain and also provide them with technical data.

- How does IKD interact with sales/marketing department? The answers and data collected are as below.
    - IKD provides the technical data. In a case of conflict between customer and sales division may interfere as an expert.
- How does IKD interact with finance department? The answers and data collected are as below.
    - The manufacturing and marketing departments have the main relationship with finance department. Design and quality control departments have the least relations with finance dep. In a case of change request from the customer (IKD), the cost analysis management prepare a detail report about every new cost imposed by new changes.
- How does IKD interact with the above departments when dealing with changes? The answers and data collected are as below.
    - After changes are approved with the customer, the technical data will be changed and will be published to other departments and related suppliers.

Questionnaire B-5: Problems and Challenges Use of ICT:

- What are the main problems and challenges in dealing with customer requirement changes? The answers and data collected are as below.
    - Lack of technical data.
    - Lack of Knowledge transfer processes
    - As modern technologies are not native here & developing them here is not possible such as (ABS system for brakes).
- What are the main advantages and shortcomings of existing ICT systems in support dealing with the above changes? The answers and data collected are as below.
    - With ICT systems data transfer between departments is much faster and other section will be informed faster about the changes. But the ICT department, which controls and runs the needed soft wares, is not efficient enough.
- What capabilities would expect from future ICT systems in support of dealing with the above changes? The answers and data collected are as below.
    - Updating old and disorganized software, which doesn't help.
    - Developing web based databases in order to easier accessibility.
    - Develop the new knowledge transfer process

- Is information and knowledge sharing an important issue in collaboration with customers and suppliers? The answers and data collected are as below.
    - Not even is important, in fact is essential and highly important issue, but the links of knowledge sharing is not complete and not strange enough and some related companies would not be informed of changes made. Also it should be noted that due to the market competition normally is not possible to transfer and share the all data and information's.
- What are the main problems and challenges in information/knowledge sharing across the supply chain? The answers and data collected are as below.
    - Complicated and disorganized algorithms of ICT system.
    - Lack of detail technical data and reference standards.
- What capabilities would expect from future ICT systems in support of information/knowledge sharing across the supply chain? The answers and data collected are as below.
    - Algorithms of ICT systems are complicated and are not efficient and user friendly.

4.7.3 The Manufacturing Department

Questionnaire C-1: The Information About The Manufacturing Processes

- What are the main engineering requirements (from design department) for each product? The answers and data collected are as below.
    - Technical data including (technical &detail drawings, test methods).
- What processes used to manufacture the product to meet the above requirements? The answers and data collected are as below.
    - Reverse engineering.
- What machine tools used to perform the above processes? The answers and data collected are as below.
    - Various machines, lathing, milling, press machines and prototype modelling.
- What is the unit cost of manufacturing each product (and how to calculate it)? The answers and data collected are as below.
    - The price analysing management is responsible for calculating the total price for each part. The total price per part. the price of raw material needed for each part + the price of outsourced processes& standard parts+ labour cost+

Depreciation of machines & dies involved in manufacturing of the part + packing & shipment costs + Overhead costs (design, test equipment's, tax)

- What is the time taken to manufacture each product? The answers and data collected are as below.
  - It depends on products. If our collaborative supplier be on time normally between 60 or 90 days. Normally because there is no knowledge transfer between industries it brings difficulty to the project.

Questionnaire C-2: Process of Managing Changes:

- What are the main design and customer requirement changes? The answers and data collected are as below.
  - Replacing the driver cabin with new and more comfortable one.
  - More electronic facilities.
  - Powerful engine with less fuel requirement
  - IN some cases redesign automotive car body
- What are the main manufacturing changes to respond to the above changes? The answers and data collected are as below.
  - Making new dies to manufacture new cabin.
  - Replacing the engine with more powerful and less polluting one.
  - New car body
- What is the way IKD work with the design department? The answers and data collected are as below.
  - IKD receive the technical data from design department then all the manufacturing or outsourcing process starts.
- What is the way IKD work with customers? The answers and data collected are as below.
  - Manufacturing Dep is direct contact with customers. Manufacturing Dep received they commonest from: questioners, website survey
- What is the way IKD work with suppliers? The answers and data collected are as below.
  - The suppliers in some cases are in direct contact with us. It checks if the parts can be produced and develop in easy way, less costly and capable with customer requirements.

- What is the procedure in dealing with changes in design requirements? The answers and data collected are as below.
  - Mostly the changes starts from new obligations and new regulations dictated by government or institute of standard and industrial research of Iran. For instance using anti lock brake system. Then the design department starts to prepare the technical data and manufacturing process meanwhile other departments are looking for qualified and reliable suppliers. If necessary the lay out of assembly line will be changed.

Questionnaire C-3: Relationship With Other Departments:

- How does IKD interact with design department? The answers and data collected are as below.
  - The design department to verify if the proper tools are used and new methods are implemented in the assembly line checks manufacturing process regularly. Using of nonconforming products is only authorized by the design dep.
- How does IKD interact with purchase department? The answers and data collected are as below.
  - Nonconforming parts are reported to the purchase dep by quality control dep and will be in charge to reject those parts to the relevant suppliers.
- How does IKD interact with sales/marketing department? The answers and data collected are as below.
  - IKD receive the customer complaints and if necessary corrective and preventive actions are applied.
- How does IKD interact with finance department? The answers and data collected are as below.
  - IKD are not interacting with finance department directly but if cannot provide the whole supply chain with enough financial resources the manufacturing department is the one that is affected the most.
- How does IKD interact with the above departments when dealing with changes? The answers and data collected are as below.
  - The most influencing department in supply chain is finance dep. If for any reason the finance department cannot provide the supply chain with proper cash flow, it will affect the whole enterprise. Thus the precedence of payments to the suppliers is determined by manufacturing dep.
- Any more to add? The answers and data collected are as below.

It's believed that there are lacks of knowledge collaboration between suppliers; if had strong collaboration framework that could have reduces the production cost and even product lead time. It should also mentioned that some of supplier start new information sharing which could see good results of it and hope in future have more strange information sharing between our suppliers.

Questionnaire C-4: Problems And Challenges Of ICT:

- What are the main problems and challenges in dealing with design and customer changes? The answers and data collected are as below.
    - Lack of enough budgets/knowledge to dealing with engineering standards.
    - No CRM department has been considered.
- What are the main advantages and shortcomings of existing ICT systems in support dealing with the above changes? The answers and data collected are as below.
    - Integrated soft wares, which are used among different departments, hang a lot.
    - Even hard wares are not compatible to the new soft wares.
- What capabilities would expect from future ICT systems in support of dealing with the above changes? The answers and data collected are as below.
    - Provide better hard wares in order to be able to use up to date soft wares.
    - Developing knowledge exchange and better product development
    - Enhance the interface of Wi-Fi network.
- Is information and knowledge sharing an important issue in collaboration with customers and suppliers? The answers and data collected are as below.
    - Of course it is, it's believes that one of most important aspect in automotive industry is knowledge sharing. It also believes that transferring data it would help us to improve our production perspective, quality and reducing cost but because of competition market they do not wish to share they knowledge. It should mention that there is not very strange framework for this process.
- What are the main problems and challenges in information/knowledge sharing across the supply chain? The answers and data collected are as below.
    - Complicated and disorganized algorithms of ICT system.
    - No CRM department has been considered.

  - The ICT department is empty of knowledge framework chart.
  - Less trust in collaborative industries
  - Poor software process

- What capabilities would IKD expect from future ICT systems in support of information/knowledge sharing across the supply chain? The answers and data collected are as below.
  - Using more knowledgeable and skilful software writers to achieve the goal.
  - More information is flue between industries.
  - Helping automotive industries to support prototype and new product development

4.8 Discussion of Questionnaire Results

One of the aims of this research is to bring new technologies and processes to support the sharing of information and knowledge between automotive and glass industries where multiple design and manufacturing engineers are involved in producing automobile components at different stages. In such situations, there may be a clear division of human resources, in which different engineers take responsibility for different components or different stages of the product development process. The scenarios that can be addressed between automotive and glass industries include situations in which the product development teams were geographically distributed. In such situations, knowledge should be shared in order to reach consensus, divide work and synchronise independent parts of the decision-making tasks. However, with knowledge sharing collaboration processes, it would allow the CarGlass design team to provide better information to make an important trade off in the design. The information provider wishes to preserve sensitive knowledge, on the other hand, they wish to provide all knowledge necessary for a successful collaboration. For example, CarGlass has been requested to develop windscreens for a new automobile design which is currently under design, and to develop the prototype glass, the knowledge sharing required caution by both organisations. CarGlass wishes to continue to provide this service for the automotive company in the future, and therefore does not wish to transfer the knowledge of how to design a windscreen for a new automobile. They only wish to transfer knowledge of how to effectively use the specific design that they are providing.

Additionally, the automotive company does not wish to provide unnecessary details regarding their new automobile design, so that they can control when and how others find out about the new automobile. A second reason, the windscreen designer in glass industry does not want to share their knowledge, because such specialist companies often provide similar services to competitors. For example, CarGlass may provide windscreen designs for a number of companies in the automotive sector. Therefore, some of the knowledge that they bring to the current design task may have been gained when working on designs for competitors. It is obviously important that no details of the previous design collaboration emerge during the current design task. However, sharing knowledge not only protects the previous collaborative partner, but also increases the confidence of the current collaborative partner in that sensitive knowledge from this design process will not leak into future collaborations

4.9 Classification of Knowledge

This section describes the techniques used to classify the knowledge identified from the IKD sources referred to in pervious section. It concludes by proposing a classification of knowledge used and generated knowledge sharing in the NPD process based on its content, also referred to here as its domain.

4.9.1 Method Used to Classify Knowledge (Data)

As already alluded to, the knowledge identified in previous section acted as the principal source of evidence used to devise the knowledge classification. In order to guide the classification process, two additional sources of information were referred to. These were: the project folder screenshots from the NPD project leaders, project managers and engineers which provided an insight into the way NPD practitioners organise their explicit knowledge, and the typology of NPD information proposed by Zahay et al. (2004), which provided a literature based perspective. This latter investigation sought to answer the question 'what information is relevant to developing new products in automotive industry to have a better collaboration process?'

A convincing and robust typology of knowledge types must be able to accommodate all of the knowledge items identified in previous section (Note: the questions are available in appendix A) and would be expected to incorporate the knowledge types identified in previous research. Therefore, the typology provided by Zahay et al. (2004) was used as a starting point for the classification. The information types from this classification were placed on a mind map. Then, starting with the knowledge items identified from the knowledge audit, an attempt was made to place each item under its relevant category on the map. Those knowledge items that did not fit under the existing categories were set aside. Once the available knowledge items had been exhausted, proposals were made for new categories to subsume the knowledge items that been set aside, or for changes to the boundaries of the existing categories. Using the modified classification as a starting point, the exercise was repeated for the knowledge items identified in the knowledge sharing investigation. This process is illustrated in figure 4.6 when a typology had been reached that included the knowledge items identified from both sources the process was terminated.

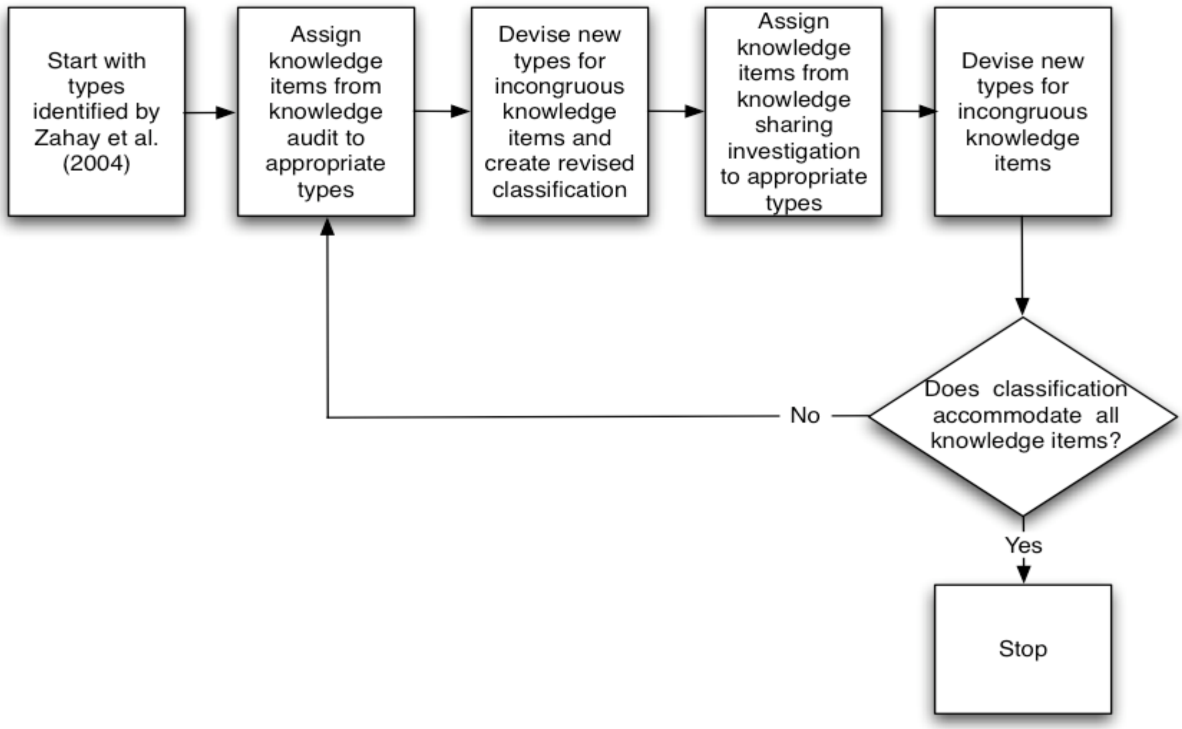

Figure 4.6 - Steps for the development of the NPD knowledge classification (Zhay et al 2004).

4.9.2 Resulting Classification

Twelve classes of knowledge were identified. These were (1) project management and performance, (2) computer based tools and applications, (3) strategic, (4) quality (product, process and suppliers), (5) NPD process, (6) NPD project experience, (7) regulatory, (8) technical design, (9) Financial, (10) information about competitors (11) supplier requirements knowledge, and (12) information about the knowledge itself. The knowledge classes or categories and the knowledge items from the knowledge audit and knowledge sharing investigation that fit into these categories may be seen in Appendix B respectively. An explanation of each of these knowledge categories follows.

‘Project management and performance’ refers to information mostly used by the project leader to plan and track the progress of the project. Examples of this information drawn from the knowledge sharing investigation (source 4) include the overall ‘project plan’, the project ‘test plan’ which dictates what tests must be carried out for the product to be sold in its markets, and a project ‘milestone checklist’ (see Appendix B). Instances taken from the knowledge audit (source 3) are the ‘pre-launch report’, ‘balanced scorecard’ report and the ‘key performance indicators’ report for the project (see Appendix B). Most of the project management and performance knowledge then is mostly explicit in nature and is in the form of information or data. The project leaders interviewed in the knowledge sharing investigation stored such information on their network drive folders under titles including ‘project control’ and the ‘project cockpit’ or also known as “project roadmap”.

A plethora of information systems technology tools are needed in the course of an NPD project. 'Computer-based tools and applications’ encompass the knowledge required to use these tools. For instance, specialist knowledge is needed to use quality management systems and computer-aided design packages such as CAD/CAM. Specific examples of these from the knowledge audit source include ‘APIS’ a database of ‘Failure Mode and Effect Analysis’ reports from the ‘Risk analysis concept’ sub process interview, ProEngineer, a computer-aided design (CAD) package, and the ‘test database’ a system containing product test protocols and test data. The latter two were mentioned in the ‘definition of system on component level’ interview.

This knowledge is experiential and more in nature. It is gained from training and repeated and regular use of a software tool. It should be borne in mind that this research project would not explain the method of design, but only working on the knowledge sharing processes to support the rapid response in the automotive industry with better collaboration.

‘Strategic’ knowledge covers knowledge such as ‘new product strategy’, “production process strategy” “collaboration strategy with other supplier” company ‘sales strategy’ and ‘market share’ data, all of which are examples taken from the knowledge audit. Other knowledge items from this source that fell into this category were definitions of ‘global strategy for the brand', and manufacturing strategy knowledge like 'availability of parts from the supplier', and 'flexibility and capability' of the supplier'. One further type of strategic knowledge, 'predictions about future knowledge technologies', was revealed in the knowledge sharing investigation. This concerns knowledge about existing and emerging technologies that could be applied in new products with collaboration relation in other industries. An example is the application of IKD as the automotive company with CarGlassco as the glass manufacturer and the KS process to support the NPD. It may be ascertained strategic knowledge originates mostly from the senior management, design and production functions, and may be either quantitative or qualitative in nature. Since even in its qualitative form, it is communicated in documents, it may be argued that it is largely explicit. This is a broader category than its counterpart type in Zahay et al. (2004).

'Quality' encompasses all knowledge required for, or generated by, quality initiatives in the course of knowledge sharing in NPD process. The category covers issues relating to the quality of the physical product itself, the quality of suppliers of components and parts (i.e. how capable are they are of supplying parts to the desired specification), and process quality (i.e. whether the business processes been executed according to specification). It is asserted that quality knowledge is an important category of knowledge for product development projects using a stage-gate process. Ulrich and Eppinger (2003) noted that a benefit of a well-defined product development process is to assure the quality of the final product. This is achieved in part through the use of judiciously specified quality stage-gate reviews. The knowledge required for, and generated in these reviews may be classified as knowledge related to quality.

'NPD process' knowledge refers to information about the NPD business process itself. This knowledge acts, as a guide to project team members as to what tasks must be completed at different stages in an NPD project. It also indicated what the expected output from each of these tasks would be. This knowledge is mostly explicit and was found in the business process documentation (source IKD Organisation chart), specifically in business process flow charts and training presentations included with the process on the compact disc. Although not necessarily attributable to organisations other than the case study company, it is worth noting that project team members are obliged to attend a training programme intended to acquaint them with the NPD business process. This highlights the perceived importance of NPD process knowledge at the firm. In a firm using a formal NPD process, an understanding of the business process provides project team members with important contextual information about the tasks they carry out.

'NPD project experience' addresses knowledge that an individual gains from the act of being involved in an NPD project. This knowledge could take a number of forms. It may be used in subsequent projects to assist in decision making, especially where expert judgement is required. This might occur during an NPD project audit in a stage gate review, or at point in a process where no historical data or information is available to guide the individual or team taking the decision.

A specific instance is the knowledge gained by a cost analyst when they perform a cost analysis. The cost analysis is highly experiential and there is no explicitly documented way to carry out the action. This point is illustrated by the following extract from the 'Target costing and cost tracking' sub-process interview report in the knowledge audit source: 'Analysis knowledge is about experience, rather than tangible, explicit knowledge. Cost controllers tend to exist "in their own world". They have their own rules and their own language. These rules and language are very difficult to understand if one does not work within this "bubble"'.

Another instance of knowledge in this category is knowledge about which individuals in the company executed given roles in an NPD project, an issue raised by the IKD and CarGlass project managers in the knowledge sharing investigation. Their answer to the question 'What kind of information/knowledge do you and your project team need in the course of a project to support the rapid response in NPD?' included the statement, 'Responsibilities in former projects; How a new automobile design would be developed?'

'Regulatory' knowledge concerns information about regulations, laws and legislation in place in the product markets that constrain or otherwise influence the product design. 'Patents', 'contracts' with customers and suppliers, 'technical standards', product 'distribution networks', 'rapid prototyping process', 'Quality marks' are all examples of regulatory knowledge found in the knowledge sharing investigation. Generally, regulatory knowledge is mostly explicit and is captured in documents.

'Technical design' knowledge is a broad category that covers all knowledge related to the design and manufacture of the product. Design knowledge might be product 'design rules' or testing expertise. Predominantly explicit design knowledge items are 'materials data', 'bill of materials', functional and performance 'calculations', conceptual designs, and digital product models. All of these examples were taken from the knowledge audit and knowledge sharing investigation sources. An awareness of technology trends, mentioned in the knowledge sharing investigation, is also important for engineers, but here the emphasis is on the technology itself, rather than its strategic role in the product development. Manufacturing-related knowledge, also taken from the knowledge audit and knowledge sharing investigations, features ‘machining rates’, ‘machining routines’, and the tooling required to fabricate and assemble different parts of the product. Knowledge in the technical design category then, is mostly explicit. Many other examples of knowledge items placed in this category may be found in Appendix B.

The **‘Financial’** class includes various finance and cost information and data. ‘Price positioning’ of a product in the market, ‘machining costs’, ‘prices for standard components’ used in the product, the impact of project plan changes on profit and loss and cash flow, sales figures, and other cost calculations are all knowledge items that fall into this category. Project target cost tracking activities are presented in ‘cost analysis reports’ and an ‘Absolute Cost Control report’. Financial knowledge is also embedded to varying degrees of richness in a collection of templates and tools. The ACC tracking tool supports absolute Cost Control (ACC) activities and a template was developed for creating project business plans. All of these knowledge items were identified in the knowledge audit. This knowledge is generally quantitative and manifested in an explicit form.

Knowledge in the **‘Competitor knowledge’** category concerns the products and organisational traits of market competitors. Knowledge about competitor products is sourced from product brochures, data sheets, and actual appliances. This latter source provides knowledge about the product functions and about the impression of quality that it conveys. This knowledge is disseminated in the form of photographs, presentations and reports.

Examples of knowledge items pertinent to competitor products are ‘product function’, that is the functional capabilities of the product, ‘quality impression’ or the perceived quality of a product, and ‘competition context’, which concerns the markets that competitors are attempting to capture with their current product range. Assessment of the perceived quality of a product is largely based on visual cues and handling of an actual appliance, or examination of photographs, as mentioned above. Geographical location of manufacturing facilities and the level of supply chain integration are knowledge items about a competitor’s organisation. All of these knowledge items are taken from the ‘Analysis of competitor products’ and ‘ Risk analysis concept' sub-processes in the knowledge audit. Knowledge in this category can be either mainly tacit or mainly explicit.

'Supplier requirements' knowledge is gathered by the supplier function. It may be in a qualitative form such as description of desired functionalities of a product, or in a quantitative form indicating the number of suppliers desiring a particular product feature (see Appendix B). Supplier requirements are explicitly defined as far as possible in a matrix containing the desired technical functionality and performance, appearance, and handling properties. This exercise is carried out by the Research and Development (R&D) function, which use it to develop a product concept that is ideally both technically feasible and desirable to the industry, as part of the 'House of Quality' sub-processes. This evidence was sourced from the knowledge audit. At the product strategy phase, the knowledge gathered from supplier is in a variety of formats, including product 'impressions'. In the product conception and development phases though, this knowledge is usually found in documentation, and so it can be said to be mostly explicit.

Finally, **'Information about knowledge'** concerns information that an individual or information system can provide about other knowledge items used in the execution of the knowledge sharing in NPD process. Some data inputs and outputs are defined in the process flow maps that make up the NPD business process documentation. These inputs and outputs refer to specific documents or data that may be required for, or generated by, a process, as well as links to relevant document templates. Nonetheless, the evidence from the knowledge audit and knowledge sharing investigation showed that a far wider spectrum of knowledge is used than is described in the data flows. Indeed, knowledge is in many formats and may be distributed across organisational functions and geographical locations. A project manager in IKD interviewed in the knowledge sharing investigation remarked, "Information must be compiled from a wide range of sources and tools." The CarGlass project leader participating in the same investigation commented, "The biggest bit of knowledge that we would need is, a knowledge of, it sounds stupid, but a knowledge of what knowledge is there already."

An important knowledge item in this category is information about methodology of knowledge. Discussing their understanding of the term knowledge, the automotive engineering expert in Germany noted: "For example, often a person who has lots of experience inside the company is able to have this synthesis of information. So for me for example, something quite important, a way to get a quickly an information is to know the good person." Asked what knowledge they used in the course of an NPD project, a project manager in Germany stated that one kind of knowledge was information about "... responsibilities in former projects – who was the project leader? This is important in order to exchange experience."

Information about knowledge is by definition explicit knowledge. However, it can refer to both explicit knowledge like reports, and implicit knowledge, such as knowledge residing in the mind of a person.

4.10 The Role of Product Manager in the Automotive Collaborating Company

The investigated automotive company was founded in mid-1990s. It is a relatively new company compared with other international automotive enterprises. When it was founded, one of the main strategies is product innovation. Therefore its management structure of new product development is organised in a similar way as existing companies in the same business. Each individual product development project is managed by a role named Product Manager who is a member of the top management (board of directors), e.g., vice-president. The Product Manager has enough power to plan, design and integrate products directly, and directly communicate with chair of the board. Another main responsibility of the Product Manager is to manage new product development as an individual project. The Product Manager controls cost, process, investment, benefits, quality and performance in the product development process.

The role of the Product Manager in the collaborating company is more than the traditional Project Manager in manufacturing enterprises. Usually, a traditional Project Manager just controls the new product development as one single project, and he/she handles simple products well. However, the Project Manager does not have enough power during large and complex projects, particular in big decision-making, assessment of people's performance and personnel management, since his/her project team members are drawn from different departments. When the cooperation of people from different departments has some problems, the Project Manager does not have enough power to handle it without consulting to their departmental heads. This situation may lead to longer development time and more cost. Another possible problem is that the horizontal communications among departments at the same level are weak. The Project Manager is good at vertical communication in the project, but in horizontal communications, the Project Manager is weak. It may influence the main objective of this project. Product knowledge loss is another problem due to the lack of authority of the Project Manager in personnel management. Good knowledge management should be based on a stable and self-giving communication environment, which contains a matrix structure with both vertical and horizontal communications.

Therefore, in the large and complex product development projects such as automotive products, the senior role of Product Manager (who is a board member) is a good arrangement compared with the less senior traditional Project Manager in managing large and complex product development projects. Therefore, the Product Manager is the best person to capture knowledge at the enterprise level.

4.11 The Role of Rapid Prototyping Response in Automotive Industry

Rapid Prototyping has been emerging in the automotive industries since the early 1980's. In automotive industries, rapid prototyping is an established engineering solution for reducing time to market, time to production and development costs. According to the Mr. Tehrani, President of Volvo in Tehran/Iran, one goal of rapid prototyping is to quickly determine the requirements that have to be specified for final products prior to the target implementation phase.

The horizons of automotive industrial world are changing rapidly. Automotive industrial planning, in the past, tended to assume that markets were almost infinite and that whatever was manufactured could be sold if the price was low enough, but now, with different competitors and economic crises, the situation has been changed; they have had to reduce the lead time of production as well as cost. The advantages of rapid prototyping in the automotive industries is to develop the new products that, would allow the designers or design team to consider all aspects of product design, manufacturing, selling and collaboration structure in the supply chain at the earlier stage of design cycle, so that design iteration and changes can be made easily and effectively and most importantly it would bring a reduction of the cost and lead time in new product development. However, designers or design teams in the automotive and glass industry should bear that in mind that the rapid prototyping processes need also to be chosen with the consideration of materials, dimensional precision, surface finish, automobile body shape, building speed and cost according to the industrial requirements and expectations.

Nowadays, in automotive industries, rapid prototyping is being used as a communication and inspection tool in the process of rapid feedback of the design information developing in new products. However, according to information from automotive industries, Figure 4.5 demonstrates the dynamic, controllable and simultaneous structure of rapid prototyping in new product development in automotive industries. To develop rapid prototyping in automotive industry, very strong knowledge collaboration between industries is required. Without this collaboration it would not be possible to get the prototype in first place and it may bring cost and product lead times to the higher level.

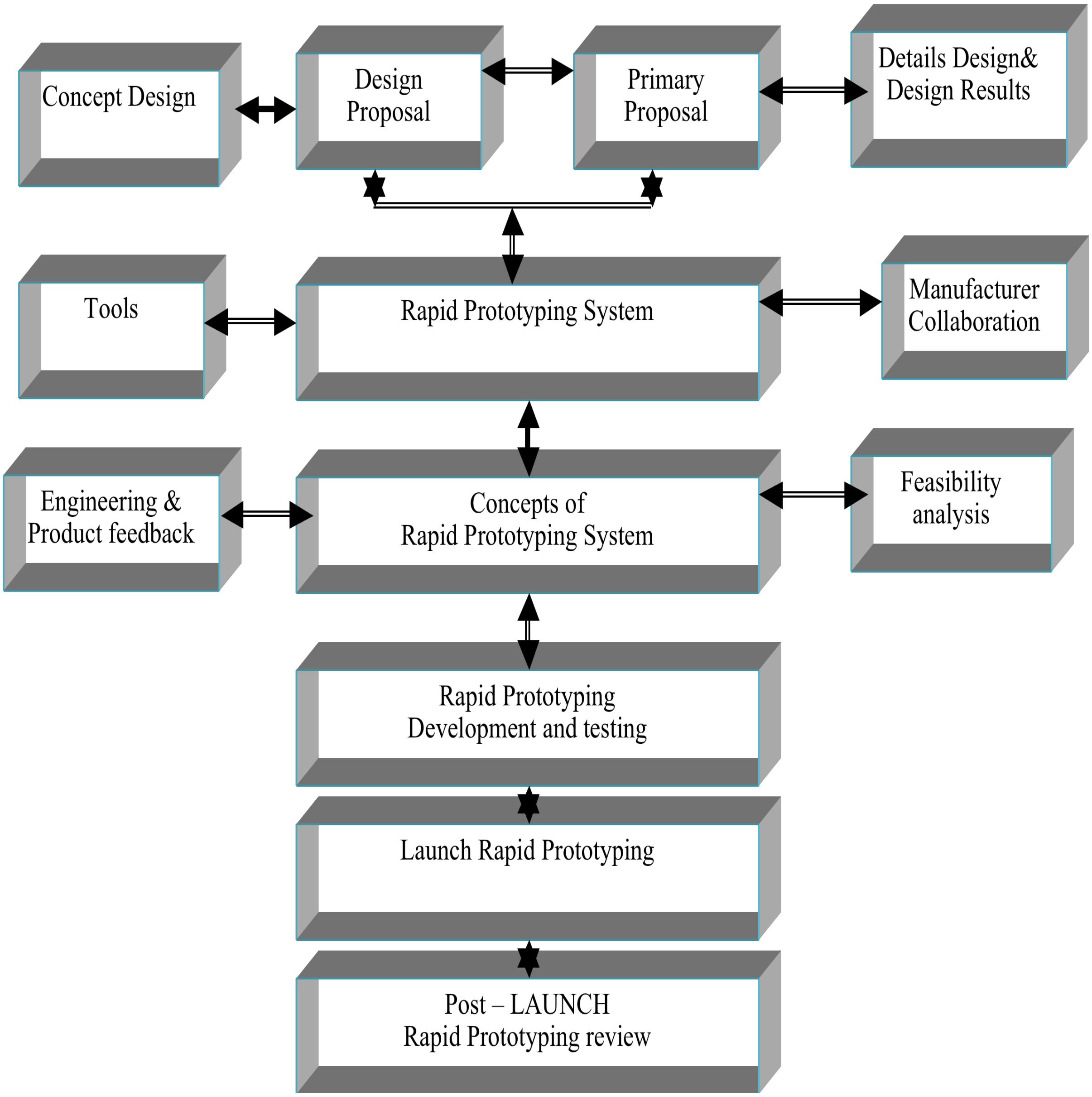

Figure 4.5 - The Dynamic Simultaneous Structure of Rapid Prototyping in NPD in Automotive Industries

4.9 Summary

The industrial investigation into real world business operations and problems of the collaborating company suggests that one of the most important solution to the problems in new product development in automotive supply chain is a knowledge sharing framework that will support rapid prototyping between automotive OEM and glass supply industries. Some basic factors of Rapid Prototyping should be understood. In automotive and glass industries, to develop the new product, the design analysis is conducted based on rapid prototype evaluation. Rapid prototyping allows the engineers and designers to predict information about a product's behaviour, manufacturing processes and production planning. The aim is to use rapid prototyping tool to have better decision-making about final product before it is launched on the market. From the literature review it has been possible to understand that if industries want to reduce production costs and production lead times, they should have a better knowledge sharing collaboration at an early stage of design and must continue through all the downstream stages.

Chapter 5

The Proposed Knowledge Sharing Framework to Support Rapid Response in Automotive Industry

In the previous chapter, industrial investigation and problems has been admitted. From Literature review and industrial investigation, it is possible to identify that the lack of knowledge sharing it cause the big problem in automotive and collaborative industries. In this chapter the work will be conducted to support the knowledge sharing framework design Roadmap (KSFDR) to support the rapid response to design and develop rapid prototype facilitate in the new product development (NPD) process. The implantation and development of this Knowledge Sharing Framework (KSF) tool is described in next chapter.

5.1 Introduction

From the literature review, it has been possible to recognise that there are some urgent requirements for improving collaboration between manufacturing industries to design and manufacture new products. It has also reported that collaborative rapid prototyping can help organisations to address complex system and manufacturing alignment problems through advanced information and communication technologies (ICT) to achieve more value at lower cost and better production lead times. However, the specific information and knowledge management issues in collaboration in the rapid prototyping processes, specifically in automotive and glass industries has not been sufficiently addressed as main themes in the research community.

First of all, the conceptual methodology should be appropriate for both information system development and knowledge sharing system development. The pure information system without considering knowledge is no longer satisfying current industrial requirements. Most companies have already used some kinds of information systems to manage their daily work and knowledge sharing collaboration process. There is some information/knowledge existing in the current systems. However, the proposed methodology can be used to ensure what information/knowledge has already been managed by the current system, it can be used in order to better manage information/knowledge sharing systematically.

The process of developing the proposed methodology is shown in Figure 5.1. Firstly, there are some requirements from companies. These requirements are sometimes general and implicit. The requirements are investigated through the literature survey and real industrial investigations, in order to identify the gaps between industrial requirements and existing knowledge sharing technologies. After that, the gaps need to be analysed, and then the proposed methodology developed. The supporting data of developing the proposed methodology is captured from the real industrial environment, in order to ensure that the proposed methodology is suitable for the real industrial applications.

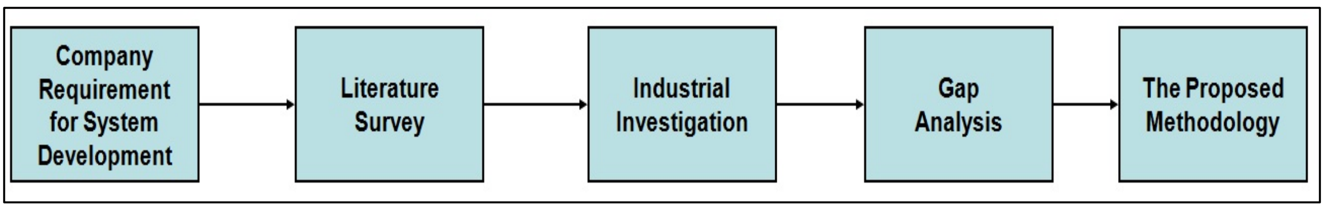

Figure 5.1 – The Process of Developing the Proposed Methodology

5.2 Improving Collaboration for Rapid Prototyping in Automotive Industries

Based on literature review and industrial investigations, it has been clear to identify that during rapid prototyping in industry, very strong knowledge collaboration procedures are required which would allow OEMs and suppliers to work together to develop better prototypes in shorter times and at lower costs. Therefore, in industries such as automotive companies, when they extend manufacturing environments, improved rapid prototyping would give them the opportunity to make better decisions during new product developments. Rapid prototyping in automotive industries would allow them to have a quick production of model parts for demonstration, evaluation or testing. Sample parts such as windscreens, side glass and rear glass in automobiles are typically fabricated directly from computer models, using advanced layer manufacturing technologies. However, rapid prototyping in new product development would bring automotive and collaboration companies procedures to reduce development times, allow design changes to be rapidly implemented and tested, avoid expensive mistakes, limit sustaining engineering alterations and extend the lifetime of a product by adding necessary features and removing redundant features in the design stages of automobile equipment.

With reference to the literature review and industrial investigation, the process of new product development (NPD), collaboration methodology and rapid prototyping development processes have been introduced and discussed. It was possible to determine that the main function of using rapid prototype in automotive and collaborating industries could be to develop and improve the current knowledge exchange cycle which would bring better collaborative procedure in industries. Therefore, knowledge exchange cycle, collaboration methodology and process of support and development of rapid prototyping in automotive industries for new product development will be the focus.

The main purpose here is to understand that during rapid prototyping in developing new products, where knowledge exists between industries so that collaborative frameworks can be designed to achieve better knowledge management and system decision making process with reduced costs and production lead times. The traditional collaboration methodology to support rapid prototyping in extended manufacturing facilities includes four interactive steps that relate to the industrial collaboration. The first step is to broadcast key component characteristics. It means that at different design stages the designer needs to broadcast the product design specification for evaluation and early facilitation of rapid prototyping. Design teams that provide communication and coordination with other functional groups in collaborating industries should support the process. Furthermore, over prescribed design parameters lead to a lack of flexibility in process and equipment selection and in many cases inefficient manufacturing. The second step is to generate process design solutions. The generation of processing alternatives should be conducted by manufacturing system design teams. Using that knowledge would allow the industrial designers to modify a feature transition of design perspectives to set of company specific process sequences, which can be used for producing the feature shape of automobile components. The third step is the generation of extended facility solution. Selection of rapid prototype facility resources is performed by facility planning of design teams to processing capabilities of extended enterprise that meets all product requirements. At this level, the rapid prototype planning process targets to the generation of complete component process within the outline rapid prototype facility boundaries. The final set of this distributed design evolution methodology is the selection of potential manufacturing resources such as machinery and rapid prototyping equipment. The final step is the moderation of the product and facility design decision.

From the literature review, it is possible to modify the knowledge sharing cycle methodology as a tool that allows interactive analysis of product and facility of rapid prototyping at early design and planning stages. This can be achieved through project moderator teams that produce comparative cost estimates by considering a set of factors including numbers of automobile parts and tools required to develop the rapid prototype.

In order to support the rapid prototype for new product development in automotive industries, it requires to flowing the knowledge on the evolution of collaboration procedures. On one hand, automotive and collaborative industries should designate resources to enable knowledge sharing. On the other hand, designers or engineers in collaborative industries should systematically gather and exchange design perspectives results to develop the rapid prototype. However, to improve the collaboration in developing the rapid prototype for new product development, it requires a knowledge management approach. It means that, in collaboration industries they should be allowed to access all design perspective at any stages of design development that would be required.

The function of using KSF in automotive and collaborating industries would be that to have a better comprehensive knowledge exchange cycle accrues the different design perspectives and improve the methodology to develop rapid prototype for new product development.

Within this model of collaboration, the design teams in industries in the process of developing the new product firstly need to establish agreement as to the design requirements to develop the rapid prototype for automobile parts. However, the object structure within the rapid prototyping process requirements can be used to reflect the division of design tasks between the two industries. Once agreed, the shared knowledge requirement of automobile part design can be duplicated to provide of the KSF and elaborated by each collaborative companies. It would be necessary at this stage of KSF, that to recombine elements of independent automobile part design into shared conceptual models. One important reason for automotive and collaborative companies is that they need to specify the interface between parts elements of the decomposed design problem, as well as checking rapid prototype design development progress.

The conceptual stage to developing a rapid prototype design specification in the KSF can then be exported and recombined with design of automobile design parts representation that were not shared with collaborative companies to meet aspects of rapid prototype development. However, if collaborative industries cannot wish to share some of they design perspectives with automotive companies, the private conceptual models can be developed for them and re-represented into archives. This process of knowledge exchange cycle can only not help automotive and collaborative industries to support the rapid prototype development to developing new product but can also help them to reduce the cost of production and better control the cost of production.

Nevertheless, KSF can provide support for the cautious sharing of design knowledge in new product development between automotive and collaboration industries. KSF can also support either the handover of design history to the industries or collaborative design among teams from different organisations. Also, KSF would helps to support the consistent omission of parts of the design aspects as well as the generalisation and specialisation of design perspectives. However, in the terms of collaboration in industries, KSF can be beneficial in a way to support knowledge sharing and management of design process in developing a rapid prototyping.

5.3 The Development of the Knowledge Framework

Knowledge maps have been applied to the automotive industries to support rapid prototyping response problems in research domains as diverse as Economics, for example Howard (1989), and Education, as reported in McCagg and Dansereau (1991). More recently, the knowledge sharing literature has identified the knowledge map as a key tool for understanding knowledge flows and communicating knowledge within a business (Hansen and Kautz, 2004; Burnett et al, 2004). Eppler (2001) discussed how knowledge maps might be used to improve knowledge sharing processes such as product development by contextualising information and connecting it with pertinent sources of expertise and experience. According to Wexler (2001), in this way the information is made ‘actionable’, creating knowledge in the minds of the map users. Moreover Wexler (2001) claimed that knowledge maps are an effective means for organisations to capture, disseminate and share knowledge in most automotive manufacturer.

A widely cited definition of a knowledge map in the context of knowledge sharing process in automobile industry was provided by Vail (1999): ‘A knowledge map is the visual display of captured information and relationships, which enables the communication and designer of knowledge by observers with differing backgrounds at multiple levels of detail.’ Davenport and Prusak (1998) commented that knowledge maps do not actually hold the knowledge they represent, but rather they provide pointers to the knowledge. Crucially, this level of abstraction allows knowledge maps not only to point to sources of information like documents, but also to direct attention to the knowledge possessed by people, an assertion supported by Vail (1999).

A Knowledge map is really a blanket term for several different types of map found in the literature. Wexler (2001) identified five types of knowledge map: competency maps, strategy maps, causal maps, cognitive maps and concept maps. Carnot et al. (2001) commented that concept maps are distinct from knowledge maps in that although they represent concepts connected by labelled links, they are mostly hierarchical in construction and contain concepts with single labels.

Eppler (2001) in contrast, viewed both concept maps and ‘cause’ maps as knowledge mapping techniques and proposed five types of knowledge map that might be used in a corporate environment. These were knowledge source maps, knowledge asset maps, knowledge development maps, knowledge structure maps and knowledge application maps. Of these types, knowledge application maps are perhaps the most relevant to this research, since they illustrate the type of knowledge required at a given phase of a business process and provide information about specific knowledge, such as its source. Eppler (2001) observed that individuals engaged in knowledge intensive processes like product development employ this type of map. It should be borne in mind that knowledge map in future would be used as supportive tools of knowledge sharing framework (KSF) to develop the research framework.

Two important enabling technologies for the application of knowledge maps in a collaborative product development environment are the Microsoft office and the World Wide Web. These allow a knowledge map to be constructed and then presented as a 'clickable map' on a corporate Intranet (Eppler, 2001), in a form similar to the concept map browser tool introduced by Cañas et al. (2004). Additionally they afford access to the knowledge map for anybody within or collaborative company able to use a Web browser client.

5.4 The Knowledge Sharing Framework

As it has previously been describe, the knowledge sharing framework (KSF) for the collaboration between the automotive company and its suppliers are based on 3 key elements (1) a business process model consisting of its individual activities identified during the industrial investigation, (2) associated information/knowledge and (3) a communication mechanism.

Previously the first knowledge barrier as knowledge Map has been introduced. The next knowledge-sharing barrier is using a formal modelling methodology, called Design Roadmap (Park and Cutkosky, 1999). The basic elements of Design Roadmap are tasks and features. A Task (shown as a rectangle) is the primary unit of the process, which represents a function or knowledge sharing action in the process. A feature (shown as a rectangle with round corners) is the input and output of Tasks. The arrowed lines are used to represent the knowledge process flow and link the Tasks and Features of OEM together. The hash line represents a feedback loop from collaborative industries such as CarGlass in this research study. As the discussions in the literature review, DR uses rectangle to represent task, which is the main activity in the process and uses the rounded rectangle to represent the features, which are the inputs or outputs of the tasks. The arrows are used to represent the rapid prototype process flow and link the tasks and features together.

As shown in Figure 5.2, the Activity prior to this process model is Product Analysis with the marketing department and collaborative companies such as CarGlass in this research study. Its output is the Idea and demand specification statement, which is the starting point of this model. When the new Product Management Department in automotive industry receives the idea and demand statement from top management and market, the product concept proposal task can start.

As defined in the Design Roadmap, Tasks may include lower level sub-processed based on specific needs. The output of the product concept proposal Task is the set of possible product concepts plan, which is the input of the next Task propose structure, subsystems and components parts. In this task, there are more than one prototype product idea identified, and four of them should be defined as the output of this task. The selected initial product configurations of the possible product concepts, as input to the next Task, which is 'analyse feasibility of the possible concepts'.

In the practical situation, there are several possible prototype concepts generated. Therefore, all of these product concepts need to be evaluated and selected in the next task based on bills of materials of selected feasible concepts. After the bill of materials concepts has been reviewed then the input to the next task is to develop the physical prototype in automotive industries. The output of the task than is to initial physical prototype. From this stage, there would be a link to the collaboration industry such as CarGlass in this research study to get the feedback and improved the physical prototype of automobile design (In the figure 5.2 shown as communication level).

After receiving the feedback from collaborative industry, the next task is feasible analysis evaluation of prototype concepts that the output of this task would be to select on prototype design, which after the selection of prototype the output of the task is to improve the selected prototype. This means that if so far they have realised some of the prototype concepts if is not suitable for the further design, then they can improve from the output of this task.

The selected one needs to be evaluated with supplier and market. If the selected concept passes the evaluation, then the output of task concept will be identified and agreed. If the selected prototype concept does not pass the evaluation, there is a feedback loop (dashed line in the Figure 5.5) to the product concept proposal and the structure and components parts task and the process is repeated.

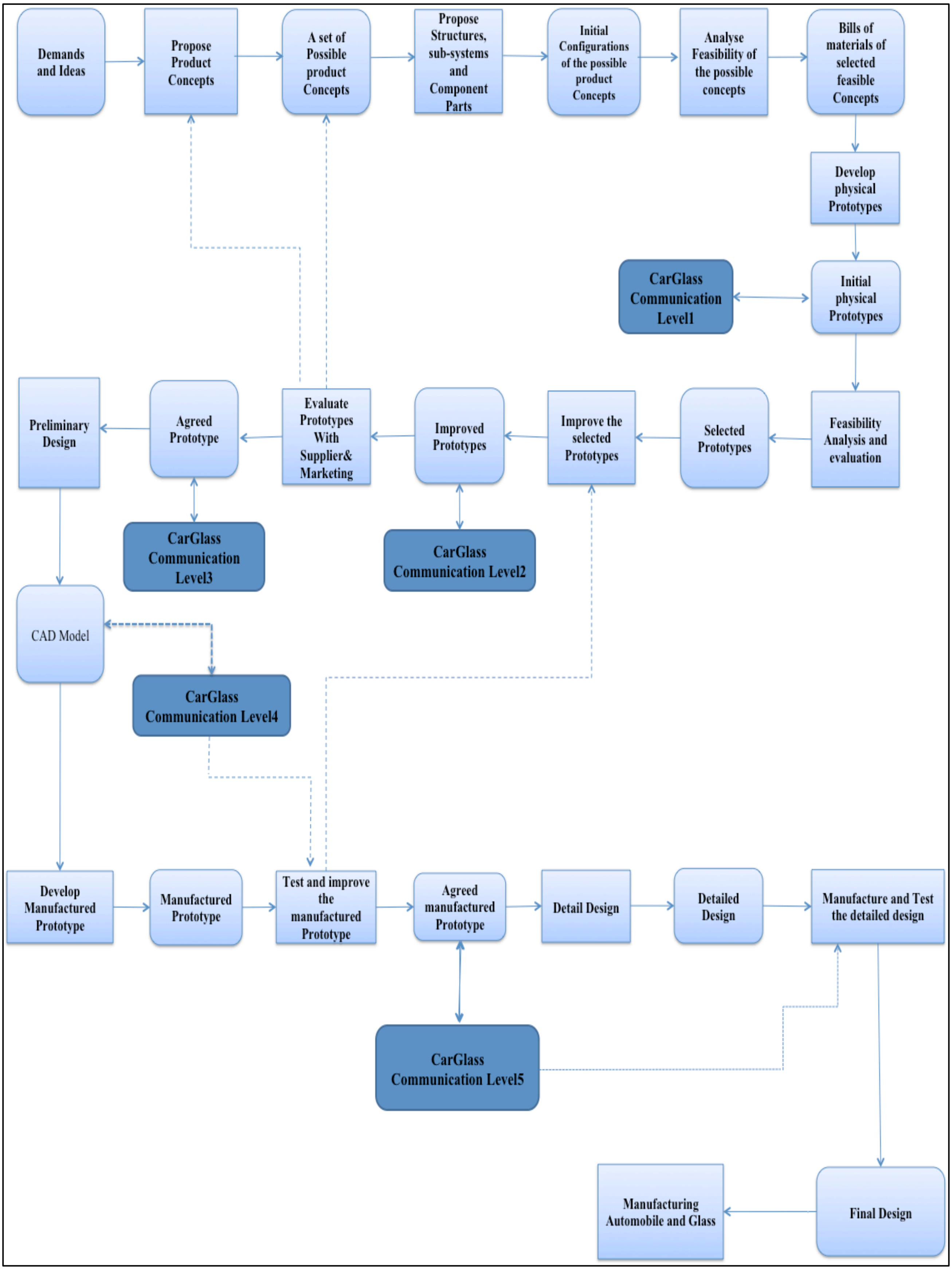

Figure5.2 -The Knowledge Sharing Framework Modelled Using Design Roadmap With Collaborate Companies

Then detailed specification will be generated based on the selected concept. After agreed the prototype by both automotive and collaborative industries such as CarGlass the next task of the process is the Preliminary Design specification of prototype. The preliminary design specification will be inputted to generate the CAD Model design, which it would be used in both industries, and develop and support the prototype.

The next Activity in this task now is to develop and manufacture the automobile prototype. It should bone in mind that from this stage, the concept of prototype would be reduced to one concept and output of this task is to manufacture the prototype, which would come to the next activity of testing and improving the prototype. If the selected prototype passes the test, then the output is to manufacture the prototype in both industries. If it does not pass the test, again it goes back to the task to be re-selected and improve the prototype and follow the process to improve the prototype.

The next activity of this process is to review the details design of both prototype from automotive and Glass industry. The output of this task is also to check the details design and if approved, the prototype would be manufactured and tested. In this activity the concept of details design would be reviewed and tested. The final design of the prototype and the output of this process are to manufacture and assemble the real product and release to the market.

5.5 The Knowledge Sharing Framework From the Glass Supplier Point of View (CarGlass)

As in the previous descriptions, the new product development has large possibility is led by requirements change rather than technology push in current manufacturing. In the automotive company, when a new product is being developed, the product will be viewed as an individual project. The structure of the project team should consist of product manager, who manages the whole product development, and the managers of each department, who are included in the product development process and sharing the knowledge with collaborative industries. As shown in Figure 5.2, knowledge sharing framework process to support the rapid prototype process in automotive company communicates with the glass industry (supplier) in 5 stages from collaborative company, which called communication levels. In some levels of the activities design roadmap process the automotive company has to transfer their knowledge to collaborative company CarGlass.

5.5.1 Communication Level 1

The communication level of this activities design roadmap in Figure 5.3 (level 1) would describe the process of improving rapid prototype concepts to develop the glass for automobile prototype. At the communication level 1, after the initial physical prototype is developed, CarGlass will review the process.

The first task at CarGlass Company is proposing the glass structure, sub-systems and components parts that would be in used to develop the prototypes. The output of this task is the conceptual level of analyse the glass shape, size, shape and thickness. The next task is to estimate the glass prototyping cost. It should be mentioned that at this stage the CarGlass Company is working on two prototype concepts for the project. The output of cost estimation in next level is to propose cost of two glass prototype concepts.

The next task, which it would be contain the important concept for the CarGlass, is to generate the prototype materials concepts requirements. After that the next task is schedule prototype concepts that would allow the company to propose the glass prototype concepts with estimation of total cost and manufacturing lead-time. After that they would refer back to the automotive company to follow next level of prototype processing.

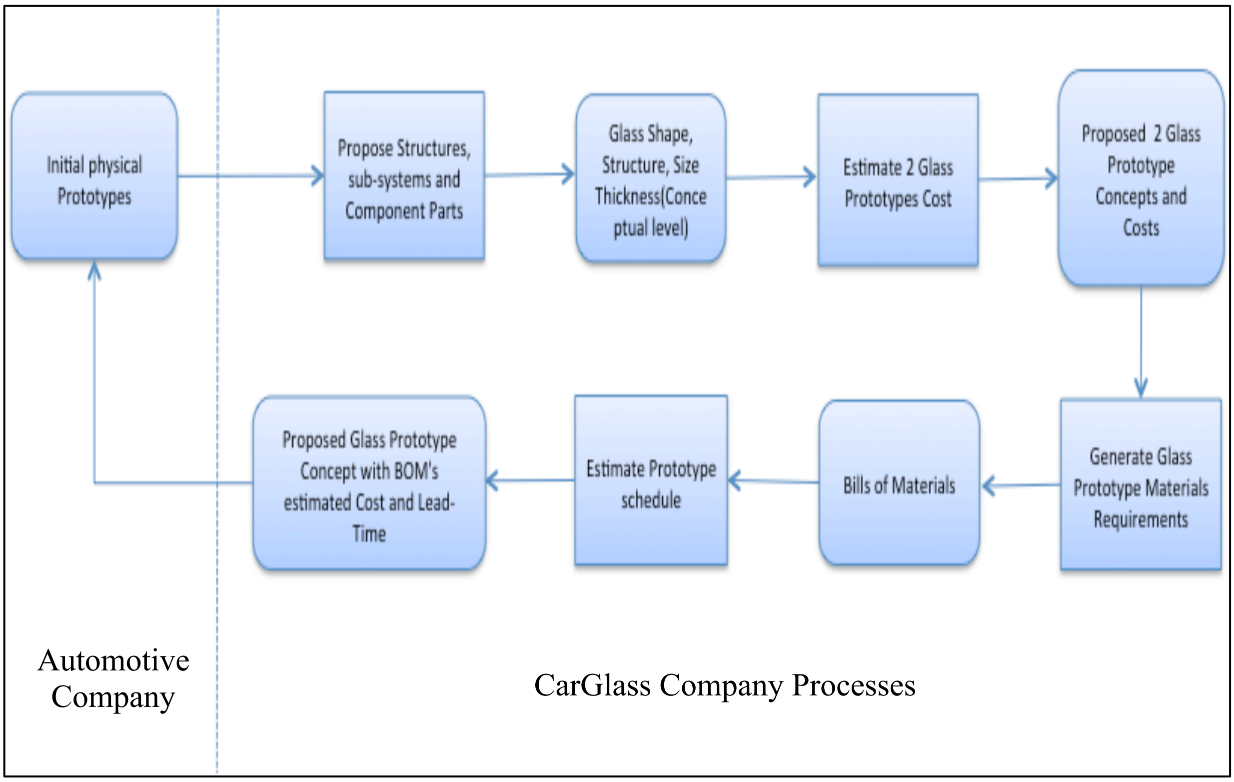

Figure 5.3 - CarGlass Processes Corresponding to Communication Level 1

5.5.2 Communication Level 2

In the next communication level 2 - after prototype Analysis has improved, the improved prototype concept will be imported to the CarGlass company to improve the knowledge and requirements based on the glass thickness, shape, dimensions and specifications which is the output of this task and is to improve the concept of further prototyping to support the task to generate more details of Bills of Materials and selected feasible Concepts respecting to the cost and lead-times. This level would also support communication level 3 (Figure 5.5) to improve the two prototype concepts and after analysis the cost and lead-time in communication level two they would refer back to automotive to have further improvement as shown in Figure 5.4.

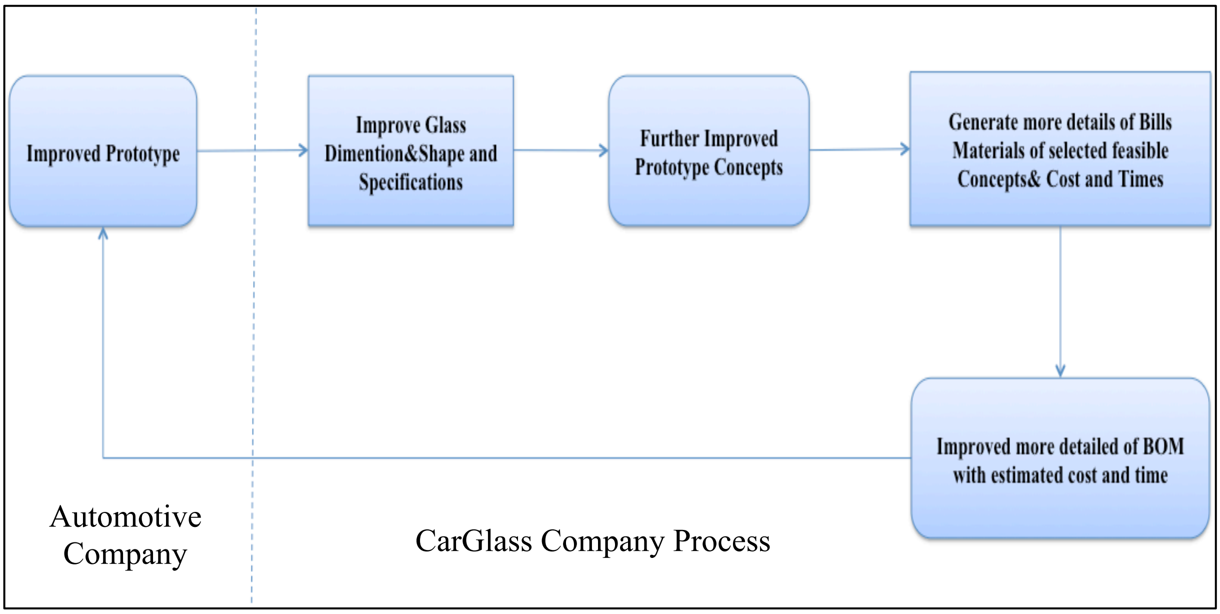

Figure 5.4 - CarGlass Processes Corresponding to Communication Level 2

5.5.3 Communication Level 3

In the next communication level 3 – after prototype Analysis has improved, the improved prototype concept will be imported to the CarGlass company to improved the knowledge and requirements based on Glass thickness, shape, dimensions and specifications which the output of this task is to improve the concept of further prototype to support the task to generate more detail of Bill Materials and selected feasible Concept respecting to the cost and lead-time. This level is also similar to communication level 2 (Figure 5.4) to improve the prototype concept and after analysis the cost and lead-time in communication level two they would refer back to automotive to have further improvement as shown in Figure 5.5.

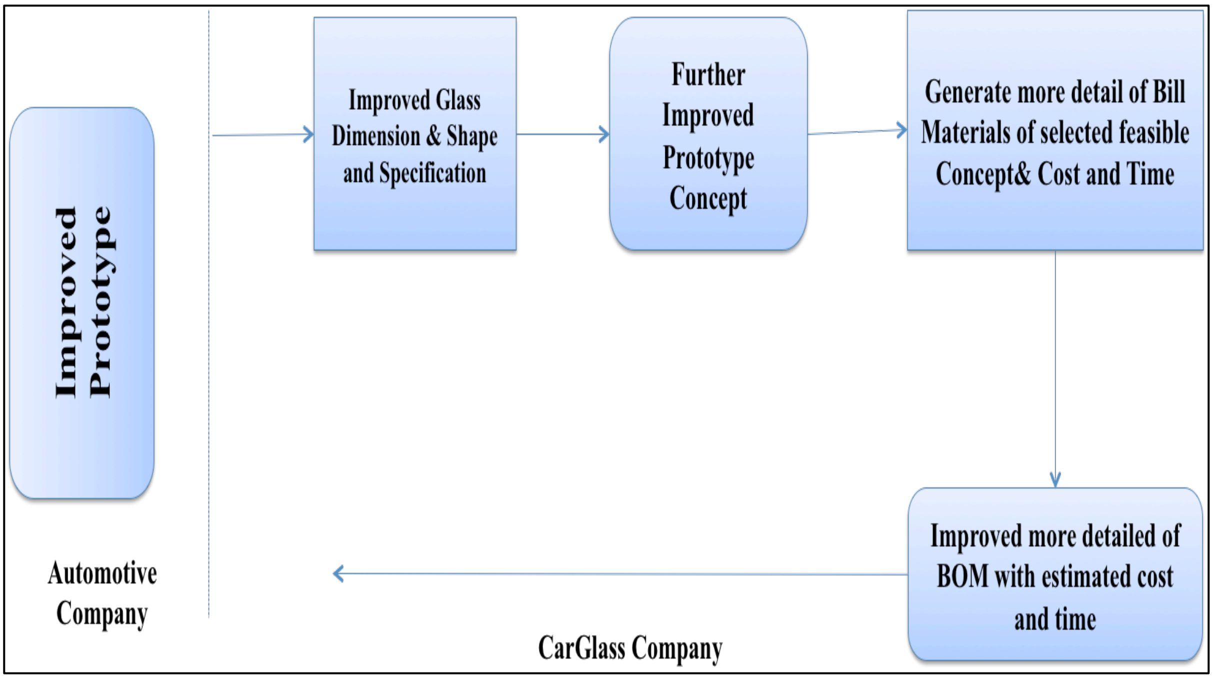

Figure 5.5 - CarGlass Processes Corresponding to Communication Level 3

5.5.4 Communication Level 4

In the next communication Activity level 4 (shown as Figure 5.6) is when the automotive industries preliminary design is approved than the CAD Model would be generated. From this level, it will be passed over to CarGlass to improve the two concepts of prototype and reduce down the concepts to the one. After the Development CAD model Plan is identified, the evaluation of glass concept with supplier would be reviewed. The output of this task is to improve and finalise the glass prototype to be reviewed by automotive preliminary glass design. From this task than CarGlass Company can generate they own CAD Model to support them to produce and manufacture actual glass prototype. After generating the actual glass prototype than CarGlass Company would be able to test and improve they prototype concept and pass it over to the automotive industry for the further and final improvement of prototype.

The appropriate Prototype Concept is tested, and there is a feedback loop from the Concept Test to Concepts Generation of CAD Model as shown as Figure 5.6, because if the prototype concept is tested failed, the new possible product concepts are generated and selected again until the prototype concept pass the test. Finally, the prototype concept is broken down and generated the design specification.

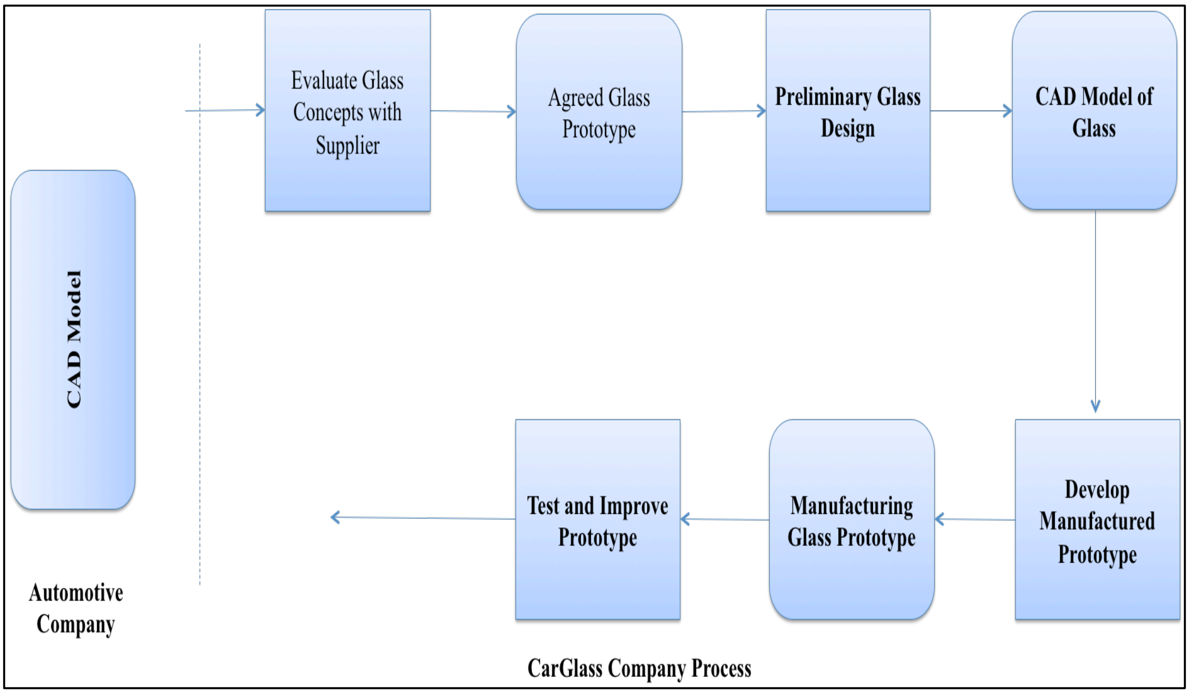

Figure 5.6 - CarGlass Processes Corresponding to Communication Level 4

5.5.5 Communication Level 5

In the next communication Activity level 5 (shown as Figure 5.7), the prototype design in system-level and detailed level based on the design specification has been approved and manufactured. All the design parameters are transferred to manufacturing parameters. Finally, the Manufacturing Specification will be developed in the Activity. Before manufacturing the product in batch production, the component and the holistic product need to produce prototype and be tested. As shown in Figure 5.7 when the Manufacturing Specification imported in the Activity, the components need to be produced a prototype, and then the prototype is tested. If the prototype has some problems, they will be refined until they pass the test.

After the component prototype passes the test, the components will be composed as a holistic product prototype and tested again and imported to the CarGlass Company. In CarGlass company the actual prototype would be reviewed and test with they own specification. After the improvement CarGlass Company will produce the actual product and assemble it with automobile. From this stage both industries would be consider the mass production of actual product. In the product development process, the product requirements are converted from customer requirements to manufacturing requirements. Each Activity always checks the requirements from the previous activity, in order to guarantee less misunderstanding and avoid unnecessary cost and developing time period. In the next section, the knowledge user's requirements of the knowledge management system design will be described and discussed.

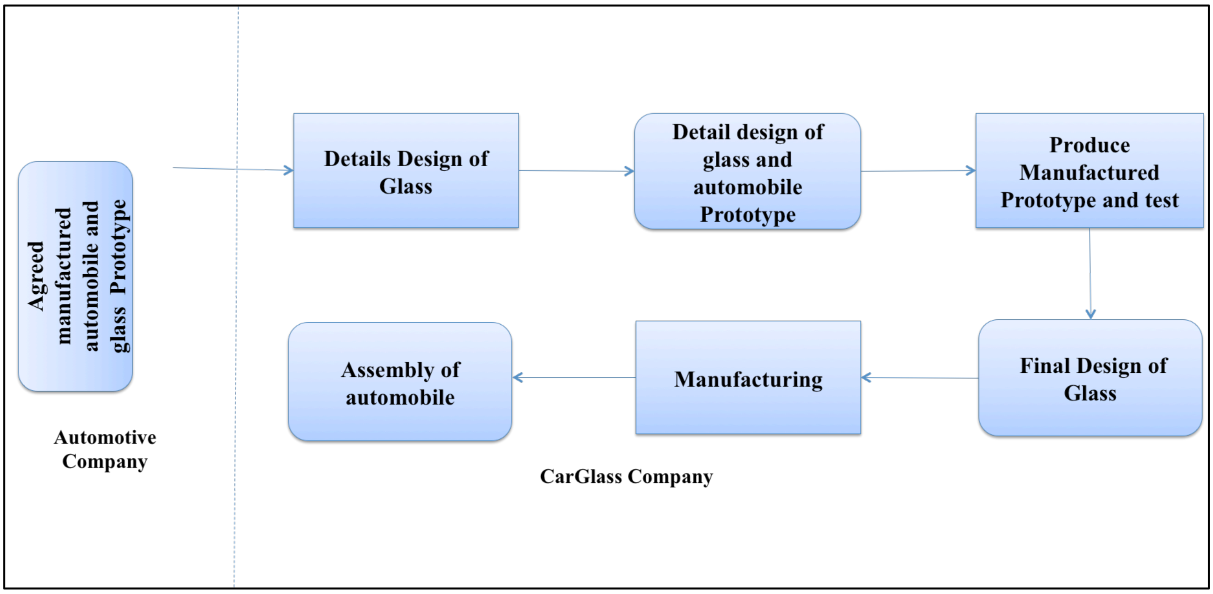

Figure 5.7 - CarGlass Processes Corresponding to Communication Level 5

In the practical situation, there are several possible product concepts generated. Therefore, all of these product concepts need to be evaluated and selected in the next task based on various constraints. The selected one needs to be tested. If the selected concept passes the test, the final product concept will be identified and broken down with details. If the selected product concept does not pass the test, there is a feedback loop (dashed line in the figure 5.7) to the product concept generation task and the process is repeated. The final output of the process is the design specification. The Roadmap design specification will be inputted to the Design Activity in the communication-level of industrial process.

Based on the industrial investigation and illustrations, the proposed methodology has been proved that it can be applied and implemented in the collaborative company. Although the case study does not cover the whole company, in one of the key departments it has been proved that it can be fully implemented in the real industrial environment.

One of the main problems is that the stage or activity of the industrial process is not fully matched with the functions in the department or groups. For example, the Product Management Department not only contain the functions of producing the product concepts, but also contain one group, which is to analyse the market and help the other departments to set up the cost and product lead time, which is one of the goal of this research study. The actual reason to allocate the department like this is that the product knowledge sharing between these departments is usually linked; therefore this structure is convenient and efficient.

5.6 Summary

The findings of the review of technology-based NPD knowledge sharing management concept in the literature indicated that further research is required into the development of tools to facilitate knowledge sharing in the new product development process by tackling the knowledge-sharing Road Map barrier. The new product management department is used as an example to show the full KS Design Roadmap (KSFDR) cycle works for the process at department level. This proposed methodology has several advantages. It can help companies to develop their knowledge sharing systems based on their own organisational structure.

In section 5.2 of the empirical investigation of knowledge sharing barriers in automotive industry, it was stated that the two barriers identified prevent NPD teams from achieving a shared or common understanding of the knowledge used and generated in the NPD process to support the rapid response in automotive and collaborative industry. A review was conducted of knowledge sharing technologies that are intended to encourage a shared understanding of a knowledge domain, as presented in section 5.3. Two approaches were considered: knowledge maps and Road Map. The findings of this review suggested that a KS Design Roadmap is employed as part of a knowledge sharing facilitation tool for an NPD environment. The KS Design Roadmap would allow the formal, explicit definition of information about NPD process knowledge to support the rapid response in automotive and collaborative industry.

Chapter 6

Implementation of Knowledge Sharing Framework

As discussed in the chapter 5, the requirement to the framework consists of a guideline (in the form of a flowchart), an improved Knowledge Sharing Framework (based on Roadmap), and a "Folder-based KSF Implementation". The proposed KSF has already been described and discussed in the last chapter. Before proceeding any further, it is worth noting that when 'knowledge' is referred to in the context of a knowledge base, it is defined differently to knowledge in the sense of rapid prototyping (RP) development process knowledge'. The objectives of Knowledge Sharing Framework implementation:

1. To illustrate the functionality of the DR framework, by using it to capture information about knowledge used and generated in Roadmap between CarGlass and IKD.

2. To determine what changes to the knowledge acquisition framework component of the knowledge sharing DR framework might be required as a result of capturing this information about knowledge.

The implementation involved demonstrating the functionality of the Knowledge Sharing Framework Design Roadmap (KSFDR), and providing a test of the knowledge sharing content classification used in the framework. This was carried out by using the knowledge acquisition framework component to capture information about knowledge used and generated by tasks and activity (as it has been described in figure 5.2) to supporting rapid response in the NPD business process of the case study company, between CarGlass and IKD.

6.1 The Folder Based KSF Implementation

The proposed Knowledge Sharing Framework (KSF) implementation was derived from coalescing key findings from the existing literature and industrial investigation. The framework seeks to implement the folder based DR to provide tools for better using the developed framework with a guideline for information system developers. As stated previously one aims to implement the improved Knowledge Sharing Framework in a simple and flexible way and is independent of any specific software. Any system developer in industry can use it with some basic knowledge to develop the knowledge system. The relevant support knowledge can be stored and managed using the folders that are similar to Microsoft filing folders. Any format of knowledge can be contained such as figures, processes, models and so on. The Folder based DR implementation contains all the concepts of Roadmap such as input and output of each stage of KSF circle as shown in figure 5.4. If system developers are not familiar with Knowledge Sharing Roadmap (KSRM) framework concepts, the framework is flexible enough to follow the instructions and requirements of each DR component to finish their own knowledge management system to develop the new Product.

The implementation contains a set of folders and several worksheets of Microsoft Excel. The worksheets provide links to the folders that contain the supporting knowledge for system development. System developers can make use of the contained knowledge of each element of the Improved KSF. System developers can directly use the guidelines to develop their own knowledge sharing system. If system developers want to further understand the contents of the three elements of the Improved KSF, they can click the corresponding icons and then the folders will be opened (As stated in Figure 6.1).

When the proposed product concept of DR is clicked, the main iteration will come up in another Excel worksheet. System developers can click any stage of Design Roadmap Perspective (DRP) to get guideline on any necessary data to support the rapid response in automotive and collaborative industries, such as, how to develop that stage including any inputs, outputs, procedures, details design, and design specification as described in section 5.4. Alternatively, if any collaborative or automotive industry developers want to check the contents of any stage for they NPD, they will also click that stage of DR and find its contents (as shown in Figure 6.2).

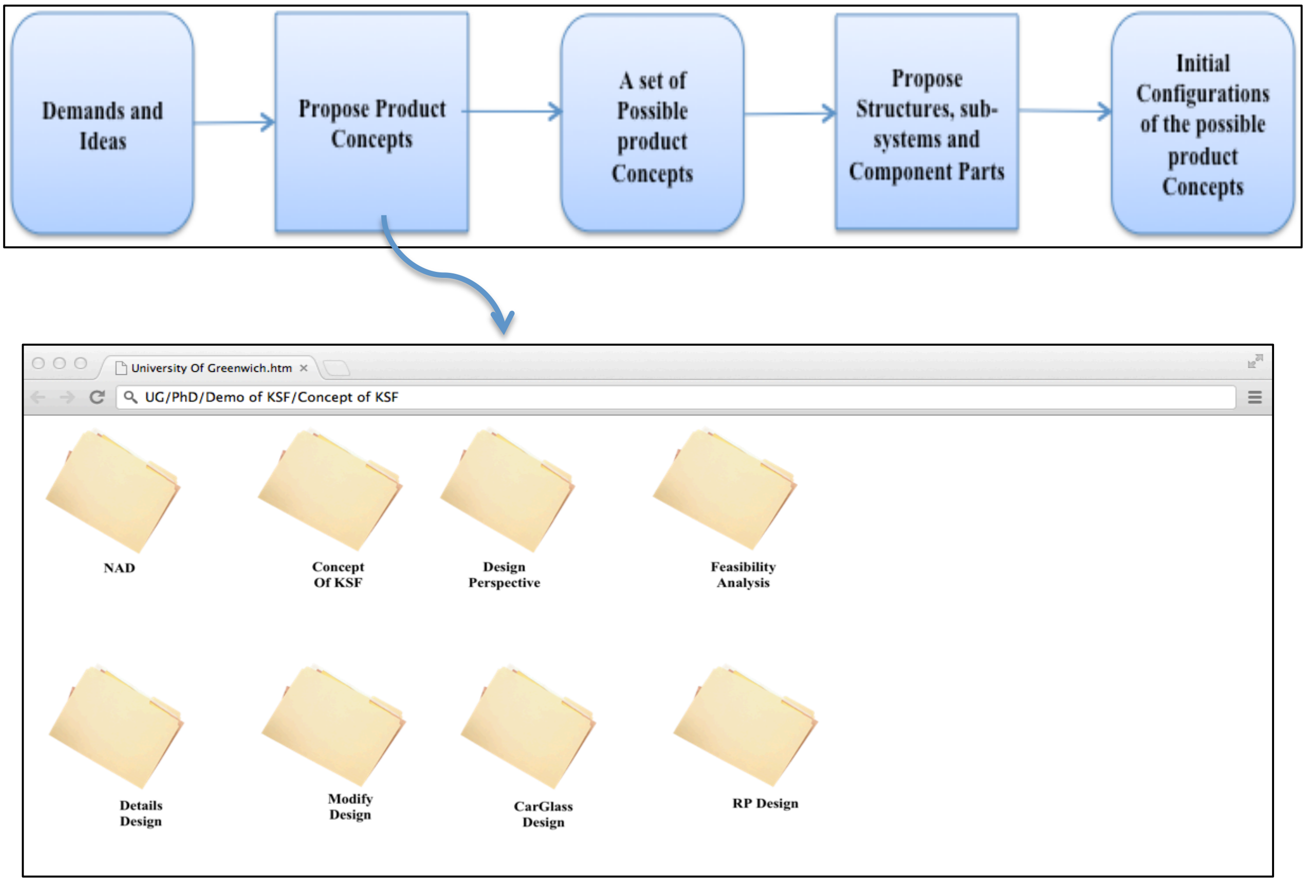

Figure 6.1- Links Between The Main KSF Interface and the Developed Folders

Figure 6.2 represents the links of DR stage from Analyse Feasibility of the possible concepts to the corresponding folders that are represented by an individual folder. The folder contains the relevant knowledge of the corresponding stage in the DR circle. Figure 6.2 shows two example folders of the Design Perspective and Concept of RP.

The first example is Analyse Feasibility of the possible concepts. As mentioned previously in chapter 4 and 5, due to the competitive natures of the market, industries do not wish to exchange and share all of the knowledge. The developed methodology in this research study concerns both efficiency and capability of knowledge user's requirement. Also, it's shown the design and knowledge sharing in requirement management folder, i.e., detail design folders, possible product concept, collaborative product concept and analysis feasibility concept folder. Each of these folders contain the documents to help the automotive industry with respect to collaborative knowledge industry at any time that is requires. Therefore, it is the relevant knowledge; ready for invoking when it is required. As previously discussed in section 5.4 when automotive industry finalise their details design with their collaborator such as CarGlass they can review it and, even work on the collaborative part at same time, which can reduce the production lead time and costs which was a primary goal of this research project.

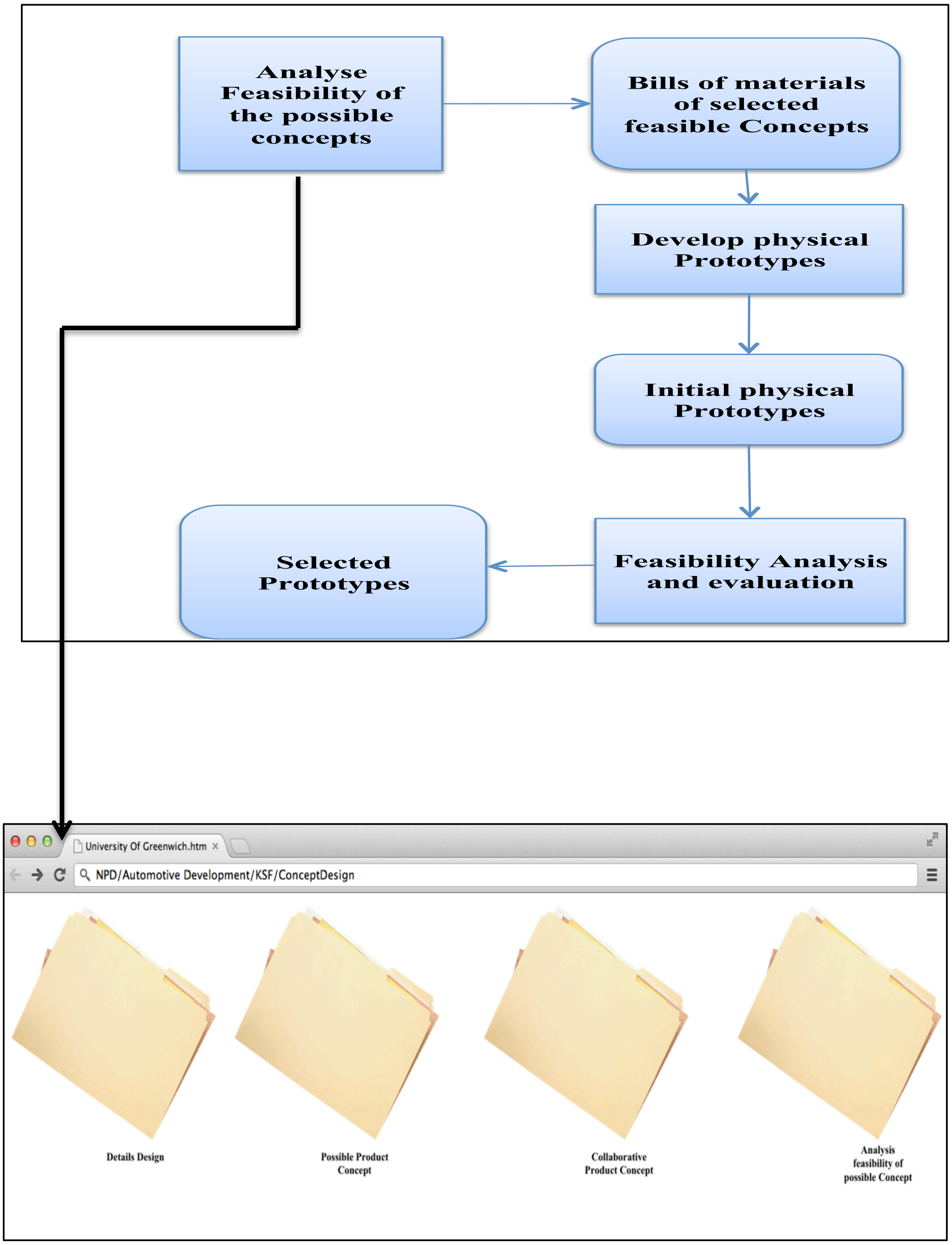

Figure 6.2 – Links between KSF and Corresponding Folders

The second example shown in Figure 6.3 is the improved prototype that contains three main elements: design concept, automotive structure, sub-systems & components and describe design perspective. These three elements support system developers to build the design

Perspective to support the rapid prototyping in NPD. The design concept and automotive structure, sub-systems & components are the supporting knowledge when the design perspective is developed. As discussed previously, the design concept is the main structure of the design perspective. Design concept folder is contains the main concepts of NPD to support the rapid response based on each department and group for further development of rapid prototyping.

Some points of the KS roadmap framework have been explained and the rest of the elements of the main KSF interface are simple to follow. System developers simply need to click them, and then the contents can be brought up. The contents include the relevant knowledge and the development methods.

The main advantage of the folder-based KSF implementation is that it provides an easy-to-use method of applying the proposed methodology. System developers can understand the perspective of their knowledge sharing system by following the simple interfaces and guidelines in the form of flow chart. The relevant knowledge can be easily stored in the computer folders. It provides a flexible way to manage any format of knowledge, such as processes, models and reports. The details of the "Folder-based KSF Implementation" will be provided in Appendix B

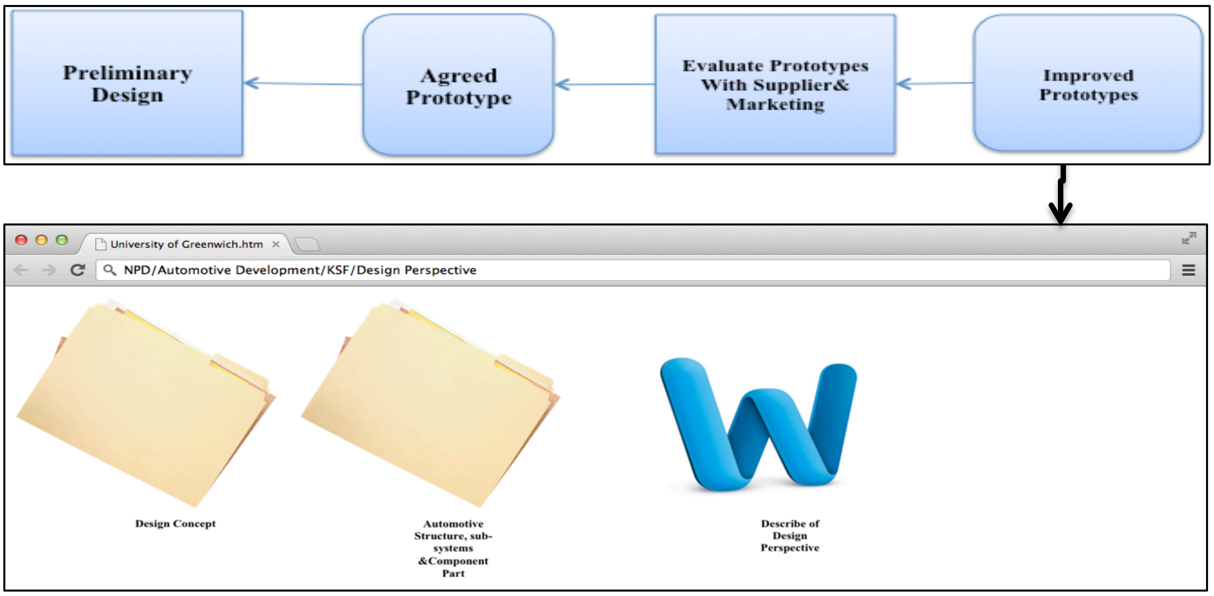

Figure 6.3 – Links between KSF and Corresponding Folders

6.2 Overview of the KSFDR System Development in CarGlass Company

This Roadmap framework includes steps to capture, share and analyse industrial knowledge and specific knowledge for the automotive and collaborative industry to develop the rapid prototype in NPD. A case study for this knowledge sharing framework and the folder based KSF implementation that will be described in section 6.3.

In this research study the aim of any system and software development project is to transfer knowledge and data specifications required for developing the rapid response in automotive and collaborative industries. However, requirements for knowledge sharing systems tools are more complex for traditional IT system. More companies find that a set of single numbers and facts in databases do not mean much and are sufficient for making decisions in the current business environment. Sometimes knowledge users cannot clarify exactly what knowledge they require and generate. Therefore, knowledge sharing DR framework can help system developers specify knowledge requirements and generate knowledge to support rapid response. The framework provides a process that is concerned with both automotive and collaborative knowledge, which is required at the same time, in order to develop system specification through capturing, analysing and integrating knowledge.

When automotive industry reached the position of initial physical prototype (as shown in Figure 5.2) than the collaborative industry automatically will be involved to follow the procedure and start working on they parts which known as communication level. In figure 6.4 collaborative companies such as CarGlass in communication Level 1, knowledge would be transfer to collaborators and they will be start to work from the first task as structure, sub-systems and components parts that would be in used to develop the Glass prototypes.

The task and output features in communication level 1 contains the documents inside which collaborators designer by clicked each folder, the main iteration will come up in another Excel worksheet. As it shown in figure 6.5 structures, sub-systems and components parts task contains 4 documents inside such as, concept design, glass design perspective, bill of materials and costs.

Once instances of real NPD tasks and knowledge items have been added to the KSF tool to create a knowledge base DR, it is envisaged that a collaborator user such as CarGlass would navigate the instances of tasks relevant to their role in order to discover information on pertinent knowledge items.

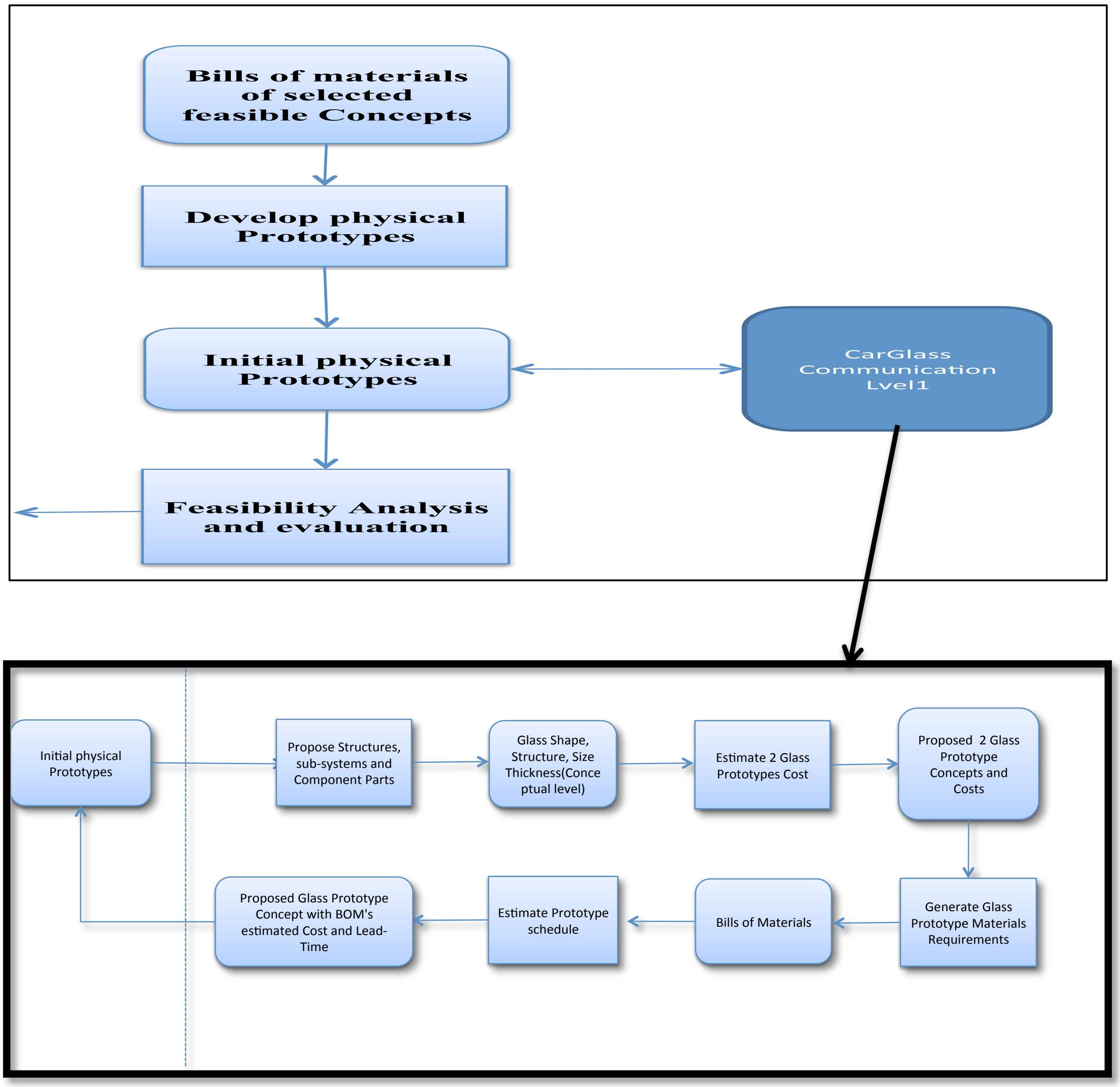

Figure 6.4 – Links between DR and Communication Level 1

The NPD business process based on DR provides a common reference point because it is used by all the functions participating in an NPD project in different industry in same time. Indeed, the class hierarchy representing the KSF process itself constitutes the backbone to the tool. A project team leader, designer or project manager on the other hand, may wish to understand the significance of a given knowledge item within the process and seek information such as what tasks require or generate that knowledge. In this case, they may search for a knowledge item directly and see which tasks contribute to the creation of that item, and which tasks are dependent on it. CarGlass system developers simply need to click them, and then the contents can be brought up. The contents include the relevant knowledge and the development methods. The rest of communication levels are simple to follow.

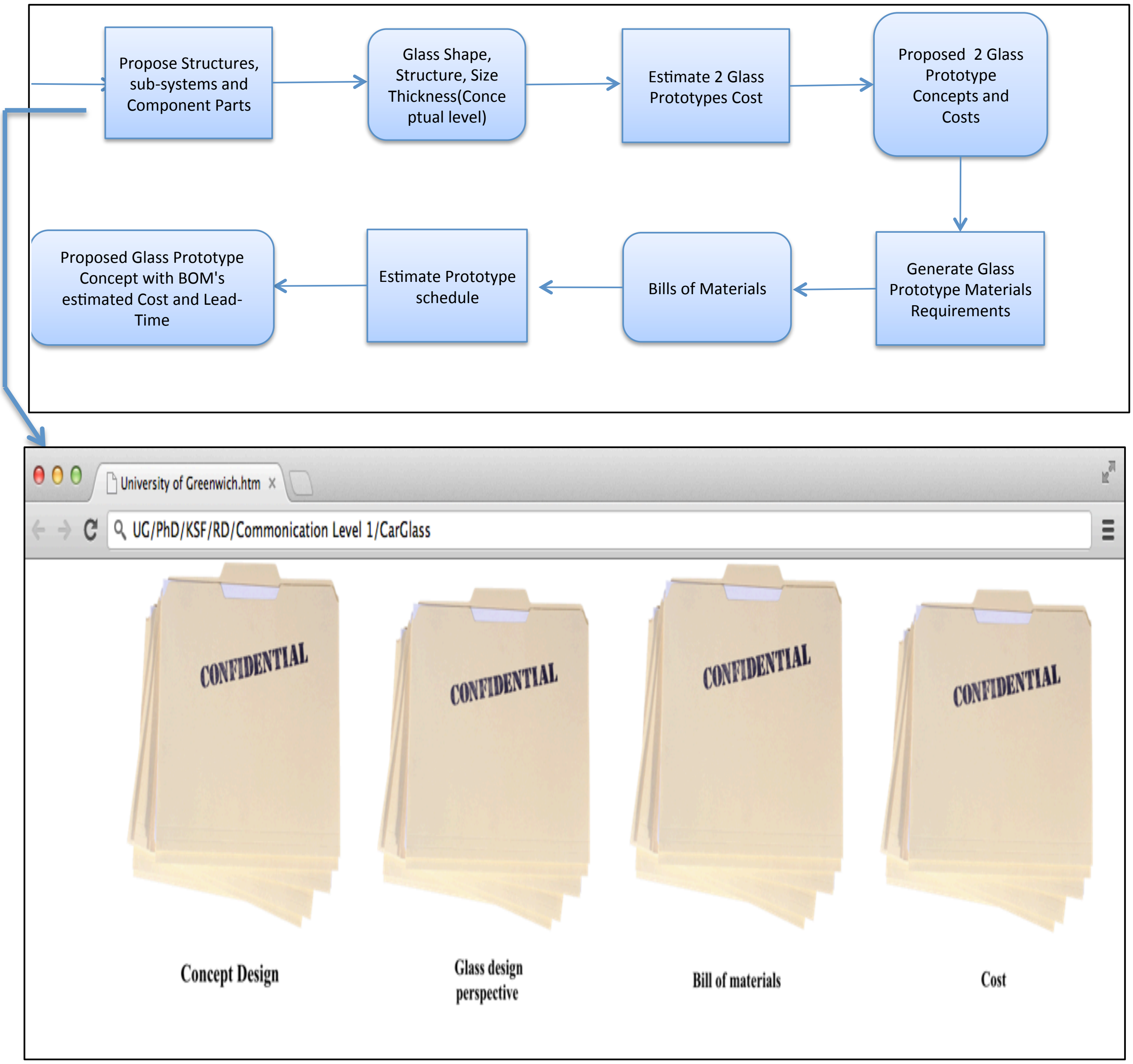

Figure 6.5 – Links between Communication Level and Corresponding Folders

Since there a large amount of relevant documents and knowledge in the Communication Level DR is to be considered, therefore, there will be available in appendix B to be followed. In DR framework, firstly, each element, including tasks and features, needs to be modelled as a single folder. There are two main elements of the guideline based on Design Roadmap technique. The task represents activity of the process, and the feature represents input and output of the process. Therefore, folders for these two different elements need to be developed separately. Figure 6.6 shows an example of links and document inside Framework between the DR and its relevant folders in communication levels

Figure 6.6 - links and Document Inside Framework DR in Communication Levels

As figure 6.6 shown, all folders of the tasks in DR contains in communication level processes. This process shows the procedure to the system developer in CarGlass Company. The procedure to produce glass for automobiles normally contains several steps, and potential problems, which might occur during the process. Comparing tasks, the folder for the feature contains relevant knowledge that can reduce these problems acceptable level. It should bone in mind that this knowledge is not only supporting knowledge for the next stage in collaborative company, but also generated knowledge from the last stage. This knowledge can be in any format, such as report, models, processes, CAD model and meeting minutes. All of these folders exist individually in the Folder-based DR implementation.

The aims of the folder based DR prioritisation mechanism in industries are, firstly to provide a means of indicating the priority of a given knowledge item and secondly to provide a way to assign criteria knowledge to each communication level between automotive and collaborative industries to support the rapid response with respect to RP development in NPD.

Lambrix et al. (2003) noted that DR has been designed 'as an easy to use tool for knowledge extraction'. An evaluation of the tool was carried out by Lambrix et al., which addressed usability issues such as DR tools to visualise the framework and the complexity of the user interface. They praised the graphical, tabbed pane interface approach adopted by the DR framework. They noted: 'This approach gives the user a good overview and feeling of control' and the tool was 'easy to learn'. Due to limited time, it was not possible to illustrate all documents and folder inside KSFDR.

6.3 Implementation of the Knowledge Sharing Framework Using Case Studies

An industry based case study was undertaken in order to illustrate the functionality of the knowledge sharing framework DR tool by using it capture information about knowledge used in a real new product development (NPD) process, and to provide an albeit limited test of the knowledge sharing domain classification in the framework to support rapid response to develop the RP between IKD as automotive company and CarGlass as glass supplier. Case study has also been used for the testing the Knowledge Sharing Framework Design Roadmap (KSFDR) to support the rapid response in respect of rapid prototype development in automotive and collaborative industries, by Ramesh and Tiwana (1999), and Donnellan and Fitzgerald (2004).

The setting for the case study was glass manufacturing for new automobile prototype between CarGlass and IKD Company in Iran, which as explained in the earlier stages of this research study and research was conducted under the auspices of CarGlass Company. In chapter five, it was established that the automotive and CarGlass Company should use KSFDR multifunctional stage-gate-type process to support KSF to develop the RP in new product development projects. As it has been introduced previously in figure 5.2, the model of this KSFDR consists of several stages or phases which is starts from: demand and ideas, propose product concepts, A set of possible product concepts, propose structures, sub-systems and Component Parts, Initial Configurations of the possible product Concepts and so on. Each of these stages is broken down into sub-processes, which are further broken down into activities, henceforth to be referred to as 'tasks'. The hierarchy of phases, sub-processes and tasks is illustrated in Figure 6.7, in which each titled box represents a phase at the phase level, a sub-process at the sub-process level and a task at the task level. Also, figure 6.8 presents the stage from proposed product concepts and all documents that will be located inside which automotive industry would be followed to support the NPD.

Since these tasks were the lowest and most detailed level of activity described in the KSFDR process documentation and available to RP development process in automotive and collaborators companies, it was this level of the process hierarchy that was chosen for analysis in the case studies. Each task requires certain knowledge inputs in order to be carried out, and also generates knowledge items, as depicted in Figure 6.7.

Given that the entire KSFDR process for both the automotive and CarGlass Company as collaborator company, in this research project consists of dozens of sub-processes and hundreds of tasks and activities, it would not be possible to capture information about the knowledge associated with all of these tasks in the available time. Some critical data would be available in appendix B but it was decided that the scope of the investigation should be confined to the knowledge inputs and outputs for a selection of tasks in RP response between IKD and CarGlass.

As it has been mentioned previously, when the automotive industry decided to develop the new automobile, the first task that they would work on is demand and idea which information for this task would come from market, customers and other industries.

After the data was gathered and the task was completed, the next activity is the known propose product concept. Following a review of the automotive company in they NPD process, it was decided to select the processes from the propose product concepts. This is because the constituent processes and tasks of this phase demand that the sharing of knowledge between different functions of the NPD project team and involve knowledge from a broad spectrum of sources. These assertions are supported by, Ulrich and Eppinger (2003), and Zahay et al. (2004) respectively.

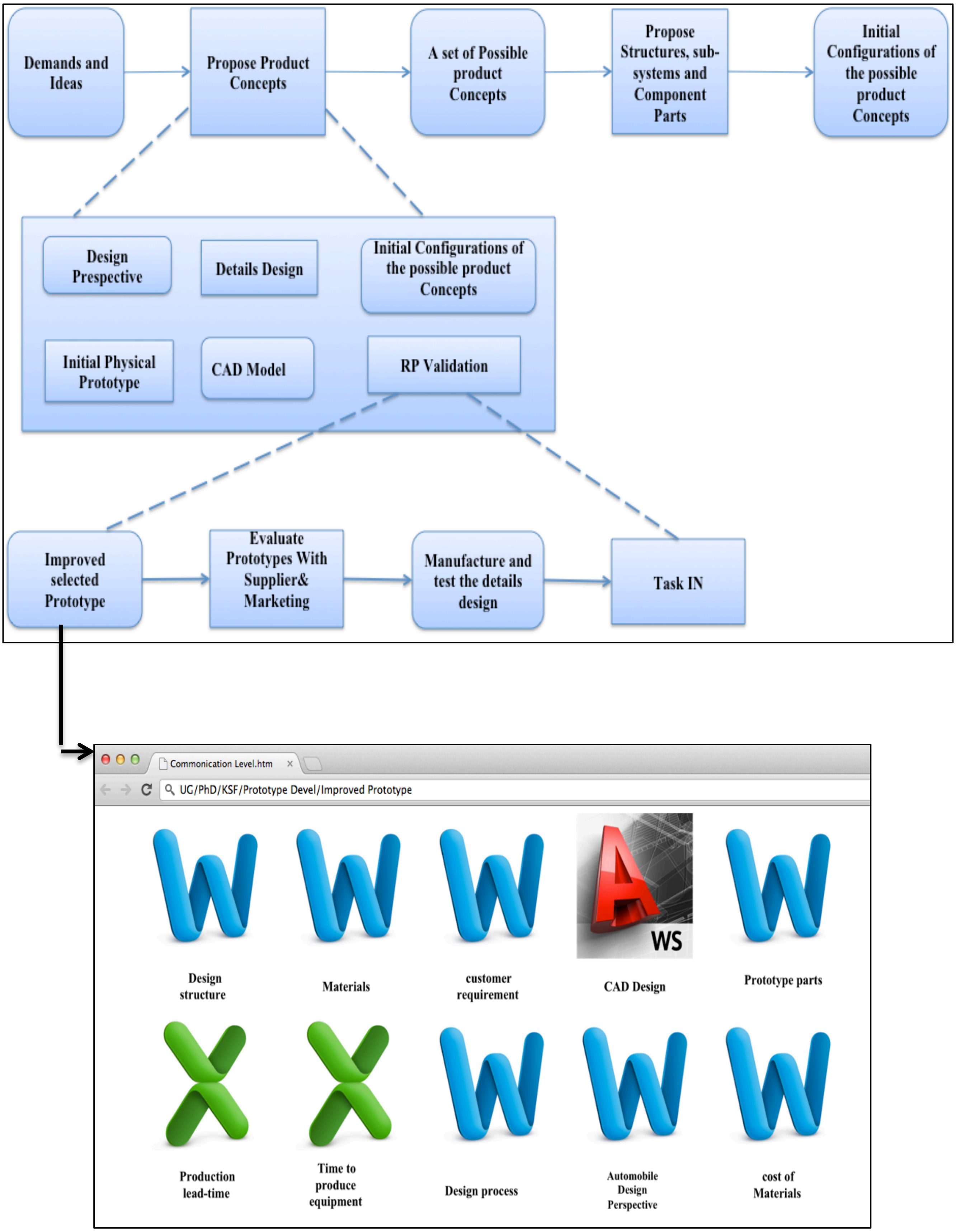

Figure 6.7- Shown KSF Phases, Sub-Processes, Tasks and Activates in the Case Study Between IKD and CarGlass Company.

Ulrich and Eppinger (2003) commented that 'the proposing product concept requires tremendous integration across the different functions on the development team'. Zahay et al. (2004) found that all eight types of information they identified in the NPD process were present in the product conception phase, which they referred to as the 'fuzzy front end'. Additionally, Hong (2004) highlighted product conception as the most important phase for knowledge sharing in a new product development project, commenting: 'It is in this stage that knowledge sharing among product development teams needs to occur'. The activities contains in the 'proposed product concepts' process are mostly of Design Perspective, Details Design, Initial Configuration of the Possible Product Concepts, Initial Physical Prototype, and CAD Model and the 'RP Validation' process.

The aim to generate the propose product concepts in KSF, is to convert product specifications provided by automotive and collaborators design and development departments into a rapid prototyping (RP) concept that could feasibly be developed into a real RP in the automotive industry. Also, the intention of RP validation is to establish a prototype evaluation and testing improvement plan and schedule that is tailored for the product to be developed in the project, and then to execute that plan according to the aforementioned schedule. RP validation involves the use of knowledge from a range of functional domains, including improved selected prototype, evaluate prototypes with customer and suppliers, Manufacture and test the details design.

In contrast, the tasks in the 'project performance' process use and generate knowledge associated with the stage-gate review at the end of each phase. This includes technical, cost and project management knowledge. From RP validation, the next task is to select and improve prototype, which inside contains all documents that would be, requires to support RP validation and KSF. As figure 6.7 shown it is possible that even at early stage of design the CAD model would be generated. In fact, CAD model aim is to produce a digital mock-up of a product concept.

The task requires various inputs, among them a component list and an assessment of the failure risk of the various components in the RP. One of activates task to supporting RP validation, as it shown in figure 6.8 is improved selected prototype. Inside this folder, which appears in figure 6.6 there is Word, Excel and CAD data. The word file contains such as design structure, materials, customer requirements, prototype parts, design processes, automobile design perspective, cost of materials and Excel files are production lead time and time to produce equipment and also CAD model (the CAD model will be explained in section 6.4). Inside each of these files there are documents that are supporting automotive industry to developing the new RP product. In figure 6.8, design structure, the file selected illustrates what documents are inside. One of the main advantages of this KSFDR is that it can contain all important of the documents in one place which can be reached at any stage when required, and gives a free hand to the automotive designers and engineers to share or combine their knowledge with other collaborative industries at any stage of production. From the literature survey and industrial investigation, it was possible to conclude that with this this KSF they can reduce their production risk, costs and production lead times up to higher acceptable level.

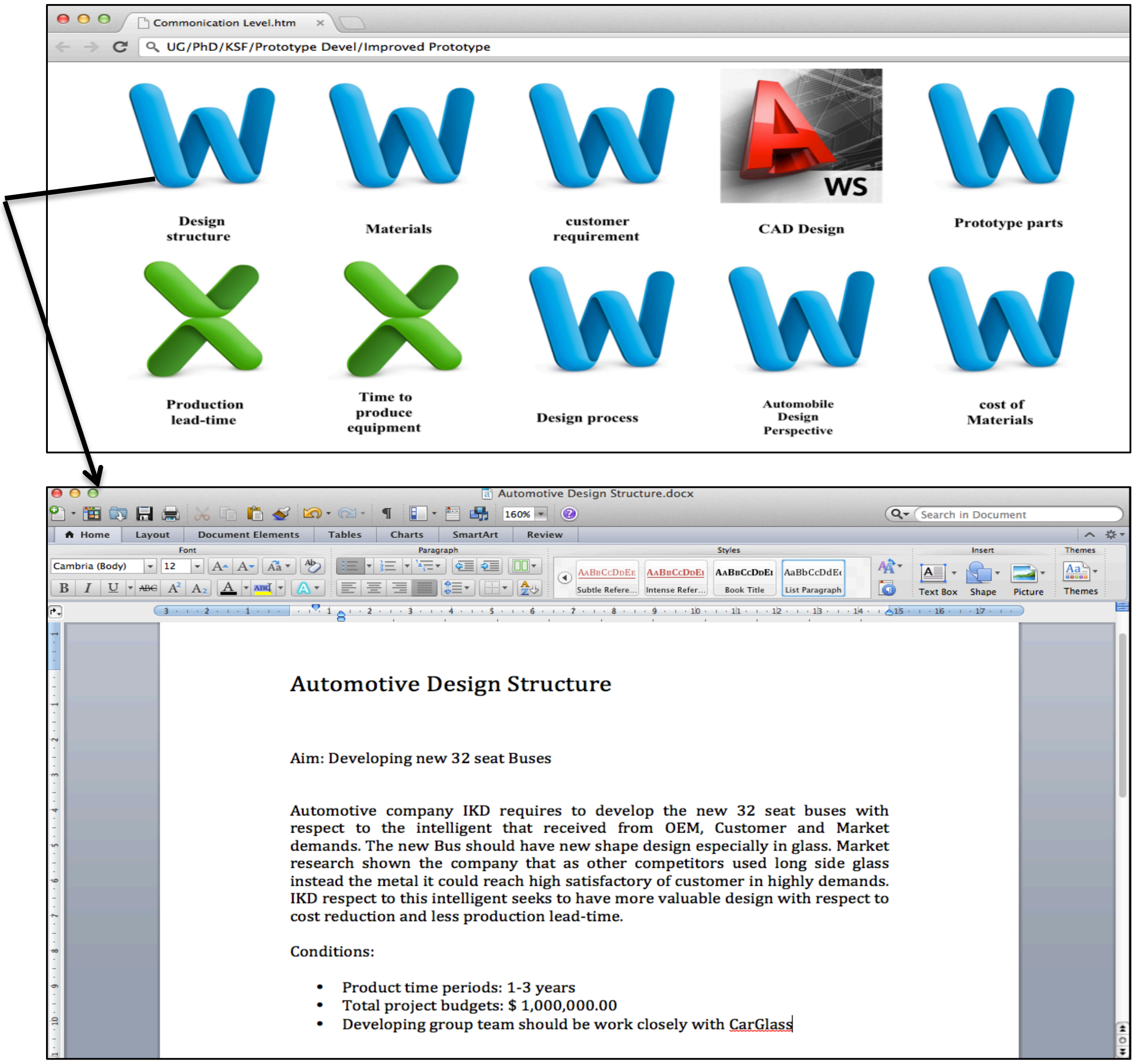

Figure 6.8 – Automotive Design Structure Implementation

6.4 Capture of Information and Knowledge Using the KSF

Capture of information about knowledge used in a selection of tasks and activities from KSFDR processes was carried out in three steps for each sub-process: capture of information about the automotive RP, capture of information about the CarGlass collaborative tasks, and capture of information about the knowledge items connected with those tasks.

As stated in the previous section, after generate the Demand and ideas the next task is propose product concepts, which is the most important task for NPD. One of the tasks inside this product concept is CAD model which respect to KSFDR should be generated at early stage of developments. Figure 6.9- shown CAD Model in KSFDR.

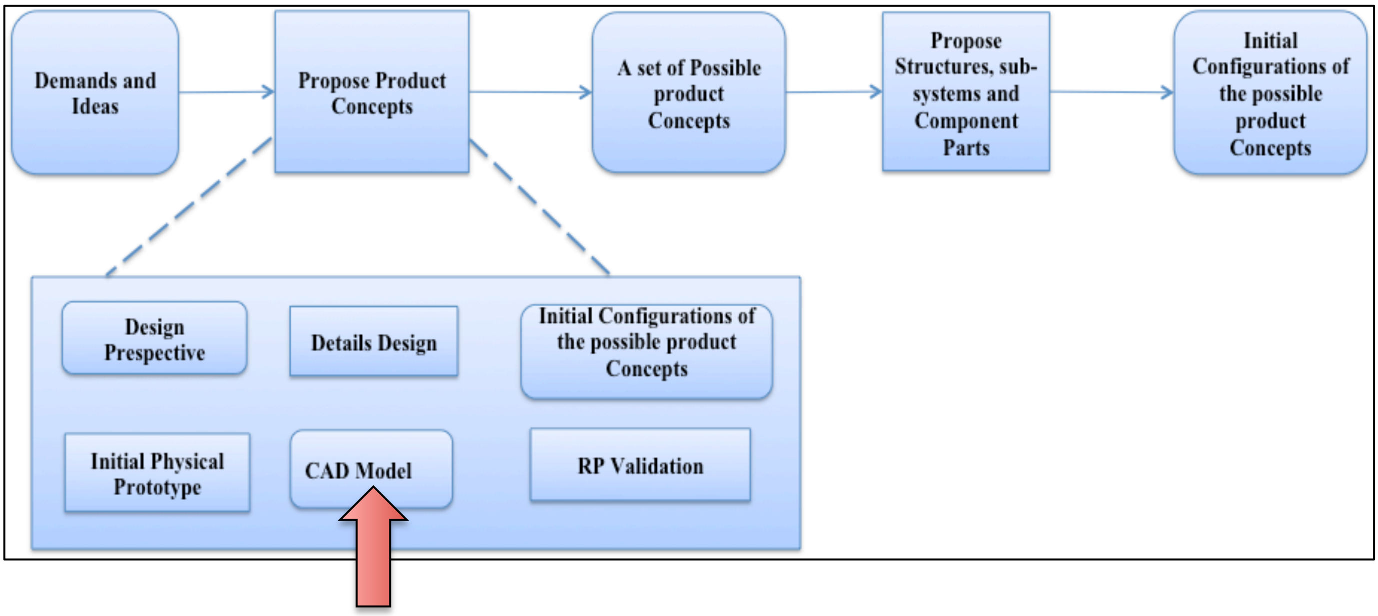

Figure 6.9 – CAD Model Location in KSFDR

As mentioned previously, CAD model assigned to product concepts' task, the aim is to produce a digital mock-up of a product concept. The CAD model requires various inputs, among them a component list and an assessment of the failure risk of the various components in the product. Figure 6.10 shown the early CAD model that generated by IKD at early stage of development and the file would be located and available in both IKD and CarGlass Company.

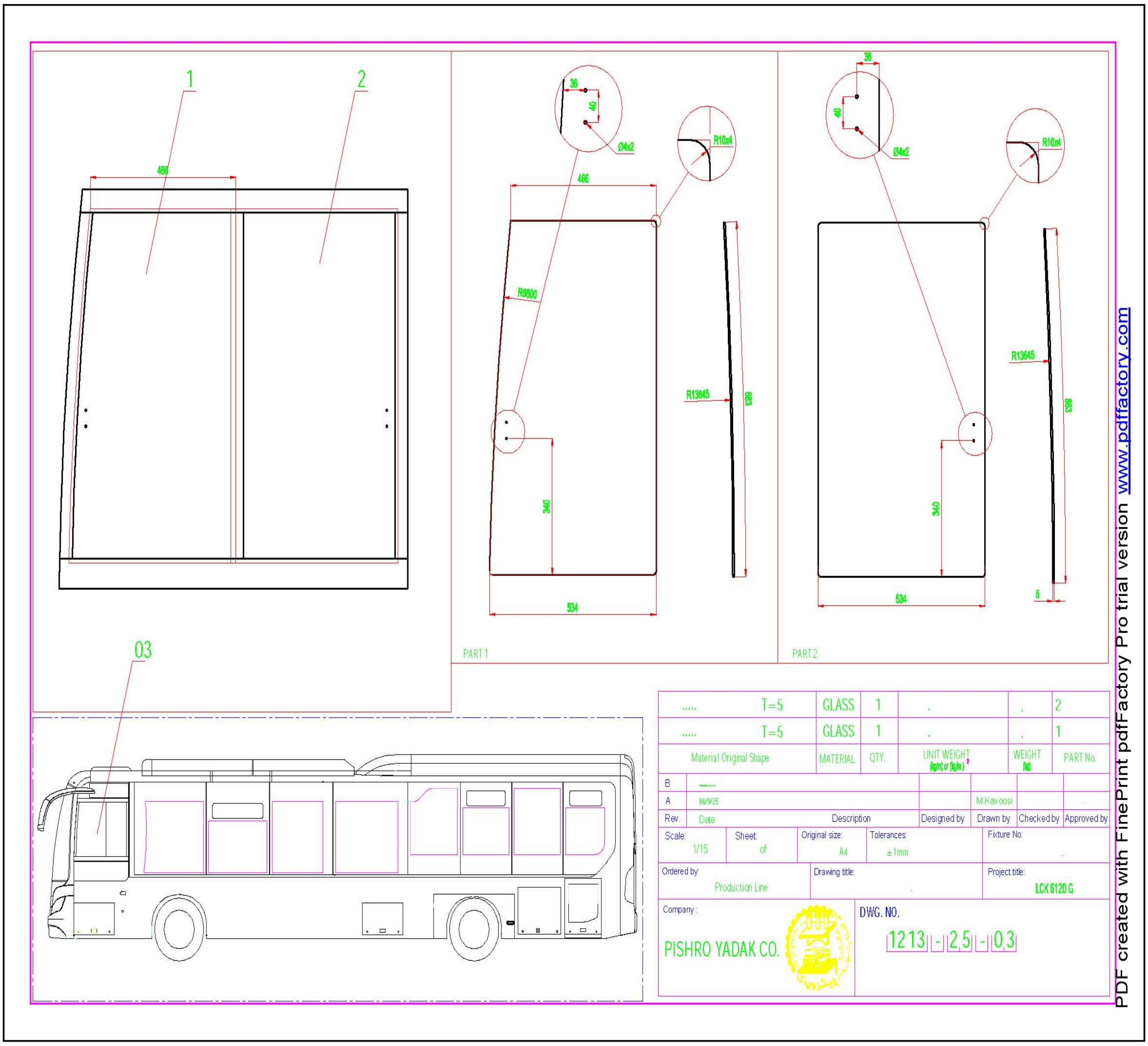

Figure 6.10 - CAD Model that Generated by Automotive Company

This CAD model includes all the information and data about automobile body specification, dimensions, shape and sizes of glass (relevant to this project) shape, dimensions and all other information that would be required to develop the automobile RP. As this project is concerned about the relation between IKD and CarGlass company, (was released in the chapter 5), one of the main advantages of KSFDR is that it would give a free hand to both industries to be involved from early stages of design and development which would allow them to work closely and in parallel. Figure 6.11 shows that at the early stage of design IKD would generate the glass design with all the specifications and which would be transferred to CarGlass to be implemented.

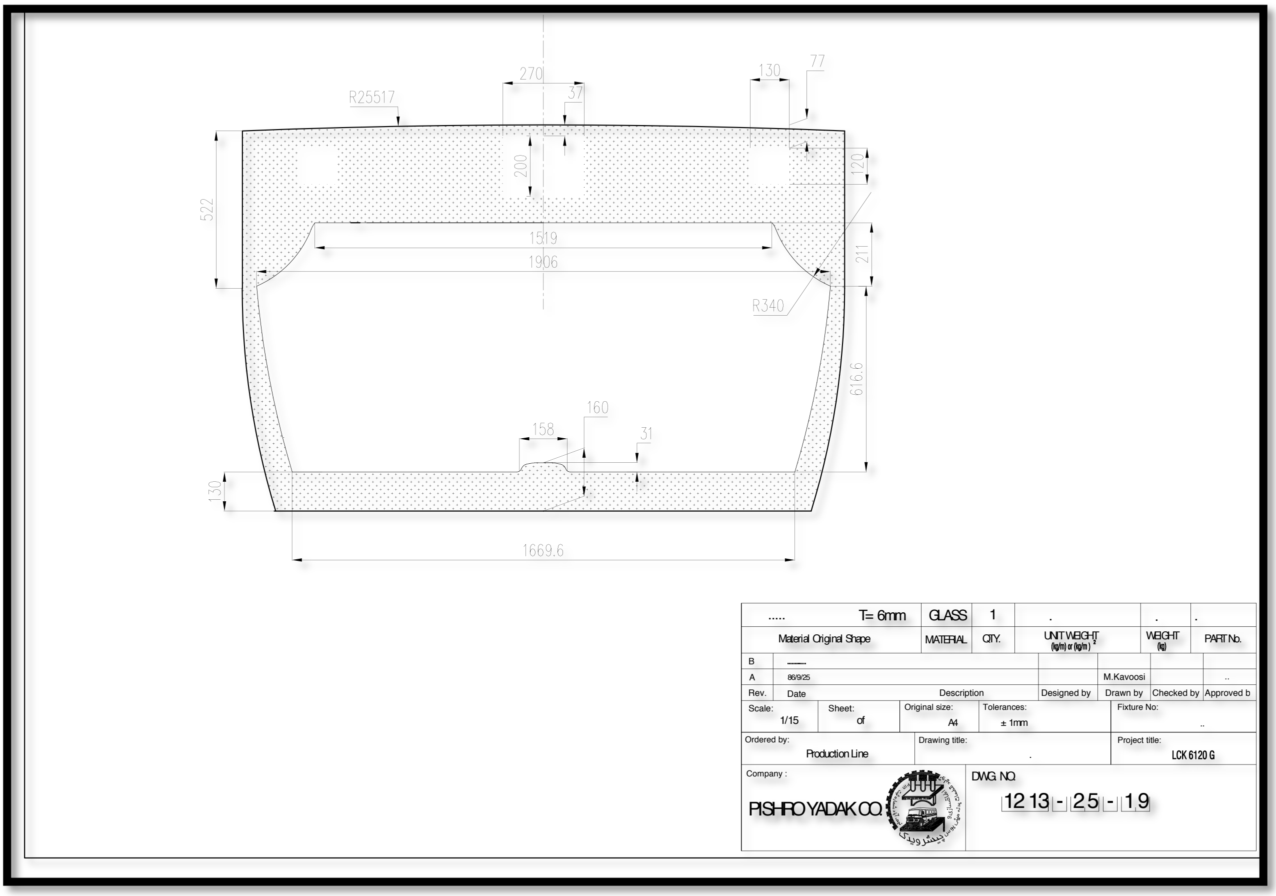

Figure 6.11 - Automobile Windscreens CAD Model

Referring back to communication level 4 in chapter 5, it is possible to recognise that in that level of communications, CarGlass generate they own CAD model and produce the glass prototype in that stage. Of course, when IKD in first task they generated automobile CAD model it would be much easier for CarGlass to just updated any changes with less time and even reduce the RP development cost. Figure 6.12 shown KSFDR in communication level 4 and figure 6.13 windscreens prototype that been generated from CAD model in CarGlass company.

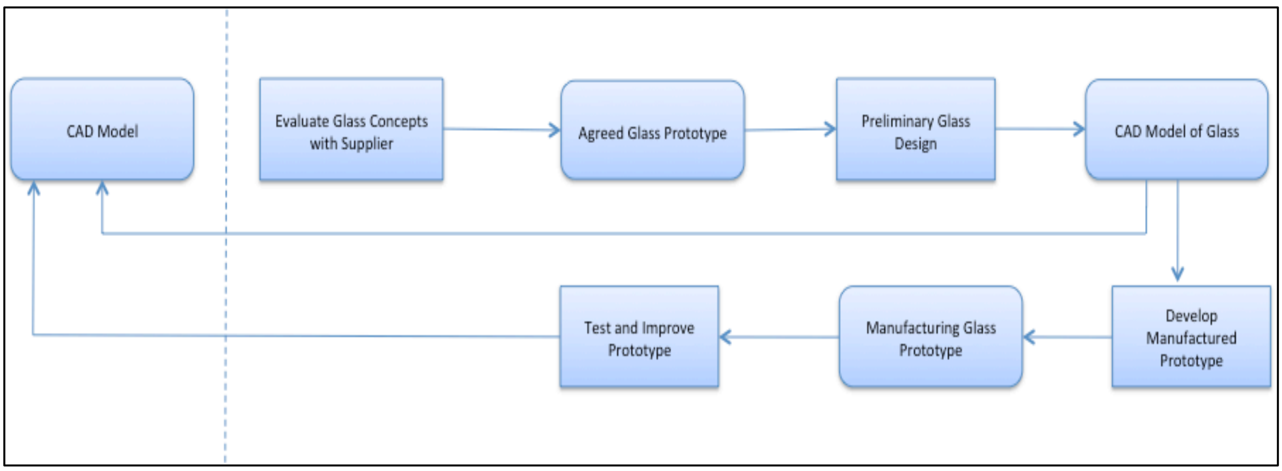

Figure 6.12 - Shown KSFDR in Communication Level 4

Figure 6.13 - Windscreens Prototype Generated from CAD Model in CarGlass.

After generating the glass prototype from the CAD model that was provided by IKD automotive company, the next level of KSFDR is to test and improve the prototype with respect to the design perspective and specification and to investigate whether the prototype has met the requirements. Figure 6.14 shown test and improve prototype in CarGlass Company.

Figure 6.14- Test and Improve the Glass Prototype

Due to the limited project time, the full scope of case study information included on the 'RP Process Task' between IKD and CarGlass is documented in the description of slots attached to the 'KSFDR Process'. The information includes the task title, the sub-process of activates and futures to which the task belongs which is filled in automatically on generation of the form, and most importantly the knowledge items required for, and generated by, the task to supporting KSFDR for this research project.

This case study has demonstrated how the framework and mechanisms of DR may be used to capture and disseminate information about this knowledge. The processes of DR came from the conception phase of the product development process, but involved a broad spectrum of knowledge types, ranging from demand and idea; propose product concepts, communication levels, technical drawings such as CAD model and etc to the rationale behind decisions taken in project review meetings.

In this way, it has been shown how the framework might be employed to facilitate knowledge sharing in IKD and CarGlass Company and even in a global product development environment.

Further research is required both to test the KSF and DR with knowledge items used in other processes of the product conception phase, and in the other phases of developing the RP in new product development processes in automotive industries. Additional work to determine whether other knowledge elements are required to describe the knowledge items would also be beneficial. The methodology and Knowledge Sharing Framework should also be implemented in other settings, that is, NPD business processes in other industries and for different product types. In doing so, further empirical evidence as to it could be obtained.

6.5 Knowledge Requirement in Knowledge Sharing Framework Features

This section provides a walkthrough of the main features of the implemented of knowledge sharing framework. The walkthrough illustrates how the framework may be used to provide support of RP development project team members in automotive industry with information about NPD process knowledge, and thereby facilitate knowledge sharing as illustrated in figure 5.2. Three usage scenarios will be considered, as listed in Table 6.1.

Scenario	Descriptions
A	Building and administration of KSFDR and knowledge base
B	KSFDR process users
C	Knowledge sharing managements of DR

Table 6.1 - Usage Scenarios for Knowledge Sharing Framework

Scenario A focuses on the functions and features of the framework pertinent to the DR administrator. It is envisaged that a framework administrator is likely to be somebody from the information technology (IT) function of a company. The administrator for the automotive or collaborative industry would gather requests for changes to the framework from sub-process owners and NPD project leaders in respect to support the RP development. The sub-process owners and NPD project leaders would need to agree on the necessary changes prior to such a request being made. For the purposes of this scenario, the framework administrator role has four main responsibilities. These are:

1. Adding instances of sub-processes, tasks and knowledge items to the knowledge acquisition framework described in chapter five to create a knowledge base on DR.
2. The maintenance of the knowledge base, which may require the addition, deletion, or editing of sub-process, task and knowledge item instances, and framework element instances.
3. Assigning priorities to knowledge items.
4. Adding framework DR knowledge labels to the knowledge items

Scenario B and C considers the typical activities that a framework user in industry may wish to perform with the framework in order to improve their understanding of the knowledge used in RP development in the NPD process. A typical framework user would be a member of the NPD project team. These activities may include locating information about knowledge items pertinent to a given task, or discovering how a knowledge item generated by a task is used elsewhere in the KSFDR process. Consequently it may be considered the most important of the three scenarios as it would give a free hand of industry to see in which stage of development they require more knowledge and whether they need to reconsider their detail design even before it reach the activities task of DR. Due to the project time limit is not possible to illustrate the all knowledge items in task and activates of KSFDR project.

Consequently it may be considered the most important of the three scenarios as it would give a free hand of industry to see in which stage of development they are requires more knowledge and do they need to reconsider they detail design even before it reach the activities task of DR. Due to the project time limit is not possible to illustrate all of knowledge items in task and activates of KSFDR project. However, the examples provided should prove sufficient to illustrate the key functionalities of the framework. Rather than using the KSFDR, it is intended that users of the DR framework will view and browse it through a Web browser interface, making it accessible to automotive and collaborating industries project team members, irrespective of their geographical location. The users are able to navigate the framework using the familiar point and click paradigm at each stage of RP product development and can also edit or do any changes at any time that requires to improving the RP processes in NPD. A figure 6.15 illustrates the resulting KSFDR in Web browser.

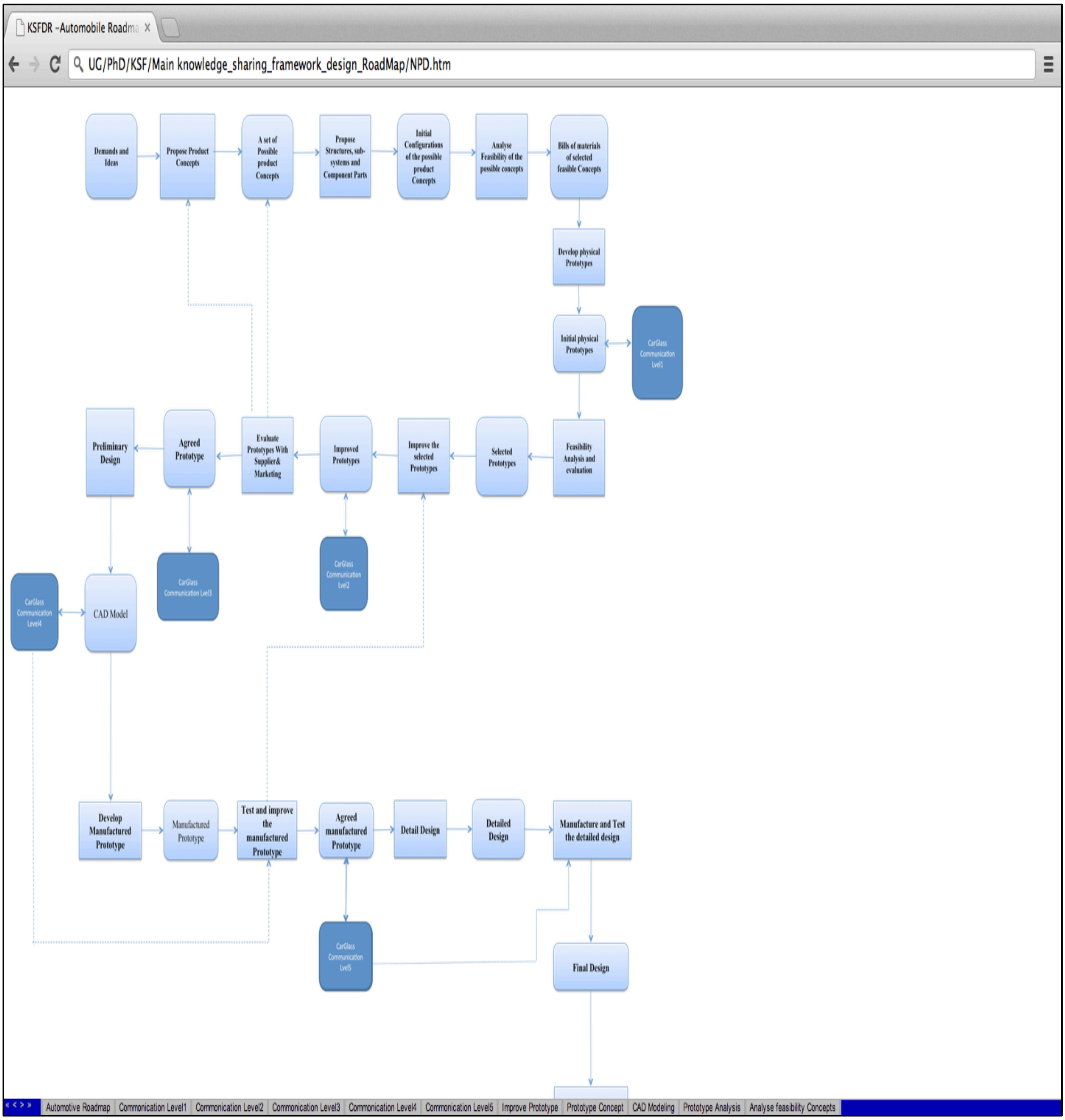

Figure 6.15- KSFDR Browser Window in Web Browser Framework

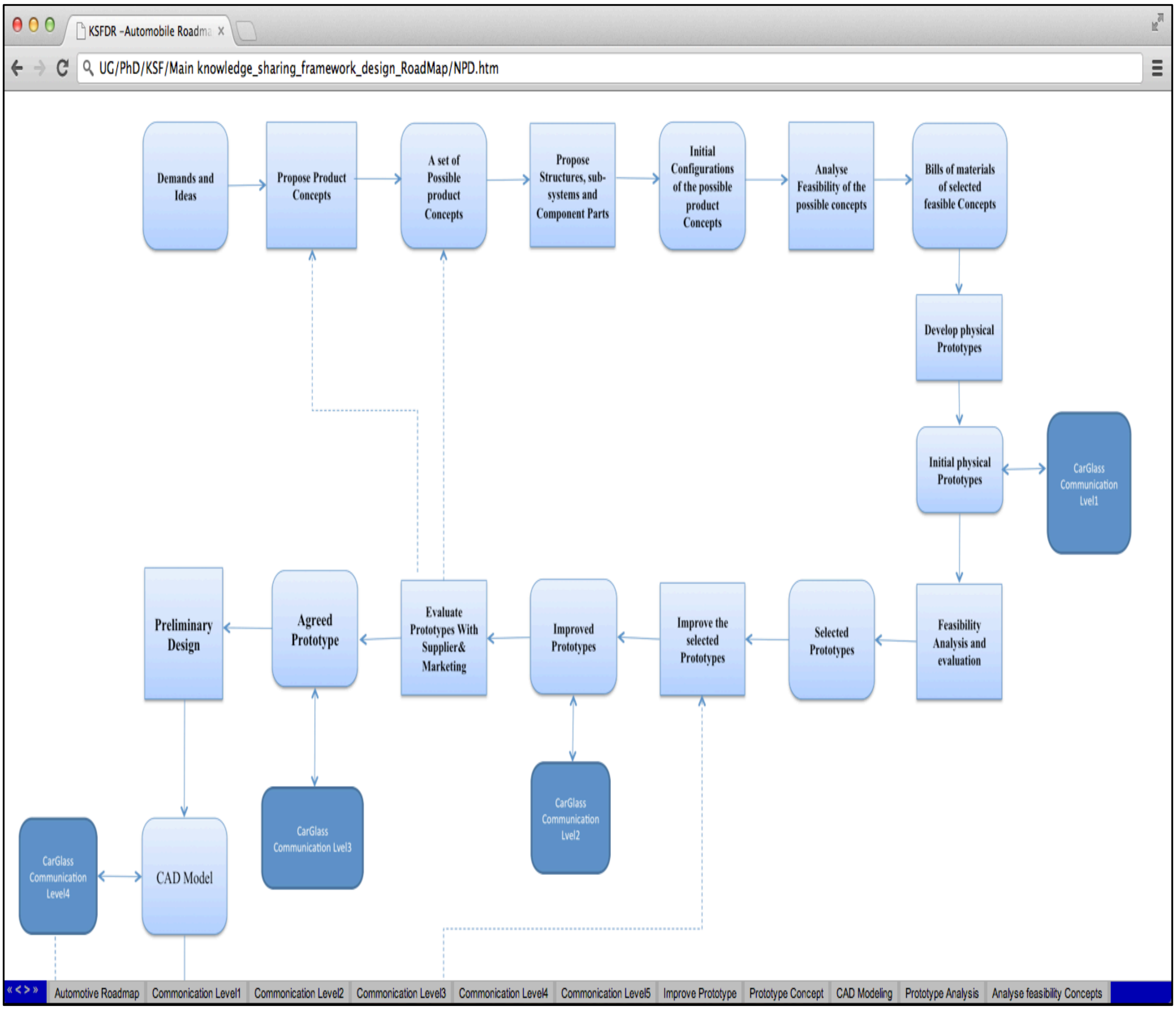

Figure 6.16 - Footnote of KSFDR in Web Browser

Figure 6.16 illustrates the footnote of the DR browser window and contains the sharing process knowledge taxonomy, arranged in a tree-like hierarchy of classes. Of these classes, the KSF process-level class is the focus here, since it is the starting point for finding the KS process tasks and associated knowledge items of interest to the framework user.

Selecting the 'KSF process' class by clicking on it will show the instances of this class in the new page of the framework browser window. Figure 6.16 shows footnote process tasks as discussed in section 6.3.

At this point, it should be restated that each footnote in the form is a label for a slot (relation) in the KSF providing information about a DR process knowledge item. Many of these slots have values that are instances of other classes. Effectively, this means that all items listed under a footnote that are highlighted in blue in the Web browser framework user interface can be clicked upon to open a form which will provide information about that instance. Selecting one of tasks under the footnote allows the framework user to view the input and output, network process, source of collaboration, set the time scale or check the product time scale, product profile of knowledge items that’s requires for that task (see Figure 6.17).

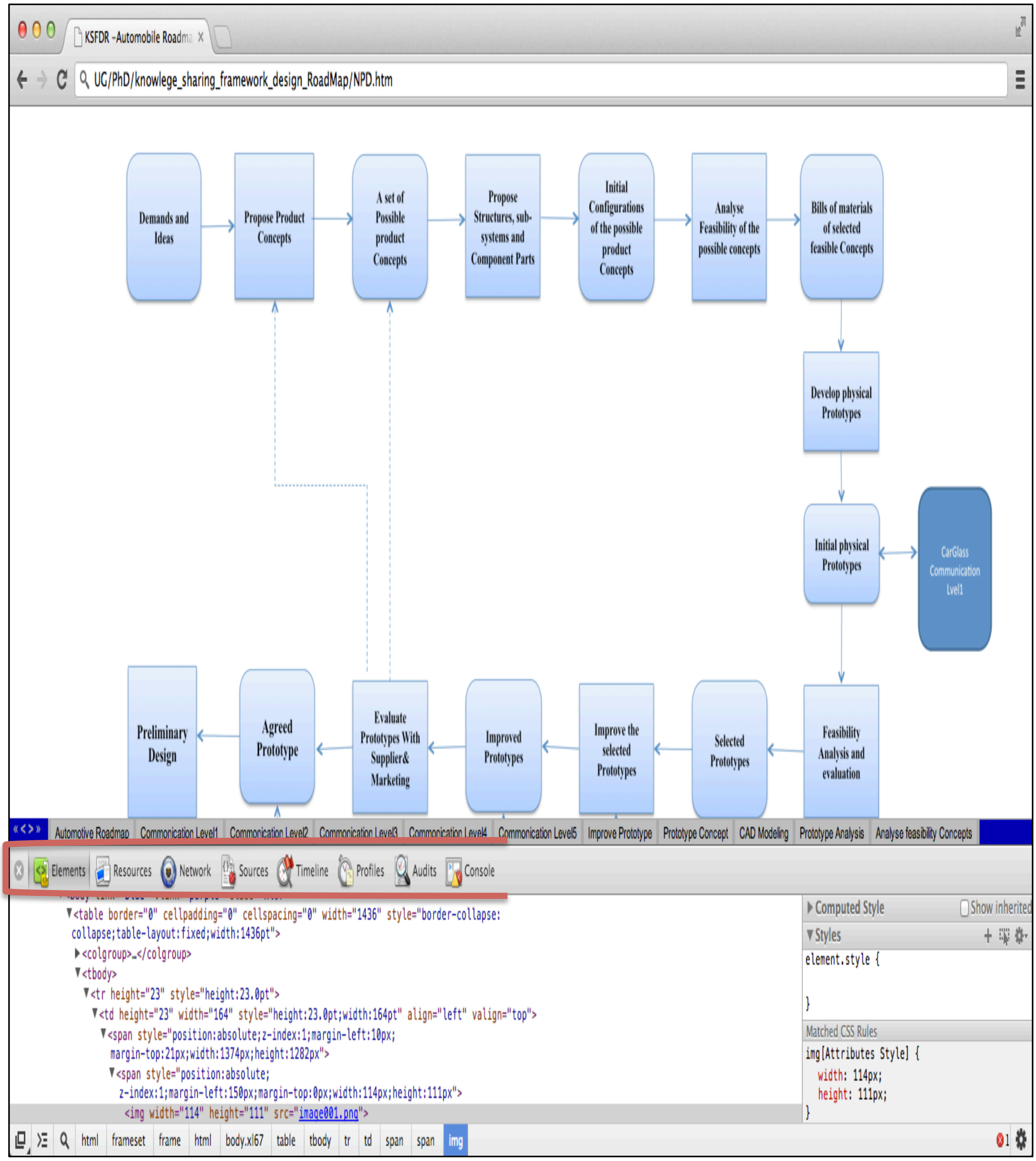

Figure 6.17- KSFDR Footnote of Label Slot

Clicking on footnote title opens a knowledge item form window in the Web browser and displays its knowledge elements, see figure 6.17. These footnote knowledge elements provide information about the knowledge item which includes: the task which generated the knowledge item, the resource tasks which use the knowledge item as an input, the time scale to shown the estimated time to be completed at each stage of KSFDR development, task and activities profile, the content or knowledge domain of the knowledge item, the assigned prioritisation criterion and the priority assigned to the knowledge item based on that prioritisation criterion.

Notably, only those knowledge elements for which values have been entered are actually displayed in the form in the Web browser interface.

This information is intended to provide automotive and collaborative industries project teams members executing a task with an understanding of how the knowledge generated by that task is subsequently used. Similarly, the ‘generated by’ tasks slot on the KSFDR item form shows in previous figures what task generated that knowledge item. The contextual information proffered by both of these slots provides framework users with an understanding of the way knowledge is used and generated in the KSF to develop the RP process.

Lastly, Scenario C highlights the features of knowledge sharing framework that may assist in other knowledge sharing management activities concerning the NPD business process. Users in this case might be NPD project leaders, NPD process owners in this research study from IKD or any party in the collaborative company such as CarGlass concerned with knowledge sharing management. These features include the ability to classify knowledge items by content (knowledge domain), by prioritisation criterion, and by priority. Although arguably less important than scenario B, since it does not directly address knowledge sharing by providing information about knowledge, scenario C shows how the framework may be used to nurture an improved shared understanding of knowledge used of KSFDR in developing new RP process. For example, when IKD as automotive industry requires developing the new automobile prototype they will need to gather and manage the all type of data. This information’s would be recognised in DR system by coding such as I_K_D2/O457_MDCG, which would be in used by NPD departments. The first part of code as I_K_D2 means IranKhodro Diesel (IKD) and number is department code and second part as O457_MDCG is model of automobile specifications. Figure 6.18 shows the coding system that is used in IKD to develop the new RP, it should be noted that these files would be located and available to be accessed at all stages in KSFDR for both IKD and collaborative companies. There is a rule for merging the requirements in DR systems. If the automotive industry in the time of developments finds that there is some requirement at lower level of development that there are the same requirements at a higher level, it will be combined and kept at a higher level. Higher levels normally have more functions. However, if the required functions cannot satisfy the lower level, the duplicated requirements are still combined in the higher level with functional supplements from the lower level.

There are other situations in the overlaps and duplications in this KSFDR. These situations are the overlaps or duplication just stay in one single level, such as the third requirement in the Department Level (I_K_D7/O457_D8) in Figure 6.18. There are more than one department, which require "digitalise graphs, figures, CAD data, Material specification and etc paperless work". Therefore, this requirement can be combined in the department level. In this stage, all the requirements still contain the IDs as in the list of initial requirements. The combined requirements should keep all the relevant IDs of the initial requirements in DR, in order to trace requirements from start to the end. In Figure 6.18, the importance point column contains of all the points for each requirement in RP development in automotive industry that will be located in Propose Product Concepts (PPC) activities task.

The use of the resulting knowledge acquisition framework to capture information about knowledge used and generated in the selected processes and tasks is shown in figure 6.18. The Knowledge Sharing Framework (KSF) can be applied to the knowledge associated with a real product development process in all automotive industries. It is possible to include information about very diverse kinds of knowledge. For example, in Figure 6.4, the second requirement (I_K_D2/O457_GCR) of the automotive industry (IKD) contains two initially captured knowledge requirements. One of the requirements gets the point of "160". The other initial requirement gets point of "170". Therefore, the highest point "170" is adopted as the importance point of this new requirement. It also keeps the original importance point of the initially captured requirements in the bracket, in order to show the number of involved knowledge users. This knowledge in KSF would also allow both automotive and collaborative companies to understand that what type of the knowledge is most critical and should always rely on them to support the new rapid prototype developments.

A	B	C	D
Initial Requirement ID	Content	Relevant Departments/Group	Importance Point
Automotive Industry (LKD)			
I_K_D_M1	To model and manage the RP development lifecycle	IKD/Automotive	160
I_K_D2/O457_P_GCR	To manage the automobile RP development process and procedure	IKD/CG	160 (160,170)
I_K_D3/C457_P_GCR	To estimate cost and Control budget of RP development	PD/Design Unit	149 (149,129)
I_K_D4/MANU_D6/MG4	To plan and manage human response based on function and possible in the process and product line	Manufacturing in both IKD/CG	178 (178,149,160)
I_K_D5	To set up check points and milestone in RP development process	IKD/CG	130
Department Level			
C_G_K1	Large knowledge based to store the CAD model, Graph and figures	Production / Design Departments	105
C_G_K2	Visibility of RP resource and controlling	Production / Design Departments	95
C_G_K3/I_K2	CAD model, Design Specification, Design perspective and Details Design	Production / Design Departments	125(115,100)
Group Level			
CG_IKD_D1	Develop a knowledge framework to support rapid response in automotive	Product concept development group in both industries	156

Figure 6.18-Shown the Coding System is used in IKD to Develop They New RP

The other benefit of this methods of KSFDR is that it allows the automotive industry to integrate the knowledge requirements at the level of propose product concepts activities task in order to enhance the list of knowledge' requirements, so that all knowledge can be managed including those indirectly specified in the users' requirements.

The easiest way to integrate knowledge into KSFDR is to compare knowledge and users' requirements, in order to find gaps in knowledge' requirements. There are three situations in the comparison. The first situation is that the knowledge to be managed has already been included in the DR' requirements. For example, one main function of the RP development is to plan the product development process. Therefore, one of the basic requirements is to model the process in the system. The process and its sub-processes are the typical knowledge in the current automotive environment. In this situation the requirements in the list do not need to be changed.

The second situation is that there is not a requirement relevant to the knowledge at all in the IKD requirements. The typical example is the meeting minutes. Dr. Mohammadi, General Manager of IKD, points that in the RP development, nobody thinks that the meeting minutes are as important as knowledge. Management of this kind of knowledge should be added to the list of requirements at Propose Product Concepts (PPC) state in understanding the relevant futures and activities in KSFDR.

The third situation is that certain requirements partly cover certain knowledge. In other words, there is more knowledge to be managed than the relevant department requirements in the list. This situation is the most popular situation in the comparison. For example, one of the most popular requirements is the basic knowledge requirement in details design, such as knowledge storage and invoking. However, this basic requirement does not specify what types of knowledge. As previously discussed, managing explicit knowledge and tacit knowledge is not be the same. Therefore, a lot of the details of knowledge should be specified in the requirements, such as, lessons learned, expertise experiences and so on. In this situation, the requirements in the list should be enhanced with more details about the knowledge to be managed.

The main aim of this section is to give an explanation for capturing and analysing the knowledge that requires based propose product concepts of KSFDR tasks. There are many examples of real data that would have provided for this KSFDR, but due to the time limitation it is not be possible to mention all of them but will be left for future work. The completed framework will be in used in CarGlass Company.

6.6 Discussions and Summary

In this chapter it was shown that how the knowledge sharing framework design Road-Map might be used to capture and disseminate information about knowledge to develop the rapid prototype development process in automotive and collaborative industries and in doing so facilitate knowledge sharing in a global product development environment.

This claim was broadly supported by the study to elicit feedback, from RP process experts at two different sites of the case study company such as IKD and CarGlass, about the perceived usefulness of the framework. The connection of knowledge framework process tasks was considered to be useful, as were the knowledge prioritisation. However, the study also highlighted some of the weaknesses of the Knowledge Sharing Framework (KSF). The most significant of these was the time required for project team members to enter information about knowledge items, which it was felt would inhibit the usage of the framework among NPD project team members.

Given that this part of the study was qualitative in nature and restricted in scope of KSFDR process experts at one organisation, further research into usefulness of the framework is needed. For example, a quantitative approach could be adopted using a measure, such as that proposed by Davis (1989), and subsequently validated by Adams et al. (1992), and Laitenberger and Dreyer (1998). This method exploits a Likert-type measurement scale to assess the usefulness of the actual framework. The data collected with this technique is quantitative in nature, complimenting the qualitative nature of techniques used in this investigation.

Chapter 7

Evaluation and Discussion of the Knowledge Sharing Framework

In previous chapters, the developed knowledge sharing framework methodology has been described with a comprehensive case study explaining how to use it. This chapter discusses the findings of the research presented in the previous chapters of this thesis document. It commences by describing how each of the research objectives was met. Next, the limitations of the research are examined, followed by an exploration of the wider scope of application of the research. Finally the contributions made to the body of knowledge are stated.

In this chapter, a case study to evaluate the usefulness of the prototype Knowledge Sharing framework discussed in chapter six is described. The study had two main aims:

- To evaluate how useful potential users of the framework consider it to be as a device for the facilitation of knowledge sharing in the execution of the product development process; and

- To obtain feedback from potential users on the shortcomings of the framework of particular interest was the usefulness of providing information about knowledge and the multilingual support and prioritisation mechanisms.

The term useful is taken here to mean 'capable of being used advantageously' as employed by Laitenberger and Dreyer (1998) in their study to evaluate of the usefulness of a Web-based inspection KSF Roadmap. Project development at the case study company between IKD and CarGlass tend to last in excess of fifteen months, so there was insufficient time available to the researcher to field test of some part of framework in an actual product development project. Consequently, the focus was placed on assessing the perceived usefulness of the framework. Perceived usefulness is used in the sense adopted by Davis (1989), that is, the 'degree to which a person believes that using a particular system will enhance [her or his] job performance'.

7.1 Evaluation of Knowledge Sharing Framework Based on Case Study

A case study approach was used to assess the usefulness of the knowledge DR concept on which the knowledge sharing framework is based, as well as the perceived usefulness of the framework itself, as already alluded to. In situations where evidence of an explanatory nature is sought, Robson (2002) advises that a qualitative investigation should be pursued. The process followed consisted of five steps, as shown in Figure 7.1.

Figure 7.1- Process for Eliciting Feedback About the Usefulness of the Prototype Knowledge Sharing Framework (KSF)

Step one of the process involved the development of a questionnaire to capture the opinions of various parties involved in new product development projects in IKD. The questionnaire consisted of open-ended questions intended to elicit responses about the extent to which respondents believe that the DR framework supports knowledge sharing and the usefulness of the framework itself. Open-ended questions were chosen because they afforded the researcher the opportunity 'to make a truer assessment of what the respondent really believes', as advised by Robson (2002), and 'to understand and capture the points of view of other people without predetermining those points of view without prior selection of questionnaire categories', as counselled by Patton (1990). Questions covered the following themes:

- The usefulness of the overall framework as a means to facilitate knowledge sharing and provide an improved shared understanding of RP process knowledge among project team members between IKD and CarGlass.
- The usefulness of the individual components of framework, including the DR elements contained in the framework, the classification of knowledge by content (knowledge domain), and the prioritisation and multilingual support mechanisms.
- Initial impressions regarding the ease of use of the DR framework.
- The relative benefits of the DR framework compared to the time required adding information about knowledge to create a knowledge base on RP.
- Areas for improvement

Steps two and three of the process consisted of developing criteria for selecting individuals to take part in the study and then selecting participants based on these criteria. Three criteria were used. The first criterion was that participants should possess experience in a range of roles in product development projects in IKD. In this way, they could provide insight into the way the Knowledge Sharing Framework (KSF) might impact different roles in an NPD project team to developing new automobile RP. The second criterion was that the participants such as CarGlass Company should be involved in NPD at early stage of development to avoid any risk or miscalculations. The third criterion was that the automotive industry should be willing and able to participate in the demonstration session. This was particularly relevant in this part of the investigation, as the sessions in which the individuals were to take part would last around ninety minutes. Experienced personnel in both IKD and CarGlass Company often occupy senior roles in the organisation and their time is precious. Indeed, due to the restricted access to such personnel, the scope of the study was limited to three NPD process experts.

Step four of the process involved presenting and demonstrating the Knowledge Sharing Framework (KSF) implemented as shown in figure 5.2 to the three selected participants. The presentation of the framework involved an explanation of the purpose and main mechanisms of the Knowledge Sharing Framework Design Road-Map (KSFDR), followed by a demonstration of the DR itself. The demonstration covered the process of adding knowledge items to the DR along with the appropriate knowledge, navigating the DR, and the function of the knowledge prioritisation and multilingual support mechanisms to develop RP in IKD as automotive company and collaborative company such as CarGlass.

The administering of the questionnaire with respect to develop the project KSFDR from IKD and CarGlass Company was followed. The participant read through the questionnaire in the presence of the interviewer to make sure that they understood the questions. The participants then either entered answers in the protocol directly or returned a digital version by email. Each session lasted around ninety minutes, with one hour required to present and demonstrate the framework and answer participant questions, and thirty minutes for the participant to fill in the questionnaire. In a quantitative study of the usefulness and usability of a software application, Davis (1989) noted that less than one hour of interaction with a prototype software system by a subject is sufficient for them to provide a meaningful assessment of its usefulness. Step five, the analysis of the responses from the questionnaire protocols, is documented and explained in chapter four.

A wide-ranging review of literature was undertaken in two parts. Part one examined the current understanding of knowledge in the literature, models for knowledge sharing, and the types and content of knowledge used in automotive industries in respect of rapid prototyping process in new product development. Part two focused on knowledge sharing in the context of rapid response of new product development (NPD) in automotive and collaborative supply chain. It considered the obstacles to knowledge sharing in organisations and modern NPD environments, and the general approaches advanced by researchers to reduce this Knowledge Sharing Framework. Literature from the knowledge management, knowledge engineering and product development domains was included. A detailed summary of the findings of the review is given chapter three.

Two views of knowledge were found in the knowledge sharing literature. The most prevalent and well established of these is that of Nonaka (1991). This view describes knowledge as being available in two distinct forms: tacit knowledge and explicit knowledge, the latter of which is essentially information. Furthermore, the view permits that one form of knowledge can be transformed into the other. The other, more recent view, informed by Keane and Mason (2006) and Hislop (2002), argues that knowledge has tacit and explicit dimensions, rather than being available in distinct forms. This second view has had growing support in recent years, following criticism of the Nonaka model. In this view, it is difficult or impossible to capture the tacit dimension of knowledge. With this idea in mind, Keane and Mason (2006) implied that knowledge sharing systems that claim to capture tacit knowledge by converting it to explicit knowledge are unable to do so. Knowledge sharing is regarded by knowledge as critical to the success of a rapid response to support the rapid prototyping in new product development project in automotive and collaborative industries. However, while much attention has been paid by researchers to managing knowledge in RP in product development in automotive and collaborative industries, relatively little regard has been given to knowledge sharing in this area. It emerged from the literature review that there is a range of obstacles to knowledge transfer and sharing in a product development environment between automotive and collaborative companies. Some of these obstacles are generic to large organisations, whilst others are more specific to the product development environment. Approaches to minimising these barriers may be divided into two categories: social policies and procedures to influence human behaviour, and information technology-based tools.

Notably, it has been cautioned that information technology tools are unlikely to make knowledge sharing take place if they are used in isolation. Rather they should be deployed as an enabler as part of a wider strategy that also embraces the use of suitable organisational policies.

Various information technology tool based knowledge sharing methodologies have been proposed that in some way seek to support knowledge sharing in NPD environments in automotive industries. However, given that there are a large number of knowledge sharing obstacles in product development, it was determined that a meaningful review of these tools could only be carried out by focusing on a key few key in a product development environment.

An investigation of attempts to categorise RP process in automotive and collaborative industries knowledge revealed that several taxonomies have been proposed. These tended to classify knowledge based on its nature. It was considered by the author that these would be of less practical use to an RP practitioner searching for relevant knowledge than a content or domain-based classification. Another limitation was that most of the classifications concentrated solely on the knowledge used by the design engineer and therefore excluded the other functional roles in an RP project team in automotive. These roles include project leader, project auditor and cost analyst. One content based classification of information and data was proposed by Zahay et al. (2004), but this was based on a shallow study covering many organisations and industries, as opposed to an in-depth study involving a large number of RP practitioners between IKD as automotive and CarGlass as collaborators company.

Eppler et al (1999) described rapid prototyping process as a knowledge intensive process. It may involve hundreds, thousands or perhaps more knowledge items. In order to help manage this knowledge, researchers in the technology domain have advocated prioritising knowledge assets according to their relevance to the business strategy in automotive industries. The author considered it to be conceivable then, that prioritising knowledge in line with its strategic relevance to an NPD project could help to facilitate knowledge sharing.

7.2 Key to Knowledge Sharing Framework

Even a brief reference to the knowledge sharing and NPD literature uncovers a litany of obstacles to knowledge sharing in NPD environments, as discussed in chapter two of literature review. It was considered that a meaningful and focused review of existing methodologies in automotive and collaborative industries in respect of rapid response for the facilitation of knowledge sharing would need to be made in the context of a small selection of key knowledge sharing framework relevant to CarGlass as sponsor company.

To this end, an empirical investigation was conducted at the sponsor company to identify key knowledge sharing framework. Importantly, the company possesses many of the traits that characterise global product development organisations, including the exploitation of local expertise and geographically dispersed multilingual product development teams to develop the RP. It also uses a stage gate style rapid prototyping processes in product development very similar to generic NPD models in the literature and widely employed in product development companies in IKD as automotive companies in this research project. The investigation and its findings partially met objective two and fully met rest of objectives.

Evidence used in the study came from a broad range of sources and data types, as mentioned at the start of this research project report. These included two interview-based sources obtained in the course of knowledge sharing project work conducted at main product development sites at the company, as well as securing an internal company survey, which collected employee feedback on the rapid prototyping process in NPD project business process between IKD and CarGlass such as windscreen in this research project. In this way, triangulation of data sources was achieved.

Similarly, defining information about knowledge sharing Road-Map processes in automotive and collaborative industries is futile, if that information cannot be made accessible to, and disseminated among, geographically dispersed product development team members. Comments made by interviewees in the knowledge audit and KSF investigation in automotive organisation of the company suggested that there is perceived to be a strong awareness of knowledge within the confines of a site. However, they also indicated that there is sometimes scant understanding of what is available at other sites. Knowledge is therefore sought locally and a heavy reliance is placed on networks of individuals who are co-located.

7.3 Limitations to Research

The discussion of the limitations to the research is divided into two parts: those pertinent to the overall research methodology and those applicable to the prototype method and knowledge sharing Framework Design Roadmap. Many of these limitations are referred to in earlier parts of the thesis document, as will be indicated.

The development of the theory and proposed framework was based on a single case; therefore further research could be taken to involve multiple case studies in the empirical investigation that led to the findings and derivation of the developed framework. A wider number of manufacturing companies from different industrial sectors that have a new product development process could have been used for the exploratory study and the validation of the theory and developed framework.

The research was an exploratory study using both a qualitative and quantitative approach due to the dearth in the existing body of knowledge relating to the research subject. By implementing both research approaches it allowed for the collection of explorative data in a valid and clear method for the development of concepts and theory. The researcher felt that by adopting both approaches it would be more beneficial to the research study as it allowed for the development of theory based on rich understanding of the subject domain. The chosen research methodology has been justified in chapter two.

7.4 Case Study Methods in Knowledge Sharing Framework

Limitations relating to the research methodology were discussed in chapter 4 and are mainly related to the choice of a single case study approach. The weakness of this approach is that only one industry and one company setting was involved in the development, implementation and testing of the framework. As a result, the findings cannot be generalised to other industries. In chapter four, though, it was asserted that scientific generalisation is not the goal of case study research, and that a case study is intended to provide a rich and detailed understanding of a phenomenon. Rather, it is the characteristics of the case that can be related to in other cases that are important (Bassey, 1981). Two such characteristics in this instance are the application of a formally defined KSFDR process similar to the generic models presented in the literature and the use of global product development teams in respect of rapid prototyping.

It was further contended that concentrating on a single company such as IKD allowed a close working relationship to be developed between the CarGlass Company and the researcher. This in turn meant that a sustained level of access to personnel and business documents was obtained. Such access is unlikely be available in situations where the company had no formal connection with, or monetary interest in, the research project. Nonetheless, the freedom to pursue a multiple case approach and apply the method and framework in other companies was constrained by the temporal and financial resources available to the researcher.

There now follows a discussion of the limitations of the research in the context of the research objectives.

Fulfilment of objective two partly involved the identification and classification of knowledge sharing in the RP process in new product development of the case study company. The principal source of evidence for the investigation related to this research objective was the data drawn from a total of several interviews across two studies. This number falls short of the twenty interviews to understand a domain recommended in the literature by Griffin and Hauser (1993). However, the interviews were triangulated with other forms of data, notably company business process documentation which indicated some of the information inputs and outputs for process tasks, and screenshots of project folder structures to gain a better understanding of how KSF process in NPD project team members preferred to classify their information and knowledge. Furthermore, it was possible to check the findings against a more general study from the literature.

Work carried out to meet objective three, the identification of key knowledge sharing framework, drew on many of the same empirical sources as the exercise to identify and classify RP knowledge process in NPD. As discussed previously in chapter four the interviews used in data sources were not specifically designed with the intention of eliciting information about knowledge sharing framework.

It should be noted that the implementation and testing of the knowledge sharing framework was restricted to knowledge associated with three sub processes from the conception phase of the new product development process, as stated in chapter six. Work by Hong et al. (2004) and Zahay et al. (2004) emphasised the diversity of knowledge used in this phase, the range of functional disciplines involved, and the importance of knowledge sharing in this stage of the product development process. Additionally, the evidence gathered about usefulness of the framework was qualitative in nature, so there was no triangulation with quantitative techniques, and the scope was confined to just three NPD experts at the case study company.

7.5 Summary

This chapter discussed the findings of the research presented in the previous chapters of this thesis document. It commences by described how each of the research objectives was met.

Also, the limitations of the research are examined and followed by an exploration of the wider scope of application of the research. Finally the contributions made to the body of knowledge are stated.

Miller (1991) stated that the purpose of applied research is ‘to create knowledge that can be used to solve pressing social and organisational problems’. Easterby-Smith et al. (2002) meanwhile asserted that applied research should result in a solution to a specific problem identified by a client. The research has made a number of contributions, not only to research published in the literature, but also to addressing problems in industry.

Three key knowledge sharing barriers associated with teams executing a cross functional, multinational rapid prototyping process in new product development in automotive and collaborative industries have been identified which is an industry based empirical investigation at an automotive and collaborative industry IKD and CarGlass respectively findings of a literature review. The literature review examined existing knowledge sharing and knowledge transfer methodologies and framework, and found that none of them addressed all of three of the key barriers.

A Knowledge Sharing Framework has been developed to facilitate knowledge sharing that addresses this Knowledge Sharing Framework Design Roadmap, thereby contributing to the body of knowledge. The framework features DR of information about knowledge used in the NPD process of the RP development. A case study at IKD and CarGlass demonstrated how the prototype knowledge-sharing framework could be used to capture and disseminate information about knowledge used in a real NPD business process.

The knowledge sharing framework is the first to adopt a DR approach rather than relying on the capture of knowledge. Initial feedback elicited from NPD practitioners in the case study to evaluate perceived usefulness indicated that KSF would improve knowledge sharing among NPD team members.

Finally, the whole body of this research project regarding to develop a knowledge framework to support rapid response in automotive and collaborative supply chain with respect of aim and objectives has been completed and in next chapter it will be concluded and future work of this thesis which should be undertake in real industry will be discussed.

Chapter 8

Conclusions and Further Research

This chapter presents the conclusions of the research project and identifies areas for further research.

8.1 Conclusions

This thesis presents a knowledge sharing Roadmap framework to support rapid response in automotive and collaborative supply chain to develop the rapid prototyping in new product development process context. An automobile company Iran Khodro Diesel (IKD) and CarGlass Company as supplier and sponsor of this research project were used to develop and test the KSFDR methodology. However, the KSFDR methodology can also be applied to other manufacturing companies and general business organisations. A main novel point to be noted is that both business objectives and knowledge Roadmap (KSFDR) requirements are used as the main drivers of the knowledge system development in IKD and CarGlass in Iran.

A literature review conducted in the scoping phase of the research revealed that effective knowledge sharing to support the rapid response in automotive and collaborative industries to develop the rapid prototype is critical to the success of NPD project team members. It was found that there are numerous methods to knowledge sharing in new product development environment, especially in multinational companies. Approaches to facilitating knowledge sharing in organisations such as IKD and CarGlass are of two main types: policies and procedures that influence human behaviour, and Roadmap methodologies and framework. Several key methodologies and tools that claimed to facilitate knowledge sharing to support rapid response between automotive and collaborative industries to develop the first rapid prototype in NPD settings were identified. Other ways of facilitating knowledge sharing were also found. Knowledge sharing among people is supported by the provision of information about knowledge or framework, the classification of knowledge, and the prioritisation of knowledge based on its strategic importance to develop the aims of this research project. It was argued that there is a need for further research into all of these issues in the context of knowledge sharing framework design Roadmap in NPD project teams.

An exploratory case study was conducted in automotive and collaborative multinational physical goods manufacturer in order to identify key knowledge sharing framework and provide further focus for the remainder of the research project aims and objectives. The study drew on sources of empirical data, including interviews in Iran with IKD practitioners and experts and an internal company survey.

This investigation identified the lack of an explicit definition of information about the knowledge used was generated to support the rapid prototyping in product development process in respect of reduction of cost and production lead time. The absence of a mechanism to make this information accessible in a multilingual environment and the lack of a mechanism to disseminate it to geographically dispersed NPD project team members.

The Knowledge Sharing framework Design Roadmap was tested between IKD and CarGlass Company in Iran. This study showed that the framework could be used in this industrial setting to capture and disseminate information about knowledge. Furthermore, a series of interviews to elicit feedback from NPD practitioners about the usefulness of the KSF was broadly positive. However, flaws remain in the multilingual support mechanism and these must be tackled. Finally, further testing of the KSFDR is strongly advocated.

In summary, the main achievements of this research project are:

- A further exploration into the nature of knowledge and approaches to managing knowledge sharing to support the RP between automotive and collaborative industries in they new product development.
- A case study investigation to inform conceptual ideas from extant literature to improve knowledge sharing to support RP.
- A developed and tested formal methodology for the design and the development of knowledge sharing systems based on Design Roadmap frameworks.
- The development of knowledge sharing framework to support the rapid prototyping in respect to reducing cost and production lead-time and also to improve the better collaboration procedure to sharing knowledge in early stage of new product development.
- Results of the verification and evaluation of the developed methodology using the industrial case study, including benefits, limitations and recommended further work.

Also, the contributions to buddy of knowledge in this research project are:

- Identification of specific collaborative practices and knowledge sharing problems and requirements in rapid prototyping across the automotive supply chain.
- The outcome of this research study provides a formal methodology to improve communication and knowledge sharing in collaborative automotive supply chain focusing on rapid prototyping.

- Capture and classify knowledge and communication processes in the critical stages of rapid prototyping in automotive industries.

8.2 Further Research

The result of this research investigation has been the provision of a method and tool for the facilitation of knowledge sharing in the early stage of rapid prototyping development process in new product development especially in automotive manufacturer. The Knowledge Sharing framework is based on Design Roadmap of information about RP process knowledge, and it was tested between IKD and CarGlass Company in Iran. This section presents the apparent limitations of this research. Though the limitations of this research study are acknowledged, they do not detract from the significance of the findings. Additionally, the literature review revealed that there is a lack of research into various themes related to knowledge sharing in new product development.

The development of the theory and proposed framework was based on a single case; therefore further research could be taken to involve multiple case studies in the empirical investigation that led to the findings and derivation of the developed framework. A wider number of manufacturing companies from different industrial sectors that have a product development process could have been used for the exploratory study and the validation of the theory and developed framework.

The research was an exploratory study using both a qualitative and quantitative approach due to the dearth in the existing body of knowledge relating to the research subject. By implementing both research approaches it allowed for the collection of explorative data in a valid and clear method for the development of concepts and theory. The researcher felt that by adopting both approaches it would be more beneficial to the research study as it allowed for the development of theory based on rich understanding of the subject domain. The chosen research methodology has been justified in chapter three. Future research could include the collection of more measurable data such as the questionnaire survey data to enhance the validity of the findings.

In conclusion, this research study has presented its research findings and contributions and achieved its aim and set objectives of developing knowledge sharing framework to support the rapid response between automotive and collaborative supply chain to develop the rapid prototyping in respect of cost and production lead-time reduction. The review of literature identified a number of research gaps, which suggested the need for an effective of knowledge sharing processes in industries. The identification of the limitations of the research led to recommendation for future work. A significant and novel contribution to the body of knowledge was also established.

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Appendices

Appendix A: The Questionnaires for the Industrial Investigation in the Collaborating Company

Appendix A

General Information about the Company

The interview with Mr. Ansari - the General Manager of Iran Khodro Deseal (IKD) took place in the general manager's office. IKD is an automotive manufacturing company and the main customer of Carglass co.

Questionnaire A-1: General information about the company:

- What is the number of employees and where are they based? Answers and data collected are as below:
  - Around 180 people in engineering, supplying and purchasing department, and 4000 people in other functions in the main plant, both of them are located in Tehran.
- How many sites and plants and what are their functions? Answers and data collected are as below:
  - Main plant (IKD engineering, supplying and purchasing department (EPCO) in Tehran, seven related plants that supply the Diesel engine (IDEM) in tabriz with associated of Benz in Germany, gear box (Chaekhgar) also in Tabriz, axel (VAMCO) in Qazvin and Propeller shaft (kppco) in Mashhad. CarGlassco supply all types of glasses (Such as glasses for trucks, buses, vans, trailers and also specific glasses) in Tehran.
- Who are your main customers and where they are based? Answers and data collected are as below:
  - Construction & Transportation companies. There are different types of customers for the company. Internal market and international. We have exported a number of our products to countries such as Turkey, Iraq, Kuwait, Central & North of Africa, UAE, Cyprus, Qatar, Syria and some other countries. The products that exported are: Cars, Trucks, Buses, which could be used in both construction and private and public transport and a number of

the parts for after sales. The after sales parts are: engines, glasses, car body parts, etc.

- What is your market position/share? Answers and data collected are as below:
    - o Most of the share in truck market; unfortunately we are losing the bus market. 66% truck, Buses 14%, 20% Vans, 25% international expert, 75% internal
    - o We should have mentioned that our Car based products has 35% international market and 65% Internal Market.
- What are your main products and units per annum? Answers and data collected are as below:
    - o Commercial vehicles including buses (city & intercity), trucks, vans and mini buses. Total number of vehicles is around 17000 vehicles per year. And number of glasses used in total 2658321 units per years.
- What is your annual turnover and profit? Answers and data collected are as below:
    - o The turnover of IKD is about 80~90 million dollars per year. Approximately 5% profit.
- What is the history of the company? Answers and data collected are as below:
    - o Iran Khodro diesel company (IKD) was founded in 1962, with the name of Iran National. Over the years, IKD has developed its capabilities and become the biggest industrial group in MENA region that performs industrial and service activities in the automotive sector in both passenger cars and commercial vehicles with 1,000,000 units of production capacity. Since the policy of vehicle manufacturing companies changed from importing parts from foreign sources to supplying vehicle parts from internal manufacturers, the supplying and engineering companies came into existence. All this process happened during 15 years.
- Who are the main suppliers and where they are based? Answers and data collected are as below:
    - o The main suppliers of IKD are vehicle part manufacturing companies and also raw material manufacturers. They are located all over the country. One of our big supplier is CarGlass company which is first biggest glass producer in Iran.

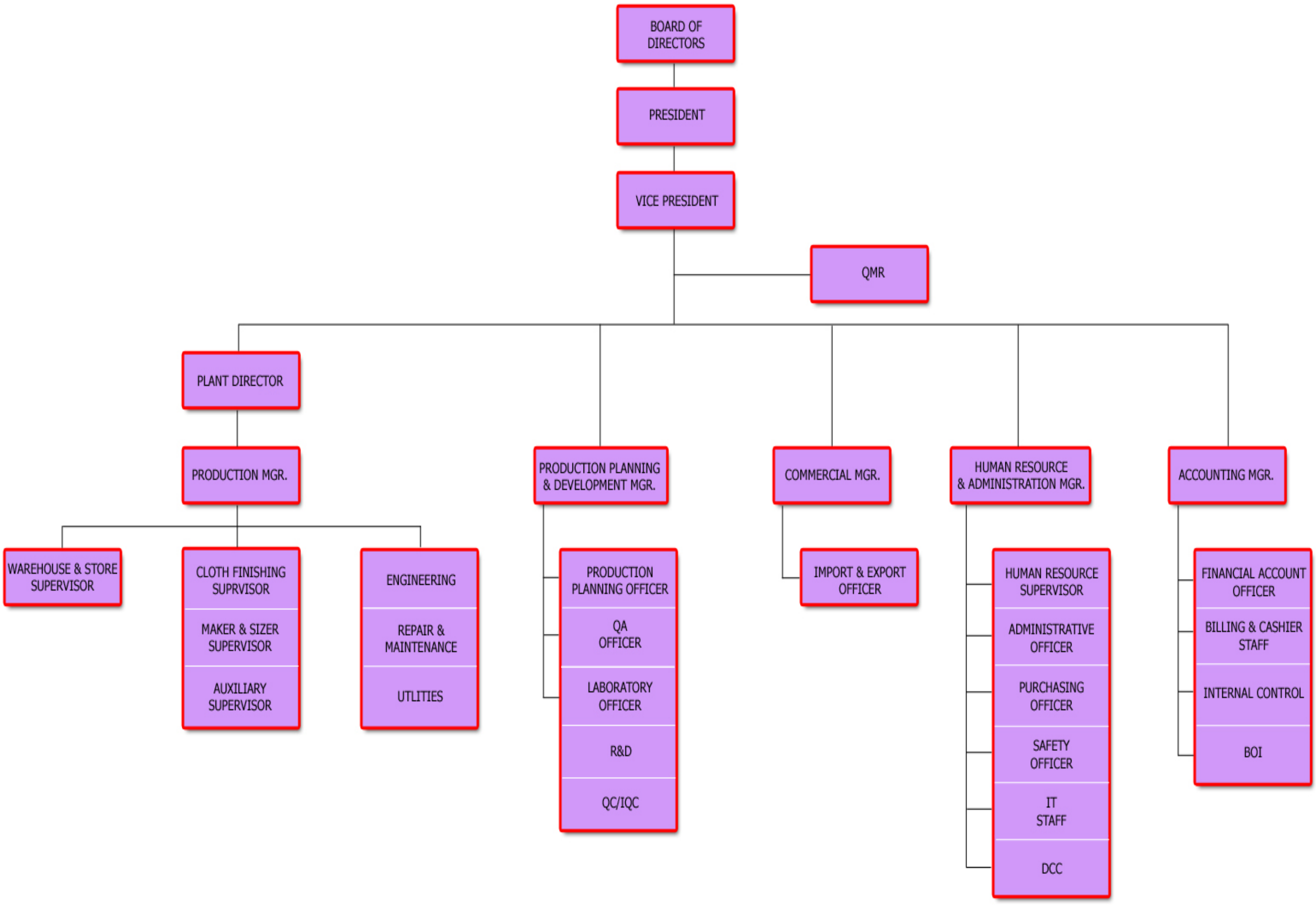
Carglass supplies us a large number of glass such as windscreen, side screen, rear glass in some cases it supplies us glass with aluminium frames for our mini buses.

Questionnaire A-2: General information about the Business:

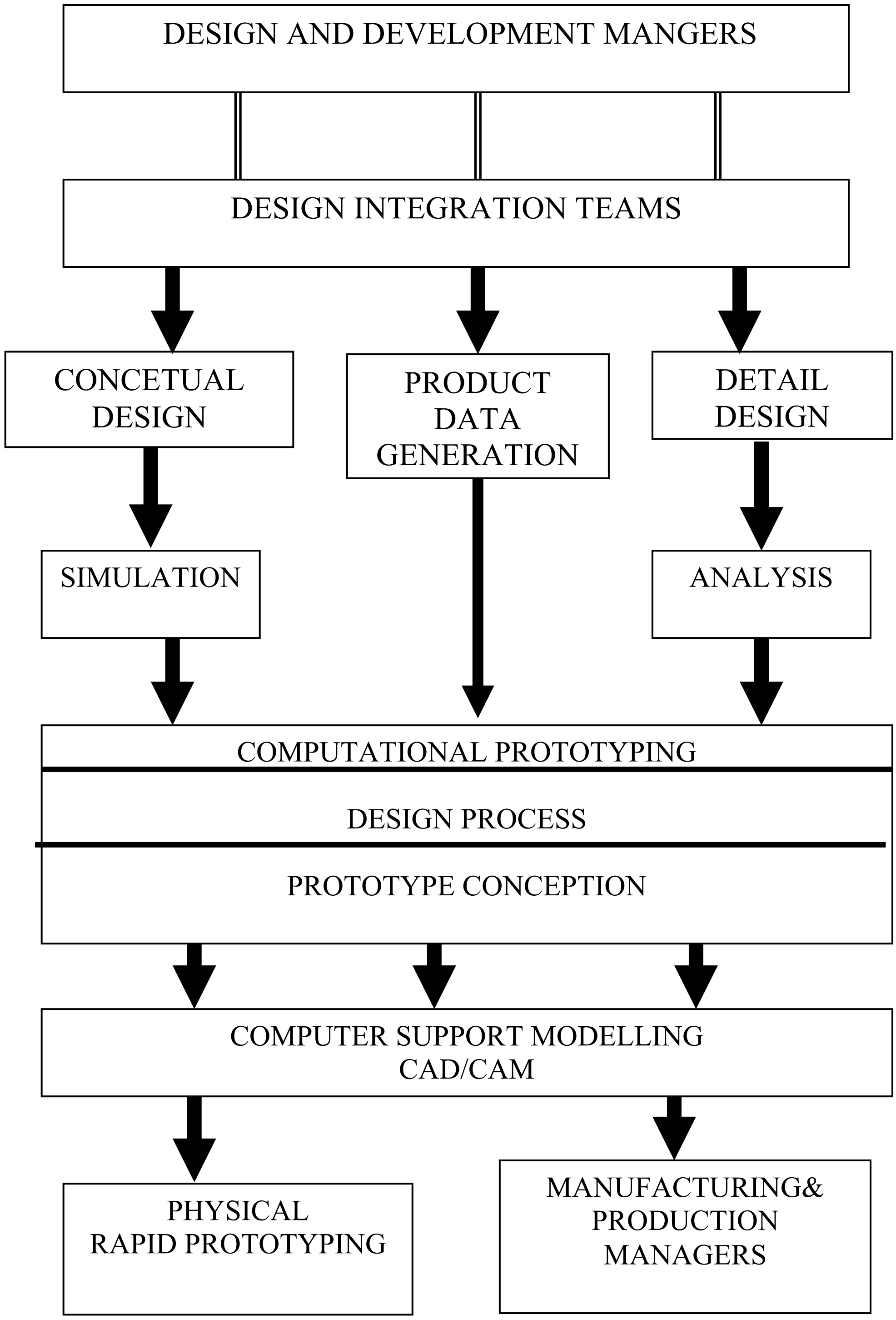
- What are the main challenges globally and nationally? Answers and data collected are as below:
  - Nationally the competitive market and competing with other companies. Globally the economic sanctions.
- What are the main difficulties/issues in the relationship with customers? Answers and data collected are as below:
  - Old design of our products. Poor collaboration, less knowledge sharing. As there is huge competition in automotive industries, normally automotive company for they own safety of the design they do not wish to share all knowledge with supplier which it cause problems such increase the production lead time and almost our total cost.
  - Poor quality of products. Because of international sanction we are not always able to get good quality of automobile parts.
- What are the main customer requirements changes that concern top level management? Answers and data collected are as below:
  - Newly designed products with more quality. As our products used in public transport it requires high level of quality standards.
- What are your business objectives in the next two years and beyond? Answers and data collected are as below:
  - Totally dependent on economic situation and it may vary. We planned to have joint venture with chine's manufacture and have new production line under there licenses.
- Is information and communication technology (ICT) important to your business and in what way? Answers and data collected are as below:
  - Yes, it could help improve lead times, total costs and quality of products. They would improve their market place in the competitive business.
- Is information/knowledge sharing in the supply chain a major issue at top management level? Answers and data collected are as below:
  - yes. It is one of main issue in our R&D

Questionnaire A-3: The organisational structure of your company:

- What is the overall management structure of the company? Answers and data collected are as below:
  - Top management is appointed from the Board of directors of IKD and totally implements the rules dictated.



- What is the structure of the design department and main responsibilities?
  - Preparing the technical information such as drawings and test plans for parts. Design team tries to bring more closed relation with our supplier to improve our products. Also the new methods of software have been introduced to our system based on Autodesk top engineering that gave us ability of 3D view.



- What is the structure of manufacturing department and main responsibilities?
    - Finding reliable sources to supply the parts for the IKD and after sales service. They operate under the supervision of top management.
- What is the structure of sales/marketing department and main responsibilities?
    - The sale and marketing department is new division in the company is growing to provide the spare part market with genuine parts. Also sales department tries to increase they business relation in international and internal market. Also with support of some IT company we try to develop our market plane.

Information about the Design Department

The interview with Mr. Emammi - the Design Department manager of Iran Khodro Deseal (IKD) took place in the general manager's office. IKD is an automotive manufacturing company and the main customer of Carglass co.

Questionnaire B-1: The information about the product (product model):

- What are the main types of your products?
    - As head of the supply chain, we provide the main factory with lots of materials and vehicle parts in 4 main categories 1- raw material and standard parts such as bolts and nuts. 2- Electrical parts 3- plastic and composite parts 4- assembled pats.
- What are the geometric parameters of your products?
    - Because of wide variety of parts we supply for the IKD, lots of geometrical parameters and test equipments must be taken into consideration and it
- What are the materials, suppliers and costs?
    - Raw material such as steel sheets and coils, steel profiles.
    - Standard parts such as bolts and nuts.
    - Electrical, composites and assembled parts.
    - The final cost may vary because of inflation ,global change of raw material price and labour cost.
- What are the mechanical properties (weight, strength, etc)?
    - It varies for every single part. There are wide variety of properties.

- Any other characteristics (colour, brightness, transparency)?

Questionnaire B-2: The customer requirements about your product:

- What are the customer requirements (in a document)?
  - Newly designed products with more conformability and quality.
  - Genuine spare parts.
  - Better after sales service.

Questionnaire B-3: Process of managing Changes:

- What are the main changes in customer requirements?
  - Proper price and reliability of products.
- What are the main design changes to respond to the above?
  - For designing new products we are not self-sufficient.
- What is the way you work with customers?
  - There is a one way relationship between us and our customers because they have no better choice in Iran.
- What is the way you work with suppliers?
  - For every purchase from a supplier a contract is made and all the circumstances is written and signed by top management. The suppliers must guarantee their sold parts for 2 years.
- What is the procedure in dealing with changes in customer requirements?
  - Every change that the customer sent to our company is assessed in design and manufacturing departments and if applicable, they will be implemented.

Questionnaire B-4: Relationship with other departments:

- How do you interact with manufacturing department?

- As a quality control representative all the Customer complaints in assembly line and after sales also non conformity of parts will be assessed accompanied with manufacturing dep.

- How do you interact with purchase department?
  - Purchasing is the main duty of manufacturing dep. actually nothing is made here. We buy and sell parts in the middle of supply chain. We provide them with technical data.

- How do you interact with sales/marketing department?
  - We provide them with technical data. In a case of conflict between customer and sales division we may interfere as an expert.

- How do you interact with finance department?
  - The manufacturing and marketing departments have the main relationship with finance department. Design and quality control departments have the least relations with finance dep. In a case of change request from the customer (IKD), the cost analysis management prepare a detail report about every new cost imposed by new changes.

- How do you interact with the above departments when dealing with changes?
  - After changes are approved with the customer, the technical data will be changed and will be published to other departments and related suppliers.

Questionnaire B-5: Problems, challenges, use of ICT:

- What are the main problems and challenges in dealing with customer requirement changes?
  - Lack of technical data.
  - As modern technologies are not native here & developing them here is not possible such as (ABS system for brakes).

- What are the main advantages and shortcomings of existing ICT systems in support dealing with the above changes?
  - With ICT systems data transfer between departments is much faster and other section will be informed faster about the changes. But the ICT department, which controls and runs the needed soft wares, is not efficient enough.

- What capabilities would you expect from future ICT systems in support of dealing with the above changes?
    - Updating old and disorganized software, which doesn't help.
    - Developing web based databases in order to easier accessibility.
- Is information and knowledge sharing an important issue in collaboration with customers and suppliers?
    - It is an important issue, but the links of knowledge sharing is not complete and some related companies will not be informed of changes made.
- What are the main problems and challenges in information/knowledge sharing across the supply chain?
    - Complicated and disorganized algorithms of ICT system.
    - Lack of detail technical data and reference standards.
- What capabilities would you expect from future ICT systems in support of information/knowledge sharing across the supply chain?
    - Algorithms of ICT systems are complicated and are not efficient and user friendly.
    - Using more knowledgeable and skilful software writers to achieve the goal.

Information about the Manufacturing Department

The interview with Mr Mr. Daryoush Ghobadi- Head of Engineering design team of Iran Khodro Deseal (IKD) took place in the general manager's office. IKD is an automotive manufacturing company and the main customer of Carglass co.

Questionnaire C-1: The information about the manufacturing processes of each product:

- What are the main engineering requirements (from design department) for each product?
    - Technical data including (technical &detail drawings, test methods).
- What processes used to manufacture the product to meet the above requirements?
    - Reverse engineering.

- What machine tools used to perform the above processes?
  - Various machines, lathing, milling, press machines and prototype modelling.
- What is the unit cost of manufacturing each product (and how to calculate it)?
  - The price analysing management is responsible for calculating the total price for each part. The total price per part =the price of raw material needed for each part + the price of outsourced processes& standard parts+ labour cost+ Depreciation of machines & dies involved in manufacturing of the part + packing & shipment costs + Overhead costs (design, test equipment's, tax)

- What is the time taken to manufacture each product?
  - It depends on products. If our collaborative supplier be on time normally between 60 or 90 days. Normally because there is no knowledge transfer between industries it brings difficulty to the project.

Questionnaire C-2: Process of managing Changes:

- What are the main design and customer requirement changes?
  - Replacing the driver cabin with new and more comfortable one.
  - More electronic facilities.
  - Powerful engine with less fuel requirement
  - IN some cases redesign automotive car body
- What are the main manufacturing changes to respond to the above changes?
  - Making new dies to manufacture new cabin.
  - Replacing the engine with more powerful and less polluting one.
  - New car body
- What is the way you work with the design department?
  - We receive the technical data from design department then all the manufacturing or outsourcing process starts.
- What is the way you work with customers?
  - Manufacturing Dep is direct contact with customers. We received they commonest from: questioners, website

- What is the way you work with suppliers?
    - The suppliers in some cases are in direct contact with us. we check if the parts can be produced and develop in easy way, less costly and capable with customer requirements.

- What is the procedure in dealing with changes in design requirements?
    - Mostly the changes starts from new obligations and new regulations dictated by government or institute of standard and industrial research of Iran. For instance using anti lock brake system. Then the design department starts to prepare the technical data and manufacturing process meanwhile other departments are looking for qualified and reliable suppliers. If necessary the lay out of assembly line will be changed.

Questionnaire C-3: Relationship with other departments:

- How do you interact with design department?
    - The design department to verify if the proper tools are used and new methods are implemented in the assembly line checks manufacturing process regularly. Using of nonconforming products is only authorized by the design dep.

- How do you interact with purchase department?
    - Nonconforming parts are reported to the purchase dep by quality control dep and they will be in charge to reject those parts to the relevant suppliers.
- How do you interact with sales/marketing department?
    - We receive the customer complaints and if necessary corrective and preventive actions are applied.
- How do you interact with finance department?
    - We are not interacting with finance department directly but if they cannot provide the whole supply chain with enough financial resources the manufacturing dep is the one which is affected the most.
- How do you interact with the above departments when dealing with changes?
    - The most influencing department in supply chain is finance dep. If for any reason the finance dep cannot provide the supply chain with proper cash flow, it will affect the whole enterprise. Thus the precedence of payments to the suppliers is determined by manufacturing dep.

- Any more to add?

  We believe that there are lacks of knowledge collaboration between our suppliers, if we had strong collaboration framework that we could have reduces our production cost and even product lead-time. We should also mentioned that some of our supplier start new information sharing which we could see good results of it and we hope in future we have more strange information sharing between our suppliers.

Questionnaire C-4: Problems, challenges, use of ICT:

- What are the main problems and challenges in dealing with design and customer changes?
  - Lack of enough budgets/knowledge to dealing with engineering standards.
  - No CRM department has been considered.
- What are the main advantages and shortcomings of existing ICT systems in support dealing with the above changes?
  - Integrated soft wares, which are used among different departments, hangs a lot.
  - Even hard wares are not compatible to the new soft wares.
- What capabilities would you expect from future ICT systems in support of dealing with the above changes?
  - Provide better hard wares in order to be able to use up to date soft wares.
  - Developing knowledge exchange and better product development
  - Enhance the interface of wifi network.
- Is information and knowledge sharing an important issue in collaboration with customers and suppliers?
  - Of course it is, we believe that one of most important aspect in automotive industry is knowledge sharing. It also believes that transferring data it would help us to improve our production perspective, quality and reducing cost but because of competition market they do not wish to sharing they knowledge. I should mention we do not have very strange framework for this process.
- What are the main problems and challenges in information/knowledge sharing across the supply chain?

- Complicated and disorganized algorithms of ICT system.
- No CRM department has been considered.
- The ICT department is empty of knowledge framework chart.
- Less trust in collaborative industries
- Poor software process

- What capabilities would you expect from future ICT systems in support of information/knowledge sharing across the supply chain?
  - Using more knowledgeable and skilful software writers to achieve the goal.
  - More information be flue between industries.
  - Helping automotive industries to support prototype and new product development

Information about the relationships with customers

The interview with Mr Mr. Moradi- Head of Head of Sales and Marketing department of Iran Khodro Deseal (IKD) took place in the general manager's office. IKD is an automotive manufacturing company and the main customer of Carglass co.

Questionnaire D-1: The information about the relationships with customers:

- What are the main customer requirements for each product and in what format?
  - As a commercial vehicle manufacturer our customers expect to get a reliable and high quality vehicle from us.
  - Because of raising fuel price they expect to have less fuel-consuming vehicle.
  - Receiving after sales service during guarantee and warranty period.
  - Receive spare parts from reliable sources.

- What ICT tools used to process/assist the above processes?
  - AutoCAD for Design
  - Website marketing.

- Commercial advertising and finding new customers and suppliers.

- How the quote (price) and delivery times are worked out?
  - The price of products usually announced by the sales representatives to the customers. Delivery time mostly has a deadline. If all the processes goes well and nothing unexpected happens the customer receives the vehicle in 4 month.
  - For example to develop the new minibus we should calculate that:
    - The time of engine delivery from south Korea
    - The design and develop the prototype minibus body normally it takes 2-4week
    - Develop the windscreen and side screen takes more longer as we could not get right dimension from prototype
- What is the time taken to work out a quote?
  - Because of official formalities normally2-3 weeks is taken.

Questionnaire D-2: Process of managing changes:

- What are the main customer requirement changes?
  - Customers want to have better quality and more reliability and more convenience and low price.
- What are the main design changes to respond to the above changes?
  - New automobile shape
  - The drivers cabin should be heat and noise isolated (in heavy automotive).
  - It should be supplied with an air conditioner and more electronic facilities.
  - The seats and interior design must be changed.
  - Engine must be revised or replaced with more powerful and less fuel consuming one.
  - New aerodynamic windscreen
- How to work out a revised price for the changed requirements?
  - Any revision to fulfil the customer requirements will affect the total price. obligatory requirements are taken into consideration such as using braking

system and electronically facilities and in most comment re-design body shape .

- What is the way you work with the design department?
  - o It depends on products. Some times is face-to-face meeting and in some circumstances we gathering information from our supplier and other industries and normally from customer survey.
- What is the way you work with the manufacturing department?
  - o Manufacturing Department is independent from other departments. They usually following they manufacturing process. It means we transfer the data and design information to them and after that they work out on data to produce the first prototype. Normally design departure develops design on AutoCAD software and base on this information they work out. Also because of competition market normally we require to reduce the final cost of product as low as possible. Also for our exported product we would transfer the customer requirements.

- What is the way you work with customers?
  - o There are many ways relationship between our customers and us. It depends on product. They can order directly to us by filling optional forms or requires through the website. In some circumstances we get the customer requirement at begging of order or before production such as military automobiles or airport transfer buses.
- What is the way you work with suppliers?
  - o For every purchase from a supplier a contract is made (Direct meeting) and all the circumstances is written and signed by top management. The suppliers must guarantee their sold parts for 2 years.
- What is the procedure in dealing with changes in customer requirements?
  - o Depends on product. Customer satisfaction is our goal but because of lack of knowledge sharing and trust some times we experiencing difficulties to satisfy our customer

Questionnaire D-3: Relationship with other departments:

- How do you interact with design department?
    - Usually new obligatory regulations are received from traffic police and will be sent to other departments to fulfil them. If any technical change is needed the design department will be in charge.
- How do you interact with purchase department?
    - Usually new obligatory regulations are received by sales & marketing dep from traffic police and will be sent to other departments to fulfil them. If anything must be purchase from internal or external sources the purchase department will be in charge.
- How do you interact with manufacturing department?
    - Usually new obligatory regulations are received from traffic police and will be sent to other departments to fulfil them. If any change in process or layout of assembly line is needed the manufacturing department is in charge.
- How do you interact with finance department?
    - If for any reason the finance department cannot pay the suppliers or creditors and if they agree, the sales department will give them vehicles instead of cash.
- How do you interact with the above departments when dealing with changes?
    - Usually new obligatory regulations are received from traffic police and will be sent to other departments to fulfil them.

Questionnaire D-4: Problems, challenges, use of ICT:

- What are the main problems and challenges in dealing with customer changes?
    - No specific flow chart has been defined.
    - ICT department, which controls and runs the needed soft wares, is not efficient enough.
    - Because of official formalities and lots of transaction reaching to proper result in right time is not possible.
    - Less knowledge flow between department and suppliers
- What are the main advantages and shortcomings of existing ICT systems in support dealing with the above changes?

    - The paperless transaction makes the job easier and faster.
    - But also it has created a lot of traffic in responding to the letters.
- What capabilities would you expect from future ICT systems in support of dealing with the above changes?
    - Developing web based databases in order to easier accessibility.
    - Revising the complicated algorithms, which are not working efficiently.
    - Employing skilled software writers to optimize the network.
- Is information and knowledge sharing an important issue in collaboration with customers and suppliers? Answers are as below:
    - Defiantly it is. But because of less trust always we feeling difficulties. We believes that if we have more trust in automotive industries we could reach high level of manufacturing.
- What are the main problems and challenges in information/knowledge sharing across the supply chain? Answers are as below:
    - Complicated and disorganized algorithms of ICT system.
    - Lack of detail technical data and reference standards.
    - High competition market
    - Not very stronger frame work in knowledge sharing and transfer
    - In some circumstances we need more web tools to support that
- What capabilities would you expect from future ICT systems in support of information/knowledge sharing across the supply chain? Answers are as below:
    - Algorithms of ICT systems are complicated and are not efficient and user friendly.
    - Using more knowledgeable and skilful software writers to achieve the goal.
    - Develop web based soft wares and databases.
    - Less production time
    - Reduce our production cost
    - And help us to reach the first prototype in such a short time.

Appendix B: screenshots Shown “Knowledge Sharing Framework Design Road-Map based on Web Browser”

This appendix represents the features (inputs and outputs) of the framework. Also it is represents the links between the KSFDR and collaborative implementation.

This screenshot represents that main KSFDR

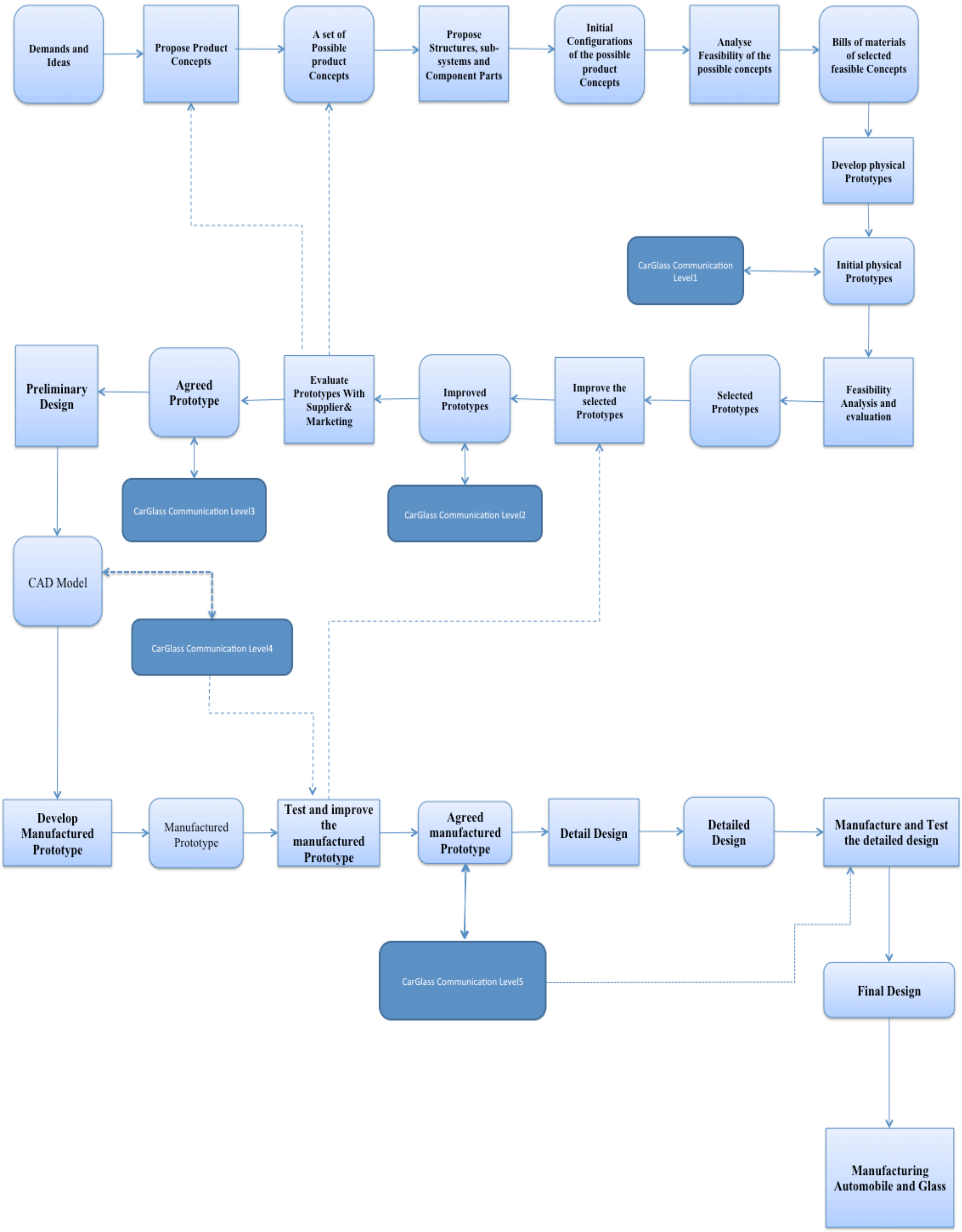
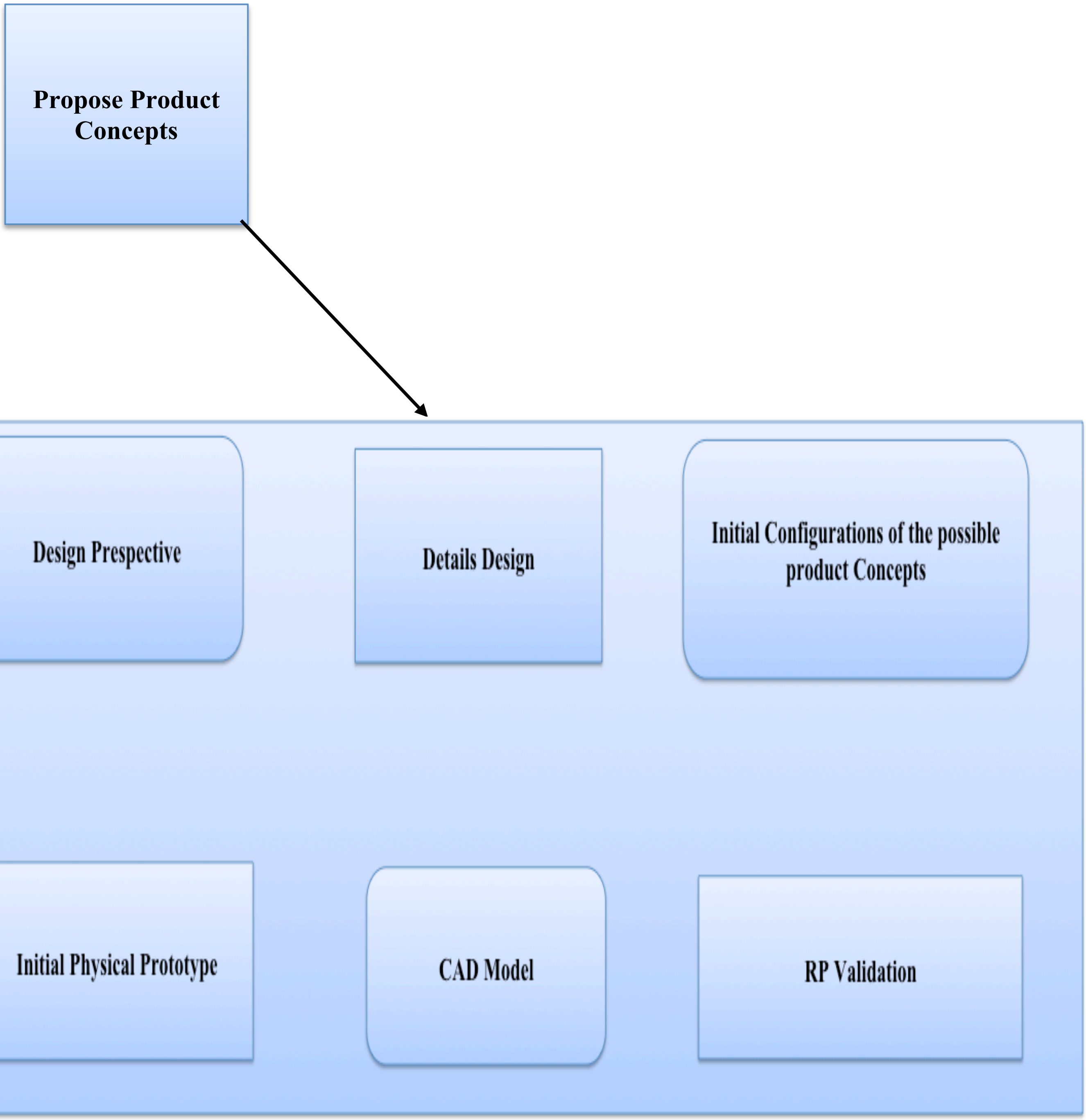
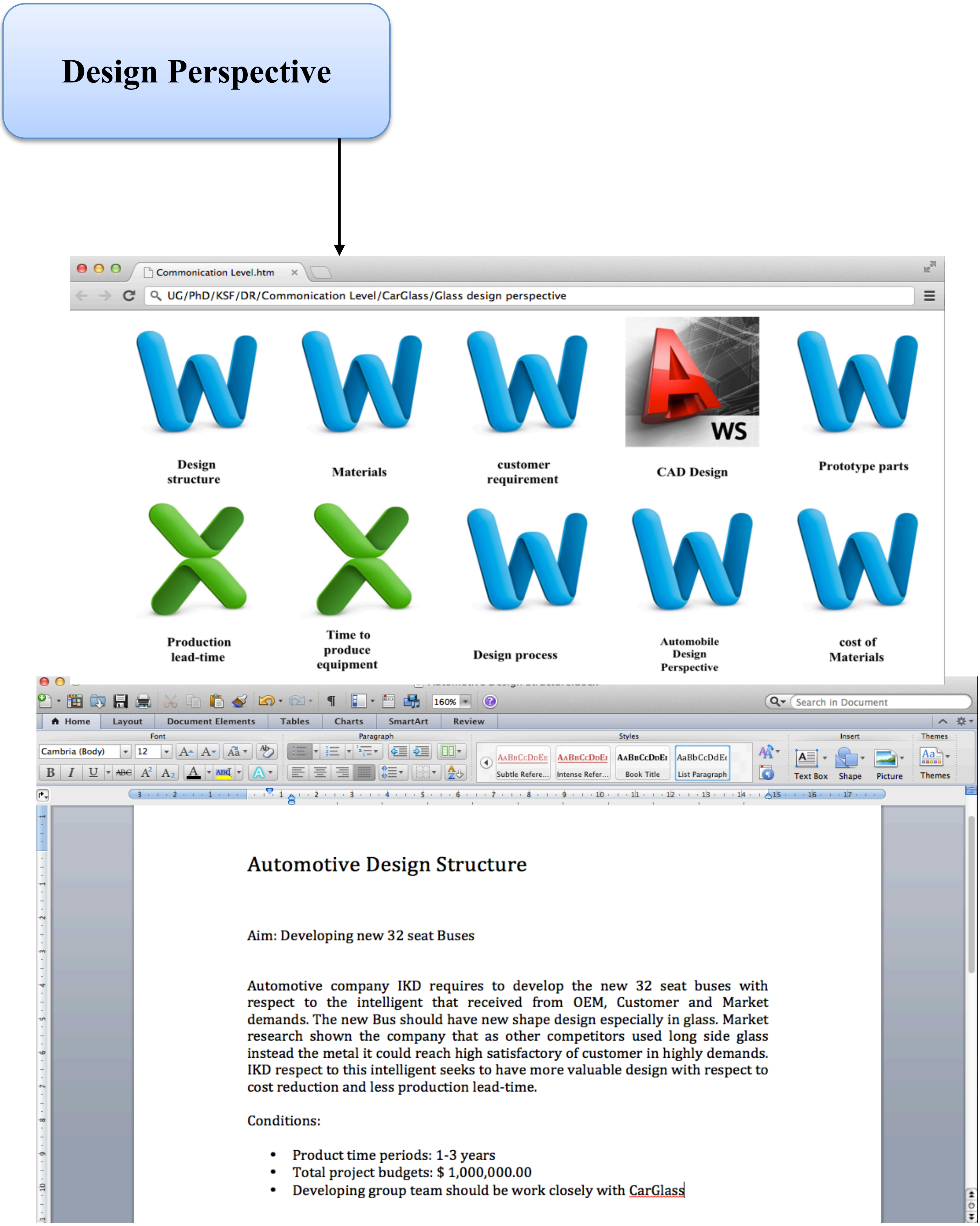


Figure B-1- Main KSFDR

This screenshot represents that system developers apply the "**Propose Product Concepts**" Feature of the framework in the "KSFDR" with examples, when they need to know the contents in the KSF Implementation.





Automotive Design Structure

Aim: Developing new 32 seat Buses

Automotive company IKD requires to develop the new 32 seat buses with respect to the intelligent that received from OEM, Customer and Market demands. The new Bus should have new shape design especially in glass. Market research shown the company that as other competitors used long side glass instead the metal it could reach high satisfactory of customer in highly demands. IKD respect to this intelligent seeks to have more valuable design with respect to cost reduction and less production lead-time.

Conditions:

- Product time periods: 1-3 years
- Total project budgets: $ 1,000,000.00
- Developing group team should be work closely with CarGlass

Details Design

A	B	C	D
Initial Requirement ID	Content	Relevant Departments/Group	Importance Point
Automotive Industry (LKD)			
I_K_D_M1	To model and manage the RP development lifecycle	IKD/Automotive	160
I_K_D2/O457_P_GCR	To manage the automobile RP development process and procedure	IKD/CG	160 (160,170)
I_K_D3/C457_P_GCR	To estimate cost and Control budget of RP development	PD/Design Unit	149 (149,129)
I_K_D4/MANU_D6/MG4	To plan and manage human response based on function and possible in the process and product line	Manufacturing in both IKD/CG	178 (178,149,160)
I_K_D5	To set up check points and milestone in RP development process	IKD/CG	130

Department Level

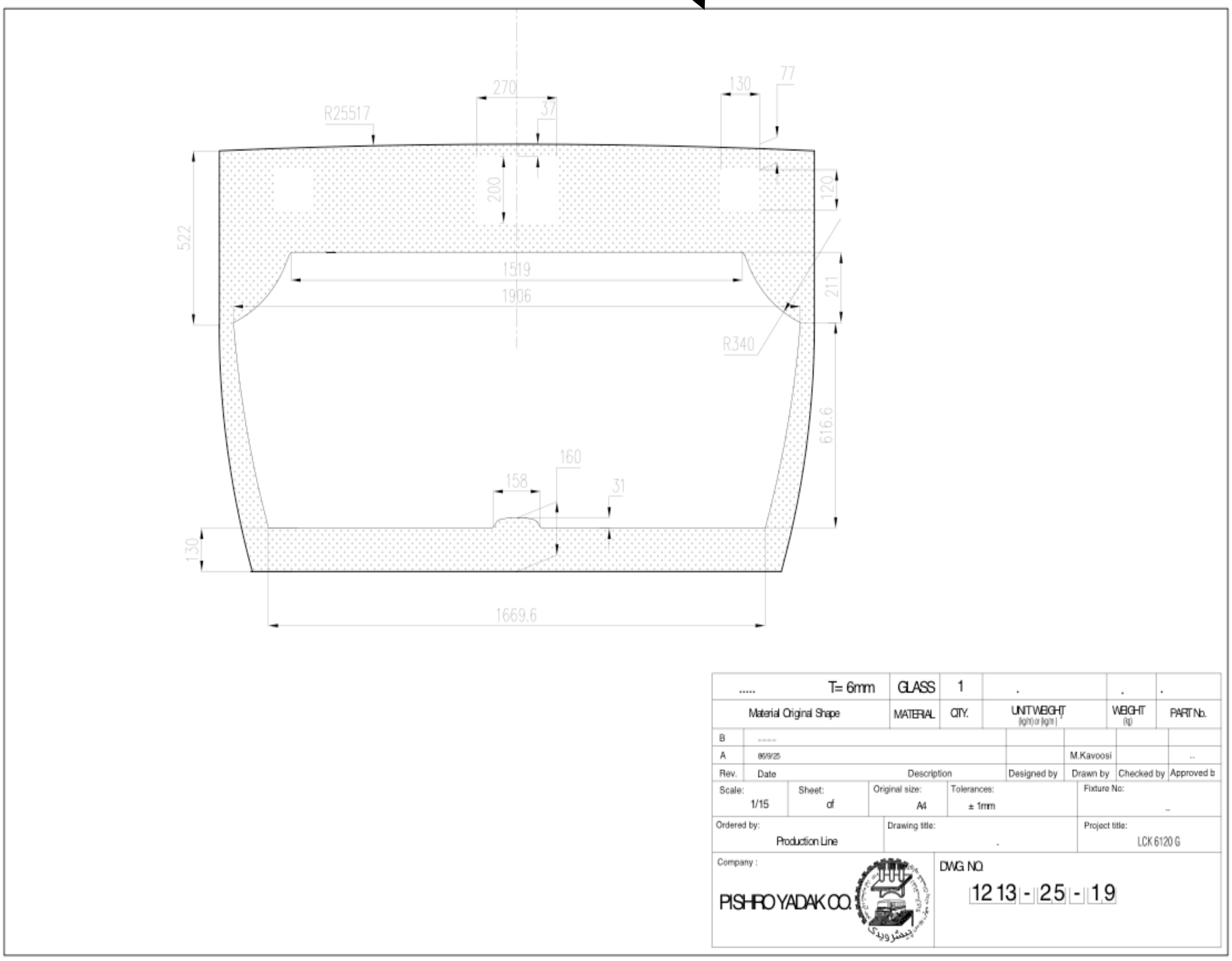
C_G_K1	Large knowledge based to store the CAD model, Graph and figures	Production / Design Departments	105
C_G_K2	Visibility of RP resource and controlling	Production / Design Departments	95
C_G_K3/I_K2	CAD model, Design Specification, Design perspective and Details Design	Production / Design Departments	125(115,100)

Group Level

CG_IKD_D1	Develop a knowledge framework to support rapid response in automotive	Product concept development group in both industries	156

Initial Configurations of the possible product Concepts

CAD Model


R25517
270
37
130
77
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31
130
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..... T= 6mm GLASS 1
Material Original Shape MATERIAL QTY. UNIT WEIGHT WEIGHT PART No.
Rev. Date Description Designed by Drawn by Checked by Approved b
M.Kavoosi
Scale: 1/15
Sheet: of
Original size: A4
Tolerances: ± 1mm
Fixture No:
Ordered by: Production Line
Drawing title:
Project title: LCK 6120 G
Company :
PISHRO YADAK CO.
DWG. NO.
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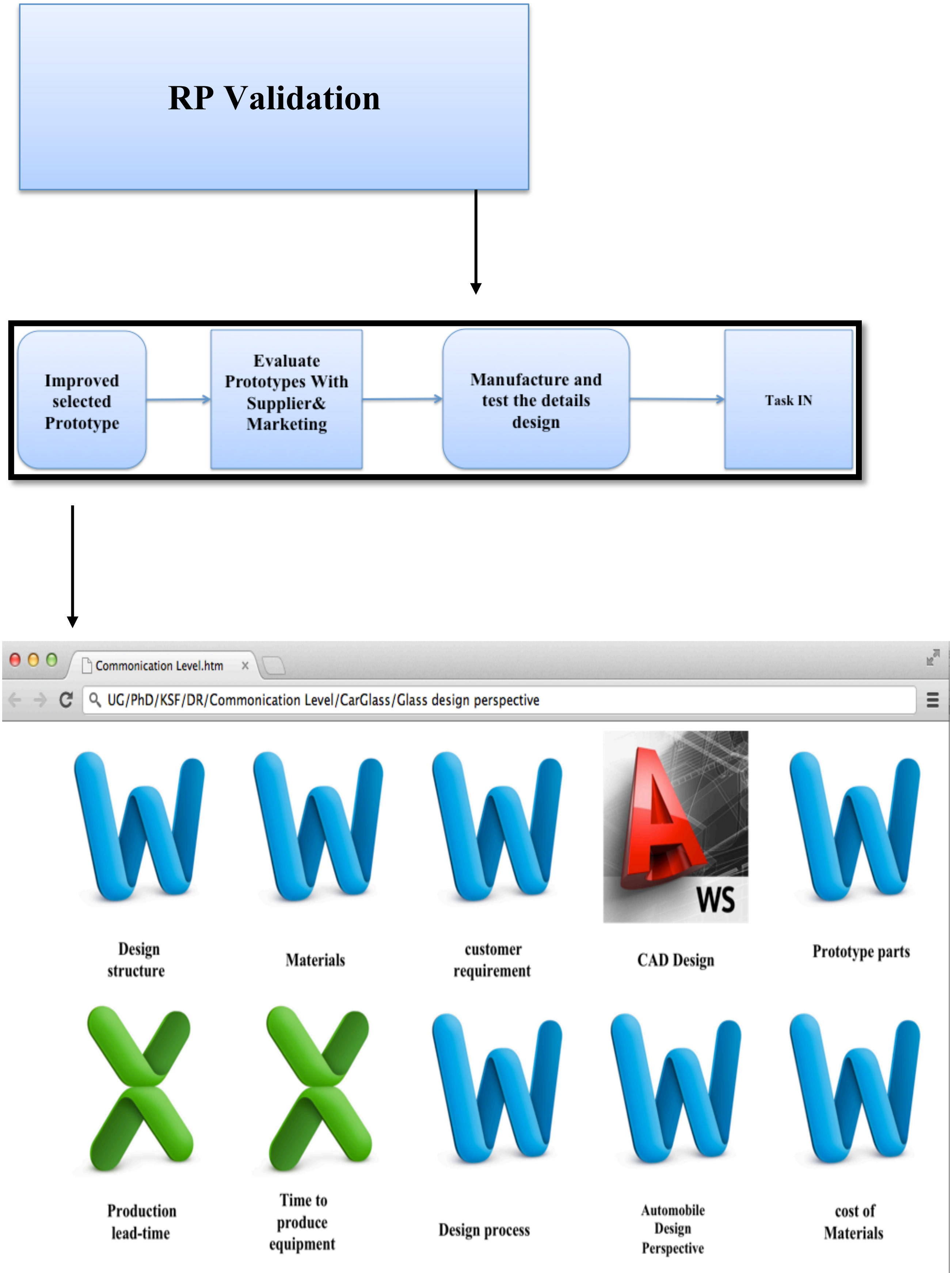
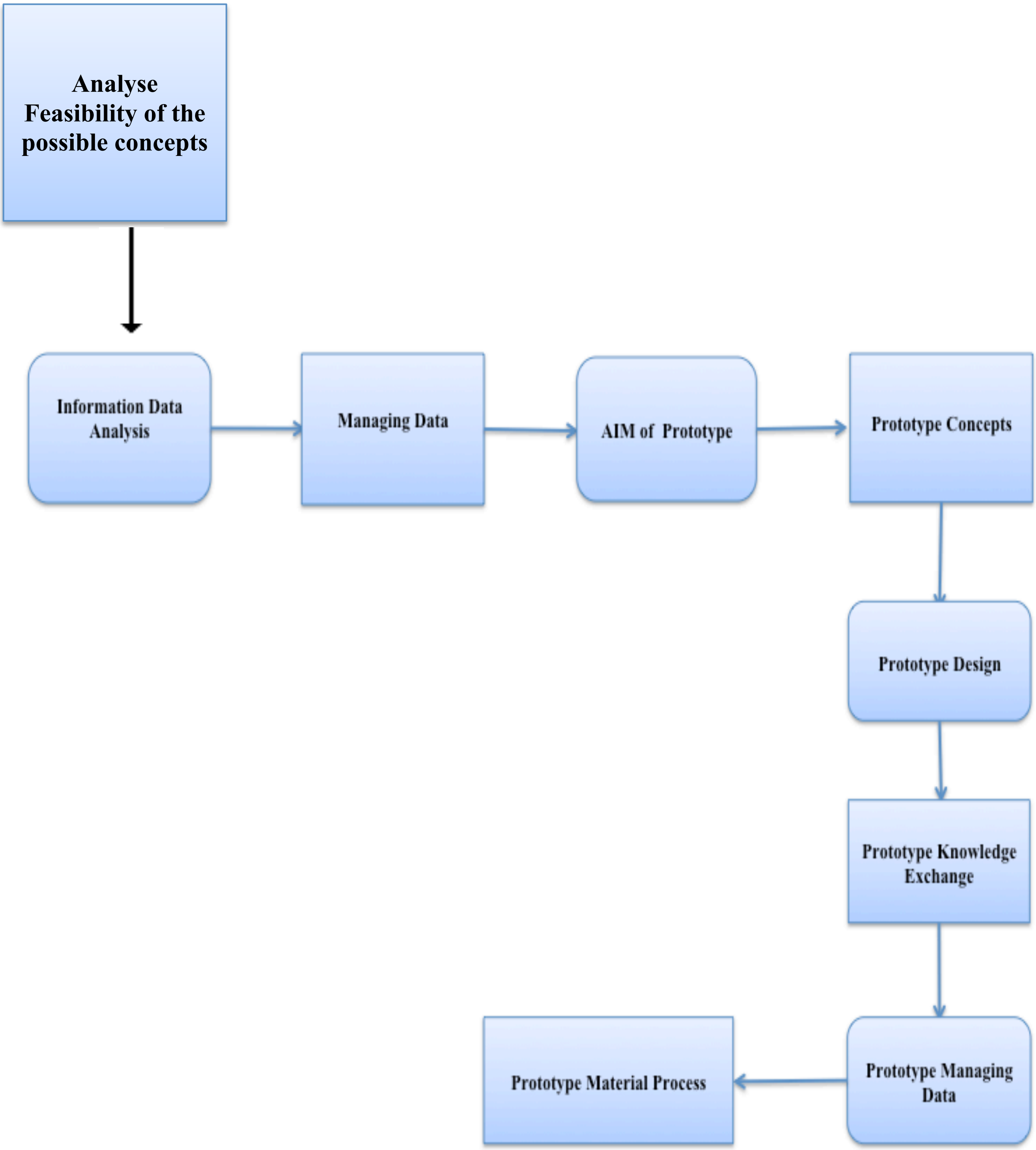
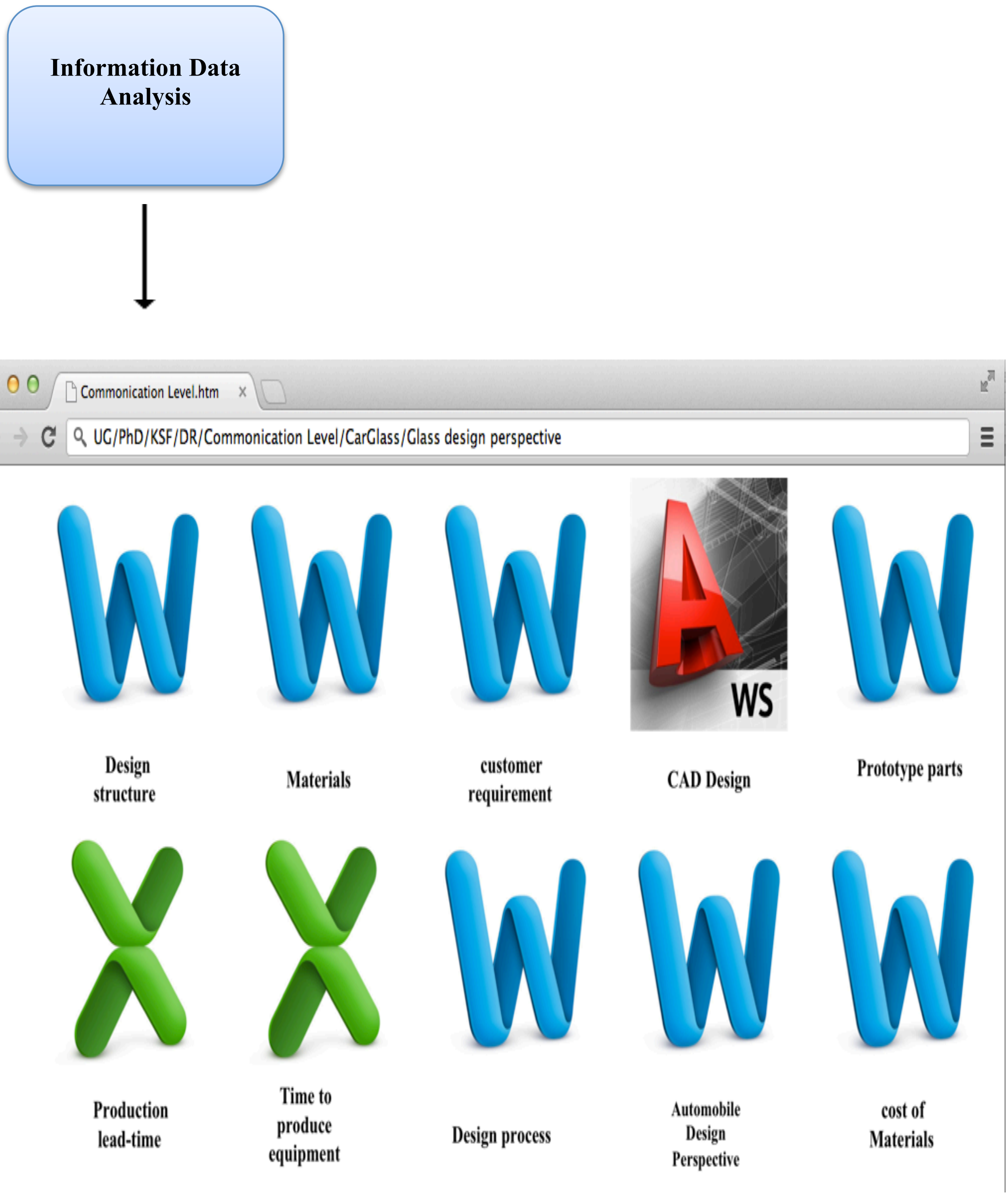

RP Validation
Improved selected Prototype
Evaluate Prototypes With Supplier& Marketing
Manufacture and test the details design
Task IN
Commonication Level.htm
UG/PhD/KSF/DR/Commonication Level/CarGlass/Glass design perspective
Design structure
Materials
customer requirement
WS
CAD Design
Prototype parts
Production lead-time
Time to produce equipment
Design process
Automobile Design Perspective
cost of Materials

This screenshot represents that system developers apply the "**Analyse Feasibility of the possible concepts**" Feature of the framework in the "KSFDR" with examples, when they need to know the contents in the KSF Implementation.

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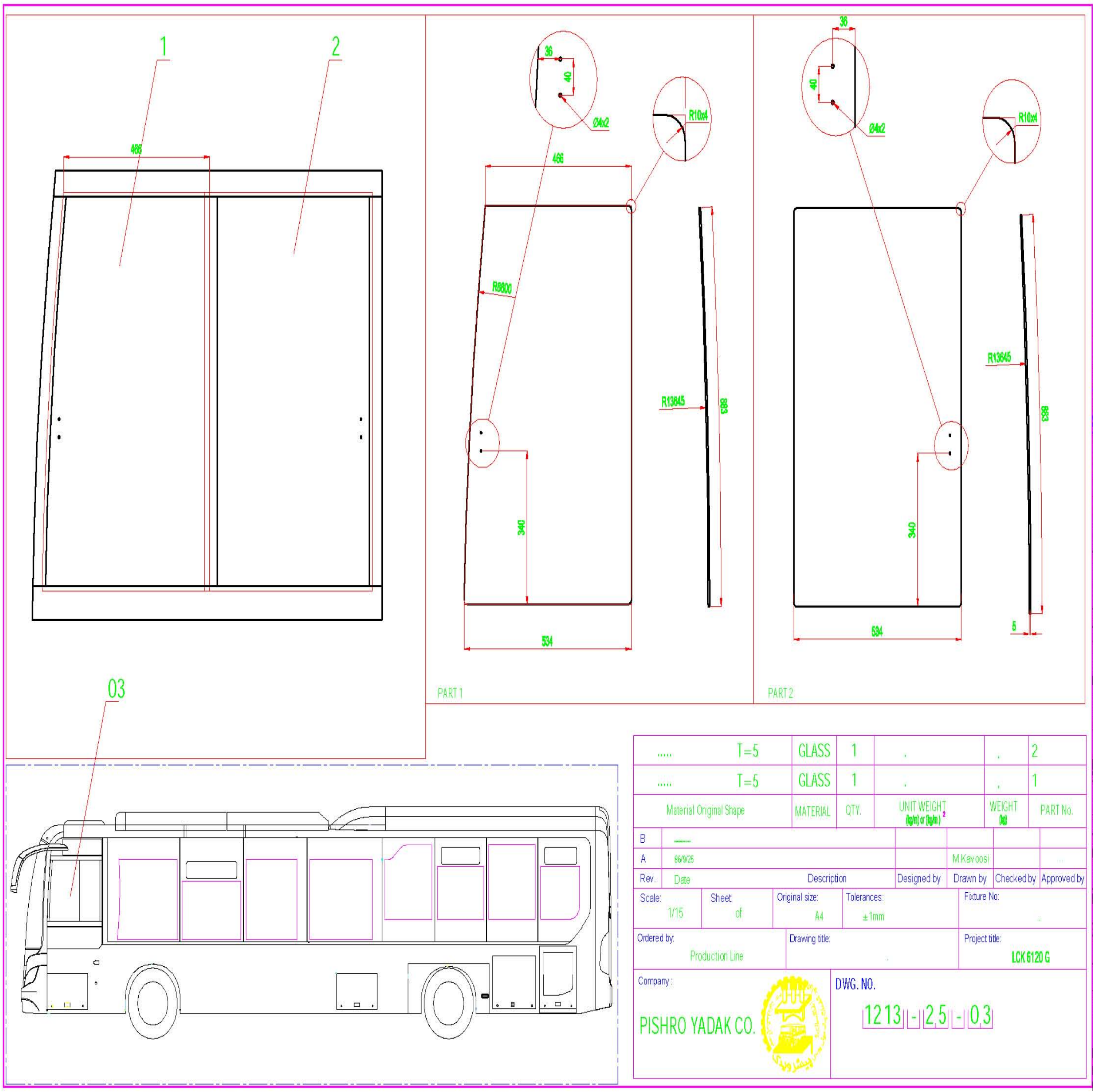
WS
Design structure
Materials
customer requirement
CAD Design
Prototype parts
Production lead-time
Time to produce equipment
Design process
Automobile Design Perspective
cost of Materials

Improved Prototypes

Agreed Prototype

CAD Model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340
534
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PART 2
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UNIT WEIGHT
WEIGHT
PART No.
Rev.
Date
Description
Designed by
Drawn by
Checked by
Approved by
M.Kavoosi
Scale:
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of
Original size:
A4
Tolerances:
±1mm
Fixture No:
Ordered by:
Production Line
Drawing title:
Project title:
LCK 6120 G
Company:
PISHRO YADAK CO.
DWG. NO.
1213-25-03