

A KNOWLEDGE BASED FRAMEWORK TO SUPPORT PRODUCT DEVELOPMENT

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ABSTRACT

In recent times, the development and manufacture of new products and the necessary tools required to carry out such activities has resulted in vast amounts of knowledge and information being generated. In product development there are no hard and fast rules determining the length of product development projects and quite often over a 10-year period several hundreds of projects could come into being, quite often coinciding with huge advances in technology over the same period. This advancement in technology has often taken over the role of the designer who carries out calculations and attempt to provide solutions. This has resulted in certain cases with designers having very little to no understanding or practical experience of the manufacturing process and design expertise required to ratify product designs. The resultant loss of information and intent and the lack of exploitation of manufacturing constraints and product knowledge can quite often lead to difficulties resulting in product re-design and in some cases failure in the hands of the customer.

In order to provide knowledge to support product development, there is a requirement to capture the knowledge of the manufacturing processes within the organization, which includes the process, materials, resource, design rules, capacity and other constraints that may limit the capabilities of the organization.

The research presented in this thesis proposes a knowledge based framework to support product development Furthermore, the research includes the development of a knowledge based system in order to identify, capture, formalize, present and utilize knowledge within a product development environment.

In this research, a knowledge based framework to support product development was developed in order to create an “AS-IS” process map of current product development practices within a case company from the cold roll forming industry. The process map guided the identification of information and knowledge required to support the product development process and formed the basis of the knowledge based system developed to provide effective decision support. Finally, the framework and knowledge based system were implemented within the case company. The results from the case study demonstrated how the knowledge based frame work and knowledge based system provided effective decision support by providing information and knowledge in the place, time and format required, thus ultimately reducing product development costs and improving quality.

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Chapter 1

INTRODUCTION

1.1 Research rationale

Industry is changing faster now than at any other time in history, with increasing market requirements, global competition and an increasing emphasis on quality, cost and reliability (Cooper 2003). Development of new products is now considered fundamental for corporate growth and sustained competitive advantage, which is due to:

- Increased competition facing organisations,
- Rapid development of technology,
- Shorter product life cycles (Yikuan and O'Conner 2003)

The rapid advancement in technology has seen a huge increase in the number of commercially available computer based product development tools for design (Solid works 2006, AutoCAD 2005 and Pro Engineer 2006), however many of these tools are individual systems with particular stand alone functionality, which lack the capability of supporting decision making in an integrated manner in the product development process. In some cases this has led to designers having very little or no understanding or practical experience of the manufacturing processes and the design calculations required to ratify a product or process. The loss of essential engineering knowledge and the lack of exploitation of manufacturing constraints and the product development process can cause inconsistencies within design and manufacturing processes, resulting in difficulties with product and process design or even failure in the product utilisation phase. Many organisations are poorly equipped to tackle this problem and it is often compounded by the fact that these organisations are highly bureaucratic with functional structures that inhibit the free flow and processing of information.

Product development process activities are becoming more and more complex and require greater depth and breadth of knowledge and because of this, organizations are now beginning to focus on their knowledge generating activities. However the identification of knowledge required and the ability to utilize it is a major challenge facing organizations. Increasing an organization's proficiency at deriving competitive value from knowledge requires an understanding of what aspects of the organization's systems and structure affect its ability to acquire, create, and apply

the appropriate and necessary knowledge. Recently there has been an influx of the so called software based knowledge management tools (Sybase 2006, Arbortext 2007). However these commercially available software systems are mainly restricted to document management and the majority do not support collaboration in product development or capture the context of engineering changes that would allow the reuse of past experiences. In fact very little literature is available on the specific engineering knowledge that is required to support product development process.

In order to provide knowledge to support product development, there is a requirement to capture the knowledge of the manufacturing processes within the organization, which includes the process, materials, resource, design rules, capacity and other constraints that may limit the capabilities of the organization. Previous research to provide structured knowledge to engineers within the area of structuring manufacturing process information (Al-Ashaab 1994; Molina 1995; Young et al., 2001; Echavarria 2005), has shown promising results. It has become expedient therefore to develop a knowledge based product development framework to enable the capture of design and manufacturing process knowledge so that the information can be exploited for future product development projects. The proposed framework shall be described as Knowledge Based Product Development (KBPD) system.

1.2 Aim and objectives

The overall project aim is to develop a systematic knowledge based framework to identify, capture, formalise, present and utilise product and process knowledge and lessons learnt for future product development activities. The measurable technical objectives are to:

1. Carry out a comprehensive literature review on the application of lean thinking and knowledge management in product development.
2. Analyse and identify the knowledge required to support decision making throughout the product development process by using process mapping tools.
3. Provide an understanding of how knowledge can be utilized to support knowledge based product development (KBPD) process.
4. Develop a knowledge based product development system to identify, capture, store and utilize product and process knowledge for future product development activities.
5. Carry out an industrial case study in an organisation manufacturing cold roll formed steel profiles in order to validate the knowledge based framework and it's support for the product development activities.

1.3 Research methodology

In order to address the previously mentioned aims and objectives the following research methodology was adopted to propose and develop the Knowledge Based Product Development framework:

1. Literature review in order to understand the state of the art which define best practices in Knowledge Management, Knowledge Modelling and how they can be used to support lean thinking within the product development process.
2. Industrial case study to identify a set of evolving issues underpinning traditional product development. Identify the knowledge required during product development activities through informal interviews, case company documents and reference manuals from British and International standards sources.
3. Apply process mapping using integration definition for function modelling (IDEF0) (Colquhoun *et al.*, 1993), to identify knowledge required to support decision making in the key activities of product development. The process mapping technique used, provided an initial insight of the required knowledge for the process, specific details regarding this knowledge was obtained through face to face interviews, text books, British and international standards and the case company.
4. Establish and define a knowledge framework in order to identify, capture, formalize and represent knowledge useful in product development. The identified knowledge will be implemented in a knowledge based product development software tool developed using Borland Delphi (2005); a Windows based application development tool and Microsoft SQL server (2005), a relational model database server.
5. Framework validation using an industrial case study.

Chapter 2

STATE OF THE ART REVIEW

2.1 Introduction

The literature review aims to give an overview of current research topics within product development and knowledge management. First, an introduction to lean and research initiatives looking at lean tools and techniques and their application to the product development process. Section 2.5 provides an overview of knowledge, knowledge classification and its role within product development. Section 2.6 looks at knowledge management and associated strategies, tools and modelling frameworks. Evolving issues facing knowledge management applications within product development are described in Section 2.6.

2.2 Lean history

Many organizations have applied lean principles first introduced by Toyota, the founder of lean. Toyota's approach to manufacturing has enabled it to earn higher profits and sustain faster growth than any of its competitors over the last 30 years. In 2003, Toyota was the third largest car manufacturer with a global market share of 10 percent (Drew *et al.*, 2004). Last year 2008, saw Toyota become the biggest car maker in the world with 8.91 million vehicles sold. Toyota's success has been attributed to its operating system: the Toyota Production System.

Toyota's production system was founded in the 1950's when it began to develop new operating principles in response to the economic problems faced by Japan. Due to the destruction of the country's economy in the Second World War, capital was scarce, limiting access to finance. Low incomes meant the home market for vehicles was virtually non-existent; therefore mass production was a non-starter. With unproven vehicle models and little to no investment available for tooling coupled with stringent employment laws its attempts to improve efficiency led to strikes and poor industrial relations. These unfortunate set of circumstances gave Toyota the impetus to develop a more flexible production process less dependent on high volume mass production.

Toyota's production system was developed around its need for frequent and fast changeovers. Dedicated tooling and equipment were eliminated; it developed and implemented equipment that

could take interchangeable tools. Toyota was tenacious in reducing the complexity of machine set up and the physical distances that tools needed to be moved, however it's main focus was it's investment in people. They had to be able to change tools when needed, operate different machines and move from one production line to another. Having a highly skilled work force gave Toyota an additional benefit: the workforce was able to help and assist in continually improving the changeover processes. This focus on people increased Toyota's flexibility, short production runs actually became a benefit rather than a burden, as it was able to respond more efficiently and effectively to changes in demand by quickly switching production from one model to another.

Over time, all these elements have been consolidated into a new approach to operations that formed the basis of what we now know as lean (Womack, Jones and Roos, 1990).

In their successful follow-up *Lean Thinking*, Womack and Jones (1998) sought a way to help the success of Lean within a production environment to be extended to an enterprise level. They defined five principles that were considered key elements to Lean production's success: value, the value stream, flow, pull, and perfection. These principles are thought to be applicable outside of production, and this has been the goal of much research (Womack and Jones, 1998).

2.3 Lean principles

2.3.1 Specifying value

Value in terms of the product or service being provided is defined as “a capability provided to a customer at the right time at an appropriate price, as defined in each case by the customer” (Womack and Jones, 1998). In other words, the value of a product is how much it is worth to the customer to have the product where and when they want it and at the required level of quality. By focusing on customer value (and thus what the customer is willing to pay for), an organization can eliminate all activities that do not contribute to its creation (those the customer is not willing to pay for), and thereby save time and money. All of Lean is based upon delivering customer value.

2.3.2 Identifying the value stream

The “value stream” is “all the actions, both value added and non-value added, currently required to bring a product from raw material to the arms of the customer or through the design flow from concept to launch” (Morgan 2002). The value stream often encompasses many business

enterprises (such as designers, suppliers, and final assemblers), and by looking at the entire value stream, one can identify how to improve the process of turning an idea into a product. According to Womack and Jones (1998), in analyzing value streams, all activities will fall into one of three types:

1. ***Value adding:*** Contributes to the value of the product
2. ***Necessary, but non value adding:*** Cannot be avoided
3. ***Non value adding:*** Should be eliminated immediately; waste.

One of the best ways to visualize and analyze the value stream of a process is to create a value stream map (VSM). Value stream mapping is a technique for drawing the value stream that allows one to see the flow of information and materials between activities. The fundamental strategy of using a value stream map involves first creating a map that reflects the current state of the process being mapped. This map is then analyzed for waste and value creation, and a future-state map is created, which represents how the process could and should operate. An improvement plan can then be created to enable the transformation from the current state to the future state. As the process is improved over time, the current state can be mapped again, and compared with the future state map again to redefine the improvement strategy.

2.3.3 Flow

Once the value of a product has been assessed, and its value stream analyzed, focus should be applied to making the steps in the product creation process flow smoothly; the output from one process task should move smoothly into the next task. When flow is not achieved, parts and information to be processed begin to accumulate up as inventory in between tasks. In a manufacturing environment, these parts take up space and must be kept in order for when they will be processed. This piling up of inventory is but one of many kinds of impediment to flow known as waste. Taiichi Ohno (1988) identified seven kinds of production waste, and Womack and Jones added one more (Womack and Jones, 1998). These will be discussed in more detail later in this chapter. The concept of flow has influenced lean thinking and practices over the years, and helped encourage the use of small batch sizes and a system of cards and bins to manage internal inventory (known as “KANBAN”), as well as the Just-In-Time philosophy.

2.3.4 Pull

Once a value stream has been aligned such that the value can flow from one step to the next, the concept of “pull” can be applied to it. This concept states that an upstream task should not be

performed until a downstream task asks for its output. In other words, any given task should behave as if the next task in sequence is its customer, and should only provide an output when that task asks for an input. Pull is the opposite of “push”-based systems of production. In a push system, an upstream task is performed and its output sits around until it can be used by the downstream task. This encourages inventories building up, is often the result of manufacturing being performed in large batches (which mass-production systems view as the most efficient way to make an item). When in a manufacturing environment, pushing a large batch of items onto a downstream task not only creates inventory, but can lead to a great deal of waste if a problem is found with the quality of the output items. In the ultimate flowing pull-based system, an order would be placed by the customer and placed at the end of the manufacturing line. The operator of the last task would ask the operators of upstream tasks for the exact items needed for his task. This pattern would continue, and each task would output exactly the number of items needed by its downstream task.

2.3.5 Perfection

The final key concept in Lean is the pursuit of perfection. All wastes cannot be eliminated overnight and production systems cannot be made to perfectly flow the first time. Lean requires an enterprise to continuously seek ways to improve its performance. As long as progress is being made, with perfection of the value-delivery system the goal, the journey to a Lean state is ongoing. Toyota, by far the recognized exemplar of a Lean enterprise, continually strives to improve itself. A company just starting the Lean journey should not think that it can “become” Lean instantly. The implementation of Lean is a considerable undertaking. In order to properly eliminate wastes and properly align the value stream such that the value can flow at the pull of downstream activities, a redefining of the work to be done is required. Departmental structures that may have existed for years (which made sense historically but now cause waste) may need to be broken down, with a new organization of functions and product teams formed. A fundamental cultural shift must be made as all employees must embrace the desire to make not only their job better, but to make the entire value stream flow better.

The concepts that make lean work have been identified, and many organizations have started to see the positive effects of employing them all as appropriate. As Lean has been transferred from the relatively high-production automotive industry to other industries, organized research has been needed to determine how to properly transfer these ideas to best fit each industry. Lean principles have spread and many related techniques are being applied in such diverse areas as

supply chain management, accounting, office paperwork, and even health care. However, the application of lean thinking and its five principles in these areas and others is in its infancy. Product development is an area particularly ripe for the application of Lean principles and techniques.

2.4 Lean thinking and product development

Many organisations, consultancy businesses, academia and research institutes have realized the potential of applying lean thinking to the product development process and are now selling the idea that applying lean principles will result in:

- The development of more products with the same resources
- Completion of new products on time, every time
- Creation of more winning products
- Development of products that are more reliable
- Reduce new product development timeframe by as much as 30% to 50% (Womack and Jones 1998; McManus 2004).
- Faster supported product redesign supported by knowledge management framework.

Studies into lean thinking have focussed primarily on developing and deploying lean approaches and methods for product development in the hope of reducing cost and cycle time. These practices are emerging rapidly as product development practitioners attempt to apply lean principles from the manufacturing environment to product development activities. Additionally, existing or emerging best practices in product development have provided benefits in cycle time and cost and are converging with what is becoming accepted as "lean product development".

Sometimes there can be confusion about which lean principles apply to product development, and indeed what is lean product development? Research and experience have shown that the product development process covers many activities and is all about creating, gathering and evaluating information and reducing risk and uncertainty (Bauch 2004). The process has several stakeholders within its value stream and consequently, a considerable amount of the research carried out has focussed on the value stream encompassing all activities and stakeholders, from initial concept through to the initial production phase. This includes customer requirements and front-end processes (sales and marketing), systems engineering, preliminary and detailed design, purchasing and initial production. The concepts of lean are firmly fixed on value creation and the

need to focus on practices that accelerate the creation of a new product with maximum value while employing the minimum resources necessary. Research topics covered under the umbrella of lean product development have been presented in Table 2.1 (p.p.11-13) and cover the following themes:

- Product development waste and value flows
- Integrating activities through common tools, databases, or information systems
- Advanced product development tools and practices
- Requirements and front-end processes
- System architecting methods
- Commonality in product architectures
- Spiral development
- Lean test and evaluation practices
- Lean software development
- Identifying value and waste in PD
- Advanced system architecting tools
- Information technologies in lean product development

Defining value within product development has received a considerable amount of interest from the research community with particular focus on defining and eliminating waste; the set of seven types of wastes established by Toyota have been adapted, modified and redefined several times. One such modified definition resulted in removing one category ‘over-processing’ and adding two further categories ‘complexity’ and ‘time lag’ (Womack and Jones 1998). The definition of categories of waste have also been viewed and redefined from a product development perspective by exploring the differences between manufacturing and product development (McManus 2004). Another adoption of the definition of waste resulted in dramatic change from the perspective of systems engineering, based on the idea that a lack of co-ordination leads to low performance in product development processes, which has now introduced eleven categories of waste, replacing all but one of the original; waiting (Morgan 2002).

Recognizing interdependency among the categories of waste defined in early studies of product development process, was again re-defined into ten categories of waste by analyzing interactions among the categories (Bauch 2004), however these ten categories do not provide an explicit answer to the question of ‘what waste is’ and ‘what gets wasted’, rather it identifies why waste

occurs. Further work analyzed the relationships amongst the categories of waste and identified root causes of waste and their effects on the product development process. The nine effects identified, are referred to as 'waste indicators' because they are not causes of waste, but indicate that time is wasted (Kato 2005).

Table 2.2 (p.14) identifies the categories of waste in product development by the various authors and organizations and is categorized on the basis of the original seven wastes established by Toyota.

The concept of lean thinking in product development needs careful consideration and must be considered in terms of what service or product it provides and what value it adds to the product. Product development can be described as the information creation process; it is concerned with gathering, interpreting information and creating knowledge in order to reduce risk, uncertainty in relation to its main function of developing new error free product that can be manufactured to provide the customer with a product at the right time, cost and quality. Previous research on applying lean principles to the product development process has resulted in very little work being carried out on the impact of information and knowledge management on the process, yet various studies of waste in product development have clearly shown that the lack of exploitation of information and knowledge has a major impact on overall product development performance (Graebisch 2005). This is further supported by other studies which has shown knowledge and experiences gained from existing projects are often poorly documented and scarcely transferred to subsequent projects (Millard 2001), and this loss of or discarded knowledge is one of the basic reasons for re-invention occurring, mainly driven by poor knowledge and information management and exacerbated by poorly defined and undisciplined product development processes (Morgan 2002). Yet the use of knowledge from previous projects has a high potential to increase quality and efficiency of product development process (Bauch 2004).

Table 2.1 Lean product development research and associated frameworks

Author	Title	Framework	Objective
Allen C Ward (2000).	Enhancing Enterprise Value: Cycles, Flow and Value stream mapping for product and process development	Value stream mapping/Analysis	
Haque (2003).	Lean engineering in the aerospace industry	Lean principles	Introducing lean principles into engineering/new product introduction
Haque and Moore (2004).	Measures of performance for lean product introduction in the aerospace industry	Lean Metrics	Development of performance measures for the NPI process within the aerospace industry.
Haque and Moore (2004).	Applying lean thinking to new product introduction	Lean principles	Defining the five lean principles in the context of product development
Liu (2003).	Product development processes and their importance to organizational capabilities	Importance of product development process and relationship with organizational capabilities	<p>Framework to determine the importance of PD processes and their relationship with organizational capabilities.</p> <p>Provide an assessment vehicle that helps organizations assess their capabilities and make improvements.</p> <p>To improve predictions of project outcomes.</p>
Oppenheim (2004).	Lean product development flow	The five lean principles to product development	Applying the five lean principles to product development
Browning <i>et al.</i> , (2002).	Complex System Product Development: Adding Value by Creating Information and Reducing Risk	<p>Value in product development</p> <p>Information/Information quality</p> <p>Risk management</p>	
Karlsson and Ahlstrom (1996).	The difficult path to lean product development	Implementing Lean product development	Identify hindering and supporting factors in the implementation of lean product development
Bauch (2004).	Lean product development: making waste transparent	<p>Waste in product development.</p> <p>Information/Information quality</p>	Comprehensive and manageable set of significant types of waste occurring in product development by investigating the transferability of the lean seven types of waste to

			product development
			Identifying a way to efficiently eliminate waste occurring
Fiore(2004).	Lean strategies for product development	Applying lean principles to product development	
McManus and Millard (2002).	Value stream analysis/mapping for product development	Value in product development	
Morgan (2002).	High performance product development: A systems approach to a lean product development process.		
Chase (2001).	Value creation in the product development process	Value creation	Development of a framework for understanding the nature of value in product development
Miller (2000).	Value stream analysis applied to product development process	Value stream mapping/Analysis	
Kato (2005).	Development of a process for continuous creation of lean value in product development organizations	Value in product development Waste in product development Value stream mapping/Analysis	Develop ideas and methodologies of LPD into tools and processes that can help PD organizations: 1. Identify and measure waste in their teams processes. 2. Identify causes and measure their impact on PD processes 3. Learn the best strategies to pursue to improve their PD processes.
Oehmen (2005).	Approaches to crisis prevention in lean product development by high performance teams and through risk management	Risk management High performance teams	
Bernstein (2001).	Multi disciplinary design problem solving on product development teams.	Effective Communication	Improve the ability of PD organizations to integrate their technical disciplines to deliver successful product
Kennedy (2003).	Product development for the lean enterprise	Applying lean principles to product development	
Graebisch (2005).	Information and communication in lean product development	Information/information quality	Efficient communication in PD processes with multiple

			participants:-
			Facilitating the seamless flow of valuable information.
Cusumano and Nobeoka (1998).	Thinking beyond lean: How multi project management is transforming product development at Toyota and other companies		
Slack (1998).	The application of lean principles to the military aerospace product development process	Applying lean principles to product development	
Millard (2001).	Value stream analysis and mapping for product development	Value in product development	Suggested method for value stream analysis and method as applied to PD activities
Whitaker (2005).	Value stream mapping and earned value management: two perspectives on value in product development.	Value in product development	Make Lean more practical within complex PD.
		Value stream mapping/Analysis	Is creating a product development value stream map effective for learning about a PD process?
Breshnahan (2006).	Understanding and managing uncertainty in lean aerospace product development	Value in product development	Explore the relationships between the principles of LPD with an emphasis on the effects of uncertainty and risk in this arena.
		Management of uncertainty	Demonstrate a relationship between risk mitigation activities and the generation of customer value in the design and development process.
Baines <i>et al.</i> , (2006).	State of the art in lean design engineering: A literature review on white collar lean.	Adoption of lean principles to product development	Establish state of the art concerning the application of lean to product design, engineering and development.

Table 2.2 Types and root causes of waste in product development (categorized as the seven wastes of Toyota).

Categories of waste	Types/root causes of waste	Author(s)									
		Toyota	Womack and Jones (1996).	Slack (1998).	Ward (2000).	Poppendieck (2003).	Morgan (2002).	McManus (2004).	Kato (2005).	Bauch (2004).	UGS PLM (2004).
Waiting/Waiting Time	Waiting/Waiting Time										
	Time Lag										
	Just in case timing										
	Limited IT Resources										
Transportation/Hands Off	Stop And Go Tasks										
	Transportation/Hands Off										
Over Processing Excessive Processing	Hands Off										
	Over Processing/Excessive Processing										
	Process efficiency										
	process delays										
	Design re-use										
	Discarded Knowledge										
	Re-Invention										
	Complexity										
	Extra Features										
	Wishful thinking										
	External Quality Enforcement										
	Testing to specification										
Inventory	Ignored Expertise										
	Change loops										
	Over specifying										
Inventory	Inventory										
	Inventory of Information										
	Large Batch Sizes										
Defects	Defects										
	Rework										
	Defective information										
	Scatter										
	Wrong Tool										
Unnecessary Motion Movement	High Process And Arrival Variation										
	Expediting										
	Unnecessary Motion Movement										
	Transaction										
Over Production Unsynchronized Processes	Data Transfer										
	Over Production Unsynchronized Processes										
	Systems Over Utilization										
	Unsynchronized Concurrent Tasks										
	Lack Of System Discipline										
	Stop And Go Tasks										
	Ineffective Communication										
	Redundant Tasks										
	Engineer as surgeon										
	Late Completion										
	loss of synchronisation										

2.5 The role of knowledge in the Product Development Process

The product development process is referred to as the knowledge creation process; a place, where raw data is interpreted within the context of its creation to provide new and useful information, and only by its incorporation, linkage and transfer can knowledge be created and used by individuals for problem solving. Data, information and knowledge are created when developing a new product or process; the output of product development process is knowledge.

2.5.1 Knowledge quality

Lean thinking within manufacturing is tightly linked with defining and measuring quality attributes of the product and or process. Quality management is based on an explicit supplier-customer oriented view and considers 'fitness for use' as the key criteria for quality. This definition can also be applied to the area of knowledge. Consequently, high-quality knowledge then gets defined by the knowledge consumer and involves two important aspects, which are the usefulness and usability of the knowledge.

Strong *et al.*, (1997) have created a taxonomy that provides more foundation to this issue. It embraces four main categories of knowledge quality with 15 elements divided between these categories:

- ***Intrinsic***: Accuracy, objectivity, believability and reputation.
- ***Accessibility***: Accessibility and security.
- ***Contextual***: Relevancy, value-added, timeliness, completeness and the amount of information.
- ***Representational***: Interpretability, ease of understanding, concise representation and consistent representation.

Beside attributes like completeness or accuracy, the elements also include the important aspect of knowledge accessibility, which is often a major problem with current information systems (Bauch 2004). Two further areas where known problems occur, concern the knowledge creation process itself and its technical side regarding problems with storing and accessing information and knowledge.

Maintaining knowledge quality throughout the product development process, whilst facing high levels of uncertainty and risk, proves to be one of the biggest challenges since insufficient and

poor knowledge can easily lead to problems, however, compared with manufacturing, when even small defects in a product or assembly often results in the product being scrapped or expensive rework, small errors in knowledge can often be corrected quickly, and can sometimes even be compensated by the knowledge and experience of the information consumer.

2.5.2 Knowledge classifications within product development

In order to provide the appropriate knowledge to support product development, it is necessary to capture the appropriate knowledge, but what is knowledge? Many research projects have been carried out on this subject in relation to product development, however there are several interpretations; knowledge is contextual and relational, people create knowledge as they interact in a social context and this knowledge in turn influences their behaviour, perception and cognition (Berger and Luckmann 1996). Knowledge has been defined as information combined with experience, context, interpretation and reflection (Davenport *et al.*, 1998). Knowledge in terms of its creation and application has been defined as the key components for decision making include data, information and knowledge, and individual organisational processes (Liebowitz and Megbolugbe 2003). Data is raw or discerned elements and when these elements are patterned in a certain way, data is transformed into information. As rules or heuristics are applied to information, knowledge is then created as actionable information for producing some value added benefit.

Engineers engaging in new product development bring to their work the formal and articulated expertise of their disciplines that have been socially constructed through time by particular professional or academic communities (Mohrman *et al.*, 2003) This knowledge initially frames their attention when they approach a problem; however by making sense of a particular problem and of the information they encounter, and by taking action and revising their interpretations, they develop, analyse and create new knowledge. The knowledge that is created and shared amongst organisational members can be categorised into two typical forms of knowledge - Tacit and Explicit (Polanyi 1996).

Tacit knowledge is highly personal, context-specific, and therefore hard to formalise and communicate, this type of knowledge is stored in the human brain, such as in personal belief, expertise, perspective and values formed as a result of experience.

Explicit Knowledge is defined as public knowledge, it covers those aspects of knowledge that can be articulated in formal language and can be easily transmitted among individuals using information technology.

How an organisation derives a competitive advantage from knowledge requires an understanding of what elements of an organisation's processes affects its ability to acquire, create and apply knowledge (Mohrman *et al.*, 2003). Knowledge helps to achieve improved business performance through product and process, and in this sense knowledge can be classified not only from the knowledge type (tacit and explicit) but also from the knowledge domain (product related and process related) (Ahna and Chang 2004). Using this definition knowledge has four classifications:

- **Tacit-product related;** know-how (human brain)
- **Tacit-process related;** human capability (human brain and culture),
- **Explicit-product related;** knowledge base (knowledge repository),
- **Explicit-process related;** workflow (workflow system).

One of the main challenges facing NPD organisations is how to acquire the required knowledge and manage sources of uncertainty in order to reduce the risk of failure of either the project or the resultant product (Cooper 2003). Acquiring the necessary knowledge to address problems, uncertainties, and potential causes of failure, assumptions and the relationship between them is difficult, maintaining that knowledge for use in further projects is even more difficult because of the volume of knowledge created during each new product development project, and these include:

- **Project Knowledge** related to the product, its production and use.
- **Technical knowledge** concerns the product, its parts, materials and associated technologies.
- **Procedural knowledge** concerns producing and using the product and acting in a project.
- **Organisational knowledge** concerning communication and collaboration.

Further problems are often encountered since the members of staff within project teams are quite often organisationally and geographically dispersed. They have diverse backgrounds and may have to speak several languages especially if the customer is based overseas. In order to develop a new product, the organisation may need to bring in experts from suppliers, customers, sub-contractors and universities. However projects are also time bound, and the people involved and the lessons learned are dispersed when the project ends, this combined with employee

empowerment and information decentralisation typical to new product development project organisations, often results in knowledge fragmentation and a loss of organisational learning.

To prevent knowledge fragmentation, systems and tools utilised to acquire product development knowledge need to be capable of managing the knowledge within the context in which it was acquired. If the system or tool captures only the documents, the context and processes behind these documents is lost. In order to retain the context and process information, documents have to be appended with meta-knowledge that links knowledge with its environment (Te'eni and Weinberger 2000)

2.6 Knowledge management: Strategies, tools and modelling frameworks

There are two basic strategies for managing knowledge (Hansen 1999; Swan *et al.*, 1999) as follows;

- **Codification strategy** is based on codifying the knowledge and storing it in artefacts and databases where it can be accessed.
- **Personalisation strategy** is where the knowledge is tied up to the persons who develop the knowledge and the sharing of that knowledge only by personal interactions.

Explicit knowledge and its codification, which is the most widely used approach to knowledge management, are driven in part by commercially available ICT tools (and there are significant numbers) with various technologies. Research has categorized these technologies by their application and divided them into seven categories (Liao 2003).

- **Knowledge management framework:** This is the basis by which an organization or system integrates knowledge, learning, culture, environment and performance together in a manner that enables the creation of organizational intelligence for decision support with the intention of creating competitive advantage .
- **Knowledge Based Systems (KBS):** The most common definitions of KBS are often human related, and that they are attempts to understand and initiate human knowledge in computer systems (Wiig 1994). Four main components of KBS are usually distinguished: a knowledge base, an inference engine, a knowledge engineering tool, and a specific user interface (Dhaliwal and Benbasat 1996), On the other hand, the term KBS includes all those organizational information technology applications that may prove helpful for managing the

knowledge assets of an organization, such as expert systems, rule-based systems, groupware, and database management systems (Laudon and Laudon 2002).

- **Data mining (DM):** is an interdisciplinary field that combines artificial intelligence, computer science, machine learning, database management, data visualization, mathematical algorithms, and statistics. Given the enormous size of databases, DM is a technology for knowledge discovery in databases (KDD). This technology provides different methodologies for decision-making, problem solving, analysis, planning, diagnosis, detection, integration, prevention, learning, and innovation.
- **Information and communication technology (ICT):** Is used to provide a broad platform for exchanging data, coordinating activities, sharing information and supporting globalization commerce, all based on powerful computing and network technology. Internet is a kind of ICT that combines with some other network technologies and services, such as Intranet, Extranet, virtual private network (VPN), and wireless web, to construct a digital environment to consistently create new knowledge, quickly disseminate it, and embody it in organizations.
- **Expert systems (ES):** Are knowledge-intensive computer programs that capture the human expertise in limited domains of (Laudon and Laudon 2002). Usually, expert systems capture human knowledge in the form of a set of rules. The set of rules in an expert system adds to the organizational memory, or could be stored learning of the organization. An expert system can assist decision making by asking relevant questions and explaining the reasons for adopting certain actions.
- **Database Technology:** A database is a collection of data organized to efficiently serve many applications by centralizing the data and minimizing redundant data (McFadden *et al.*, 2000). A database management system (DBMS) is the software that permits an organization to centralize data, manage them efficiently, and provide access to the stored data by application programs (Laudon and Laudon 2002).
- **Modelling:** Quantitative tools for exploring the issues of knowledge discovery, knowledge classification, knowledge acquisition, learning, pattern recognition, and artificial intelligence.

Several of these technologies and applications are utilized within product development processes to help identify, capture, formalize, present and utilize knowledge; these technologies have been further summarized based on their functionality (Cooper 2003).

- **Design tools;** assist in the creation, visualization, analysis, and simulation of designs

- **Collaboration tools;** facilitate storage and retrieval of drawings, documents, computer files, etc.; version and change control
- **Authoring tools;** assist in the creation of text-based products
- **Groupware;** facilitates communication and coordination between team members
- **Knowledge management systems/Decision support systems;** data analysis for structured decision-making
- **Design rationale tools;** structure and capture rationale and supporting information during design process
- **Knowledge resources;** acquisition, development, distribution and access to knowledge resources and specialized content

There has been a considerable amount of research on knowledge management within the construction industry which emphasises the opportunities and possibilities opened up by ICT and its various technologies (Egbu *et al.*, 2001; Robinson *et al.*, 2001) however many of the assumptions made in that study have been challenged by empirical studies, which questions the emphasis on explicit knowledge and the tendency for knowledge codification through technology (Swan *et al.*, 1999; Spender 1996; Tsoukas 1996).

Knowledge management literature is increasingly viewing IT as only one element of knowledge management: useful for storage of explicit knowledge, but less helpful for sharing tacit knowledge and stimulating the use and creation of knowledge. How to manage this knowledge has become an important issue in the research community and several authors have explored its nature, concepts, frameworks, architectures, methodologies, tools, functions, and as a result there are several frameworks that have been defined to manage knowledge. Table 2.3 identifies some of the existing frameworks and the associated authors.

Knowledge in product development environment is considered to consist of four activities.

1. Identification; the identification of knowledge required to develop new products, including product specifications, process, tooling, and material capabilities
2. Capture; how the knowledge is captured stored and retrieved.
3. Formalize and Present; how knowledge can be formalized and presented to ensure its use in existing and future projects.

4. Utilization; how the knowledge identified, captured and formalized can be integrated into products and decisions, and applied in other projects.

Table 2.3 Knowledge Management frameworks and associated authors

Authors	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Holsapple and Joshi (1998).	Acquisition	Selection	Internalization	Use	
Davenport and Prusak (1998).	Generate	Codify	Transfer		
Mertins <i>et al.</i> , (2001).	Create	Store	Distribute	Apply	
Kasvi <i>et al.</i> , (2003).	Creation	Administration	Dissemination	Utilization	
Liu <i>et al.</i> , (2005).	Obtain	Refine	Store	Share	
Liebowitz and Megbolugbe (2003).	Identification	Capture	Sharing	Application	Create - new
Lee <i>et al.</i> , (2005).	Creation	Accumulation	Sharing	Utilization	Internalization

2.7 Knowledge management: Evolving research issues in product development

The analysis of Knowledge Management frameworks and systems clearly illustrates that the research community has defined knowledge and many knowledge management frameworks for the identification, capturing, formalization, presentation and utilization of knowledge, however almost all the knowledge management systems have focused on supporting product development activities through document and data management. Vast amounts of work have been carried out on how knowledge is utilized in each activity; marketing, costing, design, manufacture etc, however there is limited research available on how knowledge from all activities within product development can be pulled together and utilized to provide decision support throughout the product life cycle.

The following issues have been highlighted by the literature review as issues for future research:

- A large amount of the knowledge management literature has been directed towards the development of databases to store product data files, mainly design data, or product design history with particular attention to document issue and control, engineering change control and project costs.
- Current knowledge management systems do not support all the key activities within the product development process.
- Very few systems provide decision support throughout the product life-cycle and are more geared to specific tasks with stand alone functionality.
- Very few knowledge management systems provide the means for the exploitation of manufacturing constraints and product knowledge.

- Knowledge management systems do not provide a means to identify, capture, formalise, present and utilise tacit knowledge.
- Very few knowledge management systems are capable of capturing and managing the knowledge within the context with which it was acquired.

2.8 Lean thinking: Value of knowledge within product development

The position of lean product development is that identification and concentration on value, reduction of waste, and continuous improvement of processes based thereupon, enables business viability in a globally competitive and informed environment (Millard 2001).

As stated previously and by many authors, knowledge is the output of the product development process. Lean thinking can therefore only be effective, if value and waste of knowledge can be identified. Value itself is a product which meets the customer's needs at a specific price at a specific time (Womack & Jones 2003). And the product development contribution to that is accordingly, a capability delivered at the right time, for the right price, as defined by the end user (Millard 2001).

Three main strategies emerge as fundamental to lean thinking: Quality Assurance, shorten time to market, and reduce cost.

Quality Assurance: The first strategy is to assure that the product meets exactly the customer's need for quality, which encompasses "the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs" (Rothery 1993). Product development, thus, has the task of assuring customer needs are expressed by the product specifications, and also risk (of failure to meet the requirements) is reduced. The main product development information stream is research and development, with the objective of facilitating product innovation, which can help to strategically foster customer requirements. It can be concluded directly, that activities in the main product development value stream produce valuable information and knowledge, if either customer needs are applied to product specifications, or product risk is reduced.

Shorten time to market: The second strategy with regard to value is to shorten time to market. It is thus a question concerning process improvement. Taking into account the lean principle of

perfection, process improvement is not a singular achievement, but continuous. In Lean Manufacturing, substantial reductions in production time can be achieved when die-change times are reduced. In product development, the basic tool for the generation of information is knowledge, and it cannot be changed easily. There are however two aspects that can be seen as corresponding to quick die change times in manufacturing: experts (or expert systems) that provide specific knowledge to any process participant that is in need of it, as soon as possible and multi-skilled employees that can do the work of others that are currently not available. Both ideas rely on high-quality information; in the first case, the expert has to provide information that can quickly be put to use by the receiver, in the second case, if progress has been made so far from the currently absent person, the second employee is in need of good, problem focused documentation. Both types of information enable value creation.

Cost reduction: Product development contributes to cost in various ways including:

- product development costs
- purchasing costs,
- operating costs,
- product support /servicing costs

The cost for purchasing and operation of the product is largely set during product development. Here, technical functions are chosen, materials selected, and manufacturability determined, which can equate to a large proportion of the overall product cost. The majority of product development costs are dependent on time, salaries and overhead costs. The strategy would thus be to reduce development time

2.9 Summary

Within this literature review, various aspects of knowledge and knowledge management in relation to product development have been reviewed and discussed. As the thesis focuses on providing a knowledge management framework and software tool to support the product development process, requirements for such a framework and software tool have been gathered systematically alongside the theoretical discussions.

At the beginning, the review focused on the concepts of lean thinking being applied to product development and highlighted that lean thinking does not aim to speed up machines, does not require employees to work faster and harder, and does not aim at innovation. Likewise, no single

tool for these objectives can be found within lean thinking, the potential for improvement simply stems from the inefficiencies present in the product development process; in particular having insufficient information and knowledge to provide effective decision support.

The review sought to understand various aspects of lean, what is value in terms of product development, and gain an understanding of the types of waste within product development.

2.10 Research Gap

The review highlighted that:

- Very little research has been carried out on how information and knowledge can be utilized to support the product development process, research has been more concerned with providing systems for document storage and retrieval, however for a knowledge management system to provide benefits to an organisation it must be populated with information and knowledge that is required by the product development process, including any constraints but fundamentally it must include the context in which that information and knowledge was created.
- Research has shown that the lack of exploitation of information and knowledge has a major impact on overall product development performance (Graebisch 2005). Successful leveraging of information and knowledge can only be achieved however if all activities and resources fulfil the specific requirements of the product specification. Effective use of knowledge requires a thorough understanding of customer requirements.
- Knowledge and experiences gained from existing projects are often poorly documented and scarcely transferred to subsequent projects (Millard 2001), resulting in similar problems being resolved over and over again, thus increasing product development time and cost. Organizations often fail to understand this problem, and the potential benefits that could be gained by starting new product development projects based on the experiences and lessons learned from the previous project.
- Loss of or discarded knowledge is one of the basic reasons for re-invention occurring, mainly driven by poor knowledge and information management and exacerbated by poorly defined and undisciplined product development processes (Morgan 2002). The quality of knowledge management systems is a critical factor and is governed by the ease of which information and knowledge can be input, maintained and utilized. Systems that become too complicated and do not provide the information required, will discourage its use. Additionally, the successful introduction of a knowledge management system and tools also depends on the project

engineers' willingness to utilise it, and on commitment from senior management to support its use

Product development is by no means a straightforward process, despite all the planning activities associated with the process its outcome is often uncertain. Many different ideas are developed and only a potential few are considered for further development, and ultimately only one defined solution exists. The integration of proven engineering knowledge is therefore essential in creating a formalized product development process and to ensure effective decision support to meet customer needs and or reduce product risk.

Chapter 3

RESEARCH METHODOLOGY

3.1 Introduction

Prior to the outset of this research project, the author noted some key issues and unanswered questions concerning the application of knowledge management to the product development process. A major concern was the application of knowledge management mainly focused on the storage and retrieval of knowledge, very little research existed with regard to the context of knowledge; having the right knowledge available at the right time to support decision making within the product development process. Knowledge was also seen as a key driver to improve the efficiency of the product development process, i.e. the correct information and appropriate knowledge at the point of decision making could effectively ensure a right first time philosophy, thus eliminating expensive modifications due to product redesign.

This chapter looks at the research methodology utilized in this research, in particular a case study; its aims and objectives and how this methodology was utilized to explore and address the key issues relevant to knowledge management and lean thinking within product development activities.

3.2 Management research

The purpose of research study according to Remenyi *et al.*, (1998) is to add value to the body of accumulated knowledge and attempt to provide suitable solutions to unsolved problems. Research excels at bringing an understanding to complex issues and can enhance experience or add strength to knowledge discovered through previous research study. In management studies there are more unanswered questions than in many other areas of study due to the fast changing nature of the subject. Management research raises both theoretical and practical issues, which are not usually encountered in either the physical or social sciences (Lancaster 2005). Management research is defined as “finding out things in a systematic way in order to increase knowledge about people and processes involved in the management of work organizations”, and there are three major characteristics that make management unique with regard to research as defined by Easterby-Smith *et al.*, (2000).

- *The practice of management is largely eclectic:* Managers need to work across technical, cultural and functional boundaries and need to be knowledgeable in other disciplines such as sociology, economics, statistics and mathematics.
- *Managers tend to be powerful and busy people:* They are unlikely to allow research access to their organizations unless they can see some commercial or personal benefit.
- *Management requires both thought and action:* Not only do most managers feel research should lead to practical consequences, they are quite capable of taking actions themselves in light of research findings.

Researchers have used the various research methods for many years across a variety of disciplines. Social scientists have made wide use of qualitative research methods to examine contemporary real-life situations and provide the basis for the application of ideas and extension of methods. Researchers in management studies have used qualitative methods to focus on issues relating to process efficiency and effectiveness.

Lancaster (2005) identified three distinct types of management research:

1. Theory building research; research that aims to formulate propositions that are grounded in research
2. Theory testing research; research that aims to test those theories formulated in previous studies.
3. Problem centred/practical research.

This research, the development of a knowledge based framework and software tool to support lean product development involves elements of theory building and theory testing research. The rationale for the research methodology used is defined in the next section.

3.3 Research methodology

Selecting suitable and appropriate methodologies depend on research paradigms and there assumptions (Easterby-Smith *et al.*, 2000). Remenyi *et al.*, (1998) defined research methodology as a procedural framework within which the research is conducted. According Easterby-Smith *et al.*, (2000), methodology is a combination of techniques used to enquire into a specific situation, while methods are individual techniques for data collection and analysis.

Guba and Lincoln (1994) suggest four underlying "paradigms" for qualitative research: positivism, post-positivism, critical theory, and constructivism. Orlikowski and Baroudi (1991), following Chua (1986), suggested three categories, based on the underlying research epistemology: positivist, interpretive and critical. Qualitative research can be positivist, interpretive, or critical; it follows from this that the choice of a specific qualitative research method (such as the case study method) is independent of the underlying philosophical position adopted. For example, case study research can be positivist (Yin 2002), interpretive (Walsham 1993), or critical, just as action research can be positivist (Clark 1972), interpretive (Elden and Chisholm 1993) or critical (Carr and Kemmis 1986).

3.3.1 Positivist research

Positivist research generally assumes that reality is objectively given and can be described by measurable properties which are independent of the observer (researcher) and his or her instruments. Positivist studies generally attempt to test theory, in an attempt to increase the predictive understanding of phenomena.

3.3.2 Interpretive research

Interpretive research starts out with the assumption that access to reality (given or socially constructed) is only through social constructions such as language, consciousness and shared meanings. The philosophical base of interpretive research is hermeneutics and phenomenology (Boland 1985). Interpretive studies generally attempt to understand phenomena through the meanings that people assign to them. Interpretive research does not predefine dependent and independent variables, but focuses on the full complexity of human sense making as the situation emerges (Kaplan and Maxwell 1994).

3.3.3 Critical research

Critical research assumes that social reality is historically constituted and that it is produced and reproduced by people. Although people can consciously act to change their social and economic circumstances, critical researchers recognize that their ability to do so is constrained by various forms of social, cultural and political domination. The main task of critical research is seen as being one of social critique, whereby the restrictive and alienating conditions of the status quo are brought to light. Critical research focuses on the oppositions, conflicts and contradictions in contemporary society, and seeks to help to eliminate the causes of alienation and domination.

Examples of qualitative methods within these paradigms include action research, case study research and ethnography. Qualitative data sources include observation and participant observation (fieldwork), interviews and questionnaires, documents and texts, and the researcher's impressions and reactions (Myers 2009).

3.3.4 Case study research

The term "case study" has multiple meanings. It can be used to describe a unit of analysis (e.g. a case study of a particular organization) or to describe a research method. As a research method the case study excels at bringing an understanding of a complex issue or object and can extend experience or add strength to what is already known through previous research. Case studies emphasize detailed contextual analysis of a limited number of events or conditions and their relationships. Researchers have used the case study research method for many years across a variety of disciplines, in particular Social scientists have made wide use of this qualitative research method to examine contemporary real-life situations and provide the basis for the application of ideas, theories and to extend and formalize processes.

Critics of the case study method believe that the study of a small number of cases can offer no grounds for establishing reliability or generality of findings. Others feel that the intense exposure to study of the case biases the findings. Some dismiss case study research as useful only as an exploratory tool. However researchers from many disciplines use the case study method with great success to build upon theory, to produce new theory, to dispute or challenge theory, to explain a situation, to provide a basis to apply solutions to situations, to explore, or to describe an object or phenomenon. The key advantages of the case study method are its applicability to real-life, contemporary, human situations and its public accessibility through written reports. Case study results relate directly to the common readers everyday experiences and provide an understanding of often very complex real-life situations

Many well-known case study researchers such as Stake (1995), Simons (2009), and Yin (2002) have written about case study research and suggest techniques for organizing and conducting the research successfully and include a number of steps that should be followed:

- Determine and define the research questions
- Select the cases and determine data gathering and analysis techniques

- Prepare to collect the data
- Collect data in the field
- Evaluate and analyze the data
- Prepare the report

3.3.5 Ethnography

Ethnography is a form of research focusing on the sociology of meaning through close field observation of socio-cultural phenomena. Typically, the ethnographer focuses on a community (not necessarily geographic, considering also work, leisure, and other communities), selecting informants who are known to have an overview of the activities of the community. Such informants are asked to identify other informants representative of the community, using chain sampling to obtain a saturation of informants in all empirical areas of investigation. Informants are interviewed multiple times, using information from previous informants to elicit clarification and deeper responses upon re-interview. This process is intended to reveal common cultural understandings related to the phenomena under study. These subjective but collective understandings on a subject (ex., stratification) are often interpreted to be more significant than objective data (ex., income differentials).

The ethnographic method starts with selection of a culture, review of the literature pertaining to the culture, and identification of variables of interest; typically variables perceived as significant by members of the culture. The ethnographer then goes about gaining entrance, which in turn sets the stage for cultural immersion of the ethnographer in the culture. Often ethnographers live in the culture for months or even years. The middle stages of the ethnographic method involve gaining informants, using them to gain yet more informants in a chaining process, and gathering of data in the form of observational transcripts and interview recordings. Data analysis and theory development come at the end, though theories may emerge from cultural immersion and theory-articulation by members of the culture. However, the ethnographic researcher strives to avoid theoretical preconceptions and instead to induce theory from the perspective of the members of the culture and from observations. The researcher may seek validation of induced theories by going back to members of the culture for their reaction.

Hammersley and Atkinson (1995) defined *Ethnography* as, "referring primarily to a particular method or sets of methods. In its most characteristic form it involves the ethnographer participating, overtly or covertly, in people's lives for an extended period of time, watching what happens, listening to what is said, asking questions—in fact, collecting whatever data are available to throw light on the issues that are the focus of the research". More recently, Johnson (2000) defines ethnography as "a descriptive account of social life and culture in a particular social system based on detailed observations of what people actually do."

3.3.6 Grounded theory

Grounded theory is a research method that seeks to develop theory that is based on data systematically gathered and analyzed. According to Martin and Turner (1986), grounded theory is "an inductive, theory discovery methodology that allows the researcher to develop a theoretical account of the general features of a topic while simultaneously grounding the account in empirical observations or data". The major difference between grounded theory and other methods is its specific approach to theory development - grounded theory suggests that there should be a continuous interplay between data collection and analysis.

Grounded theory takes a case rather than a variable viewpoint, the researcher takes different cases to be wholes, in which variables interact as a unit to produce certain outcomes. A case-orientated viewpoint takes cases with similar variables that have different outcomes and compares to see where the fundamental differences are. Similarly, cases that have the same outcome are examined to see which conditions they all have in common, thereby revealing necessary causes.

The grounded theory approach consists of a set of steps whose careful execution is thought to "guarantee" a good theory as the outcome, this differs with the scientific viewpoint that how you generate a theory, whether through dreams, analogies or dumb luck, is irrelevant: the quality of a theory is determined by its ability to explain new data.

The basic idea of the grounded theory approach is to read and re-read a textual database, such as field notes) and "discover" or label variables such as categories, concepts and properties and their interrelationships. The ability to perceive variables and relationships is termed "theoretical sensitivity" and is affected by a number of things including how one interprets the literature and the use of techniques designed to enhance sensitivity.

The case study methodology has been selected for this research primarily because it was felt that a more comprehensive survey of the industry would be impossible under the current time and resource constraints on the research. A focused industrial case study would allow a deeper understanding of the product development process being used by an organisation than could be gained using an industry-wide questionnaire furthermore it would allow. Often organisations have their own distinct terminology for many of the processes and their engineers will interpret design problems differently, they are likely to reach different conclusions about how to solve problems based on their own systems and procedures during product development, as such the generation of a questionnaire form understandable by and applicable to all of the organizations would have been extremely difficult.

3.4 The research framework

The context of this research was to develop a knowledge management based framework and software tool to support the product development process. A comprehensive literature review was carried out to identify research problems and develop a knowledge based framework. A unique knowledge based product development framework has been proposed in Chapter four and the knowledge required to support effective decision making within a product development environment was introduced in chapter five; this knowledge was used to develop the software tool part of the knowledge based product development system described in Chapter six. The literature review, informal interviews and discussions helped identify state of the art knowledge management, lean principles and traditional product development processes and associated issues which were instrumental in the development of a knowledge framework and software tool to support the product development process within a cold roll forming environment.

According to the literature review presented in Chapter 2, knowledge management research and applications have been directed towards the development of databases to store product data files, mainly design data, or product design history with particular attention to document issue and control, engineering change control and project costs. Evidence shows that knowledge management systems do not support all the key activities within the product development process with very few systems providing decision support throughout the product life-cycle. Furthermore very few knowledge management systems provide the means for the exploitation of

manufacturing constraints, product knowledge and capturing and managing the knowledge within the context with which it was acquired.

A case study approach was adopted to identify a set of evolving issues underpinning traditional product development and to identify the relevant knowledge applicable in a product development scenario. The case study was conducted through the use of informal interviews, case company documents, reference manuals from British and International standards sources to develop knowledge based framework and software tool. The framework and software tool were developed to identify, capture formalise and present relevant knowledge to support effective decision making within a product development environment. Furthermore the case study was utilised to test and validate the Knowledge Based Product Development framework and software tool.

The research framework developed for this study is divided into five stages, as defined in Chapter 1 (p.12).

3.4.1 Literature review

The methodology utilized began with a review of existing literature to understand the state of the art which defines best practice within product development, knowledge management and how they can be utilized to support product development. An effective review of the literature examines the context of the research problem(s) and identifies relevant concepts, issues and methods (Anderson and Thorpe, 2004). The review helps identify gaps in the available literature, refine the focus and enable the researcher to set theoretical boundaries on what is relevant to the research (Gill and Johnson, 2002).

The literature review was broken down into four major areas:

- *Lean thinking*: Lean history, lean principles, lean thinking and product development.
- *Knowledge*: Knowledge quality, knowledge classification within product development, knowledge management, strategies, tools, modelling, frameworks and evolving issues in product development.
- *Lean thinking*: Value of knowledge within product development.
- *Methodology*: Research methods, data collection, process mapping tools.

While there was a vast amount of knowledge with regard to knowledge management and lean thinking, the distinct lack of literature on how knowledge can be utilized to support a lean product development process became apparent during the literature review, as a result the development of a knowledge based framework and software tool to support lean product development became the prime objective of this study.

3.4.2 Informal interviews and discussions

Prior to conducting Informal interviews, the organizations quality procedures were reviewed and utilized to gain an understanding of the product development process. Informal Interviews were then utilized to identify problems encountered during the product development process, identify knowledge requirements, information flows and to produce a detailed process map of the product development process within the case study organization. A variety of staff were interviewed which included department heads, designers, production control, sales, tool manufacturing staff and shop floor personnel. Two people from each department were interviewed to ensure all the necessary information was captured and to clear up any ambiguity; the resultant process maps were then drafted and issued back to each department to cross check and approve. The resultant process maps (Chapter 4) were utilized to identify knowledge requirements for the knowledge management framework and software tool.

Findings from informal interviews and discussions confirmed the key issues from the literature review, in particular knowledge is the key driver to ensure effective decision making within the product development process.

3.4.3 Observations

Observation is divided into two categories:

- Participant: a method by which the researcher systematically observes people and processes whilst also taking an active part in the processes.
- Non-participant observation: a method whereby the researcher observes behaviour from a distance without interacting with the process being studied.

This study mainly used participant study as the researcher was the Manager for product development within the case study organization.

Observations were used to collect two types of data:

- Qualitative data - product development process related problems, factors that may contribute to problems encountered and to identify product development goals and objectives and compare against actual practices.
- Quantitative data – Time taken to quote, development time, estimated tooling costs, actual costs to determine efficiency and effectiveness of the product development process.

Data collected was documented in various formats, including written notes, sketches and photographs, photographs provided a means of recording data electronically. The data collected was used to develop the as-is process maps of the product development process. The observation method helped overcome issues from interviews such as personal opinion and bias as well as issues over who was to blame for the problems identified during the case study.

3.4.4 Process mapping

Process mapping is an exercise to identify all the steps and decisions within a process in diagrammatic form which:

- Describes the flow of materials, information and documents;
- Displays the various tasks contained within the process;
- Shows that the tasks transform inputs into outputs;
- Indicates the decisions that need to be made along the chain;
- Demonstrates the essential inter-relationships and interdependence between the process steps; and reminds us that the strength of a chain depends upon its weakest link.

There are many different types of process maps, each designed to capture particular aspects of work, such as travel charts that can record movement of people, materials or information in a process. During this study, process mapping was used to identify all activities, knowledge and information flows in order to create an “AS-IS” state of the case company’s product development process, thus establishing a base line from which to understand, improve, and identify knowledge requirements of those processes. Additionally the development of the process model allowed greater visibility across departmental and organizational boundaries, thus providing the means to identify and eliminate waste and non-value added activities.

The primary objective when selecting an appropriate mapping tool was to make the chart as clear as possible, so that the process under review could be clearly understood and improvements identified by almost anyone, even someone unfamiliar with the process. The process modelling technique used was Integration Definition for Function Modelling (IDEF 0).

IDEF0 is a widely used technique for the structured analysis and design of systems. Its use in improving the productivity and communications in computer integrated manufacturing systems and more recently, as a tool for business process reengineering are widely documented (Presley and Liles, 1995; Ross 1985). Typical applications of IDEF0 have included system definition and design, project management and integration, and design and specification of methodologies. However the application and use of IDEF0 has been considerably varied and an extensive review of these various applications was conducted by Colquhoun *et al.* (1993).

IDEF0 is a functional enterprise model tool that was developed by the United States Air Force (USAF) in the late 1970's, via the Integrated Computer Aided Manufacturing (ICAM) initiative to overcome some of the problems encountered with modelling and analysis methods of that time. There are five elements to the IDEF0 functional model (see Figure 3.1):

1. The activity (or process) is represented by the boxes;
2. Inputs are represented by the arrows flowing into the left hand side of an activity box;
3. Outputs are represented by arrows flowing out the right hand side of an activity box;
4. The arrows flowing into the top face of the box represent the activity constraints or controls;
5. Arrows flowing into the bottom of the activity box are the mechanisms that carry out the activity.

The inputs, control, output and mechanism arrows are collectively referred to as ICOMs (Mayer 1992).

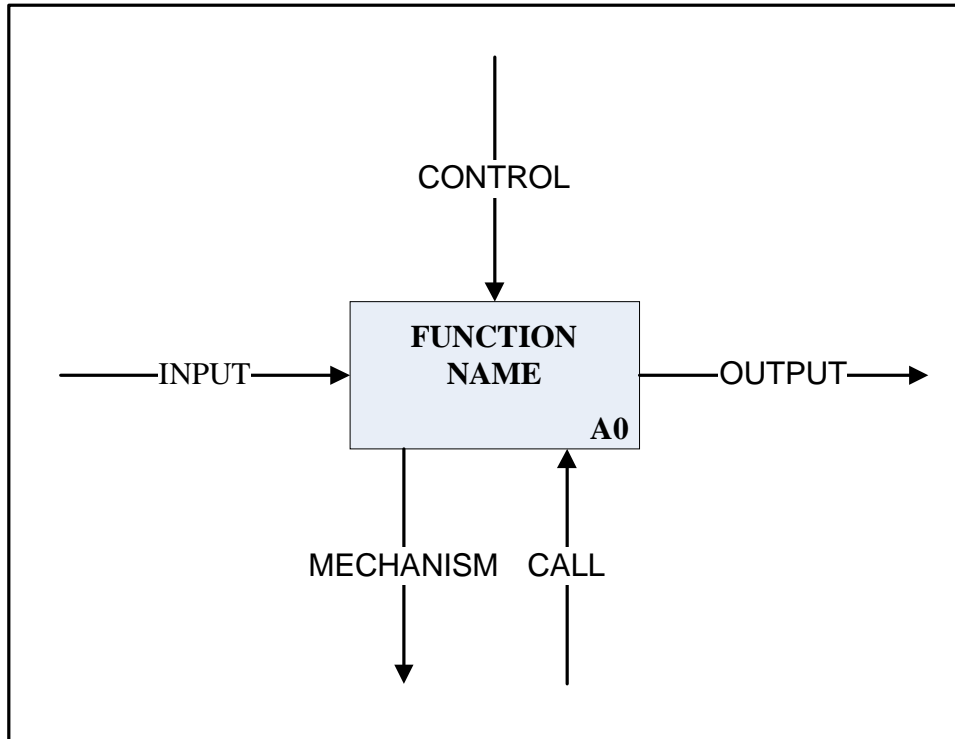


Figure 3.1: IDEF0 Box and Arrow Position and Roles

The primary strength of IDEF0 is that the method has proven effective in detailing process and system activities. Activities can be described by their inputs, outputs, controls, and mechanisms. Additionally, the description of the activities of a system or process can be easily refined into greater and greater detail until the model is as descriptive as necessary for the decision-making task at hand. In fact, one of the observed problems with IDEF0 models is that they often are so concise that they are understandable only if the reader is an expert in that field or has participated in the model development. The hierarchical nature of IDEF0 facilitates the ability to construct (AS-IS) models that have a top-down representation and interpretation, but which are based on a bottom-up analysis process. Beginning with basic information (generally from interview results with process experts), the model is developed by grouping together activities that are closely related or functionally similar. Through this grouping process, the hierarchy emerges. If an organisations functional structure is being designed (often referred to as TO-BE modelling), top-down construction is usually more appropriate. Beginning with the top-most activity, the TO-BE functional structure can be described via a logical decomposition. The process can be continuously decomposed until the required level of detail is reached (Figure 3.2). When an

existing process is being analyzed and modelled (often referred to as AS-IS modelling), observed activities can be described and then combined into a higher level activity. This process also continues until the highest level activity has been described.

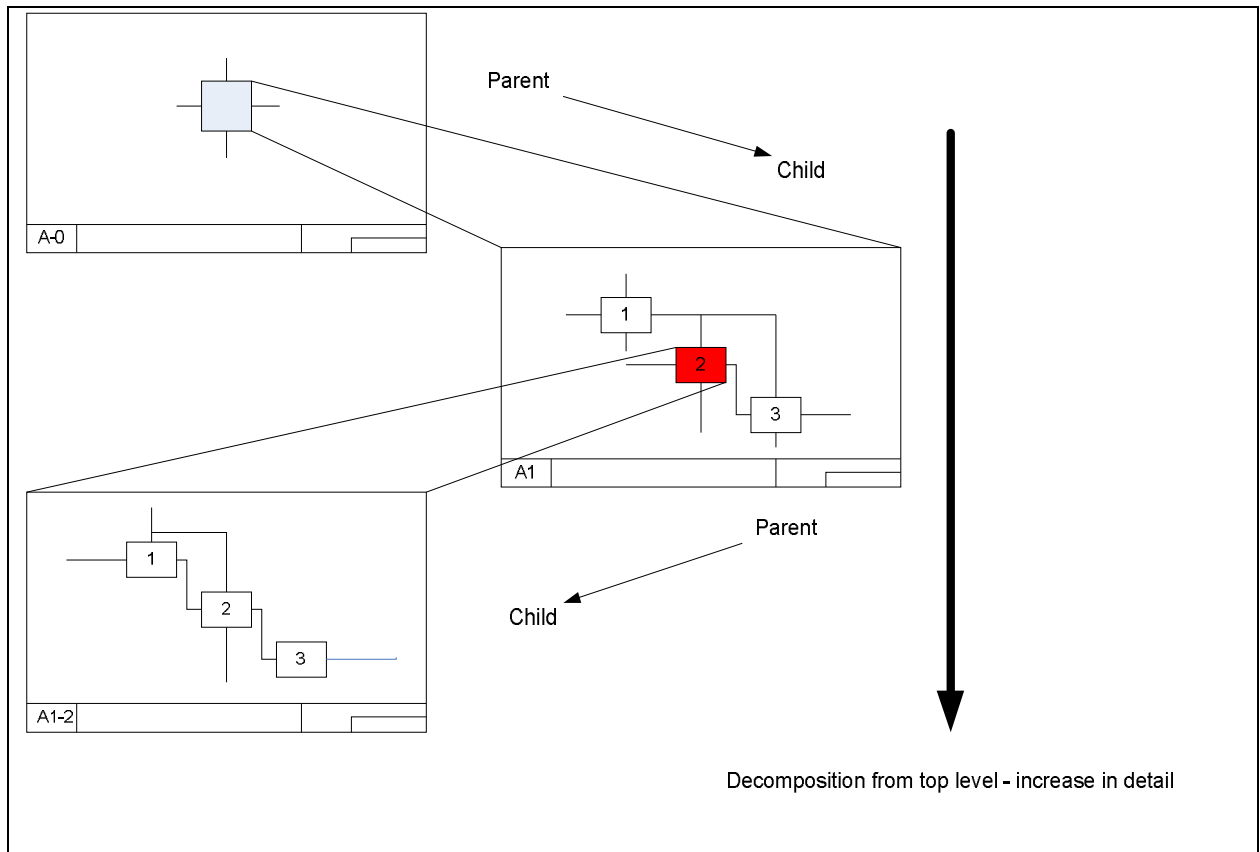


Figure 3.2: IDEF0 Decomposition from top level - overview

One problem with IDEF0 is the tendency of IDEF0 models to be interpreted as representing a sequence of activities. While IDEF0 is not intended to be used for modelling activity sequences, it is easy to do so. The activities may be placed in a left to right sequence within decomposition and connected with the flows. It is natural to order the activities left to right because if one activity outputs a concept that is used as input by another activity, drawing the activity boxes and concept connections is clearer. Thus, without intent, activity sequencing can be imbedded in the IDEF0 model. In cases where activity sequences are not included in the model, readers of the model may be tempted to add such an interpretation. This anomaly could be considered a weakness of IDEF0. However, to correct it would result in the corruption of the basic principles on which IDEF0 is based and hence would lose the proven benefits of the method (Echavarria 2005).

3.4.5 Documents and archival records

Document searches are important in any data collection plan (Barnes 2001; Yin 2002).

Documents exist in various forms and include:

- Letters, memoranda, minutes of meetings, agendas, announcements and other written reports including formal studies and project implementation evaluations.
- Administrative documents such as proposals, progress reports, company annual reports, government reports and internal records.
- Newspaper articles published in the mass media and magazines and news letters produced by companies and organizations.

Document evidence collected for this research included hard copies of reports, meeting minutes, company policies, business plans, procedures, work instructions and key performance indicators. The documentation was used to describe the background of the organization, and also acted as a reference point when conducting the process mapping exercise to determine knowledge and information flows. The documentation helped develop a deeper understanding of the product development process, highlight problems as well as good working practices.

3.5 Metsec PLC Engineering Division (case organization)

Metsec PLC has a long established history with the cold roll forming industry based on diversity, growth, technological progress and innovation.

Cold roll forming is a means of forming flat metal strip into various profile shapes by means of forming rolls. The number of forming roll stations depends on the complexity of the profile to be produced, but generally most profiles produced use between 5 and 42 forming stations



Figure 3.2: Forming stations on a cold roll forming machine.

Cold roll formed profiles differ from conventional hot rolled profiles in a number of ways and include the following:

- Relatively thin material can be formed ranging from 0.5 mm to 9.0 mm;
- The wall thickness is standard throughout the length of the profile;
- The manner of fabrication and the resulting freedom of shape;
- Assembly is possible using a meccano type system; - any number of holes can be pierced into the material prior to forming.
- Cold roll forming can be utilized for a variety of materials including Steel, Copper, Brass, Aluminium, Titanium

- Cold roll formed profiles can be produced with relatively tight tolerances.

The first branch of engineering to use cold roll formed profiles was the cycle industry (circa.1920's), the techniques proved highly suitable for producing wheel rims, before long the motor industry realized the potential of the process and it was utilized to manufacture body components and trim. The transport industry generally became, and continues to be a major outlet. The growth of the material handling industry and modern warehousing systems utilizes as range of components based on cold roll forming.

Today the building and construction industry has developed as Metsec's biggest market, with roofing, ceiling and flooring component systems sold to all major building contractors throughout the world. The markets by these difference types of industries give Metsec a sound base on which its future can be built.

Without doubt, cold roll forming, which is the basis of the Metsec's business, has proved invaluable to designers and architects. It is versatile and possesses a remarkable strength to weight ratio; it economizes on materials by taking advantage of higher strength materials with a smaller wall thickness without sacrificing the performance of the product. Today the technology associated with cold roll forming has become so highly developed that very complicated profiles can be produced and can be further enhanced by the use of manipulation and finishing operations. An example of complex manipulated profiles can be seen in Figure 3.3, the cab (safety cell) of a forklift truck.

On entering the 21st Century, METSEC, in common with others engaged in business or commerce, is facing one of the most challenging periods in modern history. In order to prosper the company will have to be adaptable and responsive to changes in today and tomorrows market.



Figure 3.3: Plate and screen shot showing Manipulated steel profiles of a JCB cab and a 3D CAD model of a safety cell for a fork lift truck.

The future of the company will be dependent on four major factors, which need to be taken into consideration if it is to survive:-

1. While some of its traditional markets are expanding, others are contracting. New uses for METSEC products must be developed, (which in turn often relies on customer product development), so as to allow replacement of customers who may not be able to provide a market outlet in the not too distant future;
2. Evaluation of future markets must take into account that traditional industries are disappearing, whilst new types of industries will be born.
3. It must be appreciated that, for some applications, plastics and polymers are taking the place of metal components. How long the use of plastic as a substitute for metal will depend on the relative cost of the two materials (including environmental costs);
4. Finally the ability to offer products that are reliable and cost efficient

One common theme for these four factors is the development of new products and equipment so that market share can be firstly maintained but ultimately increased. The objective of the case study is to look at the product development processes within Metsec and how they can be improved with the aid of knowledge management framework and a knowledge based system lean thinking to ensure that Metsec develop and manufacture products with higher standards of quality, faster than its competitors and ultimately as cost effectively as possible.

Chapter 4

A KNOWLEDGE BASED FRAMEWORK TO SUPPORT PRODUCT DEVELOPMENT.

4.1 Introduction

This chapter presents the proposed knowledge management framework to support product development activities, which addresses the research issues and knowledge management system requirements identified in chapter two. Section 4.3 describes in detail the process modelling activities carried out in line with the framework.

4.2 Knowledge based framework to support product development

In order to give a clear description of the framework, the framework has been sub-divided into five process steps linked to the knowledge management cycle as described in section 2.6; identify, capture, formalise and present and utilise (Figure 4.1).

1. Product development – process map to identify AS-IS state (Chapter 4).
2. Process mapping - Utilise process maps to identify and capture product development knowledge requirements (Chapter 5).
3. Knowledge - Formalise knowledge in order to utilise in future product development projects (Chapter 6).
4. Manufacturing Knowledge Base and Product Data Archive – Create Knowledge base to store and retrieve product development knowledge (Chapter 6).
5. Knowledge based product development system - Develop knowledge based product development system to identify, capture formalise and present knowledge in order for it to be utilised in existing and future product development projects (Chapter 6)

The arrow indicates that each stage of the framework is linked to the knowledge management life cycle and as knowledge is utilised, processes could be improved creating new knowledge which needs to be captured, formalised and presented for future use.

A KNOWLEDGE BASED FRAMEWORK TO SUPPORT PRODUCT DEVELOPMENT

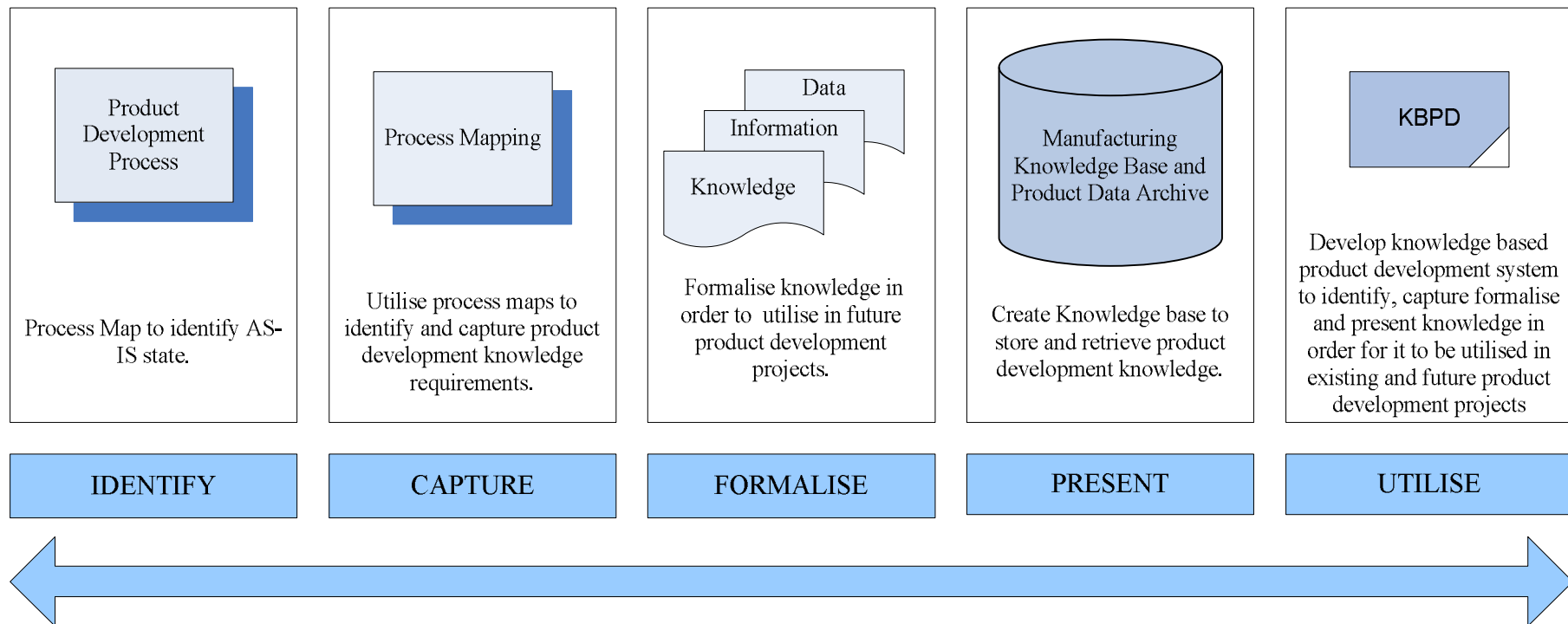


Figure 4.1: Top level interactions of activities within the product development process

4.3 Process Modelling for the Product Development Activities: Process model overview

The data gathered for this study was generally in the form of hand written notes and sketches which was then formalized in the form of process maps as described later in this chapter. The data collection process focused on identifying the steps from new product enquiry stage through to customer approval, and also explored the knowledge required at each stage of the development process. To ensure the information collected was as accurate as possible, a conceptual process model was drafted for each activity and verified within the organization through several review meetings. A conceptual process model was created for each department involved in the product development process: sales, product and tooling design, tooling manufacture and production. Each model depicted the activities within that department and each activity was modelled at the task level such as input of sales orders. This level of detail was required to ensure the knowledge required for each activity was identified. Due to the physical amounts of data processed at each stage, the knowledge required is summarized within the process models. The resultant process models and the identified knowledge were instrumental in establishing the knowledge based framework to support lean product development as detailed in chapter five.

4.4 A knowledge based product development process

Whilst carrying out an analysis of product development activities at Metsec PLC, it became clear that four elements have a major influence on the functions required for the development and introduction of new product:

- Organization – functional relationships required to support all activities within the process.
- Resource – required to carry out those functions
- Process – sequence of events required to carry out each function
- Knowledge – data and information required to support the integration and carry out those functions.

4.4.1 Organization

The organization is the source of knowledge related to those persons carrying out the new product introduction and development process. The process begins with an enquiry received from

the customer; the process is carried out by a development team made up of individuals from several functions both internal and external to the organization and the team. Each team member has responsibilities at the function level as well as the product development level.

4.4.2 Resource

Resource is the source of knowledge related to the communication, equipment, tooling, transportation etc required to carry out the development and manufacture of new product. Each resource has its own constraints which governs the overall capabilities of the organization, and thus influences what can or cannot be manufactured or what investment is required to develop and manufacture new products.

4.4.3 Process

The process is the source of knowledge that encompasses each of the key elements identified. The process is constrained by the relationships between each department, function and activity. The process defines the levels of collaboration required and identifies the information and knowledge required to support each function.

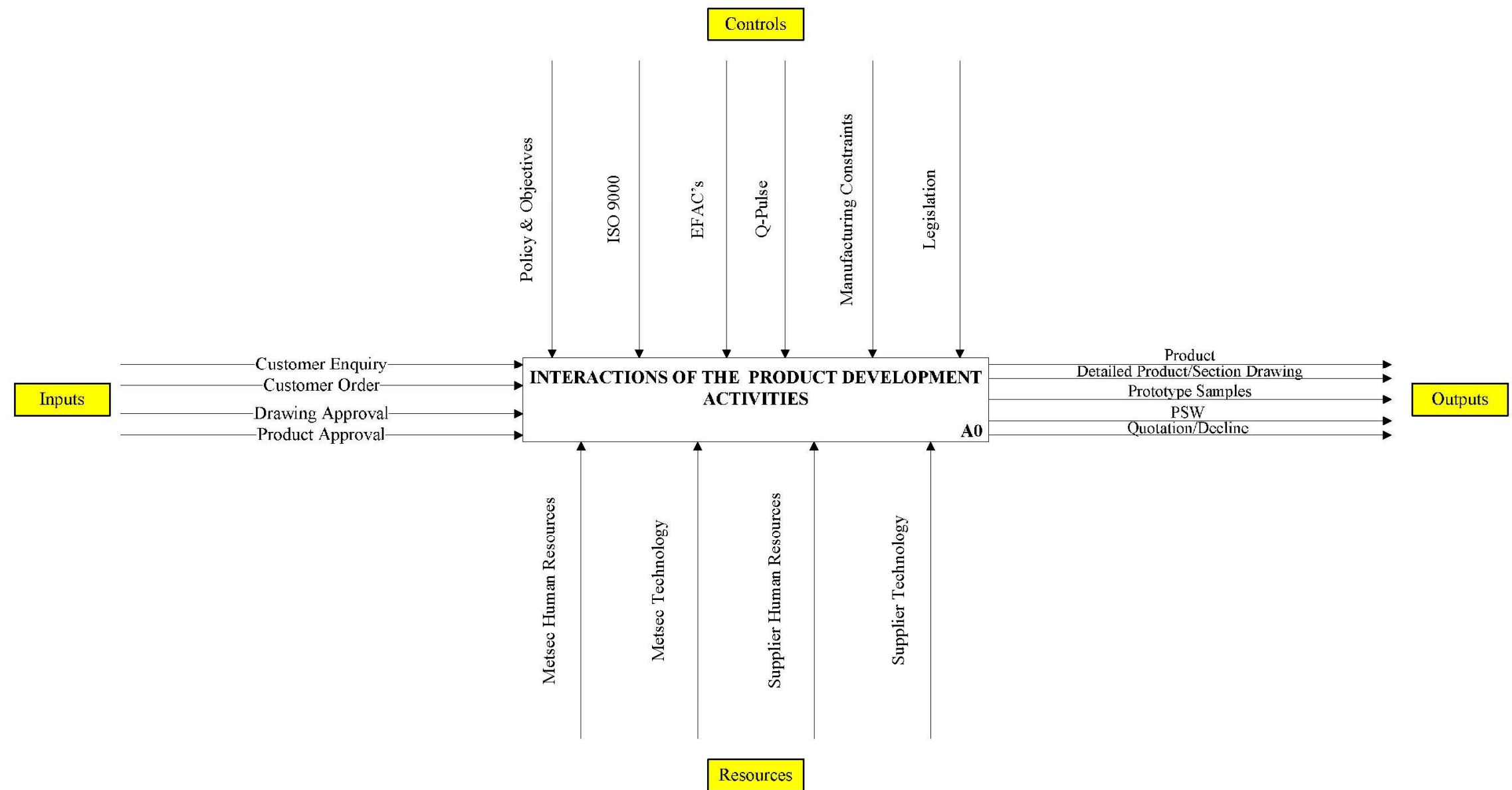
4.4.4 Knowledge

Knowledge is the source of information and data that defines those characteristics and resources of the process as well as the constraints which govern the use of the process, it is the key element required to support effective decision making within the product development process.

4.5 Development of the process model

The top level of the resulting IDEF0 model of the product development process is shown in Figure 4.2. The model illustrates a top level view of the interaction of processes that are involved within the product development process, the process inputs, outputs, resources and the process controls. For the product development process to begin an Enquiry is received, resource and controls constrain the process interactions. The process can require one or more outputs, these are dependent on the constraints and resource of the business and may result in the organisation quoting for new product or declining to quote. Where an enquiry is quoted and as a consequence orders are placed, product design, prototypes, finished product and part submission warrants confirming products which meet the requirements specified may result as outputs; this is again dependent on the constraints of the process and or customer requirements. Finally the process is completed with customer approval of the product.

The process level of the model (Figure.4.3) gives a complete overview of all those activities involved within the product development process, the model also illustrates information flows which are exchanged between the various activities, and also a representation of the information and knowledge that has an impact on decisions taken during the process activities. For instance, the output “production planning information for quotation” could affect the decision to quote or decline to quote for new product.



NODE: A-0	TITLE: INTERACTIONS OF THE PRODUCT DEVELOPMENT ACTIVITIES	NO.: 2
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Figure 4.2: Top level interactions of activities within the product development process

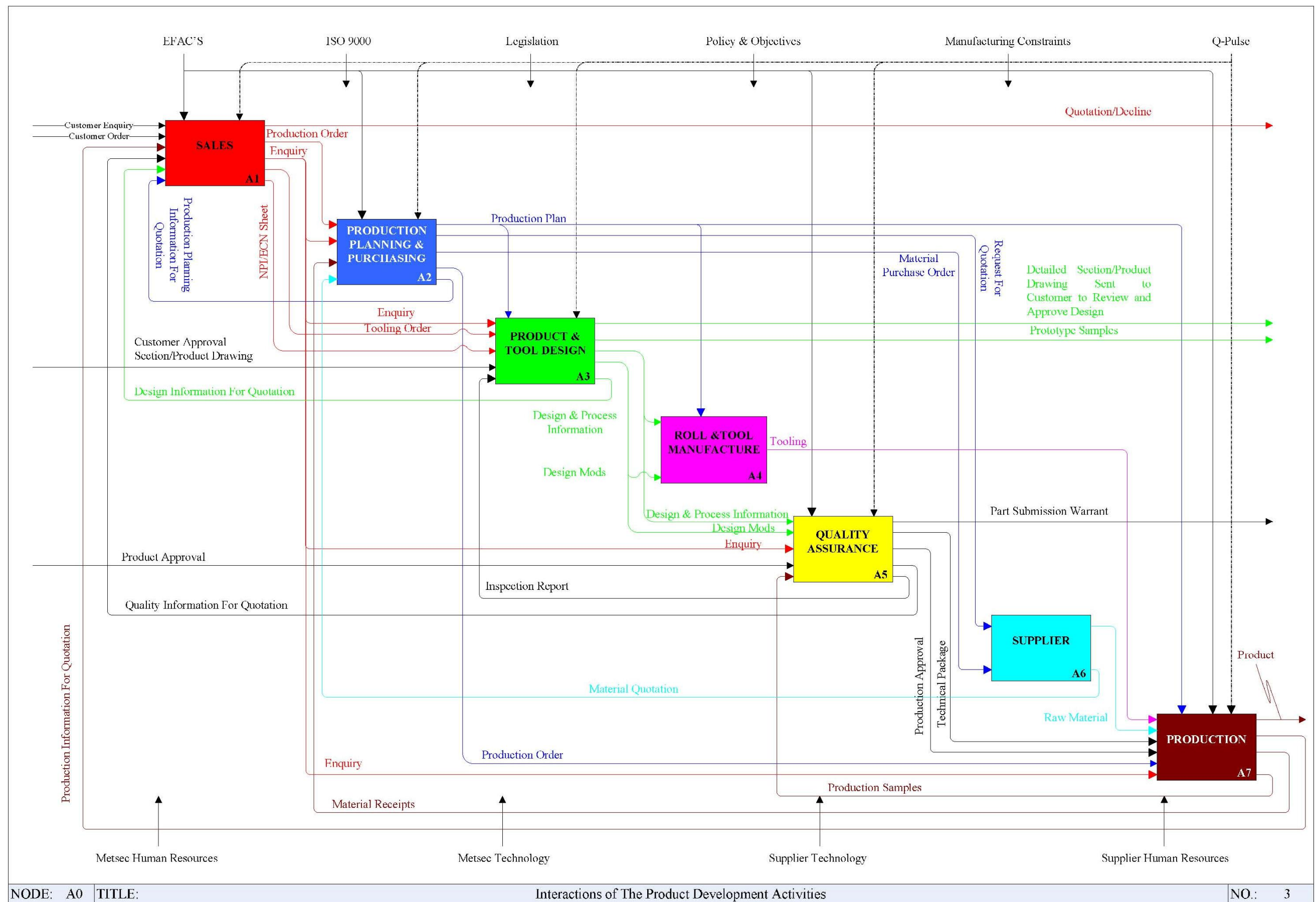


Figure 4.3: process level interactions within the product development process

4.6 Process interactions

4.6.1 Sales process

The Sales process begins when the sales engineer receives a request for quotation and the product specifications from the original equipment manufacturers (OEM's) (activity 1.1, see Figure 4.4). An enquiry file is then raised (activity 1.2) and is issued to the relevant department managers to determine feasibility. After the initial feasibility study has been carried out (activity 1.3) and the decision to quote has been agreed by the management team, the Sales Engineer issues an enquiry pack to all the relevant departments requesting the necessary information to produce a formal quotation. Once all the necessary information has been supplied to the Sales Engineer, an estimate of costs and production requirements is drafted and used as a basis to produce a formal quotation (activity 1.4), the estimates and quotation are then forwarded to the Director/General Manager for approval (activity 1.5). The estimate is then held in the enquiry file and the quotation is forwarded to the customer. If the quotation is accepted by the customer, an order to start the project is raised (activity 1.6).

Several issues were highlighted within the sales process during the modelling exercise and included:

- insufficient detail in the customer enquiry to quote,
- material and process capability was not considered when quoting,
- production estimates were manipulated to try to achieve prices customers would accept,
- orders were accepted knowing that there were capacity issues and lead-times could not be achieved,
- new tooling was made for product where the product and tooling already existed

4.6.2 Production planning and purchasing process

The production planning and purchasing process involves three main elements (Figure 4.5):

- Establishing material requirements, availability and cost (activity 2.2).
- Production planning – establish current capacity, machine availability and current lead-time -after order received (activity 2.4).
- Purchase material - after order received (activity 2.5).

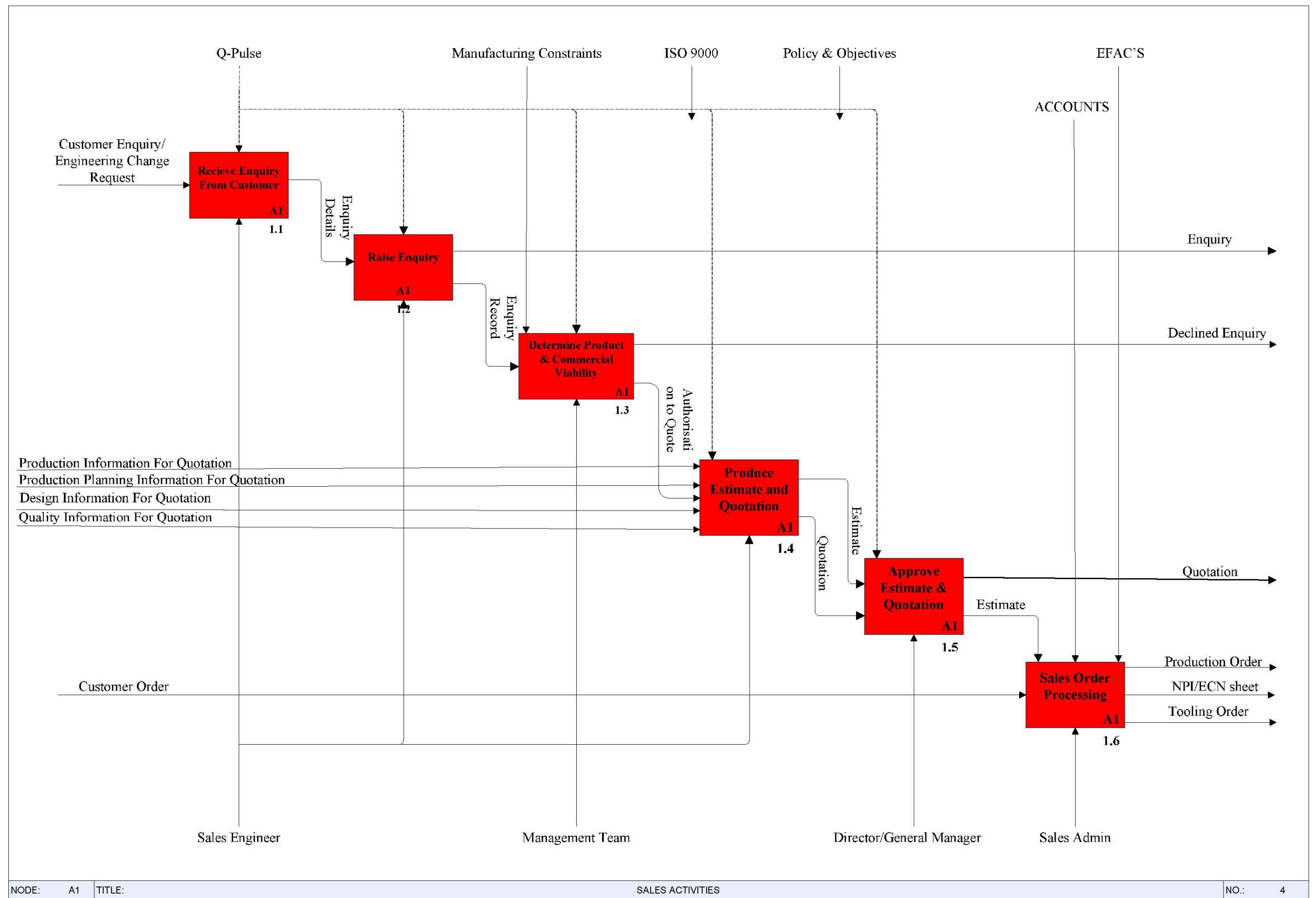


Figure 4.4: Sales activities

From the enquiry details the buyer establishes the material specification and the estimated volume required per annum and then determines if the material specification is within the scope of current suppliers or whether a new supplier is required. Where a new supplier is required manage supplier's activities and procedures are instigated (Figure 4.5, activity 2.6).

The information established from the order/enquiry is utilised to ascertain material availability and cost, and is sent to relevant suppliers in the form of a request for quotation (RFQ). Once the material quotation is received back from the suppliers the information is passed to sales and a copy is retained by production planning.

When orders are received for new product, production planning activities are instigated (Figure 4.4, activity 2.4). Production planning activities involve establishing current capacity, machine availability, and material requirements, receipt of material, raising production orders and establishing current production lead-times. The information is utilised to determine a production plan.

Several issues highlighted within production planning and purchasing during the process modelling exercise include:

- insufficient detail in the customer enquiry to enable a quote,
- material availability was not considered when agreeing lead-times with customers,
- Insufficient lead-time to purchase material.
- Spot buying material from unreliable and non-quality approved suppliers,
- Orders accepted knowing full well that delivery dates could not be achieved.

4.6.3 Product and tool design process

Product and tool design is the process of designing a product and associated tooling that meets the required customer specifications. It is in this process that most of the decisions about the product and process are taken. As shown in Figure 4.6, the process is divided into four activities:

- Produce an estimate of design and tooling manufacturing costs (activity 3.1).
- Produce detailed product design (activity 3.2).
- Produce Roll and tool design (activity 3.3).

- Prototype manufacture (activity 3.4).

The process begins as soon as an enquiry is received and the project engineers review the relevant specifications taking into account; size, shape, material specification, structural properties required, tolerances, application, specific customer requirements and features to determine how the product can be manufactured and the tooling, equipment and machinery required. When the concept of product manufacture is defined, design and tooling costs are established and then passed to sales to form part of the customer quotation.

If the customer accepts the quotation and an order is received, the sales department initiates new product introduction procedures and forwards a tooling order and new product introduction and engineering change note documentation (Figure 4.7), which includes the enquiry information, project requirements including tooling, documentation, lead-times, roles and responsibilities to product and tool design department. The next process is to “produce detailed product drawings” which are submitted to the customer for approval. The company policy dictates that no further work is carried out until customer approval is received for the product design; this is usually in the form of a signed and dated product drawing. Roll and tool design is then carried out using an AutoCAD based product specifically developed for the design of cold roll form products and associated roll tooling. Roll and tool designs are then passed on to roll and tool manufacturing department to initiate production.

Where a customer is unsure of the final product design, prototype samples can be manufactured.

4.6.4 Roll and tool manufacture process

The process begins when design and process information is released for manufacture (Figure 4.8). The information includes detailed roll and tool design specification, material requirements for tooling and confirmation of the width and gauge of material required to manufacture product. Material for product information is issued so that material can be purchased and is available for tryout and testing of tooling. Material requirements for tooling include raw material sizes and specification and grade of material. The specification and grade of material for tooling is constrained by the volume of product required, life expectancy of product, the material specification of the product and tolerances of the finished product; all these elements have an effect on the wear rate of tooling, and differing grades of material are specified for tooling with the intention of reducing this effect.

4.6.5 Quality assurance process

The quality assurance activities are split into two elements (Figure 4.9), enquiry for new products (activity 5.1), and processing of information, inspection and test when new product orders are received (activities 5.2 to 5.7). The process begins as soon as an enquiry is received; the quality engineers look at the relevant specification taking account of dimensions, tolerances, material specification, structural properties required, application, specific customer requirements and features to determine quality requirements, including gauges, measuring equipment and levels of control (activity 5.1). When the concept of how the product can be measured and the process controlled and what resource is required, costs are established and are passed on to the sales department to form part of the customer quotation.

When a new product has been ordered, and the design of product, tooling and process has been established the relevant details are passed to the quality department for the information to be entered into the organisations MRP system in order to create the necessary product data, bill of materials, and product routing (activity 5.2). The information is then utilised to create the technical documentation required to produce the product (activity 5.3), which includes:

- Customer specifications,
- Product Drawings,

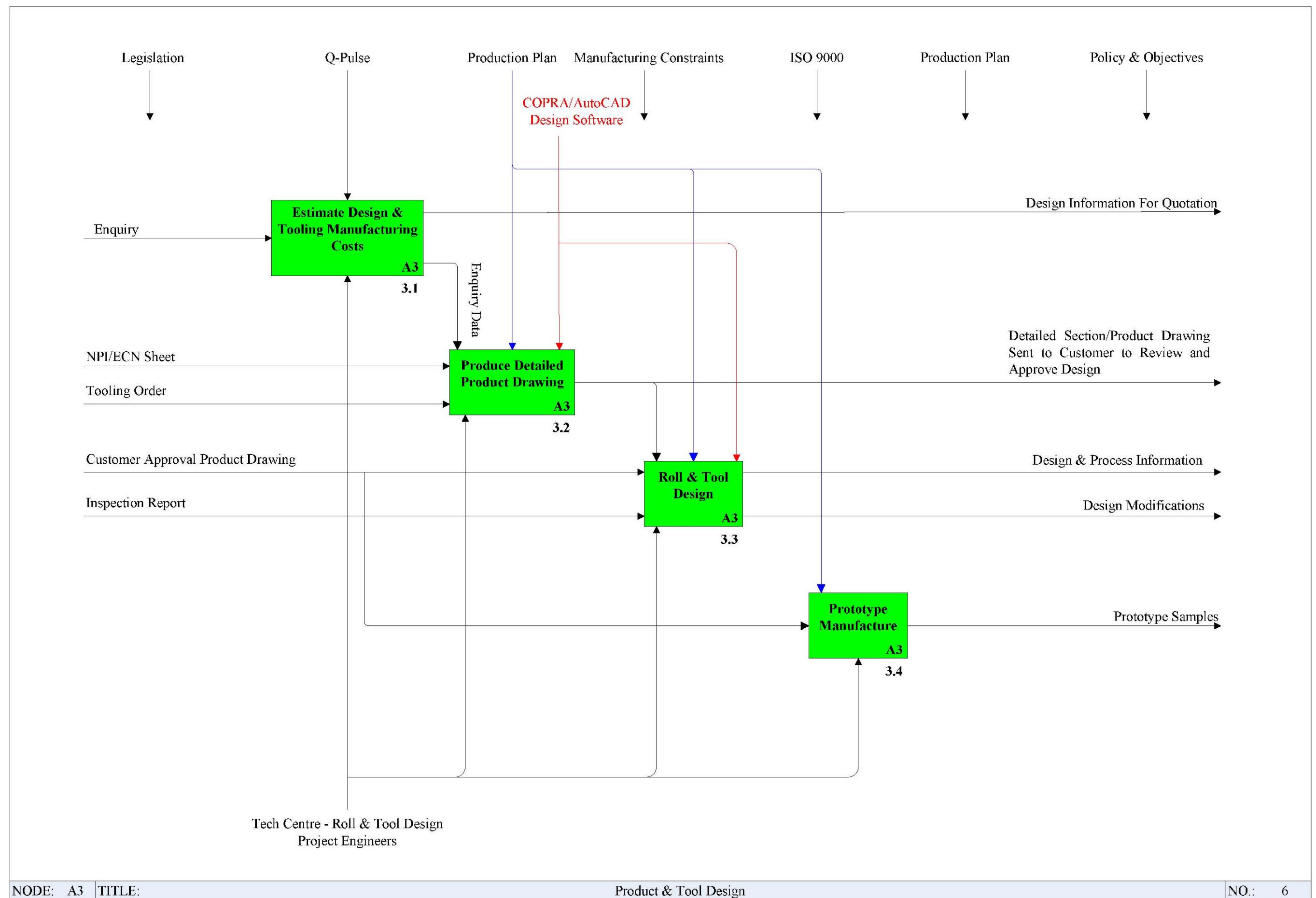


Figure 4.6: product and tool design process

New Product Introduction/Engineering Change Note

Enquiry/ECN Number		Customer	
Division		Customer Order Number	
Part Number		Tooling Order No.	
ECR Number (reference)		This Form Raised By	
Material Specification		Change Required By (Date)	
Allocated to Mill			

Tooling/Equipment Required				
	Responsibility	Required	Completed	Comments
Section/Product Drawing				
Customer - Drawing Approval				
Pre Pierce Tool Design and Man.				
Pre Pierce Tool Design Review				
Roll Design				
Roll Design Review				
Roll Blanks + Bearings				
Weld Coil + Impeders				
De-Twist Die Design and Man.				
Cut off Tool Design and Man.				
Mandrels				
Bend Tools				
Sweep Tools				
Cluster Stands/bkts/shafts				
Drill and Saw Rigs				
Gauges				
Stillages/Pallets				
Tryout WOS advised				
Coil Ordered for Tryout				
Tryout scheduled for				

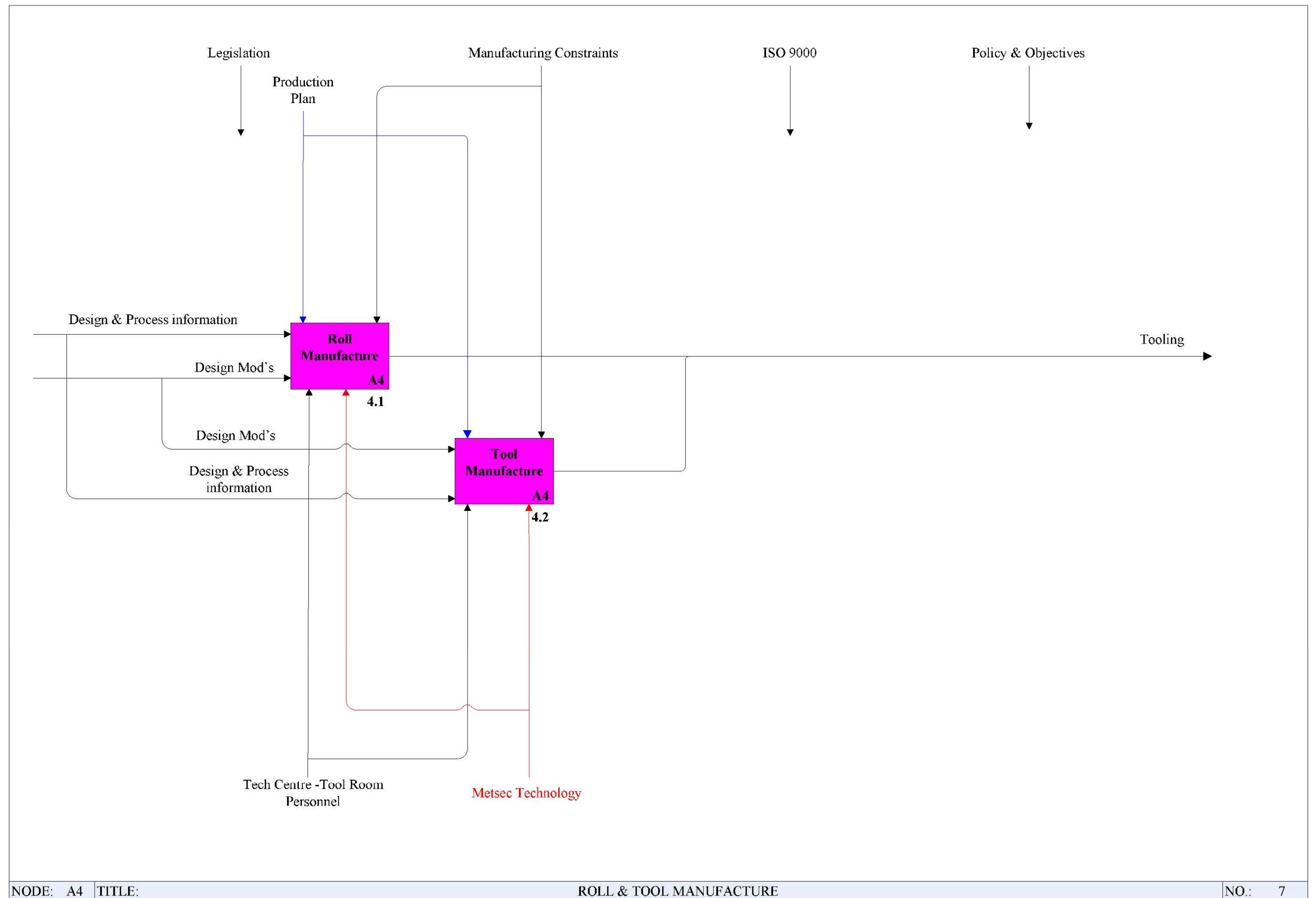
Documentation			
Documentation Required	Responsibility	Completed	Comments
Document Issue & Control Sheet			
Section Drawing			
Inspection Sheet			
Process Flow Sheet			
Setting Sheet			
Roll Drawings			
Pre-Pierce Tool Drawings			
Pre-Pierce Programs			
Flat Strip Drawings			
Cut-Off Tool Drawings			
Weld Data Sheet			
Gauge Drawings			
Packing Specification			
Control Plans			
Mill Setting Sheet			
Parts Submission Warrant			
Technical Package			

Sample Submission			
Customer requires samples to be submitted as follows:			
Customer Approval		Production Manager Signature & Date	
Date Received			
Sales Responsibility	Quality Responsibility	Production Responsibility	Technical Responsibility

Figure 4.7; new product introduction and engineering change note

- Roll and Tool Design,
- Machine setting instructions, including information to program production equipment.
- Process Layouts,
- Control plans,
- Packing Specifications,
- Labelling Instructions.

When the try out of tooling has been completed and production samples are available, the samples are then measured against the customer requirements detailed in the technical packs, and the results (inspection report) along with other supporting documentation form part of the part submission warrant (PSW) issued to the customer for approval (activity 5.5). Where product is not correct to specification the inspection report is issued to the relevant departments so that necessary modifications can be carried out to ensure product specifications are achieved. Any modification results in the technical documentation being updated and re-issued (activity 5.6). Where product approval is received from the customer, the approval is incorporated into the technical documentation and issued for production release (activity 5.7). Production approval is then issued to the production department.



NODE: A4	TITLE:	ROLL & TOOL MANUFACTURE	NO.: 7
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Figure 4.8: Roll and tool manufacturing process

4.6.6 Production process

The production process (Figure 4.10) is split into two main areas; the order/enquiry (activity 9.1) and those activities to manufacture product (activities 9.2 to 9.6). The order enquiry process begins when an enquiry is received; production engineers look at the relevant specification and compare against similar types of existing product, taking account of dimensions, tolerances, material specification, packaging requirements and other specific customer requirements. This comparison is useful in determining production output and resource required, which includes rolling speed (metres/minute), setting time, anticipated machine utilisation, number of operators required and any additional requirements for packaging; pallets, stillages etc. When the information required by the enquiry has been determined, the information is passed to sales to form part of the customer quotation.

The manufacturing activities can then commence when new tooling and the technical package is issued to the production department. Setting of the tooling (activities 9.2 and 9.3) occurs in two stages setting off line and setting on line and is constrained by two elements, the production plan and various manufacturing constraints which are applicable to the type of product and the machine which the product is designed to be manufactured on. Setting off line involves all the setting activities that can be done prior to the machine being available. While setting on line involves all the processes required to set tooling on the machine up to the point where material is issued to production (activity 9.4) ready for tryout and testing of tooling (activity 9.5). Tryout and testing involves checking that all operations required to manufacture product are correct and that production samples can be submitted for approval. Where production approval is received, manufacturing can then commence (activity 9.6) in accordance with production planning requirements.

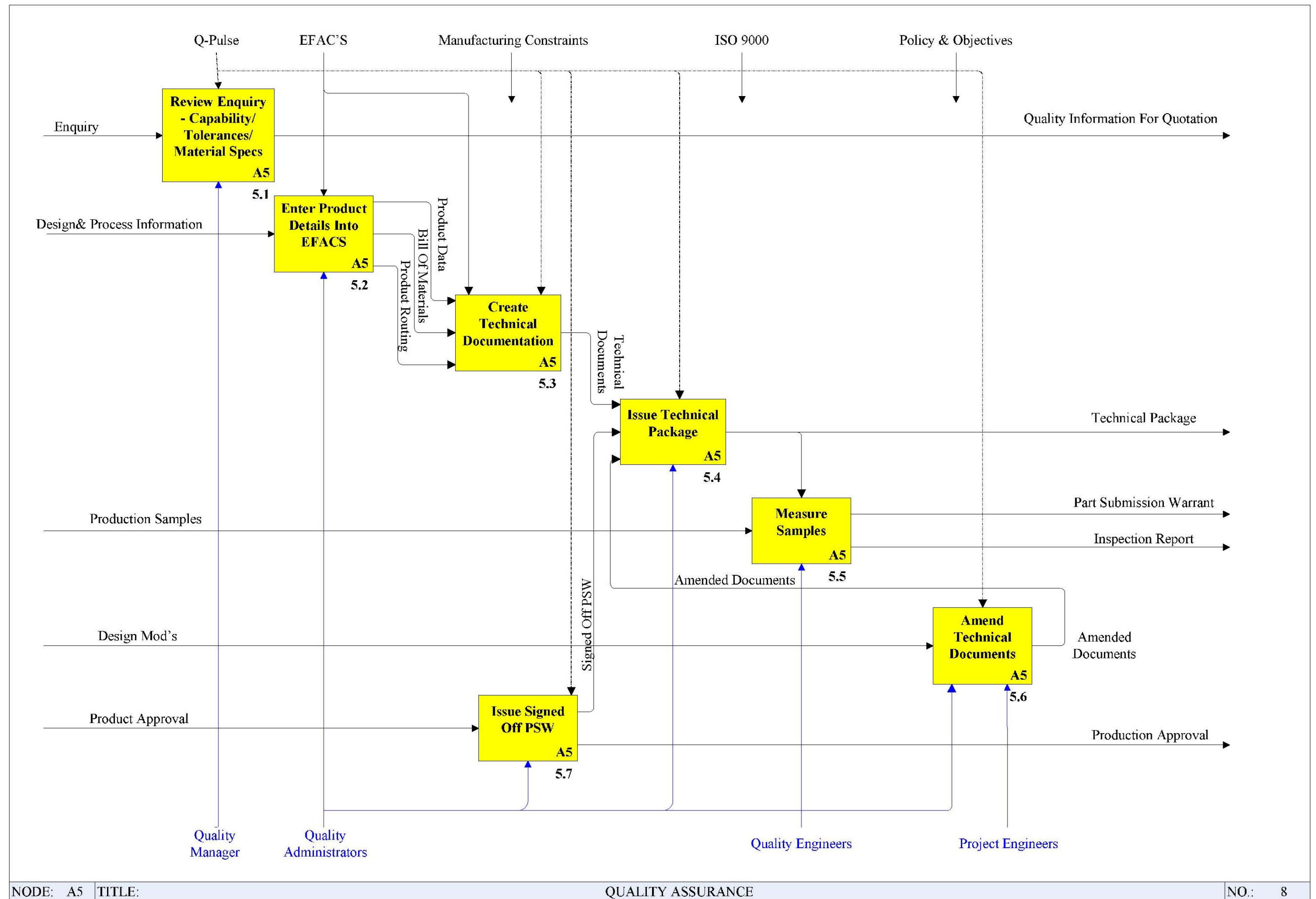


Figure 4.9: Quality assurance process

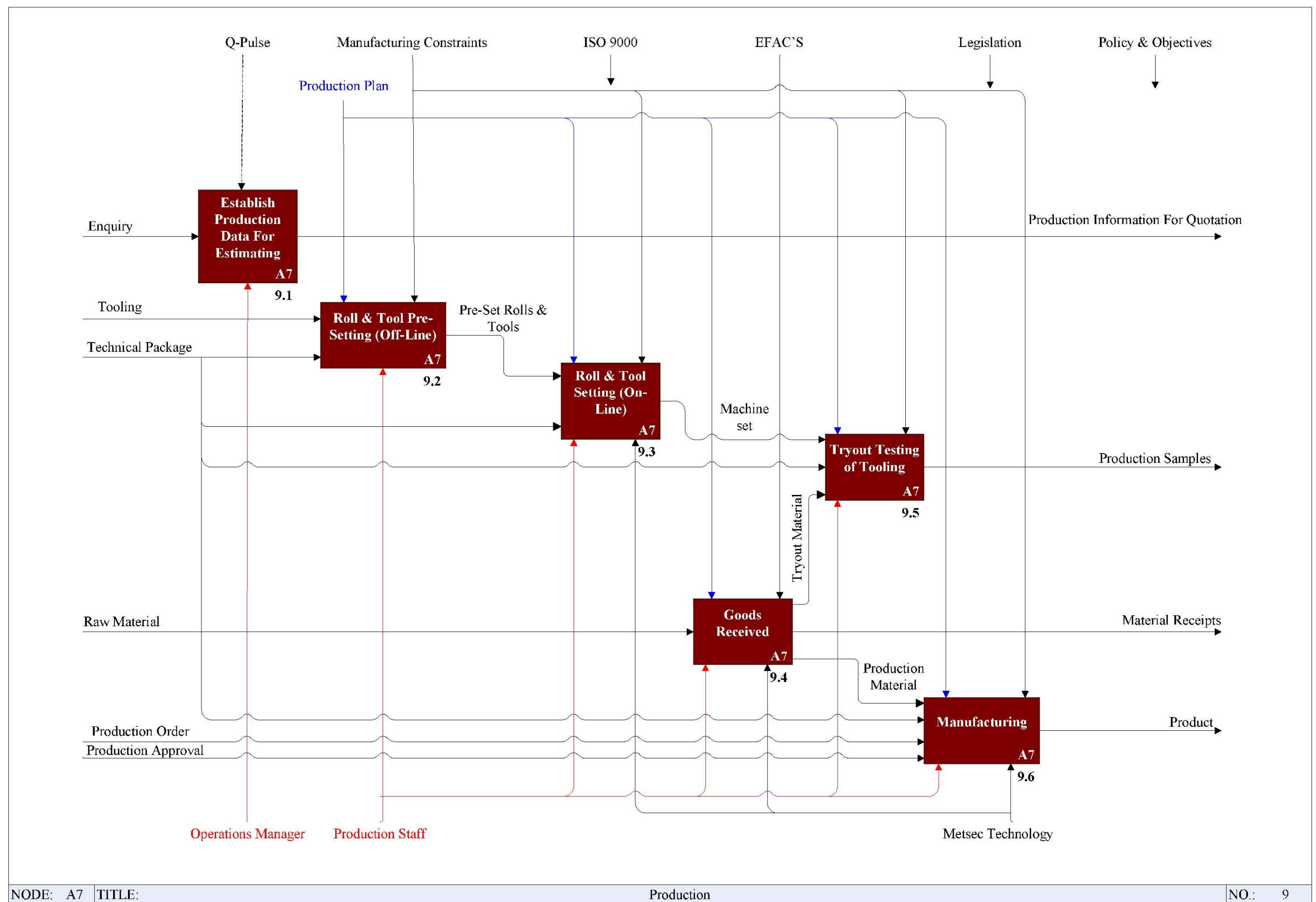


Figure 4.10: Production process

4.7 Summary

The process mapping had two significant outcomes:

1. The process mapping of the product development process showed that all activities had an output, and the output could be categorised into three distinct categories:
 - Manufacturing Knowledge; knowledge that affects the manufacturing capabilities of the process, product and process concerns and the resolution of those concerns.
 - Product data which includes the product model, manufacturing model, tooling model and product and manufacturing history (product specific).
 - A product (or service).

Kasvi *et al.*, (2003) go one stage further and sub-divide these categories into five potential outputs:

- A product (or service) delivered for an internal or external customer.
- Project knowledge related to the product, its production and use.
- Technical knowledge concerning the product, its parts and technologies.
- Procedural knowledge concerning producing and using of the product and acting in a project.
- Organizational knowledge concerning communication and collaboration.

These four types of knowledge can be process specific and product specific, however for the purpose of this research they have been identified as knowledge related to the product development process.

2. The process model helped to identify the following in product development process:-

- Available knowledge is not always captured or represented in a format that is accessible by all concerned
- Appropriate knowledge was not always available at the various stages of the process No formal NPD procedures or documentation.
- Key Performance Indicators do not measure process parameters such as cost, schedule adherence and right first time.
- Poor communication resulting in delays and capacity issues.

- Little to no involvement of suppliers or production.
- Projects often started with no clear product specification/definition.
- Sales and Engineering own agendas no common goals/objectives.
- Technical experience limited to experience gained within the organization.
- Designers do not fully understand the principles of the cold roll forming process.
- High levels of multitasking and personnel turnover.
- Engineers not collocated.
- Planning and execution over dependent on time constraints and special coordination.
- Existing product data hard to find/retrieve.
- No feedback mechanism from production/quality identifying problems associated with the product/process

Chapter 5

KNOWLEDGE MANAGEMENT TO SUPPORT DECISION MAKING WITHIN THE PRODUCT DEVELOPMENT PROCESS.

5.1 Introduction

The knowledge management cycle adopted by this research includes the following steps: identify, capture, formalize and present, and utilization of knowledge. This chapter describes how knowledge and information can be utilised to create a lean product development, and how knowledge at Metsec PLC was identified.

The process maps created identified the information and knowledge required and generated by each activity. The information and knowledge requirements were then sub-divided into four phases within of the product development process of the case organisation:

- Product Information.
- Enquiry/Engineering change request.
- New product introduction/Engineering change note.
- Concerns/Problem resolution.

The information and knowledge was then mapped out using a hierarchical tree arrangement.

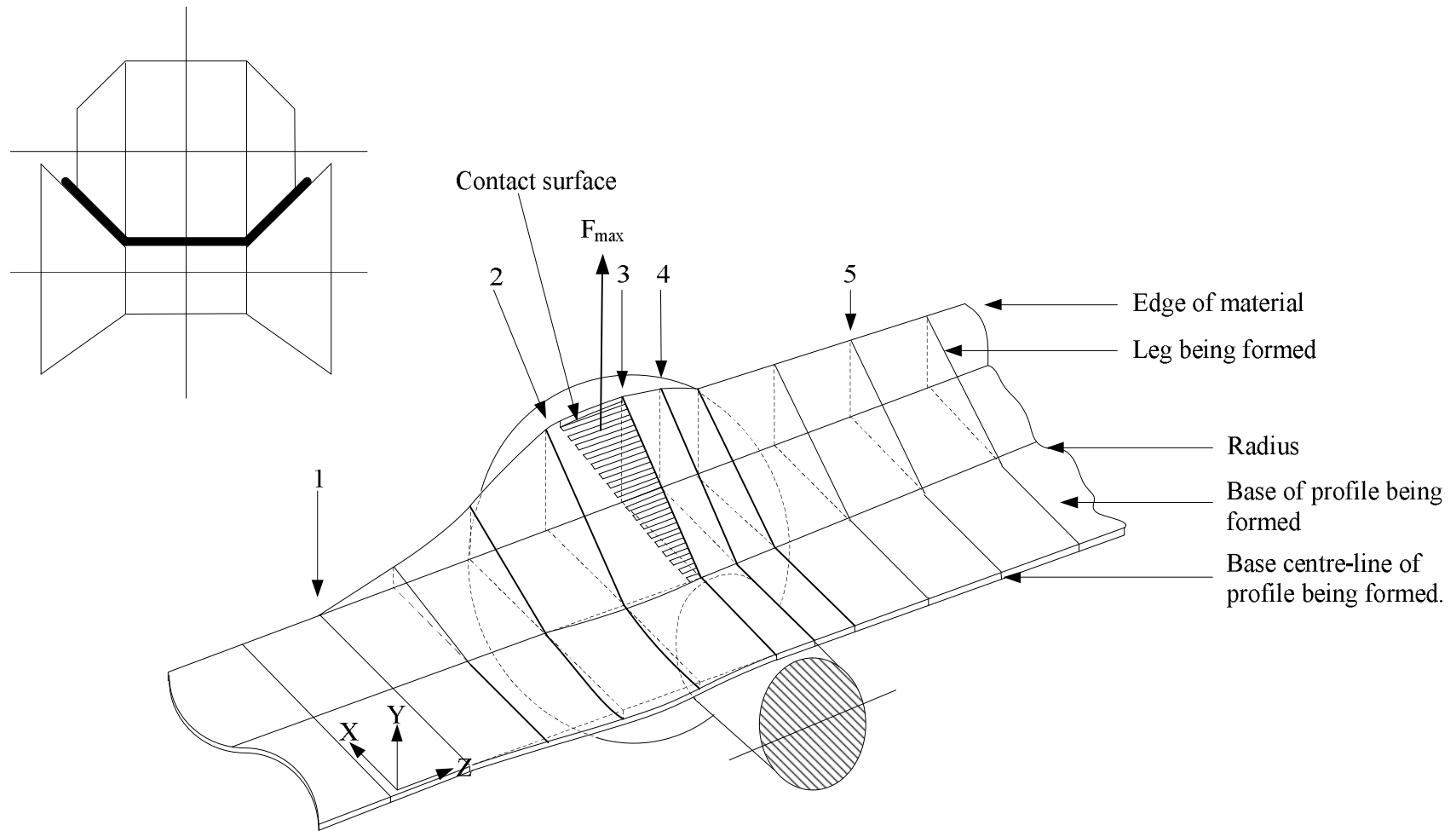
The information and knowledge identified was then

5.2 Knowledge requirements in cold roll forming

Cold roll forming is a means of forming flat metal strip into various profile shapes by means of forming rolls. Figure 5.1 shows a typical forming pass and a cross section showing how the material behaves during forming. The strip passes between the top roll and the bottom roll, which are shaped to give the correct form required for that particular part of the forming process.

As shown in Figure 5.1 each element of the material, the edge of the strip, the radius and the bottom centre line all travel through the forming rolls on a different plane to the Z axis to which they originally started, this is due to various degrees of deformation. The edge of strip between points 1 and 2 begins to stretch in the Z plane (longitudinal forming direction), as well as bending

in the YZ plane in the positive Y direction. The radius element undergoes a gradual bending in the XY plane thus forming the required radius, as the radius is formed plastic deformation of the material increases from point 1 to a maximum at point 3 where the material passes through the forming rolls. The base line element undergoes to a somewhat increased degree the same deformation as the element in the radius.



The edge of strip between points 1 and 2 begins to stretch in the Z plane (longitudinal forming direction), as well as bending in the YZ plane in the positive Y direction. The radius element undergoes a gradual bending in the XY plane thus forming the required radius, as the radius is formed plastic deformation of the material increases from point 1 to a maximum at point 3 where the material passes through the forming rolls. The base line element undergoes to a somewhat increased degree the same deformation as the element in the radius. Point 4 the stress and strain in the material begins to reduce and the material begins to spring back, point 5 is the point where the material is not influenced by the rolls and is referred to as the formed angle. Due to spring back and deflection the angle of the rolls is always greater than the formed angle.

Figure 5.1: A typical forming pass and a cross section showing how the material behaves during forming (Metsec PLC roll forming handbook)

5.2.1 Case study of cold roll forming product development in a knowledge management environment

An enquiry was received from a customer within the construction industry, for three similar profiles, which were to be used in the fabrication of lightweight lattice beams, joists and trusses. The Steel lattice beams, joists and trusses were to be utilized in a wide variety of buildings where large clear spans could be easily achieved, such as schools, hotels, sports halls, superstores and industrial buildings. The customer needed a product that would show an excellent strength to weight ratio, as the lattice beams were required to be manufactured in depths ranging from 220mm - 3000mm and be able to span up to 38m depending on building type and application.

The initial profiles proposed by the customer detailed in Figure 5.2, were analyzed to see if they could be manufactured, certain criteria such as physical size, shape and key features are checked along with the suitability of the material to cold roll form for the profiles. When agreement was reached that the profiles could be manufactured, the profiles were costed by the relevant departments and a quotation was put forward. Initial profile costs were considered acceptable, however tooling costs, were found to be too expensive for the project to be commercially viable. The tooling cost for the three profiles was £90,000. For the project to go ahead the customer required tooling costs to be no greater than £60,000. A review meeting was held with the customer to determine the critical requirements of the profiles and what features if any could be modified. Critical features identified included:

- Material properties, yield strength of 420 N/mm² minimum
- Structural properties, section modulus and I values, minimum values specified.
- The overall width of the component.
- Cost of tooling less than £60,000.

Considerable discussions were then held within the organization to determine how the profiles could be re-engineered to meet the customer specifications and reduce the tooling costs. As the profiles were very similar it was suggested that perhaps the same set of tooling could be used, with addition of spacers. The addition spacers could be used to lengthen or shorten the straight parts of the profile (within the organization this is referred to a modular/platform tooling). This was not possible with the current profile design as the forming rolls would have to be manufactured to suit the specific radii for each profile, however if the bend radii of each profile

could be standardized, so there was one common size for the three profiles, there was a possibility the roll tooling could be modularized. This again was not straight forward, and certain material properties and associated design rules had to be considered.

The minimum bend radii allowed for the material specified is directly related to its thickness. The material specification S420 MC to BS EN 10149:2 1996 states minimum bend radius for the S420 MC grade material is a minimum of one times the material thickness, therefore the minimum bend radii for each profile would be 5.0, 6.0 and 8.0 mm respectively, however tightening the radii, to one of these dimensions would result in two physical changes that would need to be considered:

- An increase in the width of material required to produce the profiles, as the tighter the radius the more material is required to form the profile, thus product costs would increase.
- The tighter the radii, the more material is required, this results in an increase/decrease in the sectional properties of the profiles. (Dependent on shape and load direction)

Further study on the profiles structural properties was required to ensure that increasing the radii on the 5.0 and 6.0 mm profile did not alter the profiles structural properties beyond the specified limits. Results of the analysis carried out confirmed that the structural properties were acceptable.

To standardize the profiles tooling fully also required dimensional modifications, there were two options considered, firstly standardize the bottom forming rolls or standardize the top forming rolls. Standardizing the top forming rolls would have resulted, in additional set up time whereby all the rolls would have to be stripped off the rolling mill to change between one profile and the next. However standardizing the bottom rolls meant the majority of the bottom forming rolls could be left set on the mill and only the top forming rolls plus the addition or removal of spacers from the bottom.

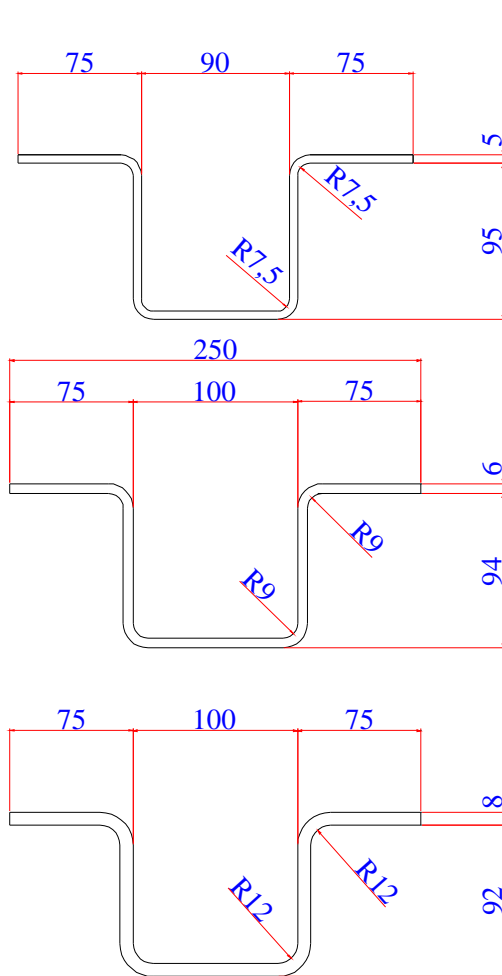


Figure 5.2: Initial profile designs put forward by the customer.

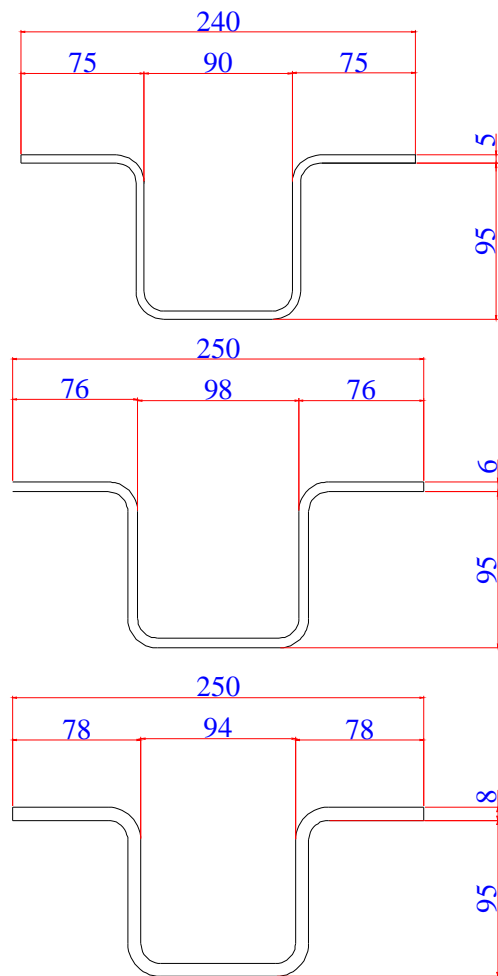


Figure 5.3: Modified profile designs to reduce tooling costs and improve productivity

To standardize the bottom rolls required the height of the channel part of the profile being standardized, again consideration to the structural properties had to be considered, standardizing to the height of the shorter 8.0 mm profile (92 mm depth of channel), would have resulted in the 6.0 mm and 5.0 mm having less material and falling out of specifications for the structural properties required. Standardization of the bottom roll tool based on the deepest profile 5.0 mm (95.0 mm depth of channel), would result in an increase in material, an increase in strength and an increase in cost (due to the additional material), the proposal to standardize the depth of the profile to 95 mm plus material thickness was put forward to the customer along with the increase in product cost. The increase in product cost was considered as still being competitive and the customer agreed for tooling costs to be established based on the modified profiles as shown in Figure 5.3.

Tool concept design was carried out based around the 5.0 mm profile, whereby top forming rolls would be dedicated to that profile; this was due to the reduced width (240 mm as opposed to 250 mm). The 6.0 mm profile tooling was designed utilizing the standardized bottom rolls and specific top forming rolls for the outer radii (18 mm) and spacer rolls to form the straight parts of the profile. The 8.0 mm profile was designed utilizing standard bottom forming rolls, top forming rolls specific to the outer radii (20 mm) and spacer rolls used in the design of the 6.0 mm top rolls.

Tooling costs, for the three profiles was reduced from £90,150 to £52,150 (£30,050 for the 5.0 mm profile, £15,500 for the 6.0 mm profile and £6500 for the 8.0 mm profile). A saving of £37,950 compared to the tooling costs quoted for the original customer designed profiles. Further benefits were seen as a result of modularizing the tooling; lead time for delivery of tooling reduced from 18 weeks to 11 weeks, however this was countered by the additional design and development time of approximately 3 weeks. Further benefits were seen in production whereby set up times for each profile would have been in the region of 8 to 10 hours (setting time based on similar type profiles), down to an average of 4.5 hours as a result of changing from 5 mm to 6 mm to 8 mm product, although initial set up of the first profile was 8-10 hours.

5.3 Knowledge identification

The next stage was to identify the knowledge required at each stage of the product development process. The process model identified controls, resource, tasks and process inputs and outputs, and was specific to the task carried out by each department. However in practice the product development process at Metsec PLC is divided into four phases:

- Product Information – information received from the customer relating to the product to be developed.
- The enquiry/engineering change request phase
- New product introduction phase
- Problems/concerns and resolutions phase.

Each phase is defined as a knowledge group and the knowledge required by each phase was mapped using a hierarchical system, Figure 5.4 shows the top level hierarchical map of the four phases (knowledge groups).

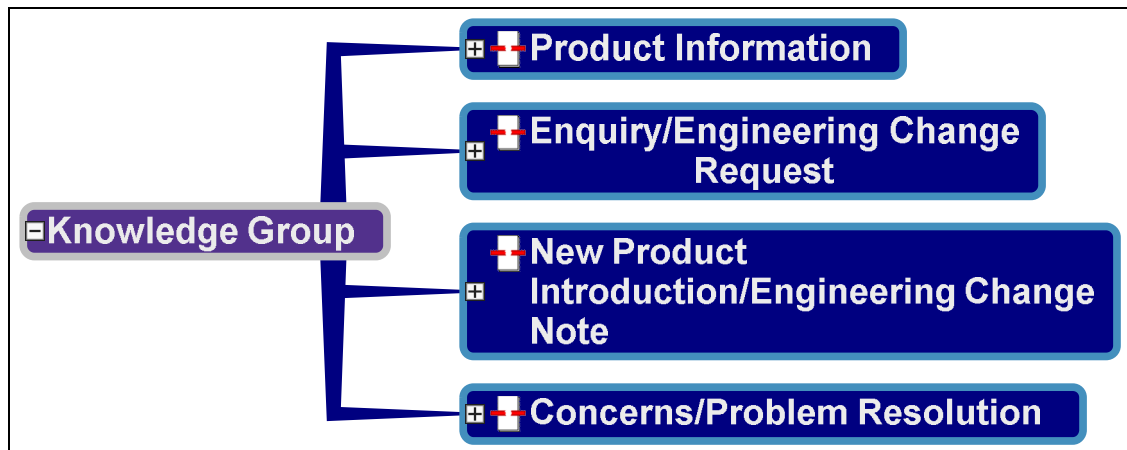


Figure 5.4: Top Level Hierarchical map of the four phases (knowledge groups).

5.3.1 Product Information

The product information phase details all the information relating to the product that is required during the product development process and is sub-divided into seven categories:

- Section no. – Part no. – The section number is utilized for product and project identification.
- Product type – product description categorized by shape and or application. – Information used to determine production methods.
- Product application – product function. – Information to determine special requirements such as surface finish and tolerances.
- Division – department within the organization that will produce or has received the enquiry. This identifies which department will produce the product and will liaise with customer from the enquiry stage through to production and delivery.
- Market sector – market sector to which the product will be supplied. Information required identifying if any specific legislation that has to be complied with during manufacture and or in use. Typical examples of this are CE marking of all steel products and fabrications used for construction purposes.
- Material specification – material details from which the product will be made, this determines a number of elements that are critical during the product development process and include:
 - i) Mechanical properties
 - ii) Manufacturability
 - iii) Surface finish/appearance
 - iv) Price

- v) Material availability
 - vi) Equipment and tooling capacity
 - vii) Product weight
 - viii) Corrosion resistance
 - ix) Heat and wear resistance.
 - x) Weldability
 - xi) Market acceptance
 - xii) Electrical, magnetic properties.
- Section properties – help determine the stresses, strains and displacements acting upon the product in service. Help determine the point at which the product will fail.

Each category is further divided into sub-groups, for example there are 24 product types utilized by Metsec PLC, (Figure 5.5 Hierarchical map of product information – sub group product type). Each product type defines the shape of the profile and/or the products application, and is used in the enquiry process to identify similar products previously manufactured so that information with regard to tooling design/costs, production speeds, problems that may have occurred in the manufacturing process can be established to determine the manufacturing and commercial viability of the enquiry. Commercially available product types such as angles and channels are described in BS EN 10162:2003 “Cold Rolled Steel Sections”. More complex profiles are often application or market sector specific, examples of market specific product type include “Cant Rail”, which is a specific shaped profile used in the commercial vehicle industry and Arrowhead which is named because of its shape and is specifically used in the manufacture of safety cells (cabs) for the yellow goods market such as JCB and Caterpillar. Examples of some of the various product types manufactured at Metsec PLC are shown in Figure 5.6: Examples of different product types.

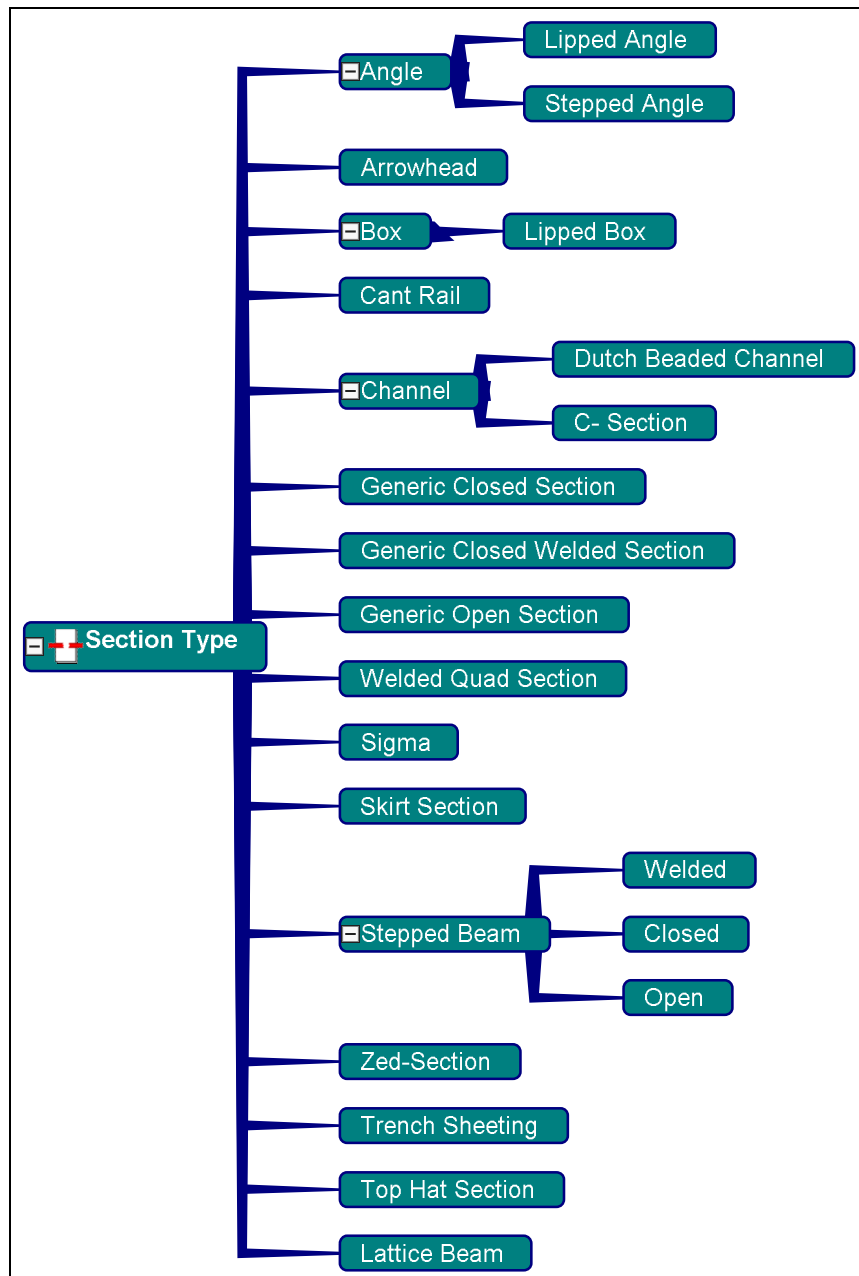


Figure 5.5: Hierarchical map of product information – sub group product type.

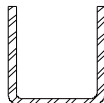

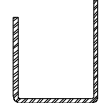




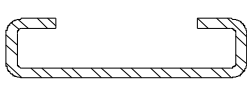
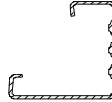
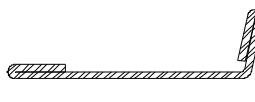
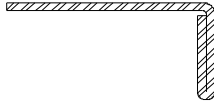
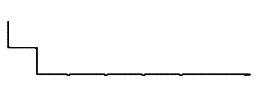
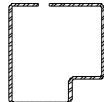
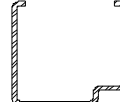
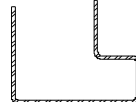
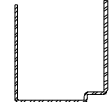
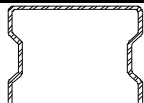
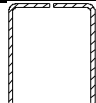
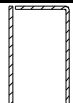
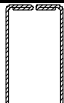
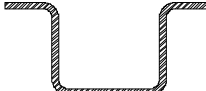


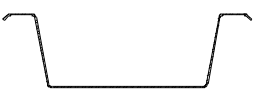

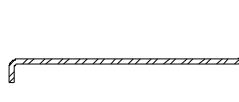

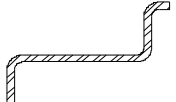
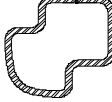



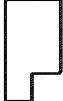

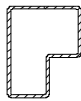
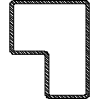

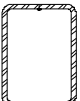
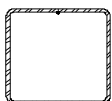
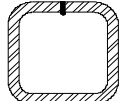

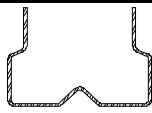
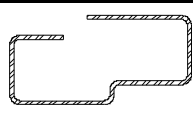
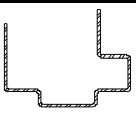
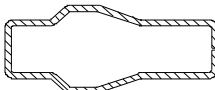
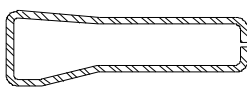
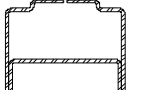
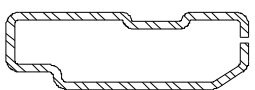
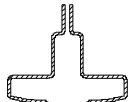
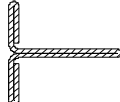
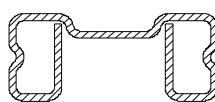


PRODUCT TYPE					
CHANNEL					
LIPPED CHANNEL					
ANGLES					
OPEN STEPPED BEAMS					
CLOSED BOX (LESS THAN 2mm GAP)					
TOP HAT					
ZEDS					
IRREGULAR SHAPED WELDED TUBE					
WELDED STEPPED BEAM					
WELDED BOX SECTION					
IRREGULAR SHAPED OPEN PROFILE					
IRREGULAR SHAPED CLOSED PROFILE (LESS THAN 2mm GAP)					
SPECIAL PROFILE					

Figure 5.6: Examples of different product types.

5.3.2 Enquiry/Engineering Change Request

The information required at the Enquiry/engineering change request phase which encompasses receipt of an enquiry through to supplying the customer with a quotation. The enquiry phase starts with the receipt of the enquiry which is logged in an enquiry register and given a unique enquiry number. The information required for each enquiry is divided into ten categories:

- Division – department within the organization that will produce or has received the enquiry. This identifies which department will produce the product and will liaise with customer from the enquiry stage through to production and delivery.
- Enquiry raised by – Information relating to the customer and which department received the enquiry.
- Reason for the enquiry/engineering change request.
- Product definition. – Details about the product to be designed developed and manufactured.
- Machine capacity review. – determine if capacity is available to manufacture product.
- Machine number/Operation – what machine the product will be produced on and the number of operations.
- Cost estimate (tooling). - The tooling required and the estimated costs.
- Product output (estimate). Information regarding manufacturing output (production rates)
- Sales review. - Information regarding number of competitors quoting, additional manufacturing processes that could be carried out by Metsec PLC that could add value (examples include manipulation, painting, plating) and the actual cost estimate to the business.
- Sample approval requirements. How the product to be manufactured is to be approved by the customer.

Figure 5.7 shows the hierarchal map of the information required at the enquiry/engineering request phase of the product development process.

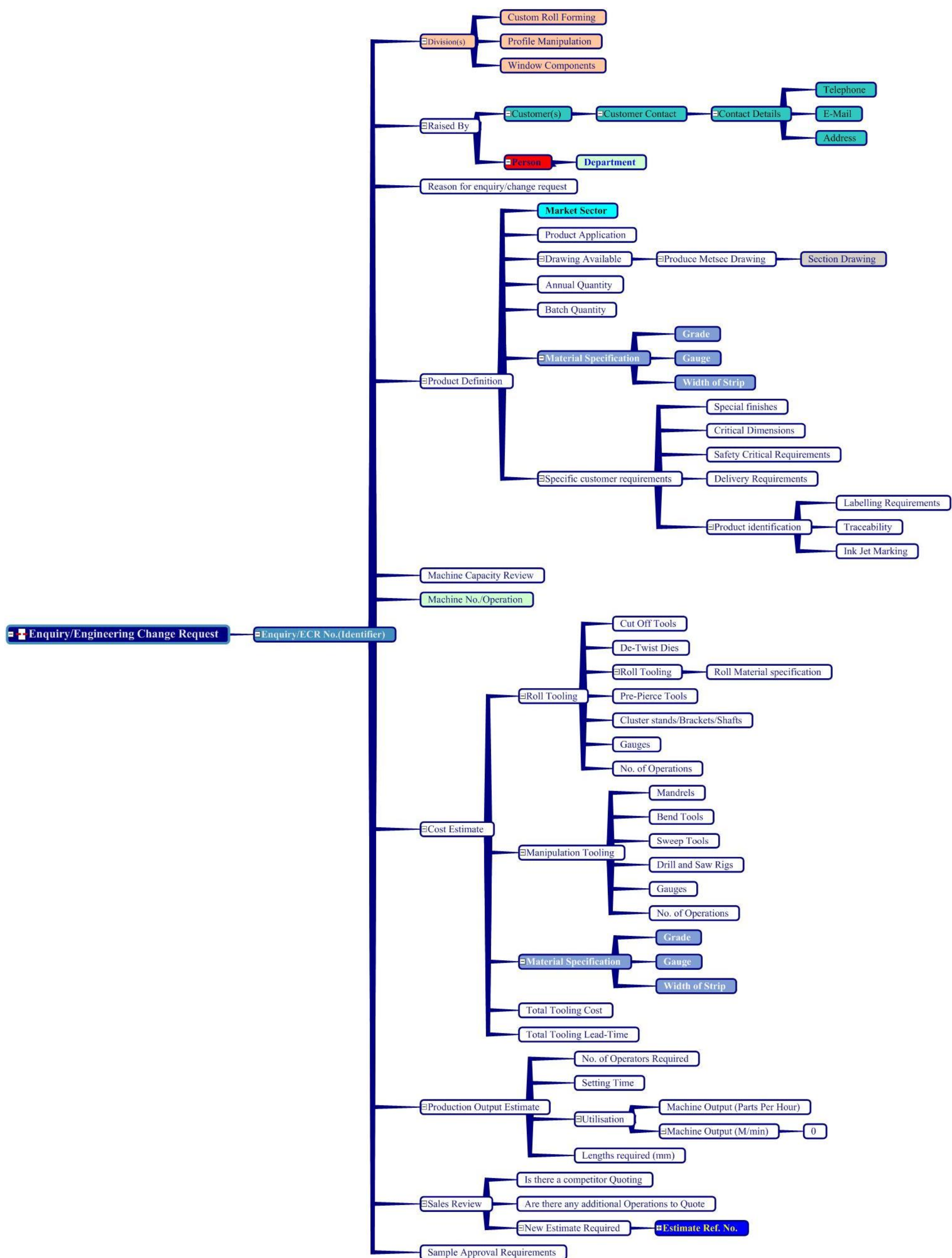


Figure 5.7: Hierarchal map of the Enquiry/engineering change request information required

Each category of the Enquiry/Change request hierarchical map is sub-divided into individual elements, for example the product definition category is made up of seven elements:

- Market sector - Sector to which the product is to be supplied.
- Product application. – Product intended use.
- Drawing availability - are drawings available?
- Estimated annual volumes.
- Customer preferred batch sizes.
- Material specification - specification, grade and sizes the material is to be manufactured from.
- Specific customer requirements – relating to the product and include special surface finishes, specific tolerances, packing specifications, safety critical requirements and product identification requirements.

5.3.3 New Product Introduction

The New product introduction/engineering change note group details all the information required to design, develop, manufacture and supply new product. Each New product introduction/engineering change note is logged and given a unique number (identifier). Each new product introduction is linked to an enquiry/engineering change request, and the information gathered at this stage forms the foundations for the product development/new product introduction phase.

The information required is divided into ten categories (Figure 5.8):

- Enquiry/ECR No (identifier).
- Division – department within the organization that will produce or has received the enquiry. This identifies which department will produce the product and will liaise with customer from the enquiry stage through to production and delivery.
- Section No/Part number (Product identifier)
- Material specification - specification, grade and sizes the material is to be manufactured from.
- Raised by – Which department will be responsible for processing the order and will liaise with the customer about the project also includes customer order details.
- Date new product or engineering change note needs to be implemented.

- Tooling equipment required, this relates to the tooling and equipment requirements to manufacture product.
- Technical package – all the necessary information required to manufacture and ensure product meets the required specifications.
- Tryout production – specific information relating to product and process approval prior to product being approved for manufacture.

Each category is sub-divided into individual elements, for example the technical package category is made up of four elements:

- Inspection Sheet – details the individual features/dimensions required to ensure product conformity
- Process flow- details all the stages required to manufacture product right from purchase of material through to dispatch.
- Control plan – details all the controls necessary to ensure product conformity.
- Packing specification – details how the product is to be packed and delivered to the customer.

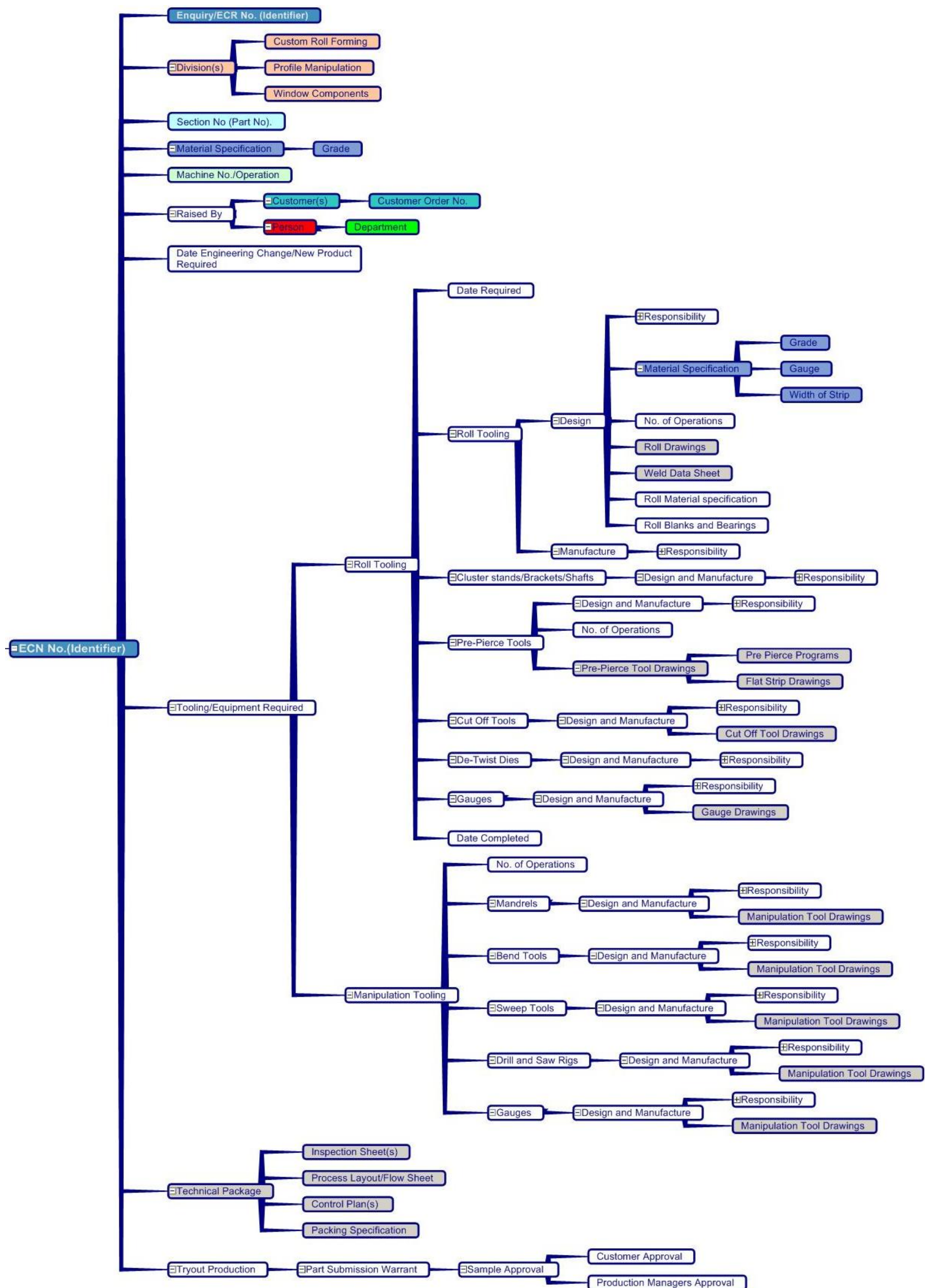


Figure 5.8: Hierarchal map of the new product introduction/engineering change note information required.

5.3.4 Product/Process Concerns/Problem resolution

The concern/problem resolution stage (Figure 5.9) was developed as a result of process modelling findings and was initially aimed at capturing knowledge based on past experiences in order to support engineering decisions and eliminate non value added activities (waste) such as product and process re-designs. The system initially was developed with the following characteristics in mind:

- Quickly and effectively identify and capture concerns from all areas of the product development process.
- Formalise and present the specific and relevant information regarding concerns and problems to the appropriate people
- Be able to utilise reports of concerns from each stage of the product development process in isolation but also collectively; and in doing so support effective decision making thus avoiding repeat concerns and problems and therefore the elimination of non-value added activities.

The concern/problem resolution phase details all the information required to identify, capture formalize, present and utilize concerns and problems identified during the product development process. Each concern is logged and given a unique number (identifier). The information required for each problem is then divided into eight categories (Figure 5.9):

- Raised date – date the concern was identified.
- Division – department where the problem occurred.
- Works order No. – used for traceability purposes.
- Machine No/Operation – The stage where the problem occurred.
- Reported by – person who raised the concern.
- Concern/problem – details of the concern.
- Resolution – Action taken to eliminate concern and prevent reoccurrence.

Each category is sub-divided into individual elements, for example the resolution category is made up of seven elements:

- Action required; action needed to address the problem/concern.
- Action tried; all actions tried whether they resolved the problem/concern to be documented.

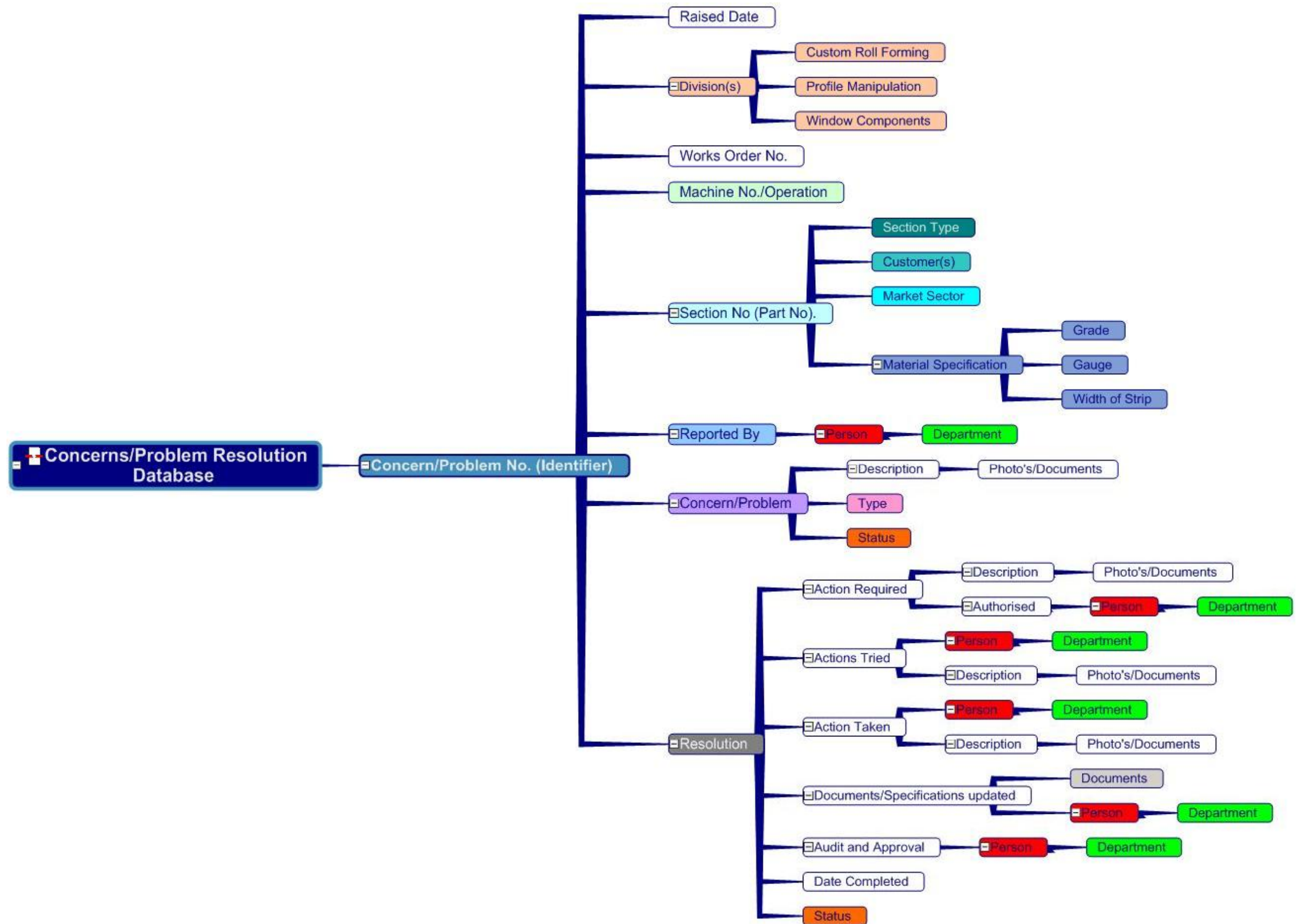


Figure 5.9: Hierarchal map of concerns/problems resolution stage identifying information required.

- Action taken; Action taken that actually overcame problem/concerns.
- Documents/Specifications updated: list of all documents/spec's updated as a result of the concern.
- Audit and Approval; who audited the actions taken to confirm concern/problems have been resolved.
- Date completed
- Status; Identifier to show if the concern/problem is awaiting actions or closed.

5.4 Summary

An initial insight of the knowledge required to support product development was gained during process modelling the product development process. This chapter expanded on this and identified the specific knowledge required during the four product development phases used at Metsec PLC. This knowledge is of critical importance and influences decision making with regard to manufacturing design, selection of production equipment, selection of process parameters, tool design, fabrication and assembly. Currently, the knowledge required to support these activities is distributed throughout the organization. The challenge is how can that knowledge be captured, formalized and presented for future use.

Chapter 6

A KNOWLEDGE BASED PRODUCT DEVELOPMENT SYSTEM

6.1 Manufacturing knowledge base system definition

Throughout the product development process, project engineers have to make decisions. The decisions taken can affect the overall performance of the final product. Each decision is motivated by some level of justification. Quite often, the justification behind the decisions taken is based on accepted assumptions and objectives. However, the justification beyond such decisions is often not well documented, forgotten, or based on illogical assumptions or a misinterpretation of the objectives.

When such decisions are reviewed in hindsight without the aid of knowing the context in which the decision was taken, it can be difficult to assess the soundness of the decision

This lack of context shows the need for keeping a record of the justifications associated with key product development decisions.

The manufacturing knowledge based product development system detailed in this chapter aims to capture decisions taken and their context in order to support effective decision making in future product development activities.

6.2 Overall system structure

In order to give a clear description of the system, it is necessary to subdivide the system into its constituent parts, as shown in Figure 6.1 (p.87), the system contains two main elements (databases): product data archive, a manufacturing knowledge base each linking to the manufacturing and product and process design activities. In the system, the end users; manufacturing staff and project engineers have access to the two databases from their work stations. The following sections will describe each of the elements and activities in more detail.

6.2.1 Product data module

The product data archive is a database with the information and knowledge required to support the manufacturing activities. The archive contains: the product model, manufacturing model,

tooling model and product manufacturing history. These models are explained in more detail in the following subsections.

6.2.2 Product model

The product model details the product specifications and covers such elements as: a product drawing, quality requirements, packing specifications, delivery requirements and material specifications. Each element has its own specific format standardized within the system, which is supported by element details with regard to revision levels and issue dates and copy holders. Examples of product model details are given in Appendix A.

6.2.3 Manufacturing model

Decision making during the product development process is often quite difficult as not all persons directly involved in the process have access to all the necessary information and knowledge related to the manufacturing process. To overcome this issue, all the necessary information relating to the manufacturing process such as capabilities, capacity, machine sizes, machine speeds, standard operating procedures etc, were pulled together to create a manufacturing model. The manufacturing model sits in the product data archive in the form of charts, spreadsheets and specifications. The Manufacturing Model is the knowledge required to identify the manufacturing methods and processes of new product.

6.2.4 Tooling model

The tooling models consist of forming roll design, cut off tool designs, piercing tool designs, tool setting sheets, plc programs for the production lines, all the necessary information to produce tooling and set tooling on the machines.

6.2.5 Product manufacturing history

Product manufacturing history provides details of each product from the enquiry, through new product introduction and manufacture and details all engineering changes relating to the product, manufacturing and tooling models.

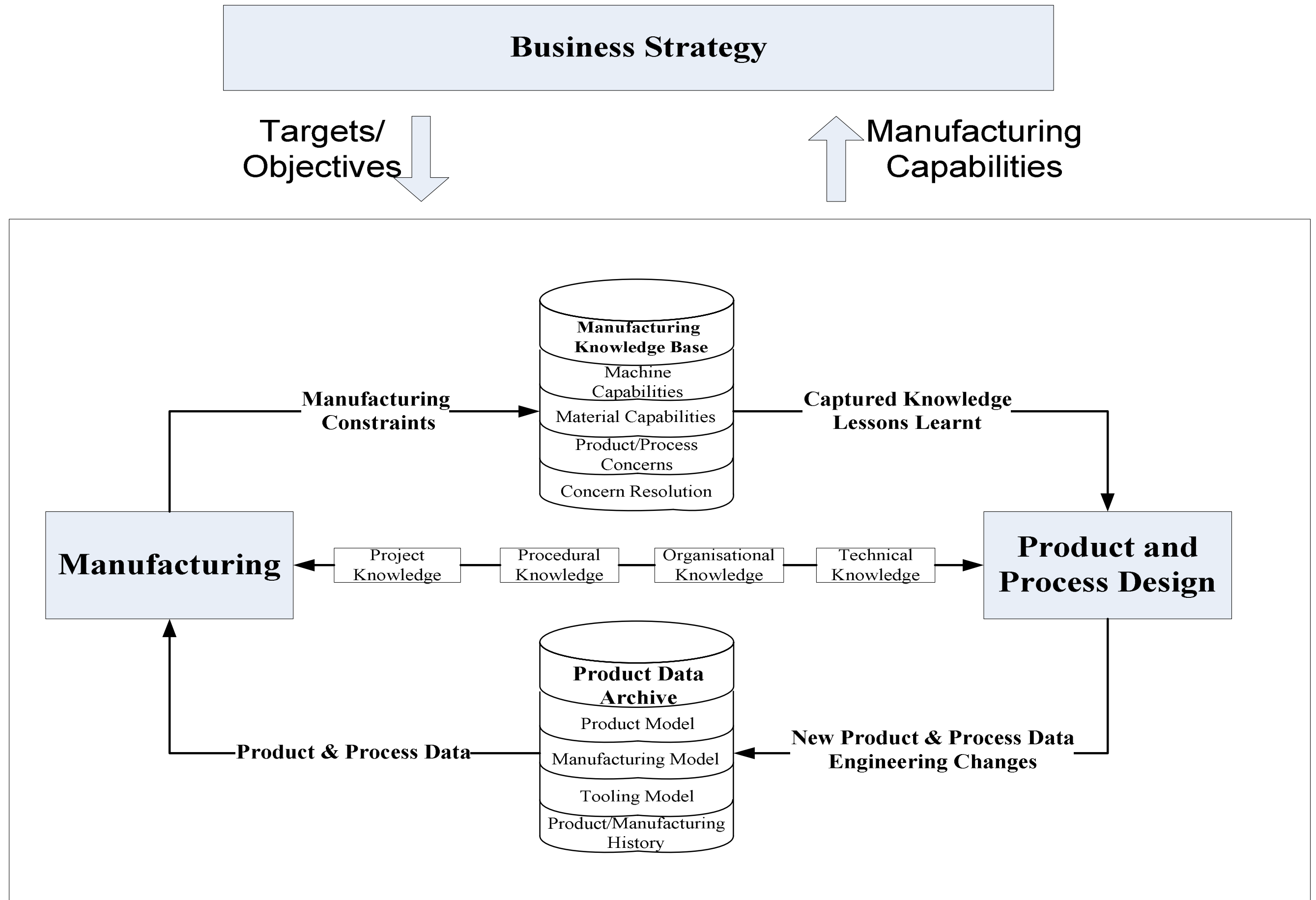


Figure 6.1: Knowledge based framework to support product development

6.3 Manufacturing knowledge base

The manufacturing knowledge base is a database with the information and knowledge required to support the product and process design activities. The database contains: machine capabilities, material capabilities, product/process concerns and problem resolution. These elements are explained in more detail in the following subsections

6.3.1 Machine capabilities

The manufacturing capabilities element of the manufacturing knowledge base is utilized to select suitable manufacturing equipment and production lines for the manufacture of a specific product. The selection of suitable manufacturing equipment is carried out in conjunction with the product model information.

6.3.2 Material capabilities

The material capabilities element of the manufacturing knowledge base is probably the most important aspect to be considered when developing new product, selection of the wrong material could result in tooling being over or under engineered. Detailed below is an example of how material properties in particular the yield strength affects process design.

A material of 200 N/mm^2 yield strength is to be used to form a “C” profile, on a rolling machine which has a distance of 460 mm between stand centres (L), what is the maximum strain permitted per forming operation, and how many forming operations would be required to form legs whose height is 120 mm.

$$\text{Yield Strength} = \sigma = 200 \text{ N/mm}^2$$

$$\text{Distance between stand centres} = L = 460 \text{ mm}$$

X = displacement of strip edge element from one roll forming pass to the next as shown in Figure 6.2.

Calculations and figures taken from Metsec PLC roll design handbook.

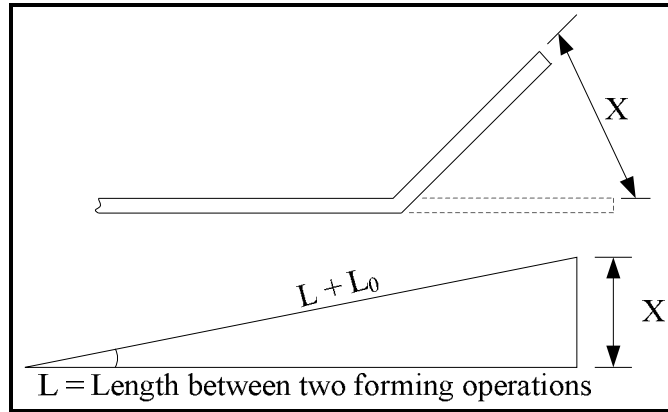


Figure 6.2: Height of form and length between forming operations

$$\varepsilon = \frac{\sigma}{E} = \varepsilon \frac{200}{205000} = 0.0009756 = \text{maximum strain per unit length.}$$

$$\varepsilon = \frac{L - L_0}{L_0} = 0.0009756 = \frac{? - 460}{460}$$

$$\text{Therefore } \Delta L = \varepsilon \times L_0 = 0.0009756 \times 460$$

$\Delta L = 0.4487 \text{ mm} = \text{maximum permitted change in length between two forming operations with } 460 \text{ mm centres.}$

$$\text{Or: } X_{\text{Max}} = \sqrt{(460.44877^2 - 460^2)} = 20.3241 \text{ mm}$$

The 20.3241 mm dimension is the displacement of strip edge element from one roll forming pass to the next, whose centres are 460 mm.

To form a leg of 120 mm the material must be displaced by 170 mm as shown in Figure 6.3.

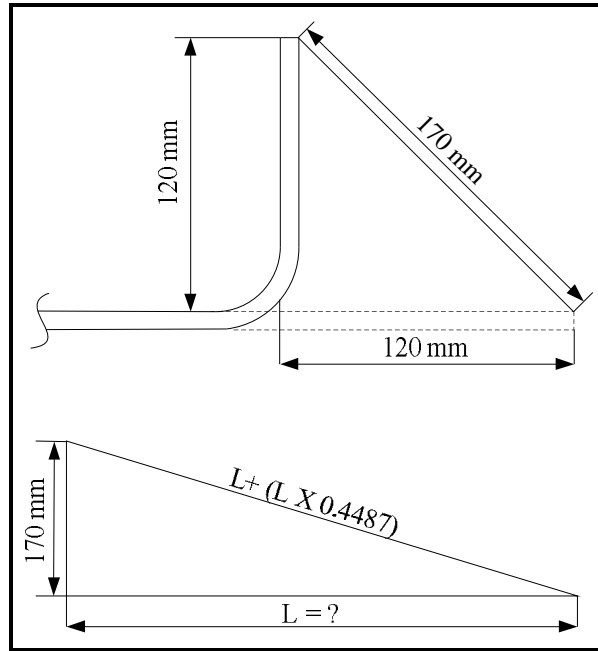


Figure 6.3: Forming a 120 mm leg.

Maximum strain per unit length (ϵ)

Permitted extension (ΔL) = $L \times \epsilon$

Displacement required (X) = $\sqrt{(L + (L \times \epsilon))^2 - L^2}$

To calculate the forming length of a leg with a displacement (X), Length (L) needs to be determined:

Transposing the formula to find L.

$$X = \sqrt{(L + (L \times \epsilon))^2 - L^2}$$

$$X^2 + L^2 = L^2 + 2(L \times L \times \epsilon) + L^2 \times \epsilon^2$$

Assumption made that $L^2 + \epsilon^2 = 0$ therefore formula equals:

$$L = \frac{\sqrt{X^2}}{2\epsilon}$$

Using figures from the example.

X = 170 mm and $\epsilon = 0.0009756$

$$L = \frac{\sqrt{170^2}}{2 \times 0.0009756}$$

Length required to form a 120 mm leg based on a yield strength of 200N/mm² and a maximum strain of 0.0009756 per unit length equals 3848 mm. The roll forming machine had forming centre of 460 mm between each forming operation therefore 8 forming operations would be required

$$\frac{3848}{460} = 7.57$$

Calculations and figures taken from Metsec PLC roll design handbook.

Due to the importance of the material during the product development process, a table of all the steel grades and their chemical and mechanical properties was established and is used as a reference guide when developing new product. An example of the table and the steel grades is shown in Figure 6.4.

Material Specification	Material Grade.	Proof Stress(Re) Yield N/mm'		Tensile (Rm) N/mm'		Elongation A ₈₀ (%)		Plastic strain ratio (r ₉₀)	Strain hardening (n ₉₀)	Chemical composition.(Ladle Analysis % maximum)														
		Minimum	Maximum	Minimum	Maximum	Minimum		Minimum	Minimum	C	P	S	Mn	Ti	Si	Al	Nb	V	Mo	B	Cu	N		
BS EN 10130:2006 Cold-Rolled Low-Carbon Steel Flat Products For Cold Forming.	DC01	140	280	270	410	28		-	-	0.12	0.045	0.045	0.60	-	-	-	-	-	-	-	-	-		
	DC03	140	240	270	370	34		1.30	-	0.10	0.035	0.035	0.45	-	-	-	-	-	-	-	-	-		
	DC04	140	210	270	350	38		1.60	0.18	0.08	0.030	0.030	0.40	-	-	-	-	-	-	-	-	-		
	DC05	140	180	270	330	40		1.90	0.20	0.06	0.025	0.025	0.35	-	-	-	-	-	-	-	-	-		
	DC06	120	170	270	330	41		2.10	0.22	0.02	0.020	0.020	0.25	0.30										
	DC07	100	150	250	310	44		2.50	0.23	0.01	0.020	0.020	0.20	0.20	-	-	-	-	-	-	-	-		
Material Specification	Material Grade.	Proof Stress(Re) Yield N/mm'		Tensile (Rm) N/mm'		Elongation - minimum requirements after fracture (A ₈₀ (%) 1 - 3 mm)(5.65/√S ₀ 3 - 11 mm)				Chemical composition.(Ladle Analysis % maximum)														
		Minimum		Maximum		Minimum	Maximum	1 ≤ e < 1.5 mm	1.5 ≤ e < 2 mm	2 ≤ e < 3 mm	3 ≤ e ≤ 3 mm	C	P	S	Mn	Ti	Si	Al	Nb	V	Mo	B	Cu	N
		1.5-2.0 mm	2.0-8.0 mm	1.5-2.0 mm	2.0-8.0 mm																			
BS EN 10111:2008 Continuously Hot-Rolled Low-Carbon Sheet And Strip For Cold Forming.	DD11	170	170	360	340	-	440	22	23	24	28	0.12	0.045	0.045	0.60	-	-	-	-	-	-	-	-	-
	DD12	170	170	340	320	-	420	24	25	26	30	0.10	0.035	0.035	0.45	-	-	-	-	-	-	-	-	
	DD13	170	170	330	310	-	400	27	28	29	33	0.08	0.030	0.030	0.40	-	-	-	-	-	-	-	-	
	DD14	170	170	310	290	-	380	30	31	32	36	0.08	0.025	0.025	0.35	-	-	-	-	-	-	-	-	
Material Specification	Material Grade.	Proof Stress(Re) Yield N/mm'		Tensile (Rm) N/mm'		Elongation A ₈₀ (%)		Plastic strain ratio (r ₉₀)	Strain hardening (n ₉₀)	Chemical composition.(Ladle Analysis % maximum)														
		Minimum	Maximum	Minimum	Maximum	Minimum		Minimum	Minimum	C	P	S	Mn	Ti	Si	Al (Min)	Nb	V	Mo	B	Cu	N		
						< 3.0 mm	≥ 3.0 mm																	
BS EN 10149-2:1996 Hot Rolled Flat Products Made of High Yield Strength Steels For Cold Forming.	S315 MC	315	-	390	510	20	24	-	-	0.12	0.025	0.02	1.30	0.15	0.50	0.015	0.090	0.20	-	-	-	-		
	S355 MC	355	-	430	550	19	23	-	-	0.12	0.025	0.02	1.50	0.15	0.50	0.015	0.090	0.20	-	-	-	-		
	S420 MC	420	-	480	620	16	19	-	-	0.12	0.025	0.015	1.60	0.15	0.50	0.015	0.090	0.20	-	-	-	-		
	S460 MC	460	-	520	670	14	17	-	-	0.12	0.025	0.015	1.60	0.15	0.50	0.015	0.090	0.20	-	-	-	-		
	S500 MC	500	-	550	700	12	14	-	-	0.12	0.025	0.015	1.70	0.15	0.50	0.015	0.090	0.20	-	-	-	-		
	S550 MC	550	-	600	760	12	14	-	-	0.12	0.025	0.015	1.80	0.15	0.50	0.015	0.090	0.20	-	-	-	-		
	S600 MC	600	-	650	820	11	13	-	-	0.12	0.025	0.015	1.90	0.22	0.50	0.015	0.090	0.20	0.5	0.005	-	-		
	S650 MC	650	-	700	880	10	12	-	-	0.12	0.025	0.015	2.00	0.22	0.60	0.015	0.090	0.20	0.5	0.005	-	-		
S700 MC	700	-	750	950	10	12	-	-	0.12	0.025	0.015	2.10	0.22	0.60	0.015	0.090	0.20	0.5	0.005	-	-			
Material Specification	Material Grade.	Proof Stress(R _{eH}) Yield N/mm'		Tensile (R _m) N/mm'		Elongation A ₈₀ (%)		Plastic strain ratio (r ₉₀)	Strain hardening (n ₉₀)	Chemical composition.(Ladle Analysis % maximum)														
		Minimum		Maximum		Minimum		Minimum	Minimum	C	P	S	Mn	Ti	Si	Al	Nb	V	Mo	B	Cu	N		
		Long	Trans	Long	Trans	Long	Trans																	
BS EN 10268:2006 Cold rolled flat products with high yield strength for cold forming.	HC 260 LA	240	260	310	330	340-420	350-430	27	26	-	-	0.10	0.025	0.025	0.60	0.15	0.50	0.015		-	-	-	-	-
	HC 300 LA	280	300	360	380	470-470	380-480	24	23	-	-	0.10	0.025	0.025	0.10	0.15	0.50	0.015	0.090	-	-	-	-	-
	HC 340 LA	320	340	410	420	400-500	410-510	22	21	-	-	0.10	0.025	0.025	1.10	0.15	0.50	0.015	0.090	-	-	-	-	-
	HC 380 LA	360	380	460	480	430-550	440-560	20	19	-	-	0.10	0.025	0.025	1.60	0.15	0.50	0.015	0.090	-	-	-	-	-
	HC 420 LA	400	420	500	520	460-580	470-590	18	17	-	-	0.10	0.025	0.025	1.60	0.15	0.50	0.015	0.090	-	-	-	-	-
Material Specification	Material Grade.	Proof Stress(Re) Yield N/mm'		Tensile (Rm) N/mm'		Elongation A ₈₀ (%)		Plastic strain ratio (r ₉₀)	Strain hardening (n ₉₀)	Chemical composition.(Ladle Analysis % maximum)														
		Minimum	Maximum	Minimum	Maximum	Minimum		Minimum	Minimum	C	P	S	Mn	Ti	Si	Al	Nb	V	Mo	B	Cu	N		
BS EN 10152:2003 Electrolytically Zinc Coated Cold Rolled Steel Flat Products For Cold Forming.	DC01 + ZE	140	280	270	410	28		-	-	0.12	0.045	0.045	0.60	-	-	-	-	-	-	-	-	-	-	
	DC03 + ZE	140	240	270	370	34		1.30	-	0.10	0.035	0.035	0.45	-	-	-	-	-	-	-	-	-	-	
	DC04 + ZE	140	220	270	350	37		1.60	0.16	0.08	0.030	0.030	0.40	-	-	-	-	-	-	-	-	-	-	
	DC05 + ZE	140	190	270	330	39		1.90	0.19	0.06	0.025	0.025	0.35	-	-	-	-	-	-	-	-	-	-	
	DC06 + ZE	120	190	270	350	37		1.80	0.20	0.02	0.020	0.020	0.25	0.30	-	-	-	-	-	-	-	-	-	

Figure 6.4: an example of material grades and properties table utilized during the design and development of new product.

6.3.3 Product/process concerns and concerns resolution

In response to the issues highlighted in the literature review and the process modelling activity, this part of the manufacturing knowledge base provides information with regard to product and process concerns identified in manufacturing and their resolution in order to ensure knowledge and the context in which it was created is fed back to product and process design in the form of manufacturing constraints and lessons learned.

6.4 Implementation of the product data archive

The product data archive was developed using a quality management compliance software tool (Q-Pulse by Gael Quality), mainly due to its document control functionality, but also its ability to be configured to Metsec requirements and not Metsec processes being altered to suit the software.

6.4.1 Document and data control

The document control module was considered key to the business due to the number of products and associated documents, in total there are currently 2082 different products, 15 document types associated to the products and a total 13229 documents.

The product data archive was initially instigated back in 2005, however several problems existed which needed to be addressed before the database could be populated;

- Document types existed in several formats included prints, photos, sketches and also in various file formats
- Documents needed to be produced in a format that could be opened from any computer that had access to the product archive.
- No formal engineering control procedure existed.

The first step was to get all the documents into a format that could be stored in the database, each document type was given a specific format, for example all engineering drawings had to be produced using AutoCAD. All inspection sheets had to be produced using Microsoft Excel. Additional to this a standard layout for each document was implemented, whereby just viewing the document would inform what document type it was.

6.4.2 Application of the Knowledge Based Product Development System

Two members of staff were employed for this task, which took two years and was finally completed in December 2007. All documents were then entered onto the system and are stored by document number which is derived from the part number and the document type for example document number “13942 IS”. The number 13942 refers to the product and “IS” refers to the document type; Inspection sheet. Prior to entering the documents onto the system concerns were raised regarding the number of documents, would the database be handle this amount of data. Clarification was sort from Microsoft and Gael quality. To ensure the system could cope with the amount of documentation, the documents have been stored outside of the database and linked back using hyperlinks. From a user point of view the documents are selected and viewed in the same manner.



Figure 6.5: Screen shot showing document types stored within the product data archive.

Prior to the documents being entered into the database the file structure in terms of engineering changes and revisions had to be established. Documents on the system exist on four status levels:

- Active; current document revision.
- Obsolete; all obsolete documents are kept to create the product/manufacturing history model
- Inactive; documents that have been made inactive, due to customer purchasing from elsewhere or the product itself has been replaced.
- Draft; document that is being amended as a result of an engineering change.

Each status level/document type has a separate file location on the system (Figure 6.6).

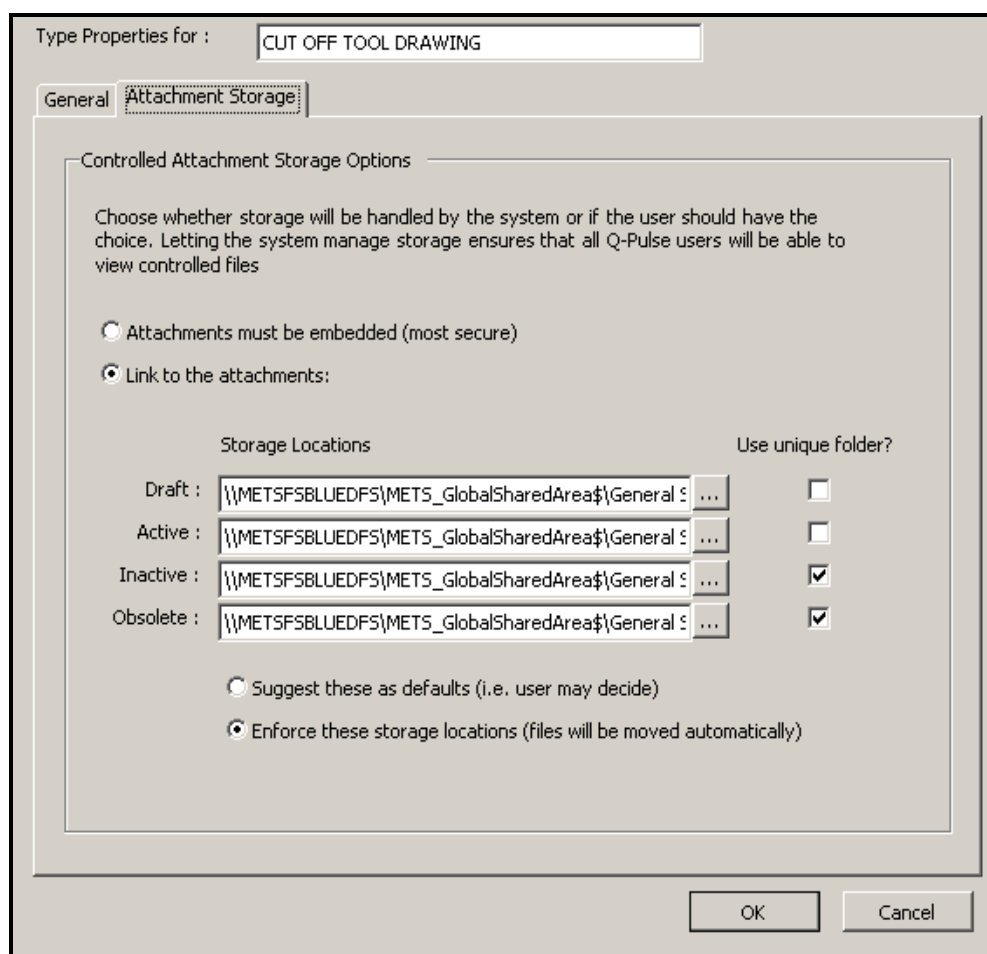


Figure 6.6: Screen shot showing file locations for document status levels for document type Cut off Tool Drawing.

The product data archive system is split into two main areas; firstly the document list screen (Figure 6.7), whereby documents can be searched by:

- Document Type.

- Part No.
- Document No.
- Revision level.
- Document owner.
- Customer.
- Product Market sector.
- Type of product.

Document Number	Document Title	Revision	Product Type	Market Sector	Active Date
13062 SD	SECTION DRAWING	9	Welded Stepped Beam	STORAGE AND RACKING	02/04/2007
13652 SD	SECTION DRAWING	6	Welded Stepped Beam	STORAGE AND RACKING	02/04/2007
12771R SD	SECTION DRAWING	7	Welded Stepped Beam	STORAGE AND RACKING	02/04/2007
12770 SD	SECTION DRAWING	9	Welded Stepped Beam	STORAGE AND RACKING	11/10/2006
12689 SD	SECTION DRAWING	9	Welded Stepped Beam	STORAGE AND RACKING	11/10/2006
12771 SD	SECTION DRAWING	7	Welded Stepped Beam	STORAGE AND RACKING	15/10/2007
11963P SD	PIERCING DRAWING	3	Top Hat Section	STORAGE AND RACKING	24/05/2007
11963 SD	SECTION DRAWING	3	Top Hat Section	STORAGE AND RACKING	25/05/2007
12976P SD	PIERCING DRAWING	6	Top Hat Section	STORAGE AND RACKING	03/07/2007
12976 SD	SECTION DRAWING	6	Top Hat Section	STORAGE AND RACKING	03/07/2007
13179 SD	SECTION DRAWING	5	Special Profile	STORAGE AND RACKING	20/07/2007
11962P SD	PIERCING DRAWING	4	Irregular Shaped Open Profile	STORAGE AND RACKING	11/10/2004
11962 SD	SECTION DRAWING	4	Irregular Shaped Open Profile	STORAGE AND RACKING	11/10/2006
13574 SD	SECTION DRAWING	2	Angle Section	STORAGE AND RACKING	20/08/2007
13062 TL1	TECHNICAL LIAISON - POLYPAL	-			

Figure 6.7: Screen shot showing document list screen – document searched by keyword (customer name)

The second area is the document details screen (Figure 6.8), which provides information about the specific document and includes:

- Document type.
- Document number.
- Document status
- Document revision

- Document author
- Document owner
- Document active date; date of issue
- File name and hyperlink
- Distribution list
- Change requests
- Document review history
- Document revision history
- Document approval
- Document associated properties; product customer, product type, product market sector.

Figure 6.8: Screen shot of document details screen component drawing for part number 113.378

The document control side of the product data archive has provided a central storage area for all documents related to the development and manufacture of products. It has prevented the use of obsolete documents and only presents the most current revision to the user. Documents are securely managed to prevent uncontrolled modifications, drafts or copies. Records pertaining to document change, history, approval and distribution are securely held for each revision of a document and are readily available for review. Document registers are automatically updated with approved changes, helping to eliminate the risk of human error. It has provided an

infrastructure to make the correct information available where needed. The module has allowed effective engineering change control.

6.4.3 Enquiry/engineering control

A fundamental part of the product development system at Metsec is the Enquiry/Engineering change request phase where any mistake during this stage can have serious consequences if new product orders are received. It is paramount that all the information received from the customer and information and knowledge created internally is documented and available to all.

Approximately 500 new enquiries and engineering change requests are received each year, and part of the process modelling exercise resulted in several concerns being raised in this area, including insufficient details to quote, product tooling being quoted which is already available. The current system at the time of the study was controlled through a hand written register and all information was progressed by the sales person receiving the enquiry, however this was very time consuming, prone to mistakes and a waste of valuable resource. In conjunction with Gael Quality providers of the product archive software a module was written specifically to control the enquiry process.

A review of the enquiry process was carried out to determine information requirements, and responsibilities as detailed in chapter five. The enquiry process was then divided into stages each stage dependent on information from the previous stage.

The enquiry procedure starts with the enquiry being received from the customer/potential customer, prior to being entered onto the system the customer is asked to provide any drawings, concepts and or specifications for the product. Failure to provide the information results in the enquiry being declined.

When all the relevant information is available the enquiry is entered onto the system and is given a unique enquiry number, drawings, spec's and any information received including customer and contact details is attached to the enquiry (embedded into the database). Once the enquiry is entered onto the system all department heads are e-mailed automatically advising that there is anew enquiry on the system. The e-mail contains a hyperlink which opens up the enquiry. The enquiry screen is shown in Figure 6.9

File Edit View Actions Window Help

Warning: Where this icon appears, refer to the tooltip for more information.

Number: CRF. ENQ. 318. 2009 Status: Open Raised Date: 16/03/2009

Source: CRF Owner: Dixon, Gary Target Date: 27/03/2009

Details: Permasteel Modification/Development
Part existing tooling??

Raised By: ☐ Internal ☒ Customer Against: ☐ Department ☐ Supplier Severity:

PERMABAN PRODUCTS LIMITED Keywords: L3000 - G1.5mm

Contact: Bradley, Tony Standard: Material Specification\DX51D +Z275 N

Process: Not Applicable Document: Resolution: Root Cause: Not Applicable

Fault Category: Not Applicable Closed By: Closed Date:

Part Number:

Tooling Estimate Equipment (3)

Material estimate (3)

Production Estimate (3)

Generate Sales Quote (3)

Approve Sales Quote (2)

Approved Quotation Sent (2)

Follow Up and Close

Properties

Figure 6.9: Screen shot showing an open enquiry

The top of the enquiry page shows the general information relating to the enquiry; the enquiry number, raised date, status, person responsible for the enquiry, customer and customer contact, brief description of the enquiry/engineering change request, and the material specification of the product (provided by the customer).

Any drawings, specifications or e-mails relating to the enquiry sit as file attachments in the properties field shown at the bottom of the screen (Figure 6.10).

Once the enquiry has been entered the sequence of steps to be taken is indicated in the drop down tabs in the bottom half of the screen:

- Tooling estimate Equipment; this field is to record tooling required, tooling costs and whether the part can be manufactured.

- Materials estimate; this field is to record estimated costs of material to produce the product and cannot be completed until the tooling stage is complete; the tooling stage confirms the material content of the component.
- Production estimate; this field is to record anticipated production speeds, output/hour, utilization and manning levels.
- Sales Quote; When the previous three stages are completed the information provided is utilized to generate a sales quote, the sales quote is vetted and approved by the manufacturing Director prior to being released to the customer.
- Approved sales quote sent; this field details when the sales quote was sent and prompts for a copy to be added in the properties field.
- Follow up and close; If an order is received details of the order are entered into this field, where the customer has declined the quotations reasons are added and the enquiry is closed.

Each stage is sequential and the system will not allow details to be entered until the previous stage is complete. All persons involved in the enquiry process are e-mailed when each stage is completed.

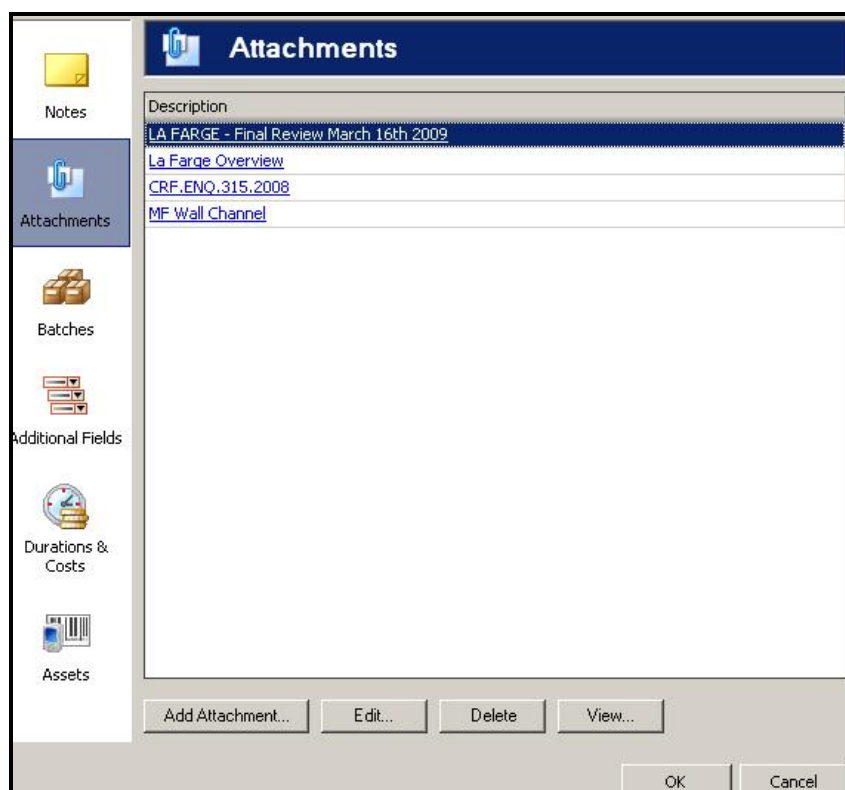


Figure 6.10: Screen shot showing documents attached to an enquiry.

The enquiry system has been running for approximately 18 months, and has reduced time taken to quote to an average of 5 days from 17 days, and due to the set up of the system has prevented quotations being raised without the necessary and appropriate information.

6.5 Implementation of the manufacturing knowledge base

The main objective of the manufacturing knowledge base is to capture problems and concerns within the manufacturing process in order to provide solutions and effectively utilize the solutions as lessons learnt, which could then be used to support effective decision making during the product development process. The knowledge base aims to achieve this objective by:

- Encouraging users to report and log all problems/concerns that would benefit from further investigation and corrective actions via engineering changes.
- Quickly and easily capture problems and concerns from all aspects of the business
- Providing reports on problems/concerns from each aspect of the organization in isolation but also collectively; and in doing so avoid further problems with associated products or processes.
- Inform appropriate people of problems/concerns specific and relevant to them and consequently help avoid repeat occurrences of the problems/concerns identified.
- Encouraging a culture of learning and continuous improvement and in doing so reduce organizational risk by preventing problems from occurring (elimination of non-value added activities), resulting in better customer experiences and improved financial performance.

The Manufacturing Knowledge Base was initially implemented as a normalized database using Microsoft Access, however due to the scale of the database and problems encountered with Access it was decided to upgrade to Microsoft SQL server (2005) and Borland Delphi (2005), this would allow other Microsoft SQL server platforms running within the organization to cross reference information stored within the system. The knowledge base was designed as a normalized data base, so that all the information (except textual descriptions and images) is selected from a pre-populated list.

The knowledge base is used to document information on a problem or concern that has happened within the organization (initially the system was piloted in manufacturing). The information is divided into two categories; information relating to the problem and information tagged to the problem such as person raising the concern or logging the problem onto the system.

The information stored for each problem includes:

Works order No; which provides details of the product, order quantity, the customer and the material used (Figure 6.11).

- A text based summary of the problem.
- Who reported the problem?
- The machine/activity/department where the problem occurred.
- A PDF scan of the concerns sheet detailing where it originated from.
- When it happened.
- When the root cause was identified and by who.
- Date action required by
- Date actions completed.
- Problem status

In addition to this, other fields are associated with each problem by the use of cross reference tables and provide additional and more specific information about the problem (Figure 6.11)

- Customers; details of customers affected by the problem
- Groups; ensures that all persons concerned are aware of the problem
- Images; images and descriptions of the images can be stored for a single problem.
- Locations; allows a more specific location to be highlighted such as machine number B1 operation number 6.
- Machines; allows for problems which may affect more than one machine/process or activity.
- Problem types; allows categorization of the problem.

The system is built around three types of user:

- System Manager; is responsible for logging the problems/concerns onto the system. The system manager has responsibility for maintaining the lists of data that are used throughout the database (i.e. machine numbers, users and works order numbers). When a problem/concern has been completed and verified the System manager is responsible for closing the problem by changing status to complete.
- Data viewers; would typically be a designer or department head looking for problems related to a specific part, part type or process or reviewing concerns that have been assigned to there department for investigation.
- Problem solvers; person responsible for investigating the problem, identifying the root cause and implementing corrective action.

KB Metsec Knowledgebase
Home screen
Concerns List
Refresh Data
Help!

Concerns list
417
418
450
479
608
641

This concern
Sheets

Part number
12114
Customer
Mabey and Johnson
Mill occurred on
B2
Works order number
Wx12114/129

Save
Undo
☐ Ongoing concern

Reported by

John Booton

Current status

Active

Date occurred

01/10/2007

Date identified

22/01/2008

Date due

22/01/2008

Date completed

16/06/2008

Summary of concern

Cut off tool modified by toolroom (dies changed).Production not informed,operators set -up to old tool

Change lists...

Actions required

Ade Element (22/01/2008 13:30:00): improved system required from the tool room to production do we need to review the process that is currently in place

Actions taken

Ade Element (23/01/2008 09:51:00): any tool that is taken up to the tool room is to have a taly added to it which can only be put on by tooling operators the tool room are to reject the tool if it does not have a taly on it a board is also in place which identifies the location of the tools and als...

Actions tried

Ade Element (16/06/2008 12:38:00): any tool that is taken up to the tool room is to have a taly added to it which can only be put on by tooling operators the tool room are to reject the tool if it does not have a taly on it a board is also in place which identifies the location of the tools and als...

Description of problem

Ade Element (22/01/2008 13:30:00): Cut off tool modified by toolroom (dies changed).Production not informed,operators set -up to old tool

Customers

Mabey and Johnson

Groups

Problem Solvers
Production Planning
Tool Design

Images

Keywords

Locations

Main solvers in groups

Mick Coleman
Jeremy Lockyer
Clive Wolverson

Machines

B2

Problem solvers

Edward Allen
Ade Element

Problem types

Section types

Lipped Channel

Sections

12114

Figure 6.11: Screen shot showing layout of concern details entered onto the knowledge base

The concern list screen is the main screen of the system (Figure 6.11), the screen is split into two areas; the left hand side is a list of all the problems identified by a unique number, the right hand screen is populated by highlighting a concern or creating a new concern. The “This concern” section is populated by entering information about the concern or problem (all fields are mandatory and cannot be left blank). Once the information is entered the system manager identifies an appropriate person to investigate the problem, i.e. a tooling problem would be investigated by a tool designer or tool maker. Investigation findings are reported back to the system manager through a weekly meeting that reviews all outstanding concerns. The results of the findings are intended to identify the cause of the problem; once this has been established persons are then allocated to implement corrective action. All actions are recorded in the actions tried and actions taken boxes. The actions tried list exist as one or more actions might not fix the initial concern.

When all actions have been completed, the systems manager will appoint an auditor to ensure corrective measures have been eliminated for the concern/problem identified. All findings are recorded in the drop down boxes on the right hand side of the concerns screen (Figure 6.11).

6.5.1 Concerns/resolution analysis

The concerns/resolutions analysis is one of the most important tools of the manufacturing knowledge data base as this records all previous problems/concerns and lessons learnt. Each individual problem/concern can be viewed in isolation and or groups of related information. Various reports can be produced and saved in personal or shared folders, drastically reducing the amount of time and effort spent searching for information as the information is available immediately. The analysis module provides extensive graphical grouping and trend reports that greatly assists in spotting related issues and importantly helps identify opportunities for improvement

The analysis module works through a filtering dialogue box (Figure 6.12), which allows searches to be carried out against the following information:

- Progress; all, unidentified, pending or complete.
- Status; None, deleted, archived, complete and verified and complete and finished.
- Users; users ID
- User group; user groups ID.

- Machine; filter by machine ID and group of machines.
- Customer; customers ID.
- Product; product number
- Product type
- Location; specific location of where the problem occurred.
- Problem Type; selected from a list of problem type categories
- Department
- Date; date problem occurred, identified, due by and date completed. Dates can also be filtered by date range (Figure 6.13).
- Text; filters can be applied to the free text fields and include summary, concern description, action required, actions tried and actions taken

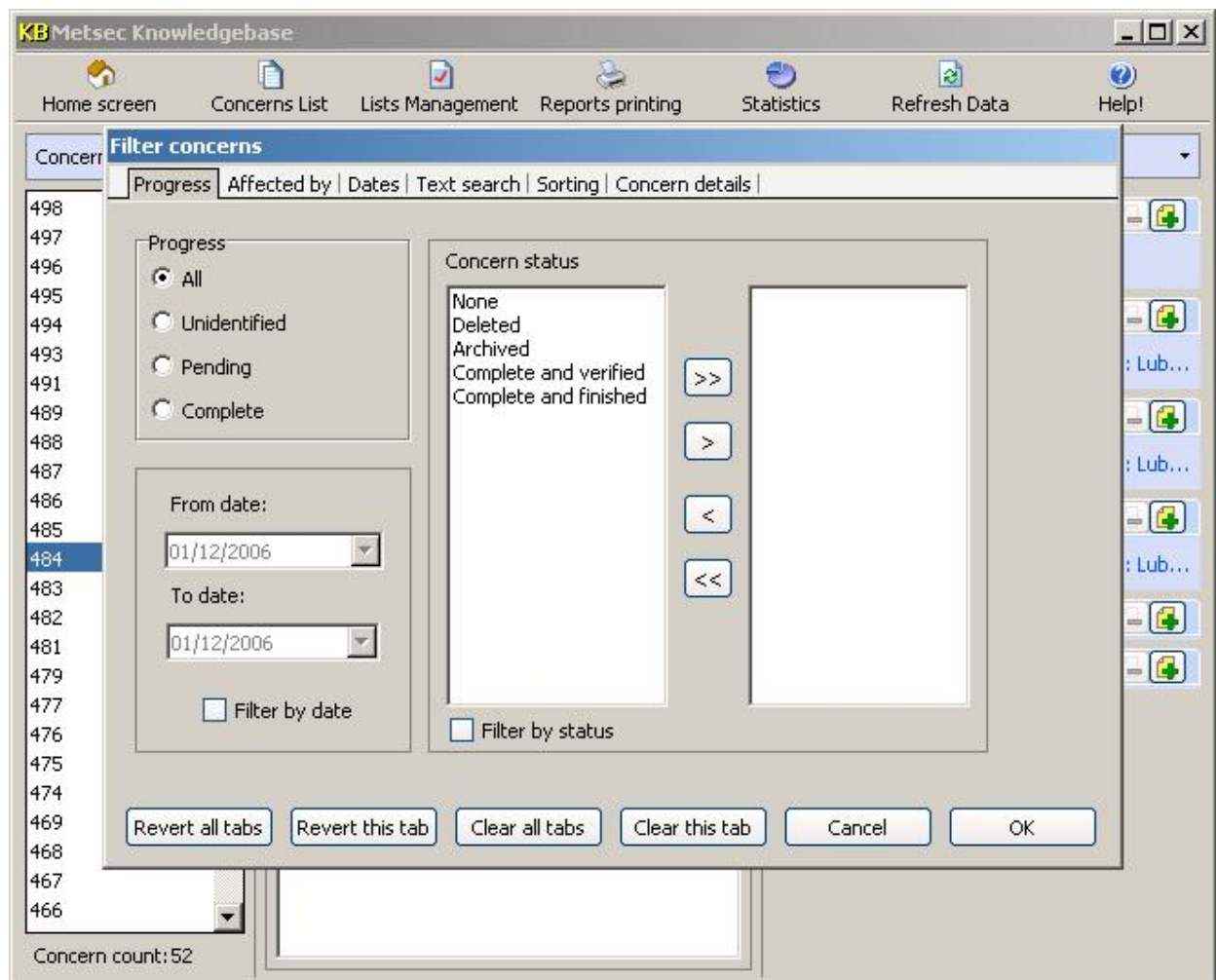


Figure 6.12: Screen shot of concerns list-filtering dialogue box.

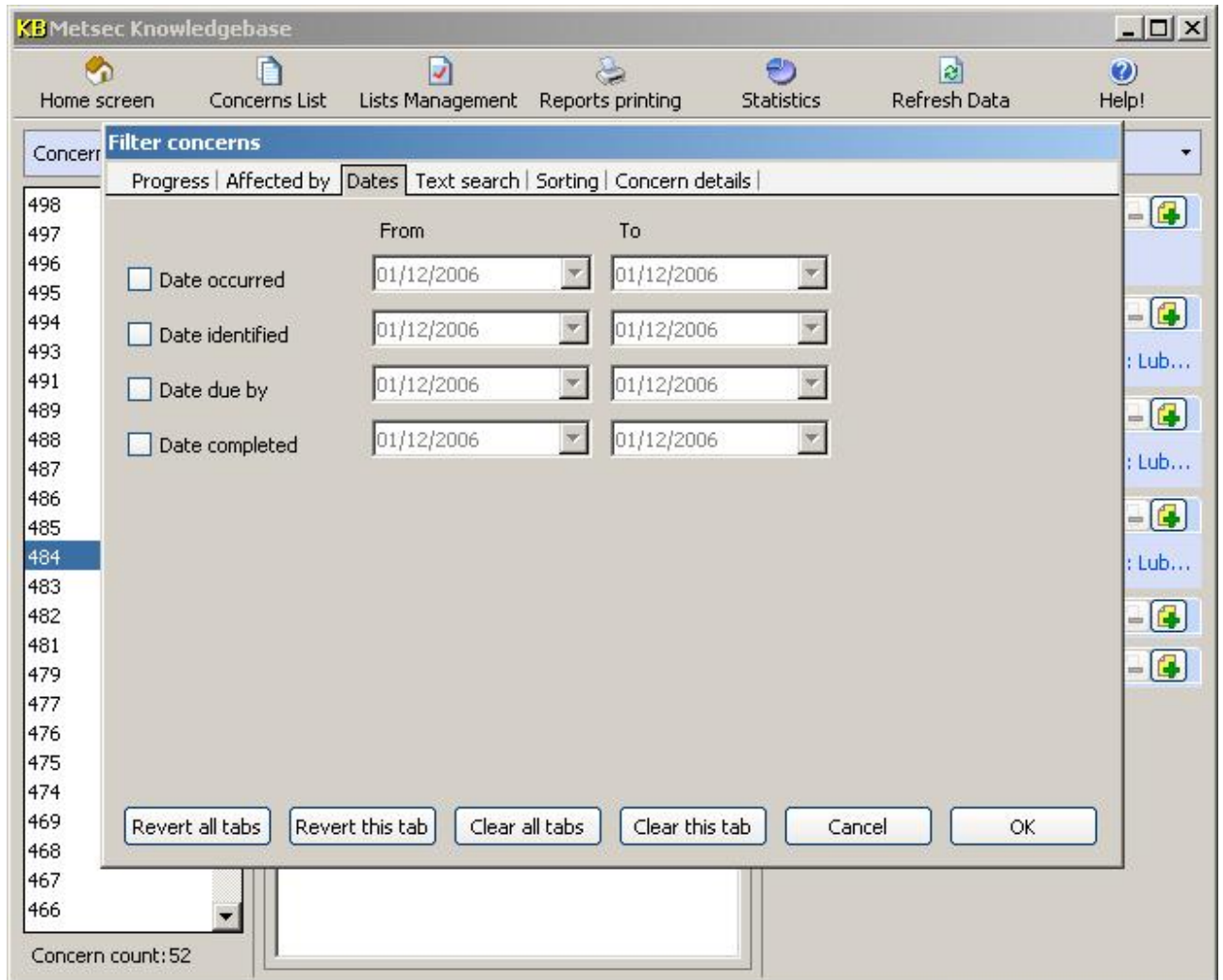


Figure 6.13: Screen shot of concerns list filtering dialogue box; filtering by date.

The graphical part of the filtering (Figure 6.14) allows statistics of the manufacturing base to be reviewed and include:

- Number of problems occurred
- Number of problems/concerns actioned and completed.
- Outstanding problems
- Number of problems outstanding against an individual
- Number of problems associated to each department
- Number assigned to a specific user.

All statistics are bound by a specific date range, and can be exported into Microsoft Excel for further analysis.

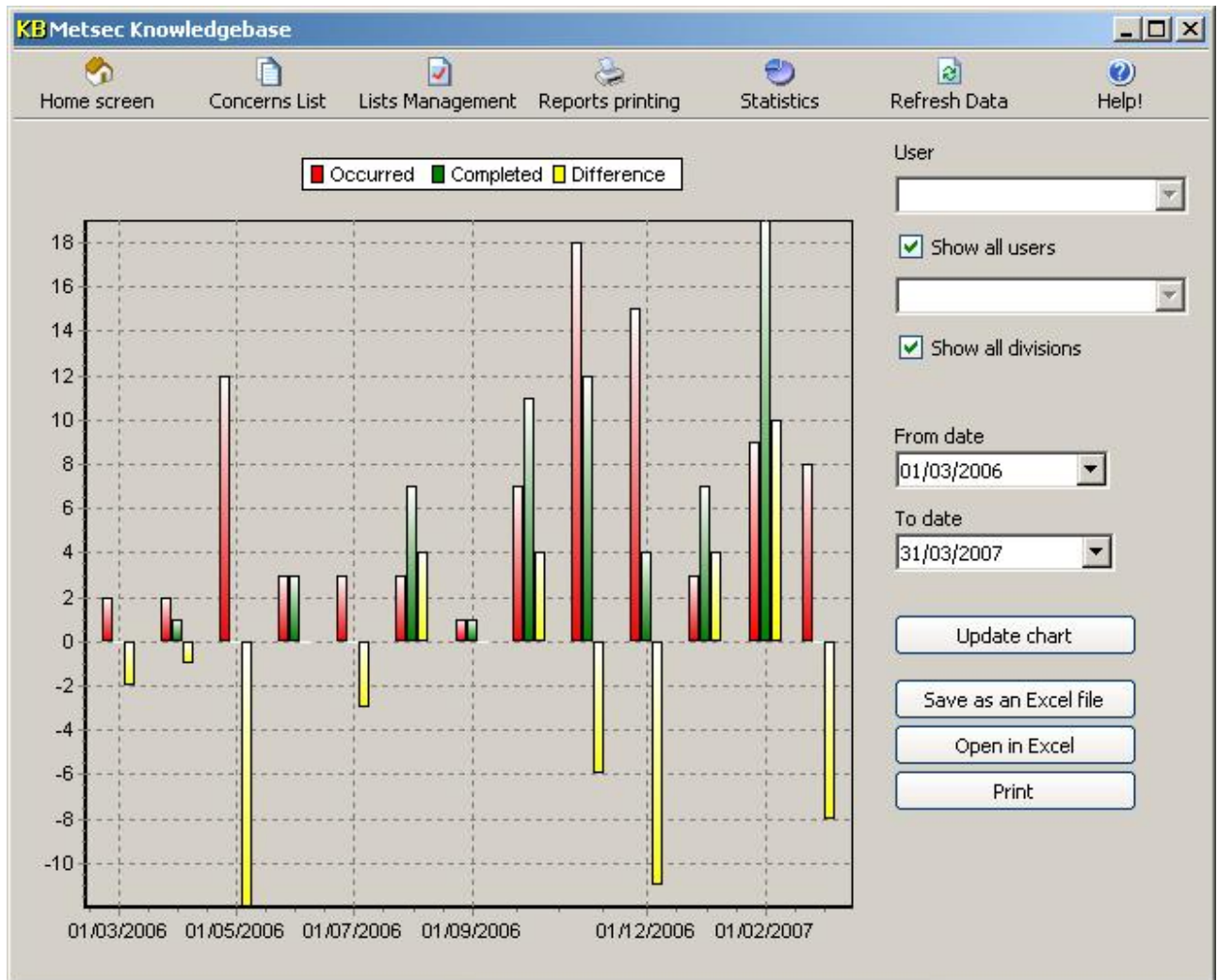


Figure 6.14: Screen shot of concerns list filtering dialogue box; Statistics

6.6 Validation

The case company's traditional approach to product development was project implementation oriented, in which a new project was started without making the best use of the experiences and lessons learned from previous projects. Furthermore, the culture within the organization was to avoid spending more time at the beginning of the project on design issues in part due to promising short lead-times to the customer. Short lead-times with the roll forming industry are considered as one of the key drivers to winning new business. The strategy was to start designing products and tooling directly and to solve any difficulties or problems later by implementing design changes. The manufacturing implications of the design were overcome by the experience of individual project engineers rather than by formalized procedures. These issues were

considered very important and needed to be addressed. Due to the organization's small design team size and the variety and number of projects undertaken, the flexibility of the workforce was also considered of great importance. Broad knowledge of a number of engineering disciplines and an understanding of the manufacturing processes were identified as critical to the organization's needs. The adoption of a knowledge based system to support the product development process was considered as critical for the organisation to improve quality, cost and delivery and ultimately gain a competitive advantage.

The implementation of the knowledge based framework was strewn with difficulties, both culturally and practically. However over time and with improved performance these difficulties have subsided. The most difficult issues were to cajole all persons into actually documenting problems and to provide the necessary information and knowledge in a format that could be understood and utilised by all persons involved within the product development process.

The results of this study are two fold; firstly there are elements such as quality, costs and delivery that can be measured to determine the effects of the knowledge based framework and its support of the product development process, secondly there are the intangible benefits that are not easy to quantify, such as improved communication, improved collaboration and knowledge re-use.

6.6.1 Quality, Costs and Delivery

The knowledge based system to support product development was implemented as part of the proposed framework. During the initial development and implementation of the framework and system, three key performance indicators were identified to measure improvements:

- Quality; The number of problems/concerns being raised, and those concerns directly related to the development of the product and the process.
- Costs; The costs associated with correcting problems/concerns. The costs include redesign, rework, remanufacture, testing, additional transport, and credit notes issued to the customer.
- Delivery; delivery in terms of the product development process was measured as product and process being right first time, i.e. no product or process modifications during tryout and initial production run prior to sample approval by the customer.

Each of the three key performance indicators was reported on a monthly basis, starting in January 2005 when the process modelling of the product development activities began. The levels of performance for each subsequent year was averaged yearly and compared against 2005.

Quality levels from 2005 to the end of 2008; the number of problems/concerns issued has dropped from 151 to 66, an improvement of 56 percent. Further improvements are expected by the end of 2009 based on year to date figures, expected to be in the region of 75 percent (Figure 6.15).

The number of concerns issued directly relating to the product and manufacturing process has improved from 109 in 2005 to 41 in 2008, an improvement of 62 percent (Figure 6.15). Again further improvements are expected by the end of 2009 based on year to date figures, expected to be in the region of 78 percent (Figure 6.15).

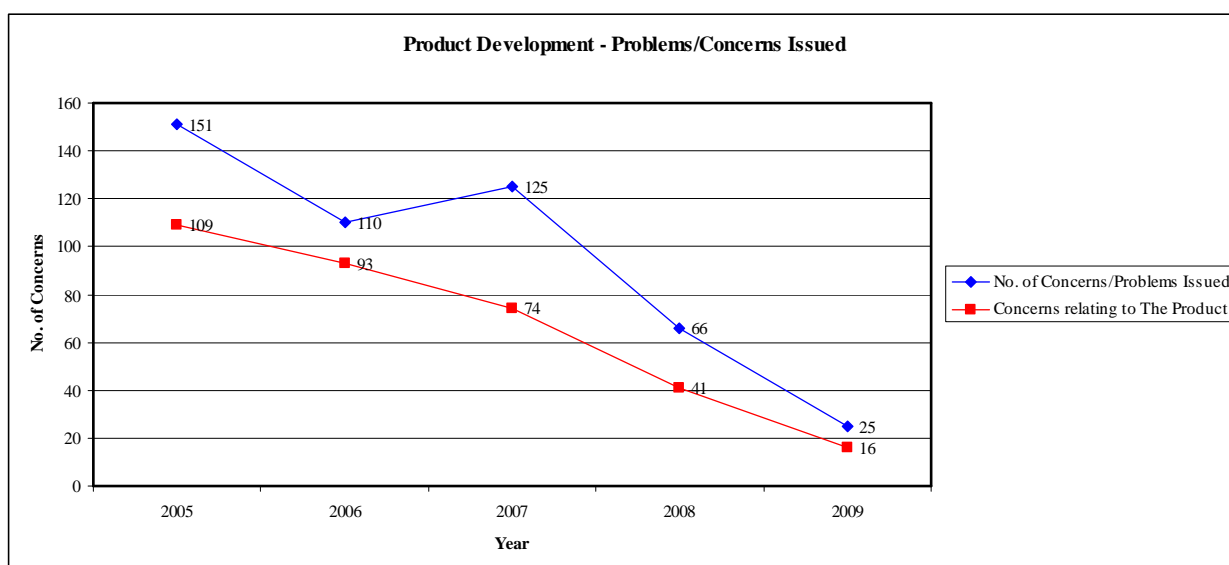


Figure 6.15: Graph showing number of concerns issued and concerns relating to product/process (2005 to Aug 2009)

Costs associated with correcting concerns/problems identified has dropped from £300,711.75 in 2005 to £46,597.87 in 2008, a reduction of 84.5 percent, the improvement to the end of 2009 are expected to be in the region of 94 percent (Figure 6.16).

Although the results appear to be impressive, they cannot exclusively be put down to the knowledge based framework, various continuous improvement programmes have ran

simultaneously, as well as a capital expenditure programme to replace old obsolete equipment. These programmes however, have generated new information and knowledge which have been captured within the knowledge based system.

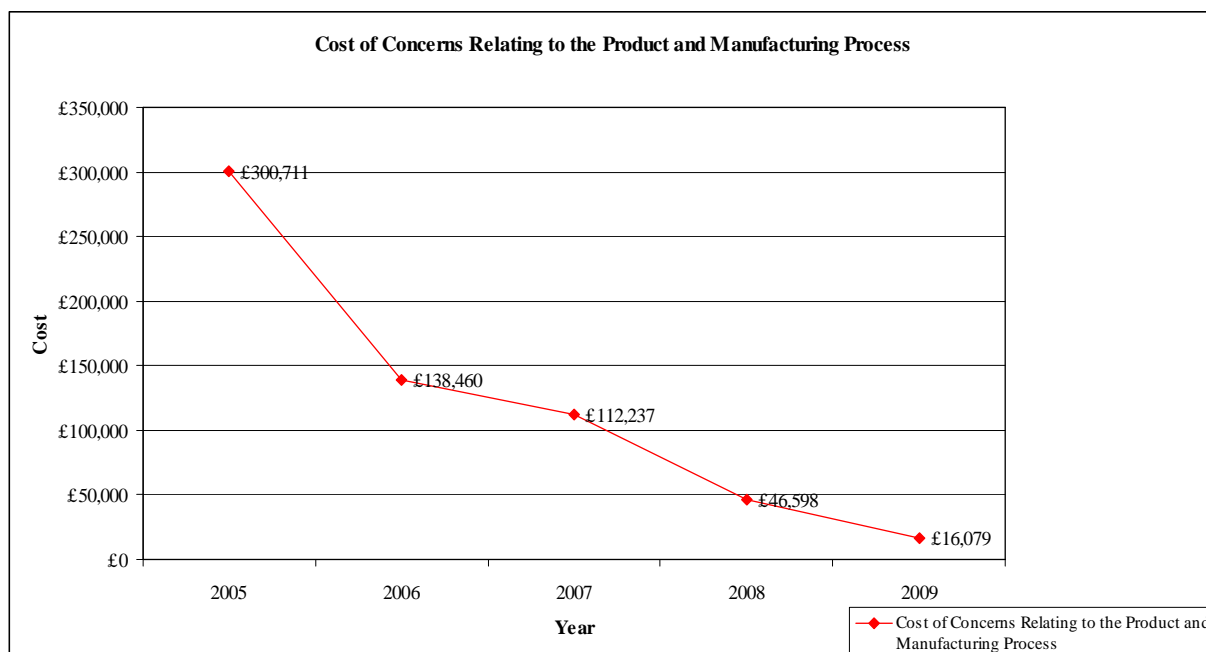


Figure 6.16: Graph showing the yearly cost of concerns issued (2005 to Aug 2009)

Right first time figures have improved from 45 percent in 2005 to 65 percent in 2008 (Figure 6.17), this improvement is not as significant as the improvements seen in the other two measures, however new products that have been developed over the period have become more complex, and have used higher strength material than have been used previously, again lessons learnt have been captured for future product development projects.

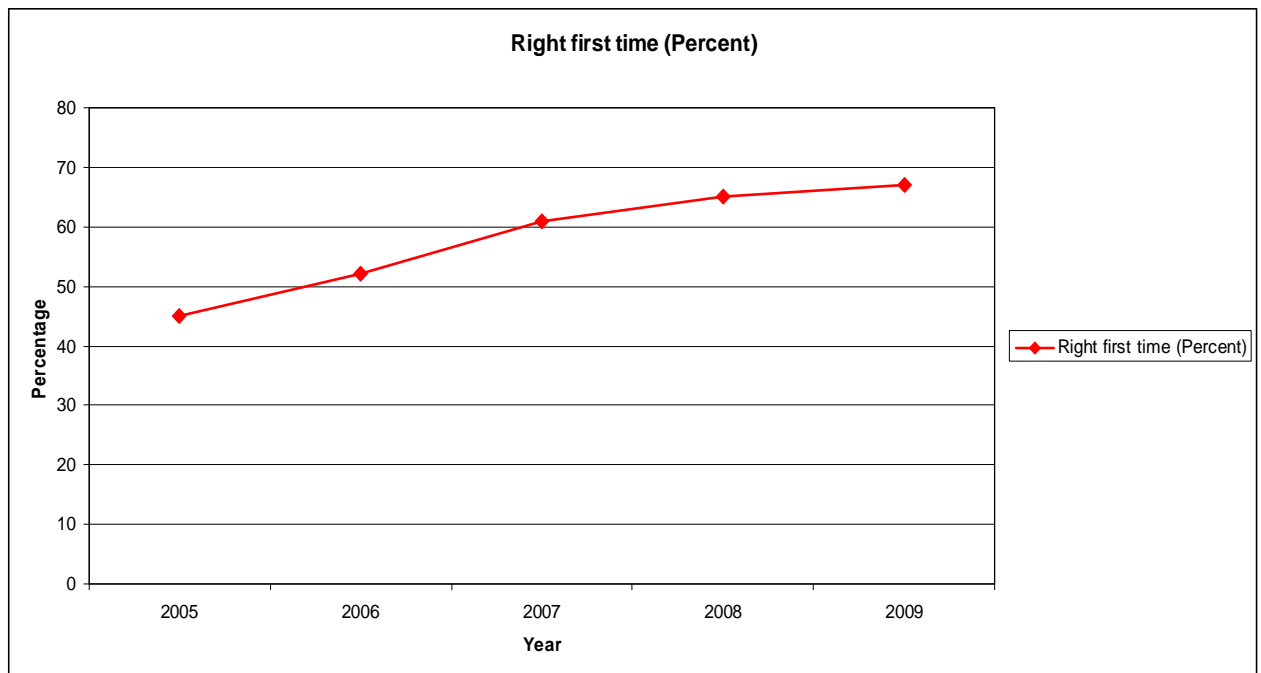


Figure 6.17: Graph showing percentage of new product development projects right first time (2005 to Aug 2009)

6.6.2 Intangible benefits.

The effectiveness of the knowledge based system is only as good as the user's ability to understand and interpret the information and knowledge stored within it. The system has not replaced the user's ability to determine the necessary actions to be taken; it has acted as a tool to apply that information and knowledge. The use of the system in this manner has greatly improved the various users understanding of the product development and manufacturing processes, thus increasing the efficiency and effectiveness of those processes, which has resulted in the performance improvements identified in section 6.6.1.

6.7 Summary

This chapter provided a detailed explanation of the knowledge based framework adopted by Metsec PLC, and gave an overview of the product data archive and manufacturing knowledge base to support the framework.

The framework and associated systems have been implemented across all departments within the organization. The framework and associated systems have not replaced any existing product development systems, as all the current systems have adequate stand alone functionality; however

the system has acted as a conduit to ensure the information and knowledge generated is located centrally and is available to improve decision support regarding product, process and new product development activities.

The results identified in the validation have shown improvements in quality, cost and delivery (right first time), and have identified increased understanding of the product development and manufacturing processes as a major intangible benefit.

Chapter 7

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK

7.1 Conclusions and recommendations for further work

This research study presented has developed a knowledge based management system that adapts knowledge management concepts into product development where the major objectives were to provide decision support to project engineers through the utilization of captured knowledge, minimize costs, achieve quality assurance and shorten time to market. Product development activities must be formalized and structured in such a way that any engineering decisions taken are based on proven knowledge and experience. Failure to apply proven knowledge and experience could result in product and process redesign, which would be seen as non-value added activities i.e. waste of valuable resource. As such there is a need for a knowledge based framework to support product development, which includes a knowledge-based system developed from an organization's knowledge and past experience.

This thesis introduced research issues concerning knowledge management systems, which have not been successfully addressed previously neither by academic research nor by the business community. This issue involves the identification, capture, formalization and presentation of knowledge and its utilization to support effective decision making within a product development environment.

The conclusions, which can be drawn from this research work, are the following:

- The literature review, presented in Chapter 2, highlighted that very little research has been carried out on how information and knowledge can be utilized to support the product development process, and showed that the lack of exploitation of knowledge has a major impact on overall product development performance. Knowledge and experiences gained from existing projects are often poorly documented and scarcely transferred to subsequent projects. Loss of or discarded knowledge is one of the basic reasons for re-invention occurring, on the other hand the use of knowledge from previous projects has a high potential to increase quality and efficiency of the product development process. The integration of proven engineering knowledge is therefore essential in creating a formalized efficient product development

process and to ensure effective decision support to meet customer needs and or reduce product risk.

- Chapter 3 defined the research methodology utilized in this research, in particular a case study; its aims and objectives and how this methodology was utilized to explore and address the key issues relevant to knowledge management and lean thinking within product development activities.
- Chapter 4 defined a knowledge based product development framework to support product development and outlined the necessary steps required to implement the framework. The process modelling presented in Chapter 4, IDEF0 proved to be an understandable and easy to use modelling technique to identify the information and knowledge required during the product development process. The process model highlighted the need to formalize the product development process and the importance of capturing and defining only value added activities. The process modelling also identified that decisions taken during the product development process need to be supported by proven engineering knowledge and experience, which needs to be identified, captured, formalized and presented in a way that will allow its utilization in future product development programs.
- Chapter 5 expanded on the process modelling exercise and defined four key phases of the product development process at Metsec PLC; obtaining product information, enquiry/engineering change request, new product introduction/engineering change note and problem/concerns resolution. Furthermore the knowledge required by each phase was identified and mapped. The findings showed that the knowledge identified is of critical importance and influences decision making with regard to manufacturing design, selection of production equipment, selection of process parameters, tool design, fabrication and assembly. However, the knowledge required to support these activities is distributed throughout the organization and must be captured, formalized and presented for future use in order to support effective decision making.
- Chapter 6 defined a knowledge based product development system and gave an overview of product data archive and manufacturing knowledge base system developed to support the framework. The knowledge based product development framework implemented at Metsec PLC has provided the following benefits:
 - Improved the communication and collaboration between the various departments and functions associated with the product development process.

- Standardization of the knowledge required within the product development process in a format that can be interpreted and used by all.
- Improved the sharing and provision of data and knowledge within the organization.
- Ensured that all of the activities within the product development are carried out according to the limitations of the process, resources and material.
- Reduction in product and process problems/concerns by eliminating most feedbacks and iterations caused by not sharing knowledge and information.
- Improved delivery performance (right first time) of product, tooling and manufacturing processes.

The author believes that there are some areas where further work is required in order to enhance the support provided by the knowledge based framework. These research directions are described below:

7.2 Future work.

- This research project focused on the implementation of knowledge based framework to support product development in one industry (cold roll forming) and evidence compiled from a literature review. Further analysis of this topic may find benefit in a more in-depth study of product development processes across several industry types, using this research as background.
- Verification of the proposed knowledge based framework is necessary to determine the effectiveness of the method, and how it may be further developed.
- Consideration of creating one data base for the product data archive and the manufacturing knowledge base, which would reduce the duplication of information and knowledge across the two systems and would reduce maintenance and system administration costs.

7.3 Contribution to Knowledge.

The aim of this research and therefore, one of its major contributions, was the development of the knowledge based framework and associated knowledge based systems including a product data archive and a manufacturing knowledge base to provide effective decision support based on proven knowledge to the product development process.

The development of the framework was guided by a methodology which enabled a process map to be produced to detail current “as-is” product development activities. The use of IDEF0 to represent those activities and identify information and knowledge in order to capture, formalise and present and utilise for future use within knowledge based product development system.

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APPENDIX A

PRODUCT MODEL DOCUMENTATION

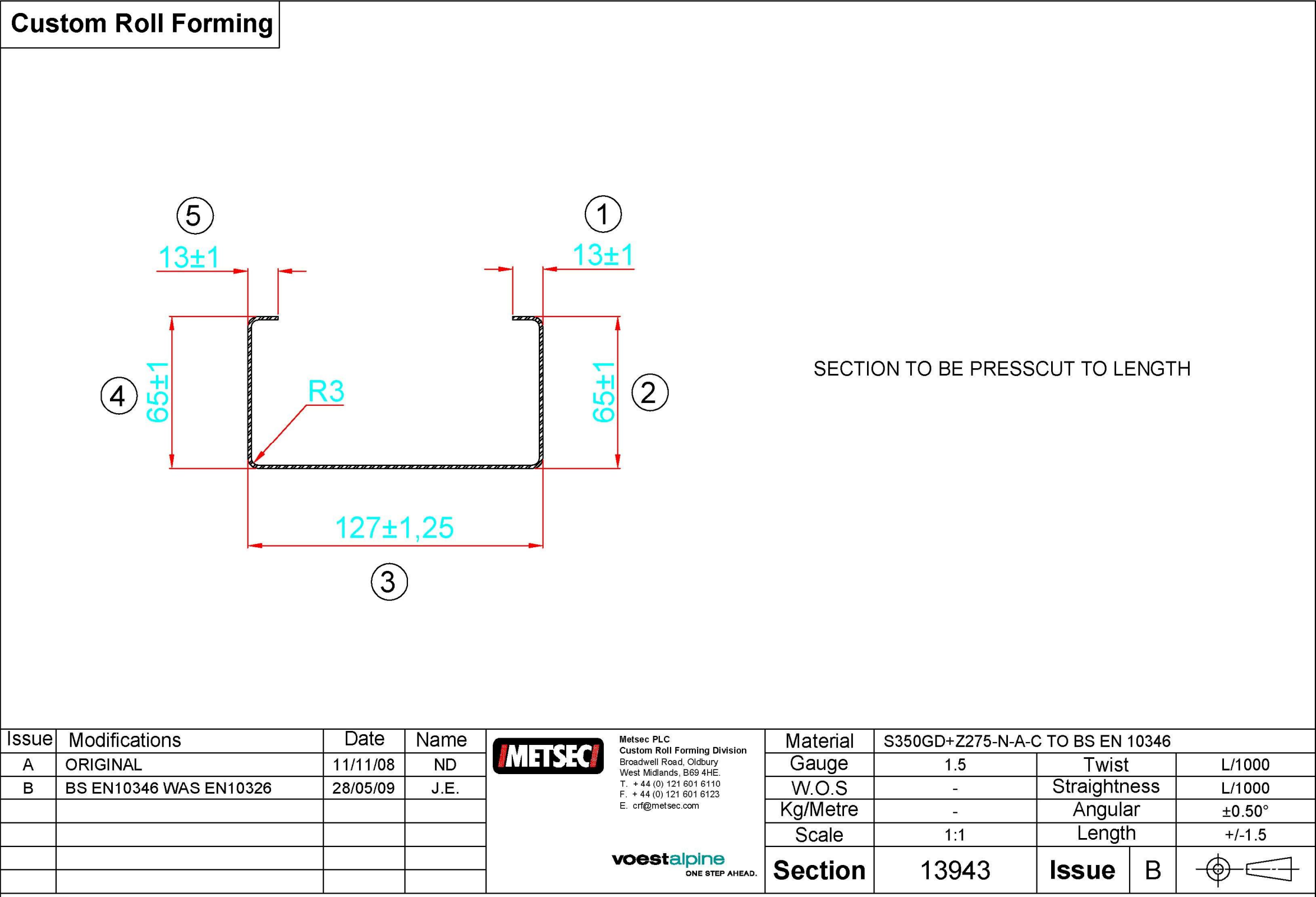


Figure A-1: Product model documentation – A typical product profile specification.

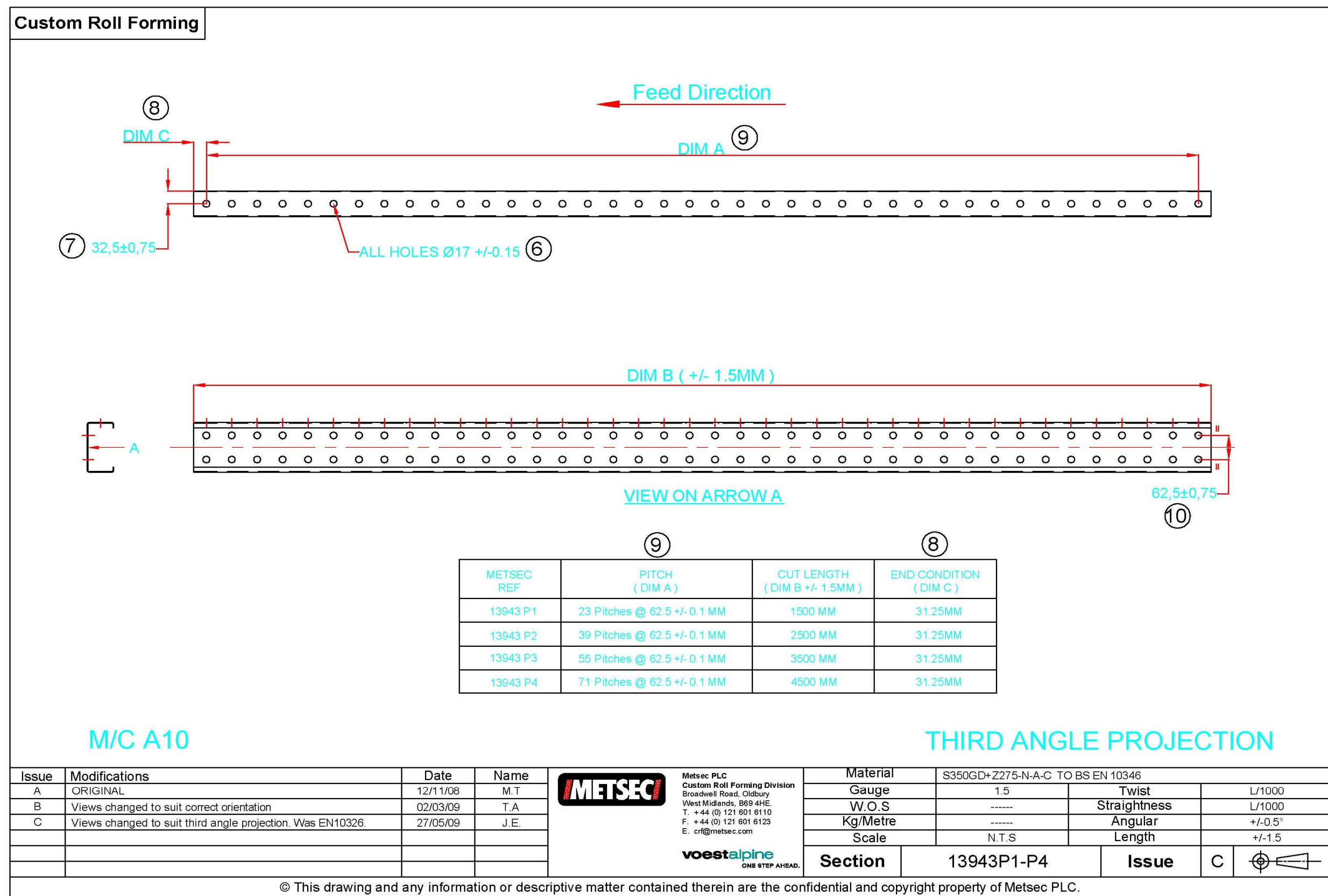



Figure A-2: Product model documentation – A typical product profile piercing configuration specification.

Setting Sheet

Section No.		Machine No.(s)		Cut off Tool Details				Section View Towards Cut-off				Issue	Modifications				Date	Name
				Type of Cut Off		S/S							Modifications					
13943		A10		Cut off Tool No.		13943/01/03						1	ORIGINAL				09/12/08	ND
				Tool Body								2	13943 Spacers added to centre of top rolls				14/05/09	ND
				Type of Blade		13943/01/03						3	Set up modifications from last rolling				09/06/09	ND
				Alternative Tool		N/A												
Stand Widths				Pre-pierce Tools														
Op.No(s)		OPS 1-8 400mm		2 Pre Pierce tools														
Op.No(s)		OPS 9-14 300mm																
Op.No(s)																		

Op No.	STRIP GUIDE		1		2		3		4		5		6		7		8		9		10	
Shaft	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top
Back Packing	41	67.2	42.5	55	46.5	60	51	60	52	64	40	72	47	77	38	89	38	60	8	30	42	45
STAND No	20		21		22		23		24		25		26		27		28		29		30	
																						25
	140-25 R6/1	160-50 R1	130-34 A28-R1	13943-OP1	150-30 A45-R1	13943-OP2	160-25 A60-R1	13943-OP3	170-25 A75-R1	200-25 A75-R3	160-20	200-17 A84-R3	160-28 R6	200-20 R3	150-100 A15-R1		200-100 A28-R1	13943-OP8	250-80 A45-R1	13943-OP9		SP624
	100-9	100-75	100-75	T1	100-75	T1	100-75	T1	100-75	13943-OP4	170-15 A84-R1	SF.370	AMPCO	13943-OP6	100-50	100-21.35	100-50	T1	100-50	T1	230-45 A60-R1	100-17
	100-50	100-18	100-37	13943-OP1	100-100	13943-OP2	100-75	13943-OP3	100-14	73.55	100-75 R1	13943-OP5	100-50	65.6	100-14	160-38 A15-R3	100-14	200-50 A28-R3	100-9.3	200-20	100-50	250-20 R3/1
	100-9.2	100-75	100-9.6	75.1	100-22	74.55	100-13	74.05	100-9.3	200-75	100-19 R1	73.4	100-40	200-75	100-9.7	160-23 R1	100-9.9	13943-OP8	100-15	250-24 R6/3	100-9.9	13943-OP10
	100-75	160-50 R1	100-50	160-25 R1	100-50	160-25 R1	100-9.6	160-50	100-75	13943-OP4	100-75	200-75	100-9.5	13943-OP6	100-50	160-50	100-50	26.25	100-50	13943-OP9	100-15	33.25
	0.5mm SHIM		100-75	160-50 R1	150-30 A45-R1	160-50 R1	100-75	160-25 R1	100-75	73.55	100-40 R1	13943-OP5	100-50	65.6	150-100 A15-R1	160-6.3 R1	200-100 A28-R1	200-50	250-80 A45-R1	29.25	100-50	250-19
	100-50		130-34 A28-R1	13943 OP1		13943 OP2	160-25 A60-R1	13943 OP3	170-25 A75-R1	200-25 A75-R3	100-40 R1	73.4	100-50	200-20 R3		160-24 R1		13943-OP8		250-20	230-45 A60-R1	13943-OP10
	100-75			75.1		74.55		74.05			170-15 A84-R1	200-17 A84-R3	100-50 R1			160-38 A15-R3		26.25		13943-OP9		33.25
	140-25 R6/1			T2		T2		T2			160-20	SF.370	160-28 R6			100-21.35		200-50 A28-R3		29.25		250-20 R3/1
														AMPCO				T2		250-24 R6/3		100-17
																					200-20	
																				T2		
Front Packing	41	66	43	55	47	60	51	60	51	64	41	72	48	78	38	89	38	60	8	30	43	45

Figure A-3: Product model documentation – A typical Roll setting sheet providing details of how rolls are to be set on a particular rolling mill

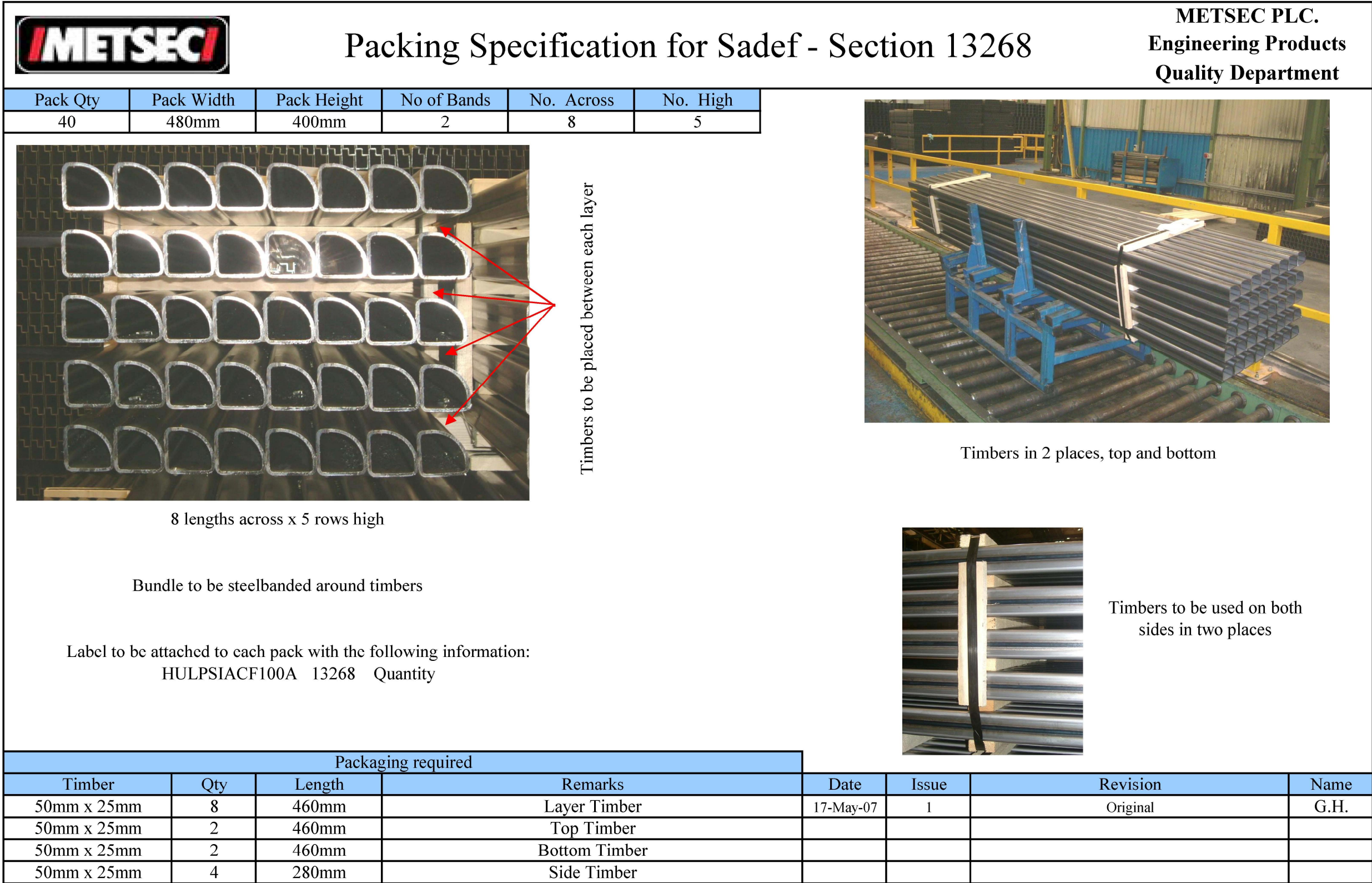


Figure A-4: Product model documentation – Example of product packing specification.