An Empirical Investigation into the Use of Product Development in the Educational Furniture Industry

A thesis presented in fulfilment of the requirements for the
Master of Technology in Product Development
at Massey University,
Palmerston North, New Zealand.

Jeffrey Martin Morgan

2001

Abstract

An empirical investigation into the use of product development in the educational furniture industry is summarised in this thesis. New Zealand furniture manufacturers are facing increased competition from imported furniture and are also exporting more and more furniture. Developing new products is therefore important to the New Zealand furniture industry's growth.

This research was based on a small furniture-manufacturing firm from Hastings, New Zealand called Furnware Industries Limited (Furnware). A product development process was developed to their specific needs by comparing their current product development activities with identified best practices in product development. Those parts of the current activities that worked well were amalgamated with the structured Stage-Gate™ process of Cooper (1998).

This process was tested by using it to develop a Mobile Technology Education Workstation range for Furnware. The aim of the project was to develop a new product for Furnware to sell and to simultaneously test the developed process. Once the project was completed, an evaluation of the product development process used was undertaken. Several areas for improvement were identified and a revised process outlined.

The use of Computer-Aided Design (CAD) software was identified as another area of improvement that would assist both product development activities and existing manufacturing processes at Furnware. Consequently, a CAD package best suited to Furnware is selected using a structured process.

The three main outcomes of the research were:

1. A product development process suited to Furnware.
2. A Mobile Technology Education Workstation range of products ready for launch, pending minor adjustments and testing.
3. A CAD software package suggested for use at Furnware.

Acknowledgements

I would like to thank all those who helped make this thesis possible. In particular I would like to thank:

My supervisor, Aruna Shekar for her guidance and support throughout the year.

The company sponsors, Furnware Industries Limited for allowing this research to be conducted on their company, with their support and assistance. In particular Hamish Whyte and Graeme Dickey for their input and guidance. Other Furnware staff that helped significantly who I wish to thank include: Jason Wilton, Huib Pronk, Sue Hay, Kevin Higginson and Dave Henare.

Technology New Zealand for their funding support in the form of a Graduate in Industry Fellowship (GRIF).

All other people who helped keep me sane throughout. In particular Carl Sheridan and Tom Robertson.

Table of Contents

List of Figures

List of Tables

1 Introduction

Product Development is the process of turning ideas into new products. This thesis outlines the use of product development in the furniture industry. The furniture industry in New Zealand is facing increased competition from overseas furniture manufacturers due to ever decreasing import tariffs. "Imports for the December 2000 year totalled US$216 million which was an increase of 9.3% over the previous year", (Dunnett, 2001). The low value of the New Zealand dollar has provided better opportunities to compensate for this new market pressure by increasing furniture exports. "Due to increasing import competition and a greater export focus, New Zealand companies are concentrating on qualities such as unique design, quality, delivery and service...", (Dunnett, 2001). The development of new furniture products is therefore important to the New Zealand furniture industry's growth. This thesis outlines the use of a structured product development process to develop a new furniture product. The process is evaluated at the conclusion of the project and refined to better suite the sponsor company's situation. It is recommended that this process be used for future projects to help improve product development at Furnware. As with any newly adopted process it should also be improved over time.

1.1 Company Background

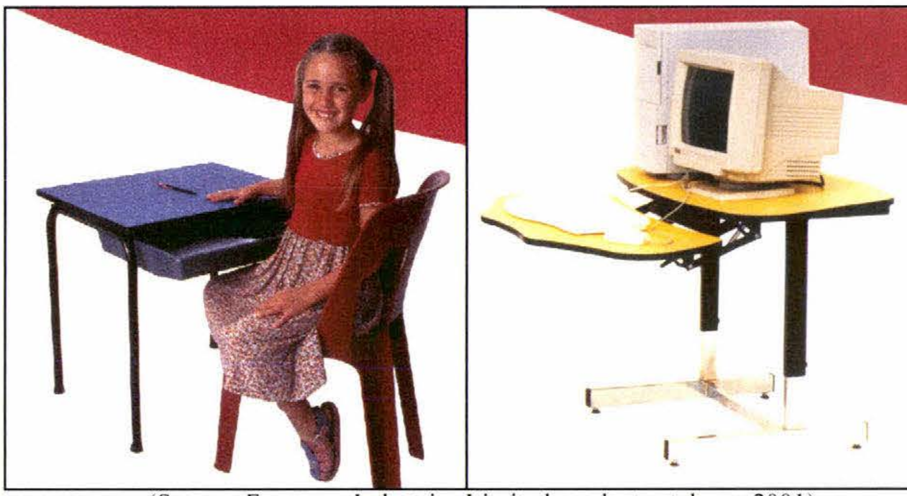
1.1.1 History

Furnware is a furniture manufacturing company located in Hastings, New Zealand. Furnware began operations in 1934 and has been a manufacturer of products ranging from children toys to coffins. Since then the company has also been a manufacturer of caravans and a supplier of kitchens for government houses. The company has also had a number of owners from large corporate companies to the present, privately owned and operated setting.

1.1.2 Current Product Range

Furnware currently manufacture products for the education, healthcare/rest home and domestic solid timber markets. The recent purchases of two companies: Permakraft Furniture and Eagle Furniture has increased the product range to over 600 standard products. Permakraft produce household solid wood furniture, while Eagle and Furnware focus on educational furniture. Several examples of the current furniture range are given below in Figure 1-1.

Figure 1-1 Examples of Existing Furnware Products



(Source: Furnware Industries Limited product catalogue 2001)

1.1.3 Business Strategy

1.1.3.1 Product

To produce high quality, well designed furniture at a reasonable cost. Product innovation and quality play a key role in protecting sales prices that are higher than the market norm. The ability to supply customers with 'one-off[1]' designs, thus better meeting the customers' needs is another key factor in Furnware's product strategy.

Furnware's current commitment to research is the result of a change in product development strategy, from being a reactor to market changes and customer demands, to being a market leader in supplying products that meet customer needs.

1.1.3.2 Marketing

Furnware's market strategy involves building strong relationships with key customers, such as school principals and then developing long-term relationships. The location of sales representatives throughout New Zealand allows Furnware to contact customers on

---

[1] One-off designs are new product designs that have been specifically requested by a customer. Sometimes referred to as custom designs.

a regular basis. Furnware is currently establishing itself in the US market, by partnering with several other New Zealand companies and the New Zealand Trade Development Board (TRADE NZ). This is expected to provide a much larger customer base, as well as an increase in sales during the traditionally slow sales months of the New Zealand winter (June-September).

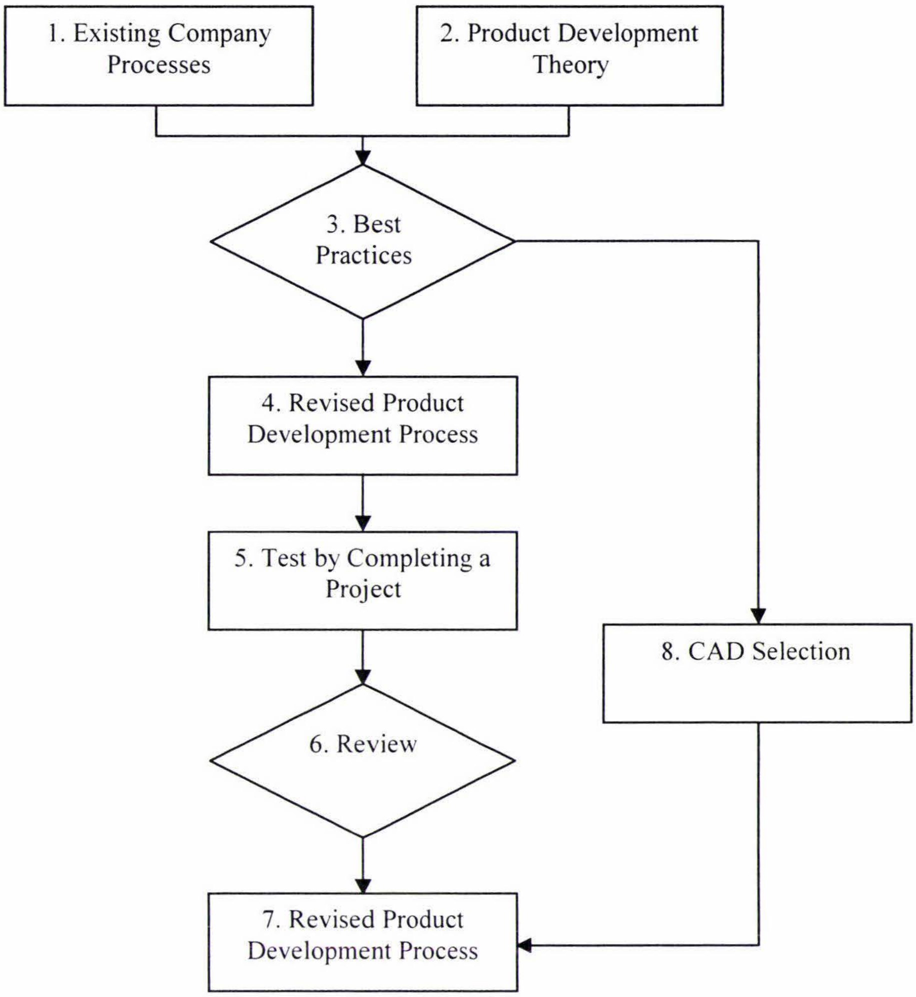
1.1.3.3 Production

To manufacture products as economically as possible, while maintaining current product quality. Production strategy involves the development of a system that can produce both standard and 'one-off' products by the date required by the customer, and be flexible and cost effective. Raw materials used consist of Medium Density Fibreboard (MDF), Melteca, solid wood (Rimu and Pine) and mild steel. The steel used is predominantly round or square tube of varying dimensions.

1.2 Overall Research Method

Provided below in Figure 1-2 is the flowchart for the overall research method. This research was based on Furnware's operations. A combination of research into existing company product development activities and product development theory was conducted. These two areas were used to develop a product development process for Furnware. Identified best practices were researched and used to provide guidelines for the revised product development process. This process was then used to develop a product idea. The purpose of this project was to develop a new product for Furnware and to simultaneously test the proposed product development process. After completing the project, the process is evaluated and revised to better suite Furnware's needs. The use of CAD technology was identified as a key factor in improving product development and production at Furnware, consequently research into which CAD package would most suite Furnware was also done. Provided below is a brief introduction to each of the research areas.

Figure 1-2 Overall Research Method



1.3 Existing Company Processes

Furnware is a small furniture manufacturing company located at Hastings, New Zealand. This company agreed to partner this research project. This section covers research into Furnware, in particular existing product development methodologies. A brief history and product background is also given. To research current product development activities at Furnware two case studies were used. These studies each reviewed a recent development project undertaken at Furnware. The studies resulted in the development of a current general process that is used at Furnware. The process is informal and most projects do not follow all the steps.

1.4 Product Development Theory

Research into current product development processes was conducted to help improve product development at Furnware. The processes will be used to provide a basis from which a product development process suited to Furnware's particular situation is developed. The details of this development are provided in Chapter 3: Process Selection.

Cooper (1998) presents a five-stage, stage-gate process that suites Furnware's industry situation. The five stages are:

Stage 1 Preliminary Investigation.
Stage 2 Detailed Investigation.
Stage 3 Development.
Stage 4 Testing and Validation.
Stage 5 Full Production.

Gates divide the stages. The gates represent times in the process where top management makes decisions on the project. They also approve an action plan for the next stage.

Earle (1999) also outlines a structured process with stages divided by decision points. The process has four stages.

Stage 1 Product Strategy Development.
Stage 2 Product Design.
Stage 3 Product Commercialisation.
Stage 4 Product Launch and Evaluation.

Decision points where top management makes a Go or No-go decisions on the project separate these stages. This process is more suited to the development of food products than furniture products. The use of a structured process, with clear decision points is consistent with Coopers process though.

The third process outlined is that described by Ulrich & Eppinger (2000). They outline a generic process with six stages.

Stage 0 Planning.
Stage 1 Concept Development.
Stage 2 System-level Design.
Stage 3 Detailed Design.
Stage 4 Testing and Refinement.

Stage 5 Production Ramp-up.

Ulrich & Eppinger illustrate the multi-disciplinary approach to product development by listing the typical tasks needed to be carried out by marketing, design and manufacturing at each of the stages. This process is best suited to a product that incorporates a high level of engineering due to the emphasis on testing and works well for high-volume production companies because it incorporates a production ramp-up stage. Ulrich & Eppinger include Stage 0 Planning in their process; this is an important part of product development within a company. While not included in Coopers process he does consider it critical to successful product development. Research into these processes assisted the development of a product development process at Furnware by providing structured approaches to product development. Chapter 3 outlines the development of a product development process suitable for use at Furnware that is based on Coopers Stage-Gate™ process.

1.5 Best Practices in Product Development

Best practices in product development are those activities conducted by companies that improve product development within the company. Griffin (1997) summarises the results of a Product Development Management Association (PDMA) research project into best practices in product development. The main findings are provided in the literature review. The report also discusses current product development trends. Cooper (1998) also provides practices that are undertaken by companies that are successful at product development. He identifies three cornerstones of success.

- Having a new product strategy.
- Having the right resources.
- Having a new product process that works.

He identifies five success factors in developing a high quality process as well. These are summarised in the literature review. These best practices are used to determine in which areas Furnware should improve in their product development activities.

1.6 Revised Product Development Process

A product development process is developed for Furnware by combining current practices at Furnware with identified product development processes. To do this a comparison is made between, the best practices and Furnware's current practices. From this analysis two areas were chosen for improvement. The first was the use of a structured product development process and the second was the use of CAD technology. Using CAD technology to increase design efficiency will help the product development process at Furnware as well as improve current manufacturing processes. Research into this area is provided in Chapter 9 of the thesis.

The research into the existing product development processes of Cooper, Earle and Ulrich & Eppinger is used to develop a structured product development process for Furnware. Cooper's process is selected as the basis for the new process. The new process also incorporates current activities identified as already working well at Furnware.

1.7 Mobile Technology Education Workstation Project

The development of a product for Furnware was done for two reasons.

1. To test the process developed for Furnware.
2. To develop a product Furnware could sell and profit from as a part of their existing range of furniture.

The development of a Mobile Technology Education Workstation range started with an investigation into three product areas:

- A mobile workstation for the technology curriculum.
- A mobile workstation for computer equipment.
- A mobile workstation for audio-visual equipment.

The preliminary investigation into these areas led to the decision to develop a workstation for the Technology Curriculum in primary schools. The project brief was:

To design a Mobile Technology Education Workstation that will assist in the practical component of technology education in primary schools in New Zealand. The workstation will attempt to cover all the areas of the Technology Curriculum. If this is not feasible, a family of workstations will be developed. The unit will provide both storage and working surface suitable for conducting typical practical technology education activities.

A detailed investigation into this specific product area was completed next. A target market was identified; competitor products analysed and consumer needs information was collected. Generation of concepts was done using a structured five-stage method.

The outcome, after screening was two concepts chosen for further development. To develop the concepts into final product designs a series of prototyping, testing and concept development was done. The concepts were developed to a stage where one idea was selected for final prototyping and testing.

There were three final tests done on the workstation. Concept functionality testing to ensure the design functioned well. Consumer appeal testing to ensure aspects such as aesthetics and price were acceptable. Structural integrity testing was the final test done. The workstations passed these tests with only a few design modifications suggested. Finally commercialisation plans are presented.

1.8 Project Evaluation

Once the Mobile Technology Education Workstation project was completed, the process used could be evaluated. The process is evaluated both by development stage and as a whole. Interviews with top management at Furnware provided the basis for much of the evaluation. A review of the literature summarised in Chapter 2 helped provide suggestions for future improvement, as did the suggestions from the top management evaluation. A revised process that integrates Stages 2 & 3 of the process used to develop the Mobile Technology Education Workstation into a single, cyclic process is the result of this evaluation. Incorporation of company knowledge and top management is also added into the process.

1.9 CAD Selection

During the comparison of current practices at Furnware and identified best practices in product development, the use of engineering tools was identified as an area that Furnware could benefit from in both product development activities and existing manufacturing processes. Consequently a CAD package is selected for use at Furnware. The selection process included:

- Collecting information on all of Furnware's current needs.
- Researching the CAD software packages available.
- Conducting an initial screen of packages by ensuring they had the features required by Furnware.

- Completing a second, more detailed financial analysis on the remaining packages to determine which package would provide the greatest return on investment (highest Net Present Value).

The software package that rated highest in the NPV analysis was not considered the best overall though, due to qualitative factors that could not be incorporated into the analysis.

1.10 Summary

This chapter introduces the sponsor company, Furnware Industries Limited and the main areas of research that this thesis covers. The structure of the overall thesis is provided and a clear explanation for why each of the areas was researched is summarised. Each section is then introduced and a brief description of the activities conducted and outcomes from them given. This chapter precedes Chapter 2: Literature Review, which provides a summary of the current, relevant literature on this topic.

2 Literature Review

2.1 Introduction

The purpose of this chapter is to present a summary of the work previously carried out in the areas relating to this field of research. Product Development is a multi-tasked and variable process that is difficult to define. This research concentrates on the use and implementation of the product development process in a small furniture manufacturing company in New Zealand. Past work relevant to this area includes information relating to the product development process, selection of a suitable product development process and factors that affect product development in the furniture industry in New Zealand. This chapter is divided into 5 sections, these include: existing product development processes, a study of best practices in product development, New Zealand business environment, factors affecting product development at Furnware and a review of proposed project areas.

2.2 Existing Product Development Processes

The three product development processes outlined below have been chosen as a representative of successful product development processes. The three processes have all been developed recently and include many of the current identified best practice tasks.

2.2.1 Cooper's Stage-Gate™ Process

Cooper (1998) describes a multiple stage and gate process usually consisting of five stages and five gates. These stages break the project up into discrete, identifiable stages. Each stage incorporates a series of parallel activities performed by different functional areas. The focus of each stage is to gather the appropriate information to make a decision at the next gate. A diagram of the generic process is given below in Figure 2-3 .

Stage 1: Preliminary Investigation.

A quick investigation into a large number of possibilities is done to better decide which idea has the most potential.

Stage 2: Detailed Investigation.

This stage involves much more research. A business case is developed for the proposed project. This is where most of the market studies are carried out. The business case usually includes the product definition, the project justification and a project plan.

Stage 3: Development.

This is the actual design and development of the product. This is an expensive stage and at the end a beta prototype or 'in house' tested prototype will be finished. Full production and marketing plans should also be developed in this stage.

Stage 4: Testing and Validation.

This stage tests all aspects of the new product. Extensive physical, production and consumer tests are carried out.

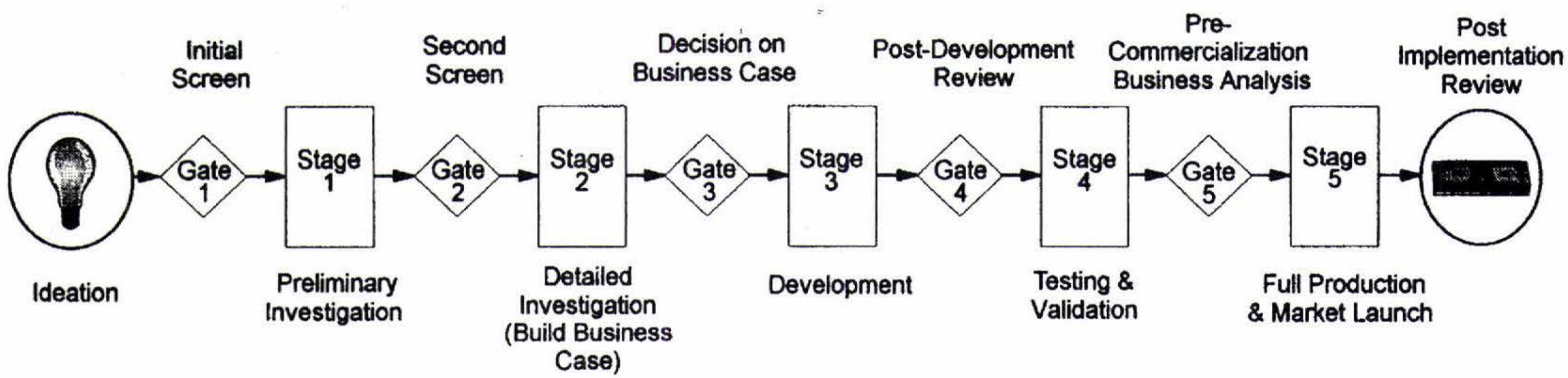
Stage 5: Full Production and Market Launch.

Commercialisation of the product. The beginning of full production, marketing and selling. Quality Assurance and post-launch monitoring plans are implemented. A Post Implementation review, of the project should be held 12-18 months after launch to close off the project and evaluate potential improvements to the process.

The Gates.

Cooper (1998) describes the gates in his process as analogous to scrums in a rugby game. They are points in the process where the team converges, new information is brought together and where the path forward for the next play or stage of the process is decided. Each gate has three common elements: deliverables, criteria and outputs. Deliverables are the information required to make the decision. The criteria are the set of hurdles the information is judged on and the outputs are the decision to go on or kill a project as well as the approval of the action plan for the next stage.

Figure 2-3 Overview of Coopers Typical Stage-Gate™ Process



(Source: Cooper, 1998)

2.2.2 Earle's Product Development Process

Outlined in Earle (1999), is a four-stage product development process specifically developed for the food industry. The four stages are Product Strategy Development, Product Design and Process development, Product Commercialisation and Product Launch and Evaluation. Between each stage top management makes decisions whether or not to continue with the project. These are called Go-No-Go decision points. Within each stage a common methodology is adopted that concentrates on gathering the appropriate information for making the Go-No-Go decision. Management decisions should be based on specific information and the information required to make this decision must be found by completing specific activities. The product development process outlined by Earle is provided below in Figure 2-4.

Activity, Outcome, Decision Relationship.

Earle provides a format for structuring and planning activities, outcomes and decisions within each of the four stages. The end result or decision to be made is identified first, once this has been determined, the required outcomes can be outlined and finally the activities that need to be undertaken to obtain the outcomes can be planned. This top-down approach to planning ensures that activities undertaken will result in informed decisions being made about the project.

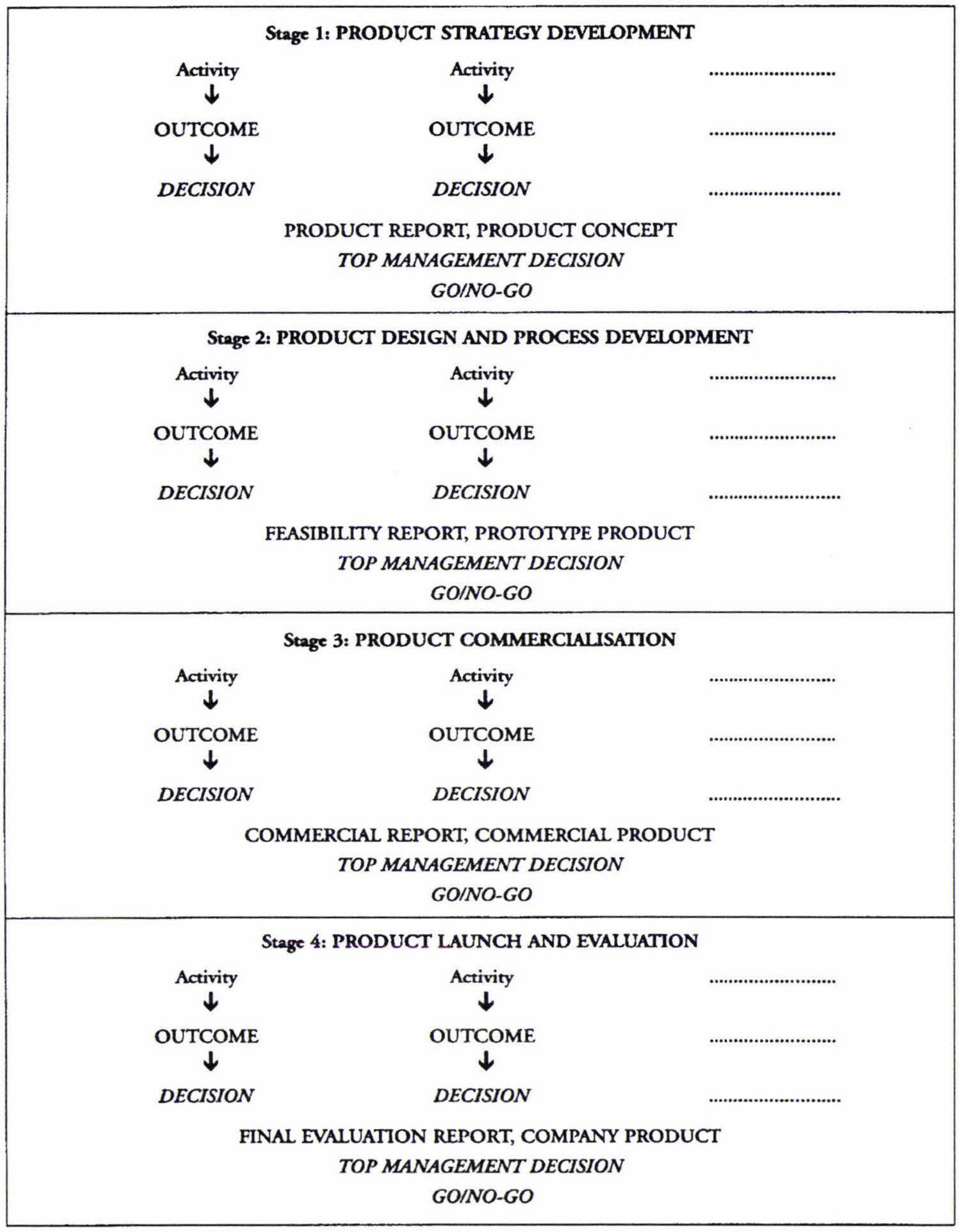
Decisions.

The Go-No-Go decisions at the end of each stage are made by top management. The decision to continue represents a resource commitment by top management to continue with the project. These decisions are based on the outcomes of the previous section, usually combined in the form of a report.

Stage 1: Product Strategy Development.

This stage ends with the decision to develop a product and the viability of the project for the company. Typical outcomes include product design specifications and the project evaluation report. Activities fall into two main groups, one developing product ideas and the other gathering support information such as marketing, financial and legal.

Figure 2-4 Product Development Process of Earle (1999)



(Source: Earle, 1999)

Stage 2: Product Design and Process Development.

At the end of this stage management make decisions relating to market suitability, company suitability, technical suitability and financial feasibility. Typical outcomes include sales predictions, prototypes, consumer acceptance and costs. Activities include: product design, consumer testing, process design and costing analysis.

Stage 3: Product Commercialisation.

At the end of this stage management must decide whether to go ahead with the launch of a new product. Typical decisions need to be made regarding the market plan, product safety and quality and the production plan and returns on investment. Activities conducted include marketing studies, marketing testing and financial analysis.

Stage 4: Product Launch and Evaluation.

At the end of this stage top management decides the future direction of the new product. Strategies for reacting to competitors' reactions are planned and increases in production efficiency are reviewed. Typical outcomes are quality and efficiency analyses, measurement of time, people and costs of the product. Typical activities include the organisation of marketing, production and distribution.

The process suggested emphasises that all stages and activities do not need to be completed for every project undertaken; rather a top down approach should be used. The objectives and outcomes should be reviewed first and then the decisions and then the activities required to be completed to achieve the identified objectives. For this reason it is very important to clearly identify the aims and objectives of each project before commencement. These should always directly relate back to the company strategy.

2.2.3 Ulrich and Eppinger

Ulrich and Eppinger outline a six-stage generic product development process. There is an emphasis on using a multidisciplinary approach. Refer to Figure 2-5 below for an outline of the generic product development process of Ulrich and Eppinger. The six stages of the process are:

0 Planning.

1 Concept Development.

2 System-Level Design.

3 Detail Design.

4 Testing and Refinement.

5 Production Ramp-Up.

Planning Phase.

The Planning phase begins before the start of an actual product development project. It includes activities such as strategy development, assessment of technology developments and market objectives. The output for this phase is the project mission statement. Included in this statement are the target market, business goals, key assumptions and constraints.

Concept Development.

In this phase the needs of the customer are identified, product concepts are generated and evaluated, and one or more are selected for further development. Usually an analysis of competitor products and economic justification for the project are also completed.

System-level Design.

This phase includes the definition of the product architecture and decomposition of the product into subsystems and components. Assembly details are developed as well.

Detail Design.

The complete specification of the product including: the geometry, materials and tolerances of all parts. The output of this stage is the control documentation for the manufacture of the product. Usually in the form of drawings and computer files.

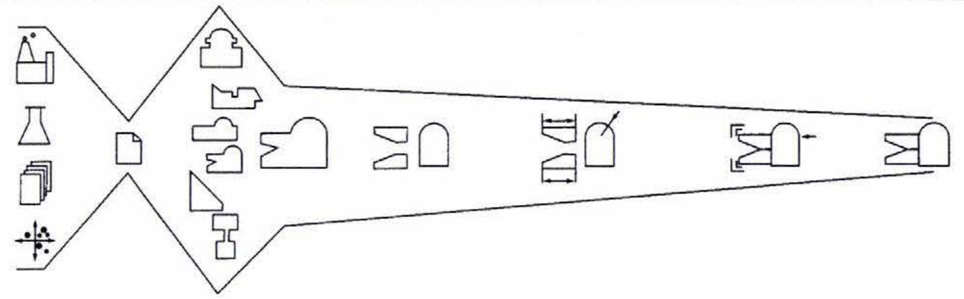
Testing and Refinement.

This phase involves the construction and testing of pre-production models of the product. Prototypes built with intended production parts, but not using the production process are made first. They are tested to ensure the product will perform as expected. Later beta prototypes or production line prototypes will also be tested, both physically and by the consumer.

Production Ramp-Up.

The product is made using the intended production and assembly system. The purpose of this is to train the appropriate staff and ensure production runs smoothly. The transition from production ramp-up to on-going production is usually gradual and at some time through this transition, the product is launched.

Figure 2-5 Ulrich and Eppinger's Generic Product Development Process



	Planning	Concept Development	System-Level Design	Detail Design	Testing and Refinement	Production Ramp-Up
Marketing	• Articulate market opportunity. • Define market segments.	• Collect customer needs. • Identify lead users. • Identify competitive products.	• Develop plan for product options and extended product family.	• Develop marketing plan.	• Develop promotion and launch materials. • Facilitate field testing.	• Place early production with key customers.
Design	• Consider product platform and architecture. • Assess new technologies.	• Investigate feasibility of product concepts. • Develop industrial design concepts. • Build and test experimental prototypes.	• Generate alternative product architectures. • Define major sub-systems and interfaces. • Refine industrial design.	• Define part geometry. • Choose materials. • Assign tolerances. • Complete industrial design control documentation.	• Reliability testing. • Life testing. • Performance testing. • Obtain regulatory approvals. • Implement design changes.	• Evaluate early production output.
Manufacturing	• Identify production constraints. • Set supply chain strategy.	• Estimate manufacturing cost. • Assess production feasibility.	• Identify suppliers for key components. • Perform make-buy analysis. • Define final assembly scheme.	• Define piece-part production processes. • Design tooling. • Define quality assurance processes. • Begin procurement of long-lead tooling.	• Facilitate supplier ramp-up. • Refine fabrication and assembly processes. • Train work force. • Refine quality assurance processes.	• Begin operation of entire production system.
Other Functions	• Research: Demonstrate available technologies. • Finance: Provide planning goals. • General Management: Allocate project resources.	• Finance: Facilitate economic analysis. • Legal: Investigate patent issues.	• Finance: Facilitate make-buy analysis. • Service: Identify service issues.		• Sales: Develop sales plan.	

(Source: Ulrich & Eppinger, 2000)

2.3 Best Practices of New Product Development Processes

This section summarises research findings into the best practices of Product Development. These practices will be used to benchmark the current practices at Furnware. Griffin (1997) summarises the results of a research project carried out by the Product Development Management Association (PDMA). It covers the trends of New Product Development (NPD) Processes in US companies of varying sizes, technological bases, product types and end consumers. It provides comparisons between businesses of different types as well as a review of the complete data set.

Main Findings.

- 60% of companies use Stage-Gate^{TM} processes, third generation models are better than the standard (second-generation) models. Third generation models are more flexible and fluid than second-generation processes. For example gates may become 'fuzzy' where go decisions may be conditional on some future event occurring.
- Qualitative Market Research techniques such as: voice of the customer, customer site visits and beta testing are the best tools to use in this area.
- Engineering tools are important and extensively used. CAD was the most important and widely used engineering tool. Closely followed by Design for Manufacturing (DFM).
- The speed and efficiency of product development processes has improved since 1992.
- The goal of more than one third of projects undertaken aims to add performance capability to current products.

The report also provides a checklist for keeping up with NPD trends

1. Implement a NPD process, improve it over time.
2. Screen out projects earlier.
3. Match the organisation to the project goal.
4. Use multi-functional teams.
5. Investigate and use market research techniques.
6. Determine whether engineering tools are needed, and use them all.

Given below is a summary of the key success drivers. The report selected the top performing companies in terms of both product success and financial success. The most successful companies were then separated from the rest and the differences in Product Development methodologies were compared. Given below is a summary of the findings.

1. Measuring NPD performance and expecting more out of NPD efforts. Best firms expect 45% of their sales to come from products commercialised in the last 3 years.
2. Focussing on doing NPD right to achieve higher results. Best practice firms achieve significantly better outcomes than other firms. On average, 49% of their sales came from products commercialised over the last 5 years, about twice the rate of the rest of the firms, and over 80% of the projects commercialised are successful.
3. Implementing Stage-Gate^{TM} processes and progressing to more advanced forms as quickly as feasible.
4. Starting NPD processes with a strategy activity and including more activities in their processes.
5. Driving product development efforts through specific NPD strategies at both the program and project level.
6. Using multi-functional teams more extensively in less innovative projects (50-60 % of the time).
7. Rewarding teams non-financially both publicly and privately, in multiple ways. Project completion dinners are the only reward used more by the best practice firms than the rest (72% versus 54%). Best practice firms currently do not use team-based financial rewards for NPD.
8. Quickly implementing new market research and engineering design tools, especially those which help them more efficiently deliver products which solve problems for consumers.

Cooper (1998) characterises what it takes to successfully develop new products. He starts by identifying three cornerstones of success: having a new product strategy, having the right resources and having a new product process that works. He then identifies five key ingredients to success from a management perspective:

1. Long term commitment to product development.

2. Develop a vision, objectives and strategy for your new product effort that is driven by the businesses corporate objectives.
3. Install a systematic, high-quality new product process.
4. Make available the necessary resources.
5. Foster innovation in the organisation.

In developing the high quality new product process, he identifies six critical success factors. These are:

1. Management emphasises doing the up-front homework in the process – both market and technical assessments – before projects move into the Development phase.
2. The new product process emphasises a strong market orientation, and builds in the voice of the customer throughout.
3. A high-quality new product process includes sharp, early product definition, before development work begins.
4. There are tough Go/Kill decision points in the process, where senior management really does kill projects.
5. There is a focus on quality of execution, where activities in new product projects must be carried put in a quality fashion.
6. The new product process is complete or thorough, where every vital activity is carried out. The process should also be flexible, where stages and decision points can be skipped or combined, as dictated by the nature and risk of the project.

2.4 New Zealand Company Environment

This section reviews previous research into the state of New Zealand business with a particular focus on aspects that are relevant to Furnware. In particular the past reforms that have taken place in New Zealand and the factors that affect Small and Medium-sized Enterprises (SMEs) such as Furnware.

2.4.1 Business Reforms: 1984- present

Since 1984 the New Zealand business environment has undergone radical changes. The aims of the reforms were to improve New Zealand's international competitiveness by making the economy as open as possible and minimizing the barriers to enterprise. The philosophy underlying the reforms is that the customer is king. Businesses must concentrate on providing what customers want at the highest sustainable profit. A free market philosophy such as this means that it does not matter who provides the products or service to the customer as long as customer needs are satisfied at a profit. Open and fair competition is the best way of ensuring that customer needs are met in the most cost-effective way.

The 50 years of business before 1984 were characterized by active government involvement in economic affairs. This policy was a reaction to the great depression of the 1930s. Governments adopted active policies aimed at creating full employment by creation of public works and expansion of government into trading activities. By 1984 New Zealand was one of the most regulated countries outside the communist world (Cameron & Massey, 1999). By the 1980s, largely due to a wage and prices freeze, a fixed exchange rate regime, and inflation of 20 percent, the New Zealand economy was in a perilous state. To reverse this decline the Labour government decided in 1984 to introduce 'the most sweeping reforms the New Zealand economy had seen in 50 years' (Russell, 1996). The main changes to be effected by the free market system introduced were the dismantling of regulations that constrain markets. For example the tariffs in the clothing, textile, footwear and car industries were eliminated.

These reforms had a very significant effect on business in New Zealand and also on product development in New Zealand. Companies found themselves suddenly in an open market with uncompetitive products. Companies had to redesign products or make sweeping changes to their businesses to survive.

Present views on the reforms are varied. The New Zealand Business Roundtable see the reforms as indicative of New Zealand moving in the correct direction, but criticizes governments for having largely lost momentum of economic reforms since the early 1990s (Kerr, 1998). However Kelsey (1995) argues that the social and economic costs of the reforms exceed the benefits. Easton (1997) argues that much of the pain that New Zealand has undergone has been unnecessary and that Australia, for example, has achieved better results over the same period using less draconian methods. There were two good years of growth in the mid-1990s but this was a temporary burst and was not sustainable. In Easton's opinion, overall New Zealanders are poorer as a result of the reforms, and appear to remain so.

The Small and Medium-sized enterprise (SME) sector in New Zealand has inevitably been affected by these reforms. The overall economic agenda of governments since 1984 has been high growth, smaller government and less state dependency. The drive for more self-reliance has forced many New Zealanders into self-employment. This has provided many opportunities for the private sector to do the many tasks formerly done by government departments, especially for SMEs.

2.4.2 Small and Medium-sized Enterprises

Deciding what constitutes a small business can be a somewhat subjective process, for the purposes of this research the definition used by Cameron (1999) will be used. A small business being defined as having 0 to 49 employees, a medium business as having between 50 and 99 employees and large businesses as having 100 or more employees. Furnware is therefore classed as a medium-sized enterprise as it employs approximately 50 staff. Small and Medium-sized enterprises (SMEs) make up a significant proportion of the business sector in New Zealand.

Table 2-1 Economically Significant Enterprises, 1998

Number of Employees	Number of Enterprises		Number Employed	
		%	FTE*	%
0 to 5	225 569	86.5%	332 290	24.0%
6 to 9	16 142	6.2%	111 590	8.1%
10 to 49	16 305	6.2%	299 360	21.6%
50 to 99	1455	0.6%	99360	7.2%
100 +	1264	0.5%	542 100	39.1%
TOTAL	**260 735**	**100.0%**	**1 384 970**	**100.0%**

(Source: New Zealand Business Demographic Statistics, 1998. Statistics New Zealand.)

Table 2-1 shows the large number of SMEs in New Zealand, in particular the high number of businesses with 0 to 5 employees. When businesses with less than 100 employees are combined into one group, they make up 99.5 percent of economically significant enterprises. The growth in number of small firms is generally regarded as a sign of flexibility and dynamism in the economy, which have been brought about largely due to the reforms of 1984 and is still continuing to present day.

2.4.3 Product Development

As a result of the reforms of the 80s and 90s, pressure was put on local companies to provide international-standard products. Product development therefore increased dramatically in importance in New Zealand. The 1994 BERL (Frater et al.) survey confirms this. It found that typically more manufacturers indicated a significant increase in intentions to expand product range (38% of respondents compared to 11% found by Corbett in 1992). Large numbers of firms were also found to derive over 50%

of their sales from new products. Clearly, product development has been an area of growing importance to firm strategies. Exporting companies in particular place emphasis on new product development. Campbell-Hunt & Corbett (1996) found that new product development was the area of greatest investment-spending among manufacturing exporters in 1995. Although Kerr (1994) found that there was no difference in the amount of resources devoted to product development but that exporters would concentrate on an average of just two products per year compared to five for non exporters.

The BERL (Frater et al.) report of 1994 found that most product innovations are inspired by customers and marketing staff. R&D staff contributes equally to innovations and process improvements. In the study of predominantly small firms senior management believed that they also make an important contribution. Campbell (1999) obtained similar results. He found that innovative companies obtained information mainly from customers, personal experience and company staff.

Campbell-Hunt & Corbett (1996) conclude that:

> *Firms' rapid expansion of product development strategies in the nineties is most strongly associated with the customization required to develop new (offshore) markets.*

Kerr (1994) found that the product development processes used by New Zealand small manufacturing companies were truncated, missing vital stages and concentrated on the development of the physical product. Companies were typically using an average of 8 stages out of the 13 suggested by Cooper and Kleinschmidt's (1986) product development process. The stages that were commonly missed included: detailed marketing study, business financial analysis, test marketing and pre-launch business analysis. The use of a more complete process was found to correlate to success in the marketplace.

In Kerr's study, he found that the techniques used by small New Zealand companies within the stages of product development were simple and easy-to-use and non-complex and were characterized by informal and reactive approaches. It is important that the necessary activities in a project are identified and the techniques chosen to give the necessary knowledge, Earle et al. (2001).

Kerr (1994) provides a typical product development process and techniques used by small companies in New Zealand. It is provided below in Figure 2-6

Figure 2-6 Kerr's Typical PD Process in New Zealand Small Companies

Idea Generation

The manager's perceptions of customers' needs and deficiencies of company's products.

Idea Screening

A discussion among a group of people without the use of any formal criteria to base their decisions on.

Preliminary Market Assessment

Assessment of the market made through direct contact with customers or intuition.

Preliminary Technical Assessment

Assessment based on product design and model development.

Prototype development

The prototype constructed with the use of design drawings or specifications.

In-house Prototype testing

Tested using functional or operating tests to ensure it worked correctly.

Customer Prototype Testing

Giving the prototype to customers to try.

Production Start-Up

Few changes to existing production facilities or equipment.

Market Launch

Launching primarily with basic promotion of trade literature and advertising.

(Source: Kerr 1994)

According to Kerr (1994), management plays a key role in Product Development in small companies in New Zealand. Small companies often had a lack of resources and personnel to complete product development activities; often the manager was personally involved in the product development projects. Although managers play a key role Kerr (1994) found that they were generally unskilled in how to complete effective product development.

2.4.4 Comparisons Among Industries

Research into product development in New Zealand companies has been done in several industry sectors. Kerr's (1994) research was conducted on food, electronics and light engineering companies. Some differences in their approaches to product development were found between the industries. Food companies gave more emphasis to the trial production stages and utilized slightly more techniques than the other industries. Food companies were found to have a higher level of innovation success while having the shortest development time and lowest intensity of development staff.

Electronics companies were relatively more committed to product development, using a higher number of technical stages and having a higher proportion of people conducting product development.

Light engineering companies completed comparably less product development than either the food or electronics industries although they did perceive themselves as being more innovative. Light engineering also used fewer stages in their development process and had the lowest level of customer involvement.

Kong (1998) found that understanding buyer behavior and meeting user's needs were important to successful product development in the electronics industry in New Zealand. Souder et al. (1997) found that New Zealand small entrepreneurial high technology firms had higher levels of new product development (NPD) performance than those of United States counterparts. This success was attributed to the relationship marketing and customer-focused NPD practices of the New Zealand firms. New Zealand companies had closer relationships and greater experience with their customers. 79% of the New Zealand products exhibited "can translate needs" characteristics compared with only 48% for United States products.

Product Development in New Zealand companies seems to have improved somewhat since 1994, especially in the high technology/ electronics fields. Kong (1998) concludes that:

> *"... A well planned and disciplined new product development process was found essential to the medium and large sized companies. Close and constant contacts with market and customers were the basis of an efficient product development process."*

2.5 Factors Affecting Product Development at Furnware

Product development is affected by a number of industry-specific factors. These need to be taken into account when creating a process to be used for the development of products in that industry. Provided in this section is a review of the factors that have the greatest effect on product development at Furnware.

2.5.1 Product Development in the Furniture Industry

2.5.1.1 Custom Designs and Standard Range (Catalogue) Products

Furnware design, manufacture and sell furniture products using two methods, standard products and custom (one-off) products. Standard products form the core business. These products are sold out of a catalogue to clients who require typical educational furniture. Customer choice is limited to the colour combinations of melteca used and edgebanding used. The design and development of these products has been completed some time in the past using a product development procedure chosen by Furnware. Development of new standard products requires the use of a product development process.

Custom furniture is furniture requested by a customer that is not part of the standard range and must be designed and manufactured specifically for that customer. A customer order can include a combination of standard and custom products. The customer also expects that the order of both custom and standard products will arrive together and promptly. This introduces challenges to the design and manufacturing staff. Effectively products need to be produced on a per order basis to ensure the entire order is ready at once. This conflicts with the majority of production processes, where there are considerable savings to be made in producing long runs of the same product.

2.5.1.1.1 Custom Furniture

Time to develop custom furniture is very limited. The more time saved the greater the profit margins. Using a structured product development process for custom furniture is impractical. The design of the furniture is provided by the customer. Included in the request are colour preferences, overall dimensions and a basic sketch of what the product should look like. Efficient manufacture of the design provided is the predominant concern. Factors that assist in this are: computer aided design and manufacturing (CAD/CAM) that enables the design of a product to be automatically converted into machine code and then machined into components quickly. The use of standard construction techniques and components in the custom design also significantly helps production.

2.5.1.1.2 Standard Furniture

The development of a new product to be included in the standard range of furniture follows a more typical product development procedure. The product must be designed to satisfy a customer need, fit with other products in the company's range and be competitive with other products in the market. Manufacturing of these products becomes familiar to staff and efficient manufacturing usually leads to higher profit margins on these products compared to custom furniture.

2.5.2 Product Development and the Educational Furniture Market

2.5.2.1 Educational Furniture Market Review

The biggest changes in the educational furniture market have been caused by changes in government policy. The most recent change in New Zealand government policy that has affected educational furniture is the introduction of 'Tomorrows Schools'. This is a radical new policy passed in 1988 that effectively opened up, a contract-based market where manufacturers applied for 2-5 year contracts to manufacture standardised school furniture all of the same design. Now the market is relatively open and individual schools have the freedom to choose the furniture they desire. Effectively, in just a few short years the educational furniture market was converted from a static, constant market to a dynamic and changing market that demands more and more from furniture manufacturers.

This has resulted in companies faced with increased demand for quick turn around time, new products, custom furniture and lower prices. Customers are now free to purchase anything they desire, provided it is within their limited school budget. This means that sales representatives must be able to provide customers with a range of products to choose from. Ordering procedures usually include a mixture of standard products such as chairs and desks, and custom furniture. The complete order is then requested to be ready and complete with in a short turn around time. To further complicate matters, standard products now come in a large range of melteca and edging colours. From a manufacturing perspective this means that standard products cannot be made in advance and stockpiled to help increase the flow of production. In this market the development of new products forms a critical part in company success, better products help reduce the number of custom designs requested by customers. If a standard product exists that fulfils the need of the customer then a custom product is no longer required, thus reducing development and production costs.

2.6 Review of Educational Furniture Development Areas

This section summarises the findings from initial literature research into two of the three areas identified in the project proposal. These were mobile workstation for technology curriculum and mobile workstation for computing equipment.

2.6.1 Technology Curriculum in New Zealand Schools

The aim of this research was to develop an understanding of the Technology Curriculum from both a physical resource and teaching philosophy point of view. Given below is a summary of the material reviewed.

2.6.1.1 Curriculum Statement

The "Technology in the New Zealand Curriculum, Curriculum Statement" booklet provides the aim, structure and philosophy behind the technology curriculum, it also provides examples of how the curriculum can be implemented.

Technology and technology education is defined as:

> *"...a planned process designed to develop student's competence and confidence in understanding and using existing technologies and in creating solutions to technological problems. It contributes to the intellectual and practical development of students, as individuals and as informed members of a technological society" (Anon, 1995).*

The curriculum is organised into three sectors: strands, areas and contexts. Strands are the different types of skills that can be learnt. These range from knowledge and understanding skills such as understanding the use and operation of technologies, to hands-on skills such as presenting and promoting ideas, strategies and outcomes. The final types of skills revolve around societal issues such as understanding the impacts if technology on society and the environment. Most units of work will include objectives from all three of these strands.

There are seven technological areas outlined in the curriculum:

1. Biotechnology.
2. Electronics and Control technology.
3. Food technology.
4. Information and Communication technology.
5. Materials technology.
6. Production and Process technology.

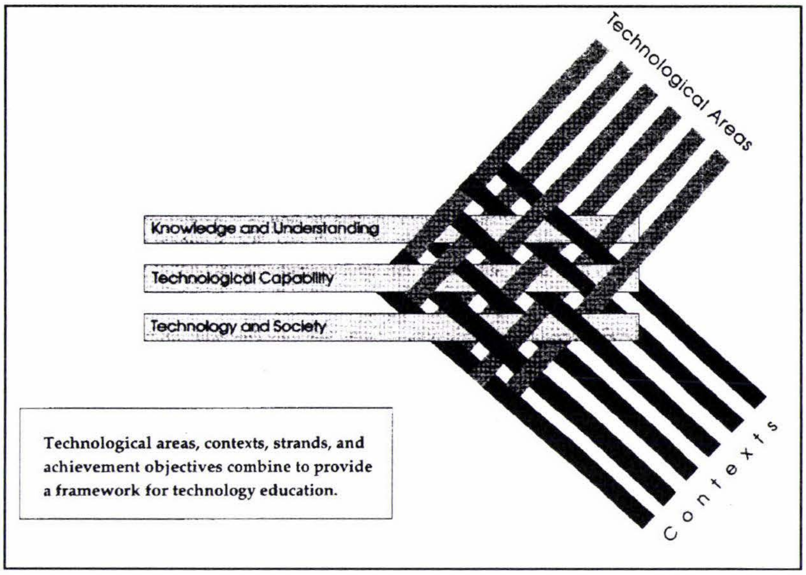
7. Structures and Mechanisms technology.

Biotechnology involves the use of living organisms to produce products. They maybe products such as: foods, pharmaceuticals or waste management systems. Electronics and Control technology deals with electrical and electronics systems as well as their design. These maybe simple circuits or robotics. Control technologies maybe electronic, pneumatic or mechanical. Food technology includes the use of safe, reliable processes for preparing, and storing food as well as the development of packaging for foods. Information and Communication technology deals with the systems that collect, manipulate and retrieve information. The communication of information can take many forms. This includes audio and graphical communications. Production and Process technology deals with the manufacture of products using of production systems. The processing of raw materials into finished goods is also included. Materials technology deals with the selection and use of appropriate materials to perform a specific purpose. Preservation and processing of materials is also included. This area also contributes to many of the other areas, especially Production and Process technology. Structures and Mechanisms technology deals with the study of a wide variety of objects that have been created using a number of components. Design is another important area in this curriculum involving freehand, technical and computer aided design skills.

There are nine contexts within which technology is taught; most projects undertaken will involve several contexts. Contexts describe the angle or perspective from which a project will be researched, and include personal, home, school, recreational, community, environmental, energy, business and industrial.

The figure below represents how these three sectors combine together to provide a framework for the technology curriculum.

Figure 2-7 Technology Curriculum Framework



(Source: Anon, 1995)

2.6.1.2 Technology Curriculum Example Project

The final section of the curriculum provides a number of example projects for teaching the curriculum. The Technology Curriculum is taught from a project base. A subject is selected, such as letterboxes (See Figure 2-8). The specific contexts and areas are then decided. Students may look at letterboxes from home, business and environmental contexts and under the technology areas of Information and Communication and Materials and Structures. Students would then follow a logical process through the achievement objectives of knowledge and understanding, capability and society.

2.6.1.3 Architectural Design Guidelines for Technology in Schools

The report by Burke & Eppel (1997) was produced following the introduction of the Technology Curriculum statement. It details a study conducted for the Ministry of Education about the building requirements for schools to accommodate the new Technology Curriculum. Both new designs and redesign plans are provided for primary, intermediate, secondary and single-sex schools. Shown below is a typical plan of a proposed technology centre (Figure 2-9). The reality is that the majority of schools will not be able to fund such a building and will need to renovate existing buildings, such as in the bottom image in Figure 2-9.

Figure 2-8 Example of Technology Education Project

SUGGESTED LEARNING AND ASSESSMENT EXAMPLES FOR LEVELS 1 AND 2

These learning and assessment examples are suggestions which teachers could develop further into units of work.

Example 1: Letterboxes

Contexts: Home; Business; Environmental
Main Areas: Materials; Structures; Information and Communication

The postal system provides opportunities for a variety of technological observations and activities which relate to all three curriculum strands. The community links can be built from the outset, through discussion with the local post office about the proposed range of activities and the part that staff might take in fostering students' knowledge.

Technological Knowledge and Understanding

- Students list the purposes served by letterboxes.
- They examine a variety of letterboxes to identify similarities, differences, and key features.
- They discuss how different letterboxes operate and are used.
- They prepare and ask questions of the postie, focusing on the types of letterboxes they prefer, and why.
- They identify what they think is the best letterbox in their neighbourhood, giving reasons for their choice.

Technological Capability

- Students collect and present data about letterboxes examined in a particular location.
- They find out about the types of improvements the postie and owners would like to make in relation to letterboxes.
- They brainstorm ideas about the type of letterbox best suited to group members which also meets the needs of the class's postal system and which accounts for constraints identified by the teacher and themselves, such as materials and time.
- They identify needs and possible difficulties associated with the designing and making of their own letterboxes.
- They discuss how their design/product meets identified needs and constraints.

Technology and Society

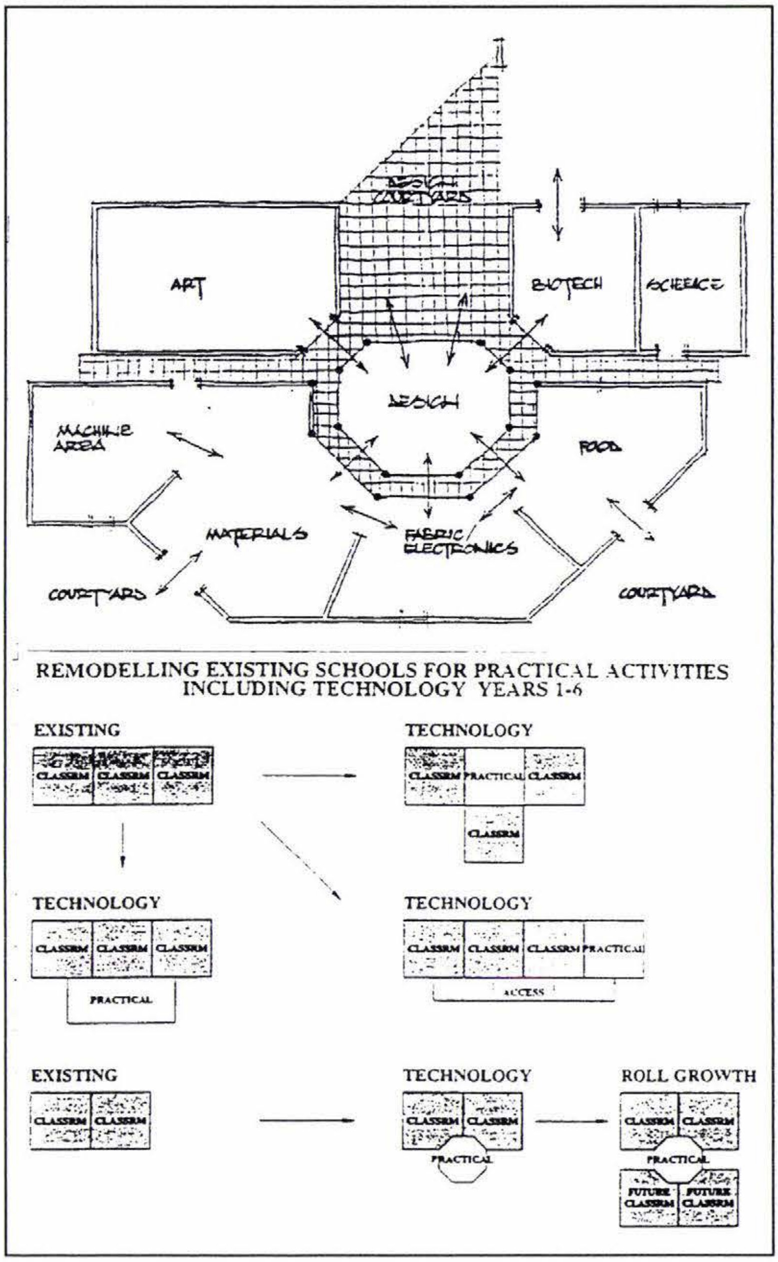
- Students discuss reasons for their selection of a design and materials for their group's letterbox/their letterbox at home/letterboxes in their neighbourhood.
- They discuss what it would be like if there were no letterboxes, and what other methods of mail delivery might be possible.

Assessment

The main focus in this example could be on the production of the letterbox, and teachers may choose to concentrate assessment on the objectives of the capability strand, mainly in terms of the choices made for a well produced solution, including choice of suitable materials.

(Anon, 1995)

Figure 2-9 Architectural Plans for Technology Education



(Source: Burke & Eppel, 1997)

2.6.2 Computer Usage in Schools

Information Technology of New Zealand (Anon, 1998) has developed potential strategies for learning with Information Technology (IT) in New Zealand schools. Topics covered include:

- IT in New Zealand schools today.
- IT in the schools of tomorrow.
- The role of Government in the schools sector.

- Potential elements of a strategy for IT in learning.
- The way forward – tasks for the government.
- Proposed strategies.
- Recommendations and conclusions.

Anon, 1998 suggests that IT should be used more in schools, and that the government should concentrate on central strategies such as:

- Providing a help desk for schools.
- IT advice and implementation planning guidance to schools including best practice.
- Central teaching resources on-line.

Other suggested strategies include the use of learning clusters. Groups of schools would be given funding to pay for full time teacher support and part time technical support within the cluster for a period of 2 years. The development of these strategies and publication of this report illustrate the governments support for IT in schools. Furniture supporting IT equipment could therefore be expected to increase in demand in the future.

Owens, (1997) covers the number, type and Internet usage and intended usage of computers in New Zealand schools. The data is somewhat outdated but does indicate that the majority of schools either had or intended to have computers in their schools by 1998. At the time of the survey the types of computers in schools were: PC (52.7%), Macintosh (22.9%), Acorn (12%) and Other (12.4%). Statistics relating to use of the Internet are considered too far out of date, given the large increase in Internet between the time of the survey (1996) and the present. The total percentage of schools that had connected and were intending to connect at the time of this survey was 86%.

Sulivan & Arso, (2000) give the results of a more recent survey conducted relating to computer usage in schools. The main findings were:

- Types of computers used in primary schools are: PCs (60%), Apple/Mac (34%), Acorns/BBC (5%) and other (1%).
- Types of computers used in secondary schools are: PCs (76%), Apple/Mac (22%), Acorns/BBC (2%) and other (0%).
- The ratio of students per computer has decreased steadily over the past 4 years from 18 to 11 for primary schools and 10 to 6 for secondary schools.

- The four most commonly used software types in schools were, in descending order: MS Office, MS Publisher, MS Works and Claris Works/ Apple Works.
- Access to the Internet has steadily increased in primary schools from 14% in 1993 to 96% in 1999.
- Access to the Internet has steadily increased in secondary schools from 44% in 1993 to 99% in 1999.
- The two most commonly used Internet service providers were: Xtra and Ihug.

3 Product Development Process Selection

3.1 Introduction

The purpose of this chapter is to summarise the development of a product development process suitable for Furnware. Analysing Furnware's past projects provided a basis for the revision of product development at Furnware. This chapter takes the knowledge of current practices at Furnware, compares them to identified best practices and then develops, a refined product development process. This process is then used to develop a Mobile Technology Education Workstation, which will be covered in subsequent chapters.

3.2 Methodology

The development of a product development process suited to Furnware's needs, will follow the process outlined in the flowchart below.

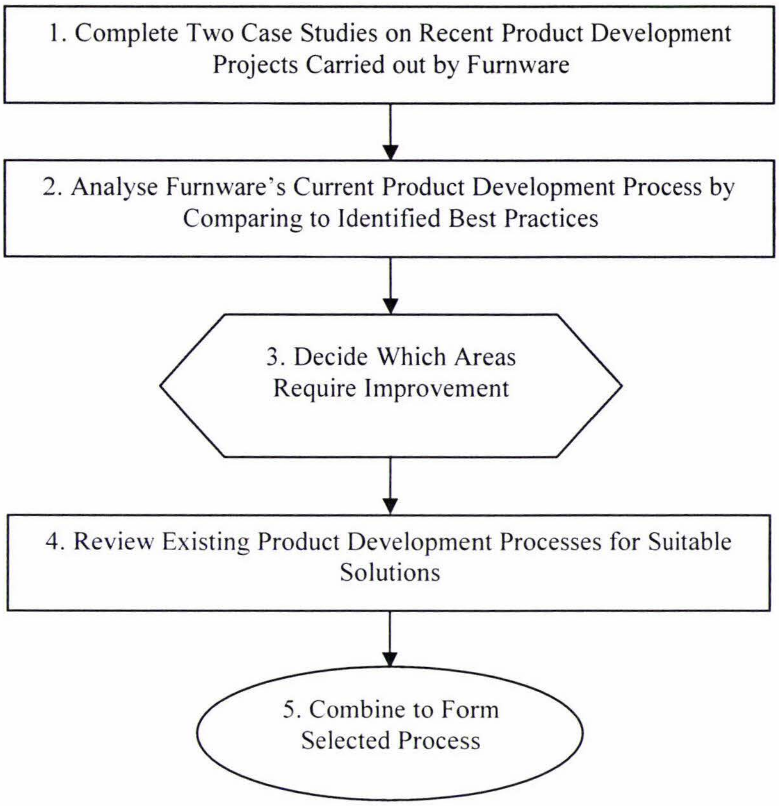
1. Complete Two Case Studies on Recent Product Development Projects Carried out by Furnware.

   Information was gathered on two past projects carried out by Furnware. To gather this information a number of discussions were held with the staff involved in the two developments. Furnware allocate a 'product champion' to projects so gathering the relevant information from Furnware staff was the simplest method to use. A summary of the findings is given below. Completing two case studies ensured that a thorough understanding of current methods used to develop products at Furnware was achieved. The information gathered is then used to produce a generic product development process used at Furnware. This process is then evaluated by comparing it to identified best practices.

2. Analyse Furnware's Current Product Development Process by Comparing to Identified Best Practices.

   The best practices identified in Section 2.3 of the Literature Review are used as a basis for analysis of Furnware's current product development methods. Each best practice is taken separately and the process currently used at Furnware is

Figure 3-10 Product Development Process Selection Method



discussed in relation to the best practice. The outcomes of this analysis are areas of product development practice at Furnware that require modification.

3. Decide Which Areas Require Improvement.

   The next step is to decide which areas should be improved at Furnware. Discussions with top management at Furnware were used to choose the appropriate areas.

4. Review Existing Product Development Processes for Suitable Solutions.

   Once the areas requiring improvement have been identified, then existing product development processes are reviewed for possible solutions. Those parts most suitable for use at Furnware will be combined with the activities already conducted at Furnware that work well.

5. Combine to Form Selected Process.

   A revised process is made from a combination of existing processes used at Furnware that have been identified as working well and those parts of the identified processes that solve the identified weaknesses of Furnware's current activities.

3.3 Results

3.3.1 Part 1:Current Product Development Methodologies at Furnware

Furnware currently develops product ideas in an informal manner or by contracting the work to other parties, such as Massey University. Furnware is continually working on product development projects with the university as a means of developing products. Furnware generally do not follow a set product development process. A 'product champion' is usually selected to carry out the majority of the development work and it is his or her responsibility to obtain any information that may be required by contacting the appropriate people as is necessary. For example steel component design may require discussions with steel manufacturing staff. A review of past projects is done to ascertain how Furnware conducts New Product Development (NPD) projects. Two case studies were investigated by interviewing those that were involved in the projects. The two projects selected vary in product type and in the development process followed. Developing a set process that is used to develop products at Furnware proved a difficult task. This difficulty highlights the rather ad hoc methodology traditionally followed at Furnware. In the past Furnware has completed relatively few product development projects, preferring instead to contract work out. Work carried out by Furnware has generally concentrated on product extensions and modifications. Outlined below are two developments recently completed at Furnware.

3.3.1.1 Case Study 1: Bordeaux Bedroom Suite

Date of Development: Jan - Feb 2000.

Development time: 2 months (part time).

Identified Need

The need to develop this new range of bedroom furniture stemmed from a decline in sales and profits of the current product range.

Process

A meeting was held between the sales manager, manufacturing manager and solid wood furniture sales representative. The bedroom furniture product range was failing to attract sales so an investigation into potential remedies was conducted (Dickey, 2000).

Main outcomes of the meeting:

- There is a need for new furniture design to help boost sales.

- The profit margin on chairs is too low to warrant development of a new range or modification of the existing product range.
- The bedroom furniture line only had one new design and all the rest were at least six years old.
- Market research was required into the bedroom furniture area of the market to identify the current trends and identify a potential need or design idea.

From the market research conducted, it was identified that the colour of the older designs was no longer popular, so different stains were investigated that could be used to change the furniture colour.

Development then concentrated on investigating different stains that had the appropriate colourings which resulted in a wiping stain being formulated using several different stains combined together. To find the appropriate formulation, trial and error experimentation was conducted as well as some consumer testing. No structured process was used to conduct these experiments. The advantages of the chosen stain, apart from improving the perceived quality of the product and taking away the reliance of the grain of the wood as a design feature, was that lower grade and hence cheaper rimu could be used to manufacture the range. It also meant that a similar product could be made from pine that would look very similar to the higher quality, rimu products.

As well as using a new stain, the manufacturing manager discovered that the designs of the majority of furniture had a square, very solid look to them. Reviewing current and past trends in furniture design revealed that in the 1970s and 1980s the Colonial styling was very popular. Designs that were 'flowery' and had intricate carvings of swirls etc on them were fashionable. In the 1990s the popular designs were solid and squat. They had an 'early settler' look. They were chunky, solid and also relied heavily on the grain of the timber to supply styling. The majority of competitor products also tended to highlight the rimu colorations. This style had been in fashion for quite some time now and it was decided to soften the design somewhat.

To do this several options were investigated. Current designs tended to have solid bases right to the ground to assist in the solid, square look. The Heritage suite range was a new design and was viewed as being a good starting point for the design of the new range. The Heritage suite, Furnware's only other recent design had legs that raised the furniture off the ground, helping remove some of the solid, chunky style. This feature was included in the new product range as well.

To further differentiate the new design from others in the marketplace, two other areas were developed: the handles and the drawer fronts. First the drawer fronts were investigated. To increase the perceived quality of the design, rounded or bowed fronts were developed, investigation into this style found that the market was willing to pay up to 20% more for a bowed front compared to a standard, square front. To minimise costs it was decided to include the bowed fronts, but to use the same drawer sizes as the Heritage suite thus significantly reducing the start-up costs of the furniture range while still providing a point of differentiation. Once the fronts were designed the final element that needed to be developed was the handles.

Furnware does not manufacture handles, so the only design decision required is the selection of a handle style from one of the many suppliers. A meeting was held for this and after much debate and comparison of handle costs, quality and style the handle most appropriate for the design was chosen. This completed the product development process for the Bordeaux Bedroom suite.

The suite was shown at the Auckland Furniture show early in 2000 and won the best bedroom suite design. The Harvey Norman retail chain liked the suite and arranged to be the exclusive retailer for the suite. Consequently, no further marketing or promotion was required for this suite. As part of the development of this new range of bedroom furniture, the old range was reviewed and a lot of the old, non-performing designs were discontinued.

<u>Summary</u>

- The current ranges of bedroom furniture were reaching the end of their profitable lives and sales were declining.
- Something had to be done to boost sales and profit and upon investigation and discussion, a new bedroom furniture range was designed and some of the older designs were dropped.
- Upon investigation into the current marketplace and competitors, several different styling changes were developed.
- To minimise production costs existing proportions and hence components were used to manufacture the new range.
- Launch of the new design at the Auckland tradeshow yielded an exclusive retail buyer for the range.

3.3.1.2 Case Study 2: Mayfair Product Range

Date of Development: Feb - May 2000.

Development time: 3 months (part time).

Identified Need

The amalgamation of Eagle Furniture Ltd and Furnware Industries Ltd in 1998 provided the opportunity to develop a new office furniture range that was currently being sold by Furnware but manufactured by a contract company.

Process

Sales of school office and administration furniture were increasing and Furnware did not have a product range of their own to cater for this area. The number of one-off designs being made for schools was increasing and taking up a large amount of design and programming time. The standard products ordered were made by a contract company and so profits were not maximised from these sales.

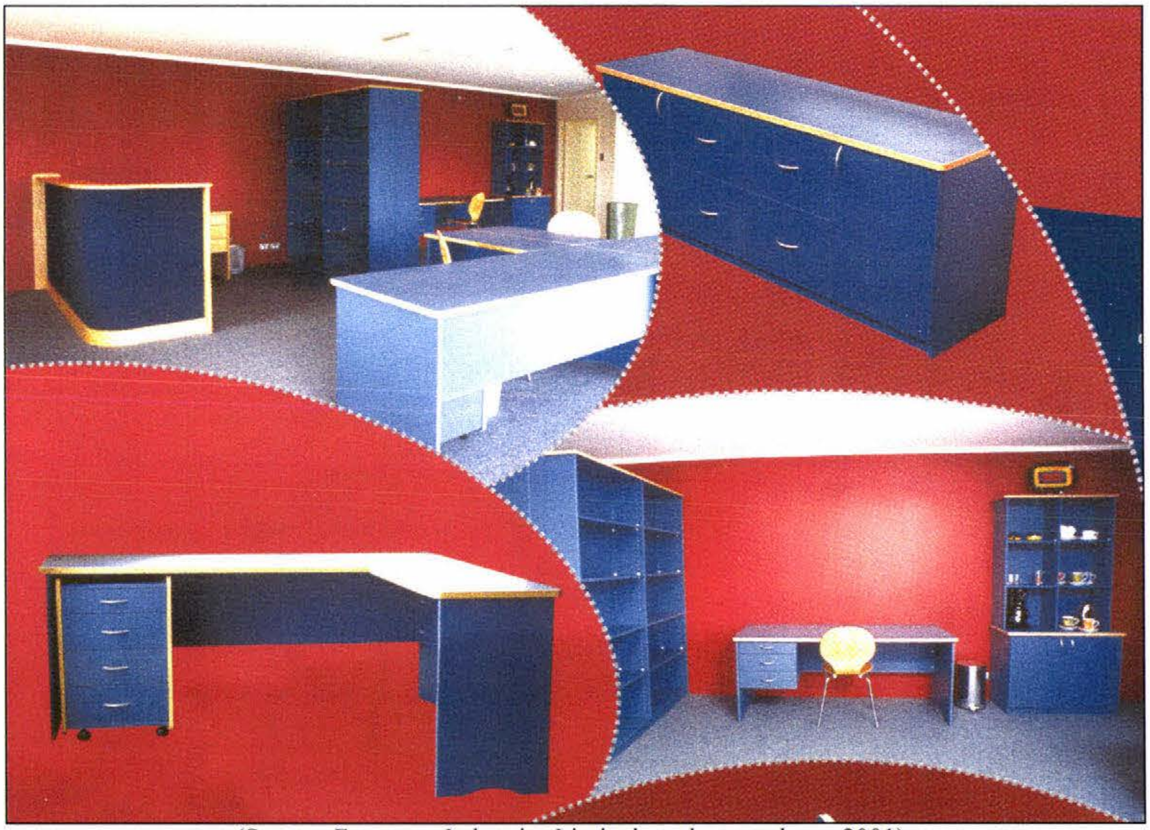
An introductory meeting was held to discuss the problem and devise a solution. The people present included the sales manager, manufacturing managers, and CAM programmer. It was decided that the sales manager would conduct market research into the needs of the customers and determine which designs were most popular and thus which should be included in a new range of products. The aim of which was to provide a range of products that would satisfy the majority of customers, while minimising the number of items in the standard range, thus reducing manufacturing and administration costs. By reviewing the orders placed in the past a range of office furniture products and recommended dimensions were identified that should be included in the range. A subsequent meeting between the sales manager and the production management staff was held to determine which products could be included and how they would be manufactured. The final range is presented in a 9-page brochure, included in the range are: workstations, cupboards, bookcases, meeting tables, coffee tables and accessories. Examples are provided below in Figure 3-11.

The list of products to be included and their dimensions were given to Astir Design, the contractor that produces catalogues for Furnware using a CAD software program called Solid Vision. The 9-page brochure of the Mayfair range was produced in collaboration with manufacturing staff, sales staff and Astir design. In conjunction with this task, the appropriate product model coding was developed to aid manufacturing and administration of the range. As orders were received for the new products the supporting CAM instructions were completed at Furnware.

Summary

- Change in manufacturing capability yielded an opportunity to increase the product range and profitability.
- A meeting was held by sales and production staff to decide the best approach
- A range was developed by the sales department, predominantly from past sales and experience.
- The new range was tabled at a second meeting and the next stage of tasks assigned.
- A nine-page office furniture brochure was produced, programming of the designs to be completed as orders are received.

Figure 3-11 Sample of Mayfair Office Furniture Range



(Source: Furnware Industries Limited product catalogue 2001)

3.3.1.3 Other Projects

A large number of small product development projects are initiated from one-off products made for customers. If a particular product appears to have merit, it is often modified slightly and entered into the product range. While this method of developing new products does yield some valuable ideas, it relies on reaction to a market need long after the need was created.

3.3.2 Outcomes: Process Description

Provided below in Figure 3-12 is a flow chart of the identified general stages completed in the development of products at Furnware. Note that this process is not currently formalised and for the majority of the projects not all stages are completed. It merely provides a pictorial representation of the most common stages undertaken to develop new products at Furnware as identified from the two case studies.

3.3.2.1.1 Idea Meeting

Ideas are gathered from several different areas such as conferences, (national and international), sales representatives, overseas products and one-off designs. They are reviewed at a meeting. Top management, sales representatives and manufacturing management representatives attend the meeting. New product ideas are tabled and discussed. If an idea presents a distinct advantage and everybody is generally positive about the idea, a decision is made to start development. Usually one person is assigned the responsibility of overseeing the whole project. This 'project champion' will complete the majority of the development work, requesting information from various people only as required.

3.3.2.1.2 Research

The necessary work is then carried out, to flesh out the idea and determine its viability as a product. This stage is often very short and full-scale prototyping is used to develop ideas as soon as possible.

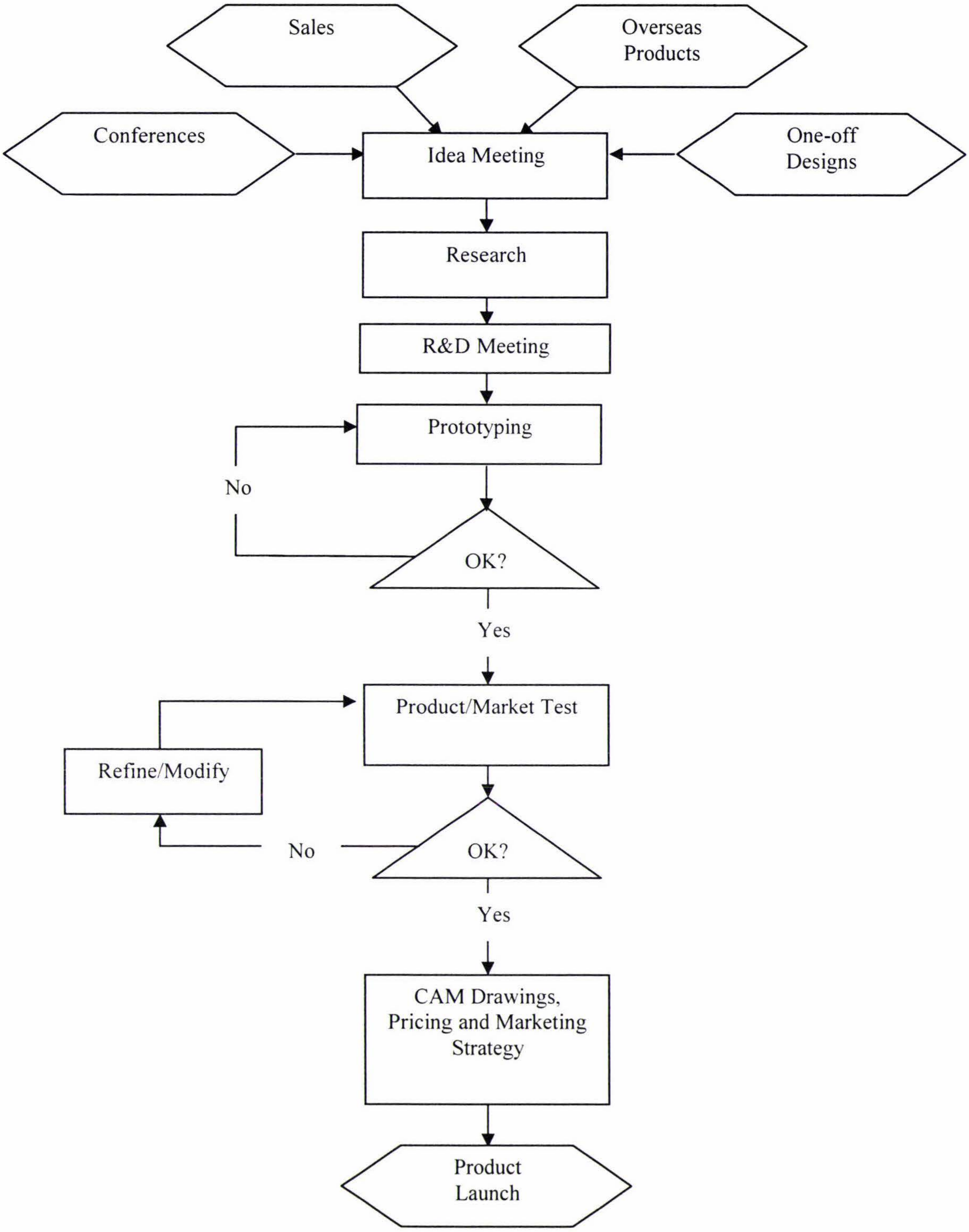
3.3.2.1.3 R&D Meeting

Sometimes meetings will be held to update management on the progress of projects, and any problems are tabled and potential solutions generated.

3.3.2.1.4 Prototyping

The majority of projects conducted at Furnware concentrate on existing manufacturing capability hence prototyping that involves manufacturing staff is conducted as early as possible and using the actual manufacturing process and materials that the final product is expected to be made from. Prototypes are usually full-scale, final material prototypes.

Figure 3-12 Current Product Development Process at Furnware



3.3.2.1.5 Product/Market Test

Once a solution has been designed that fits the criteria and can be manufactured, it is tested. Usually some informal market testing will be done by visiting the local community and presenting the prototype for evaluation. The objective of this stage is to ensure product benefits and product costs match customer expectations.

3.3.2.1.6 CAM Drawings, Pricing and Marketing Strategy

Once the design has been finalised, the detailed drawings are produced, and the bill of materials and pricing are completed. Top management deals with marketing and launch strategies. Some typical examples include:

- Sending out fliers to schools.
- Advertising in school bulletins and papers.
- Incorporation of the product into Furnware's catalogues.
- Display at conferences.

3.3.2.2 Summary

The two example case study projects outlined above provide a detailed insight into the manner in which Furnware currently conduct product development projects. A typical process is outlined to include some of the main stages of their development process. Any one project may skip some of these stages, depending on the nature of the project. The information gathered here will be used to compare Furnware's current development process with identified best practices. A product development process incorporating both current methods and best practices will then be developed and used to develop the Mobile Technology Education Workstation.

3.3.3 Part 2: Analysis of Furnware's Product Development Process

The aim of this section is to identify areas for improvement in Furnware's Product Development activities by comparing the current product development activities at Furnware with identified best practices.

3.3.3.1 Use of a Stage-Gate™ Process

Furnware do not have a structured process that is documented and followed for all product development activities. Researching past projects showed that sometimes an informal stage-gate process is followed where information is gathered, then a meeting is held, decisions made and development moves on to the next set of activities.

3.3.3.2 Use of Qualitative Market Research Techniques

Furnware do complete qualitative research. Customers' needs are researched at the beginning of a development project. Furnware's strong market orientation and close relationships with customers, aids the use of qualitative market research techniques. More consumer input should be put into stages further along in the product development process, such as prototype testing.

3.3.3.3 Extensive Use of Engineering Tools

Computer Aided Design (CAD) was the most important and widely used engineering tool identified by Griffin (1997), closely followed by Design for Manufacturing (DFM). Furnware do not currently employ any engineering tools. Design of new products does usually incorporate a lot of manufacturing and assembly considerations to reduce product cost. Furnware currently operate Computer Numeric Controlled (CNC) machinery using powerful CAM software. This could easily be integrated with CAD software to improve the product development process at Furnware and help speed up both new product development time and the existing manufacturing process.

3.3.3.4 Improving the Speed and Efficiency of the Product Development Process

Furnware do not currently use a set process. Current activities concentrate on completing only the activities considered important to a development project. Furnware will first need to establish a set process before it can be made more efficient. The implementation of CAD software would also help speed up the product development process, as already mentioned above.

3.3.3.5 More than One-Third of Projects Aim to Add Performance Capability to Current Products

The majority of projects at Furnware focus on improving current products. Larger, more innovative projects are usually contracted out at present. Furnware do therefore follow this trend of more than one-third of projects aim to add performance capability to existing products.

3.3.4 Outcomes

By comparing Furnware's current product development procedures with identified best practices the following two areas have been identified as priority for improvements:

1. Furnware should develop and use a structured Stage-GateTM process and improve it over time.
2. Furnware would benefit from the implementation of engineering tools. CAD, in particular, would help improve both product development and manufacturing procedures at Furnware.

Once a Stage-Gate™ process has been implemented, then further improvement, such as moving to a more flexible process and improving development time, can be undertaken.

3.3.5 Part 3: Analysis of Current Structured Processes

The aim of this section is to analyse current processes and determine which one is most suited to Furnware. Identified in the Literature Review were three product development processes and current studies on the best practices of successful product development processes. Outlined in this section is a review of the three product development processes. They are discussed in relation to their fit with Furnware. Refer to Chapter 2, for further details relating to each of the processes.

3.3.5.1 Cooper

Cooper's five stage Stage-Gate™ process, incorporates all of the necessary criteria for a product development process at Furnware. It is suitable for the Furniture industry, as the stages outlined are relevant to the development of new furniture products. The small size of Furnware makes implementation of a very structured process such as Coopers, potentially very tedious though. Small companies do not require the communication of a product development projects progress between as many people as in a large company. Cooper (1998), does suggest that a company start the development of a process with more rather than less stages and then refining the number of stages as the company familiarises itself with the process. Cooper also suggests that progression towards a more flexible or third generation Stage-Gate™ process will improve new product success. Furnware are beginning the development of a process suitable for their environment and will need to move through the refining process as experience is gained in using a product development process.

3.3.5.2 Earle

Earle (1999) provides a simple four-stage process that provides clear guidelines on how to plan activities so that decisions can be reached to help advance the development process. The differences between food products and furniture products do cause some differences in product development process.

Key Differences Between Food Industry and Furniture Industry.

For furniture products the raw materials are almost constant: MDF, Melteca, solid wood and steel, in the food industry, the raw materials are many and varied and provide the basis for the opportunity to create a new food product. In the furniture industry you can create a prototype and test on the consumer before all details are worked out using scaled or partial prototypes. In the food industry product formulations must be developed to the stage of being safe for consumption before it is tested on the consumer. The development of the production process of making the product is also well defined in the furniture industry. The machinery and construction techniques available are known for example, while the food industry must prepare batches of product. This increases the importance of Stage 3: Product Commercialisation activities. Accurate sales estimates must be provided and to do this trial samples need to be sold. In the furniture industry the run size of any one product is unlimited. Therefore, one or two products can be made and sold to determine market potential. Products do not need to be made in batches before promotion of the new product either, as sales are obtained on a customer order basis. Products are sold direct to customers, there is no retailer that needs to be satisfied and considered in the product design in the furniture industry allowing a much more direct link between manufacturer and customer.

The use of Go-No-Go decision points in Earle's process is similar to Cooper's Stage-Gate™ structure and fits with products developed in the furniture industry. Likewise the inclusion of strategy activities is important to the furniture industry.

3.3.5.3 Ulrich and Eppinger

The generic process proposed by Ulrich and Eppinger is considered best suited to the market pull situation (Ulrich and Eppinger, 2000). This is a product development scenario where the product development project begins with the identification of a market opportunity. The company then develops a product using the appropriate technology to meet that need. Other scenarios are given such as technology push but this situation best describes most development activities at Furnware. There is a heavy influence on tooling, production process design and testing of alpha and beta prototypes in this process. Furnware usually do not require large tooling costs in the development of new products so they do not need to place so much emphasis on production processes as there is in the process outlined by Ulrich and Eppinger (2000).

3.3.6 Outcomes

Of the three processes identified, Cooper's Stage-Gate™ process best suites Furnware's needs (Table 3-2). Cooper's process will therefore form the basis of Furnware's product development process, outlined in Section 3.3.7 below. Using Cooper's process will provide structure to the product development process. Those activities that currently work well at Furnware will be integrated into this process and where further refinements are necessary, Cooper's methods will be used.

Table 3-2 Product Development Process Evaluations

Criteria	Product Development Processes		
	Cooper	**Earle**	**Ulrich and Eppinger**
Suitable for furniture industry	8	3	6
Suitable for small manufacturing company	8	6	3
Includes strategy function	7	8	6
Includes decision points	9	9	7
Top management involvement	9	9	5
Planned improvement over time	9	5	5
TOTALS	**50**	40	32

3.3.7 Part 4: Revised Process

The revised process is split up into the respective stages and a description, aim, tasks and output are provided for each step of the process.

3.3.7.1 Stage 0: Management Planning

3.3.7.1.1 Strategy

Description:

This stage provides direction to all product development activities. It ensures all activities are aligned with the company's business strategy. This is the first part of Stage 0, which is not a part of the individual product development project per se. Activities in this stage are completed before a product development project is begun.

Aim:

To guide product development activities and ensure they are aligned to the company's business strategy

Tasks:

- ➢ Preparation of Product Strategy document.
- ➢ Periodic review of document.

Output:

Product Strategy document.

3.3.7.1.2 Ideation

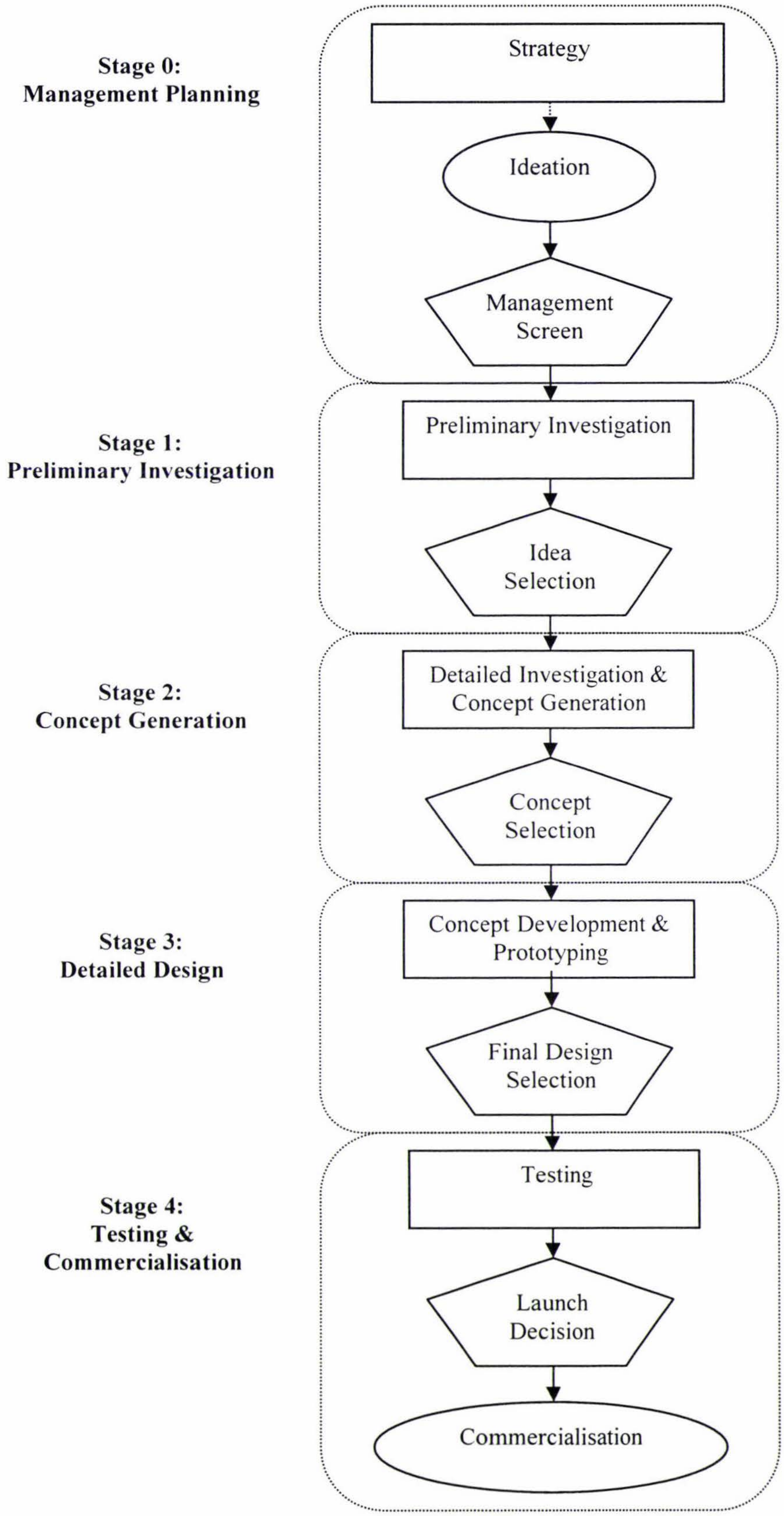
Description:

The current ideation process at Furnware is working well. The number of projects currently contracted out by Furnware is evidence of this. Furnware are consistently sponsoring at least one project per annum at Massey University and are conducting their own product improvement projects as required (approximately 20 per annum). This stage will therefore remain unchanged. Ideation involves the collection of new product ideas ready for review.

Aim:

To source ideas for new products.

Figure 3-13 Revised Product Development Process



Tasks:

- ➢ Attend furniture conferences.
- ➢ Research overseas products.
- ➢ Brainstorming sessions with top management and sales representatives.
- ➢ Review one-off designs for potential standard products.

Output:

Summary of all ideas discovered.

3.3.7.1.3 Idea Screen

Description:

Furnware staff including sales representatives, managing director, senior manufacturing staff and occasionally the CAM programmer meet to discuss business issues. One of these issues is the development potential of new product ideas. These ideas are tabled and discussed openly on their potential sales and potential problems. If a particular idea is agreed to have merit, it will pass onto the next stage of development. A project champion is also selected to guide the product development process.

Aim:

To screen ideas down to 1-3 identified with the most potential.

Tasks:

- ➢ Table and discuss ideas.
- ➢ Review past ideas.
- ➢ Table any problems with current products.
- ➢ Decide if any new ideas warrant further investigation using structured decision criteria table.

Output:

Decision to investigate 1-3 ideas for potential.

3.3.7.2 Stage 1: Preliminary Investigation

3.3.7.2.1 Preliminary Investigation

Description:

More detailed information relating to the selected ideas is obtained. All the information required to make an informed decision as to which idea has the most potential must be gathered. Due to the small size of Furnware and limited resources, only one idea may pass into the next stage at one time.

Aim:

To obtain enough information about the ideas to make an informed decision about which has the greatest potential.

Tasks:

- Research estimated market size.
- Determine production feasibility.
- Identify consumer need.

Output:

Report of findings for each product idea.

3.3.7.2.2 Idea Selection

Description:

A meeting is held by top management to decide whether or not to continue with one of the product ideas. The information gathered during the preliminary investigation is reviewed and a decision made. If a go ahead decision is made, this represents significant commitment to the product development project by top management.

Aim:

To select one product idea for further development.

Tasks:

- Compare all ideas to each other.
- Compare ideas to product strategy.
- Determine which, if any should be developed using a structured, weighted screening matrix (more formal than initial screening stage).

Output:

One idea is chosen for development. Only one project may be worked on at a time. The number of projects carried out per year is dependent on the size of the projects. Typically only one major new product development project will be done per annum, product improvements are more numerous (approximately 20 per annum).

3.3.7.3 Stage 2: Concept Generation

3.3.7.3.1 Detailed Investigation

Description:

This is the start of the detailed development of an idea. All information relating to the chosen area needs to be gathered here. The information gathered in Stage 1 forms the starting point for this. Information is usually grouped into market, product and consumer categories.

Aim:

To gather all the background information necessary to understand the entire product idea or consumer need. To begin forming concepts that address these needs.

Tasks:

- Target Market definition.
- Competitor product analysis.
- Patent search.
- Consumer needs survey.
- Initial product specification development.

Output:

Detailed information relating to the selected product area.

3.3.7.3.2 Concept Generation

Description:

Concepts are generated by reviewing the gathered information and combining ideas to the identified consumer needs into one, complete product concept. Ideas for product concepts usually begin forming during the investigation process and the detailed investigation and concept generation stages can overlap considerably.

Aim:

To begin forming concepts that address identified consumer needs.

Tasks:

- Structured concept generation method followed in the generation of concepts.
- Concepts developed.
- Screening of concepts to approximately 10.

Output:

Approximately 10 selected concepts.

3.3.7.3.3 Concept Selection

Description:

The concepts must be screened to identify those considered most promising from a customer and company perspective. 1-3 concepts will be selected for further development; screening concepts against the identified needs of the customer and the manufacturing potential of the company can be used to do this.

Aim:

To select 1-3 of the best concepts.

Tasks:

- Appropriate screening criteria determined.
- Screening done.
- Management review screening and decide whether or not to continue further development of selected concepts.

Output:

1-3 concepts selected for further development.

3.3.7.4 Stage 3: Detailed Design

3.3.7.4.1 Concept Development and Prototyping

Description:

This stage concentrates on developing the chosen concepts into finished products. All the finer details of the design must be resolved in this stage. Prototypes are used extensively to resolve problems and ensure the product concept meets the customer needs and is able to be manufactured.

Aim:

To develop at least one product concept into a complete, product design. To produce a prototype of this concept.

Tasks:

- Initial prototyping to resolve any parts of the designs.
- Focussed problem solving, cost reduction idea development, manufacturing issues.
- Production of final prototype.

Output:

Draft of manufacturing plan.

Complete prototype of final design.

3.3.7.4.2 Final Design Selection

Description:

Top management reviews the concept development stage and accepts or rejects the proposed final design. This selection ensures that a product idea has been sufficiently developed before resources are spent on testing and evaluation.

Aim:

To decide if the design is acceptable.

Tasks:

- Review of concept generation details.
- Decision on final design fit with company strategy.

Output:

Go-No-Go decision on final design.

3.3.7.5 Stage 4: Testing

3.3.7.5.1 Testing

Description:

The finalised design is tested for consumer appeal and for physical performance. Before a product design is launched all facets of the design need to be checked. Some further development work may be required in this stage, depending on the results of the testing.

Aim:

To ensure the product design is correct.

Tasks:

- Consumer needs testing.
- Consumer appeal testing.
- Physical testing.
- Minor development activities.
- Financial analysis and consumer feedback on estimated price.

Output:

Final design ready for launch.

3.3.7.5.2 Launch Decision

Description:

Top management must decide whether or not the developed product should be released into the market. For Furnware, this is not as important a decision as most companies. This is because the initial start-up costs in Furniture production are usually low and decision to launch does not indicate a large commitment of funding to the project. The product design must be safe and of high quality so that its launch does not have a negative effect on Furnware's brand image.

Aim:

To decide whether or not to launch the new product.

Tasks:

- Analyse the test results.
- Check product alignment with product strategy.

Output:

Go-No-go decision on new product launch.

3.3.7.5.3 Commercialisation

Description:

This stage deals with all of the activities involved in launching a new product. These can be divided into three main areas: marketing, finance and manufacturing. Launch activities and support marketing and promotional material needs to be organised. Final analysis of costing, price and financial risk need to be checked. All manufacturing details must be finalised and sub-contractors sought for any new component parts.

Aim:

To launch a successful new product on to the market.

Tasks:

- Marketing plan.
- Manufacturing plan.
- Financial plan.

Output:

Product and all support functions ready for launch.

3.3.8 Outcomes

Cooper's Stage-Gate™ process was used to provide a suitable structure to a revised product development process for Furnware. The aspects of current product development activities Furnware that are working well were incorporated where suitable. In particular the use of current ideation activities and commercialisation activities were used. The remainder of the process uses techniques and activities suggested by Cooper. This process will now be used to develop the Mobile Technology Education Workstation.

3.4 Summary

By analysing the current product development activities at Furnware and comparing them to identified best practices two areas of improvement were identified. The first was the use of a structured product development process and the second was the use of engineering tools such as CAD technology. Research into CAD technology is outlined in Chapter 9. The development of a structured product development process suitable for Furnware is described in this chapter. Using Cooper's Stage-Gate™ process as a guideline, a new process was developed by incorporating the best of both Furnware's current activities and Cooper's principles. This process will now be used to develop a Mobile Technology Education Workstation. The details of which are outlined in the following chapters. Stage 0: Management Planning is not included here because top management completed this stage before the Mobile Technology Education Workstation project was started.

4 Stage 1: Preliminary Investigation

4.1 Introduction

The purpose of this chapter is to summarise the gathering of information on the three product ideas that were selected by top management at Furnware. This information will be used to select one idea for further development. This research project started with a very broad product brief that covered three possible areas of development: a mobile workstation relating to: technology curriculum, computer usage in schools and audio-visual equipment. The first task undertaken in this project was to refine this brief to a more manageable, focussed brief.

4.2 Methodology

At this stage of the product development process, sufficient information needed to be gathered so that an informed decision could be made as to which product idea is best, while managing time requirements and resources. Concept generation requires detailed and focussed information on the area selected for development. Provided below is a description of the activities carried out to obtain information about the three areas.

4.2.1 Technology Curriculum

- Research government information on the new technology curriculum.
- Visited schools to determine what the new mobile workstation must do.
- Researched existing products in the market.
- Combined results of secondary data and own research to determine level of need for a new product in this area.

4.2.2 Computer Usage in Schools

- Researched the current government literature on computer usage.
- Conducted interviews with nation-wide suppliers of computers to New Zealand schools.
- Visited schools to determine the current need for a mobile workstation.

4.2.3 Audio Visual Equipment

- Researched suppliers of audio visual equipment to New Zealand schools.

4.2.4 Decision

- Compare market size and product need.
- Consult with top management to ensure proposed project is acceptable and fits with corporate strategy.

4.3 Results

4.3.1 Technology Curriculum Mobile Workstation

A review of the literature relating to the Technology Curriculum is provided in Chapter 2. The curriculum has only been recently introduced into New Zealand primary schools and is yet to be fully introduced into secondary schools. Consequently there are few products in the marketplace that currently provide resources for this curriculum. This was the area identified with the most potential for new product development. The main reasons for this were:

1. The curriculum is new in New Zealand and currently under-resourced.
2. Primary schools have never had to teach practical work like this before.
3. There are few competitors in the New Zealand market at present.

Refer to Chapter 2 for detailed information regarding the Technology Curriculum in New Zealand schools.

4.3.2 Computer Related Mobile Workstation

The need for a mobile workstation that transports computers was investigated. Refer to Chapter 2 for a review of government statistics on computer usage in New Zealand schools. A future need for a laptop computer workstation was identified in the research. The number of schools currently using laptops is not high enough to warrant the development of a product targeting this area yet. The total market size is estimated at 10% of private schools in New Zealand. There is future potential for a product of this sort as more schools move towards the use of laptops in the future.

4.3.2.1 Computer Suppliers

Suppliers of computers to schools tend to be any of the local suppliers in the area of a particular school. These suppliers purchase computers from the distributor warehouses; two of these distributors were interviewed to determine trends in the use of computer technology in New Zealand schools. Given below is a summary of their comments.

4.3.2.1.1 Compaq

The future of Local Area Networking (LAN) systems is wireless technology. This is a new technology that enables computers to be connected to a local network without the use of a wire (phone line) connection. Several schools have already implemented this new technology, which does currently have some restrictions and is currently more costly than cabling alternatives, but will improve progressively in the future. The use of wireless technologies to network computers within the school will be the best way from both a cost and convenience point of view within the next few years.

Computer hardware is generally becoming smaller and faster. Other developments include a computer which uses a standard port (USB) for all interfaces between the hard drive and other peripheral devices such as DVD-ROM drives to eliminate the need for several different connection slots and software.

4.3.2.1.2 Apple

Apple now have the capability of running a portable computer (iBook) for a period of 6 hours by battery due to increased efficiency and improved battery technology. This power ability, combined with the wireless network technology mean that, provided the funds are available, students are able to work on notebook computers in the classroom and take them with them between classrooms without the need for any internal cabling or computer suites. They also have the ability to take them home to complete homework assignments.

4.3.3 School Visits

School visits were conducted to gather information relating to both the Technology Curriculum and the use of computers in schools. The primary objective being to determine in which area the greatest need existed for a new product. Primary, intermediate and secondary schools were visited, as were both state and private schools. These schools were in different parts of New Zealand including Auckland, Bay of

Plenty and Hawkes Bay were visited. Given below is a review of the visits to some of the schools along with some photos of the schools (Figure 4-14). The reviews are given to indicate the varied methods of applying the Technology Curriculum as well as different uses of computers.

4.3.3.1 Te Kura ki Papamoa Primary School

This is a new primary school located near Tauranga. The school is completely networked and has two PCs per classroom plus a laptop for each teacher and a computer suite located in the library. This school has designated areas for conducting painting and other messy tasks (Figure 4-14b), but has yet to devote resources targeting the Technology Curriculum specifically. Typical resources used for teaching the Technology Curriculum are currently stored on standard desks and other mobile units (Figure 4-14a).

4.3.3.2 Mayfair Primary School

Mayfair School is located in Hastings; it is a well-established school. It has recently set up a purpose-built technology room. Facilities include: 4 kitchens which are fully equipped with accessories such as pots and pans etc, as well as access to electrical appliances and woodworking/materials tables and equipment. The room has been designed with a bare central area to allow for group activities to be conducted in the room.

4.3.3.3 Havelock North High School

Have recently constructed several general-purpose technology classrooms to accompany the existing technical areas such as workshops and textiles rooms. These rooms provide heat resistant working surfaces, general-purpose tables, power sockets and have access to both a storage and light machinery room. The light machinery room has vices, drills, vacuum former, band saw and other equipment. Technology is taught as a stand-alone subject and as such is taught in 50-minute intervals, for this reason technology resources need to be set up in a room prior to the class. Ideally, these classrooms would be located close to the other technical rooms, because these rooms were renovations of existing classrooms, they are located some distance from the other technical rooms.

4.3.3.4 Havelock North Intermediate School

This school has re-organised its existing technical rooms into rooms that concentrate on the different areas of the Technology Curriculum. There is a biotechnology and food room for example, as well as rooms set aside for working with different materials.

4.3.3.5 Manurewa High School

This school has integrated the Technology Curriculum into other areas such as science, mathematics, text management and economics. The school has a large number of computers that are located in six suites (Figure 4-14c) as well as inside individual classrooms. Some computers are located on trolleys and can be wheeled between classrooms within the different buildings.

Figure 4-14 Images of Computer Use and Technology Equipment in NZ Schools

a) Te Akau ki Papamoa: Resources

b) Te Akau ki Papamoa: Wet Area

c) Manurewa High School: Computer Suite

d) Rangitoto College: Materials Technology

4.3.4 Audio Visual Equipment Mobile Workstation

The development of an audiovisual mobile workstation was also suggested in the original proposal. Upon researching this market, a major supplier was found and the potential for sales estimated to be minimal. This supplier also deals closely with Furnware and to develop a competing product would not be in the best interests of this relationship.

Sitech Systems

Leading supplier of audio-visual and sound equipment to schools nation-wide. Equipment items supplied include digital cameras, TV sets, video players, projectors, radios, headphones, and overhead projectors. Sitech also manufactures trolleys for televisions, videos, sound systems and projectors. Discussions with several schoolteachers found that the trolleys supplied by Sitech satisfied their needs (Swale, 2000; Schollum, 2000; Lightford, 2000).

4.4 Outcomes

The main findings from this initial research were:

- A workstation concentrating on the practical component of the Technology Curriculum has the greatest need.
- The curriculum is relatively new to New Zealand schools. A formal curriculum document and qualifications framework has yet to be set up for senior school children.
- It is compulsory for primary schools to teach the Technology Curriculum.
- Teaching the knowledge and societal issues in technology can be conducted using existing classroom resources.
- Teaching technical skills is new to primary schools and there is a need for more resourcing in this area.
- Computer usage in schools has nearly reached saturation, although the ratio of children to computers is still decreasing.
- Computers currently in use tend to be desktop models and difficult to transport.
- The use of laptop computers is increasing and there is a potential need for a desk that caters for this market in the future.

- Mobile units for audio-visual equipment are already being produced to schools' satisfaction.

From the initial research carried out, a more refined project brief was then decided upon. The research yielded several product concepts that could be developed and provide a positive return to Furnware. Upon consultation with Furnware management it was decided to develop a product concentrating on the Technology Curriculum in New Zealand Primary Schools.

4.4.1 Project Brief

The refined product brief is:

To design and develop a Mobile Technology Education Workstation that will assist in the practical component of technology education in primary schools in New Zealand. The workstation will attempt to cover all the areas of the Technology Curriculum. If this is not feasible, a family of workstations will be developed. The unit will provide both storage and working surfaces suitable for conducting typical practical technology education activities.

4.5 Summary

This chapter summarised Stage 1: Preliminary Investigation of the Mobile Technology Education Workstation project. The aim of this chapter was to present the findings from research into the three possible project areas given in the initial proposal. The three areas were: a technology education workstation, a computer mobile workstation and an audio-visual mobile workstation. The idea that had the most potential was the technology education workstation. A product brief is provided that focuses the following work on this area. In particular a workstation that provides both storage of tools and work surfaces for completing practical tasks will be developed. The following chapter outlines Stage 2: Concept Generation of the Mobile Technology Education Workstation project.

5 Stage 2: Concept Generation

5.1 Introduction

The purpose of this chapter is to summarise Stage 2: Concept Generation of the Mobile Technology Education Workstation project. It covers two main areas: detailed investigation and concept generation. The detailed investigation summarises findings from research conducted into the consumer, product and market factors that relate to the product area. A five-stage process (Ulrich & Eppinger, 2000) is used to generate concepts that address the identified needs of the customer and market. This stage concludes with the systematic screening of concepts using a concept-rating table that directly tests concepts against the identified consumer needs. The two most promising concepts are taken through into the next stage of development, Detailed Design.

5.2 Detailed Investigation

5.2.1 Market Analysis

5.2.1.1 Aim

To gather all relevant market information relating to this product area, in particular the market size, trends and competition.

5.2.1.2 Methodologies

5.2.1.2.1 Market Statistics

Internet search

The government education website: http://www.minedu.govt.org.nz has statistics available relating to primary schools in New Zealand. This site was used to collect relevant data relating to this product area.

5.2.1.2.2 Competitor Product Research

Patent search for existing products and product ideas

Patents relating to this product area were searched for by using the search website developed by IBM for searching patents (http://www.patents.ibm.com/). Key word searches using words relating to this product area were undertaken.

School visits

During school visits aimed at refining the product brief, several competitor products were discovered. The schools that had these units were questioned about their advantages and disadvantages. A video of a classroom session was also done to research the advantages and disadvantages of the main competitor unit.

Internet search

An Internet search was conducted to gather information relating to overseas products. These products are not considered potential competitor products but sources of ideas for the development of the Mobile Technology Education Workstation.

5.2.1.2.3 Specific Product Requirements

Conduct interviews with key users and experts

The consumers that will use the Mobile Technology Education Workstation are not necessarily the best people to discuss the needs of the product with, considering the relative newness of the Technology Curriculum. Four interviews were held with academic staff at Massey University and Auckland College of Education. These interviews were recorded using a Dictaphone and reviewed at a later date to ensure no important information was missed. The names of those interviewed are confidential. All were involved in either technology teacher training or the development of the Technology Curriculum or supporting government documents.

5.2.1.2.4 Assessing the Advantages and Disadvantages of Competitor Products and Existing Products

Video of unit in use at primary school

During the initial school visits a number of technology units and other various methods of storing equipment were found. Most of these products have been made by the school using them. There is one major competitor product currently being sold in New Zealand, the Wholesale Learning Technology (WLT) trolley. This trolley was analysed for its strengths and weaknesses by filming a class using the trolley. The results of this analysis are given below in Section 5.2.1.3.2.

Perceived Advantages and Disadvantages

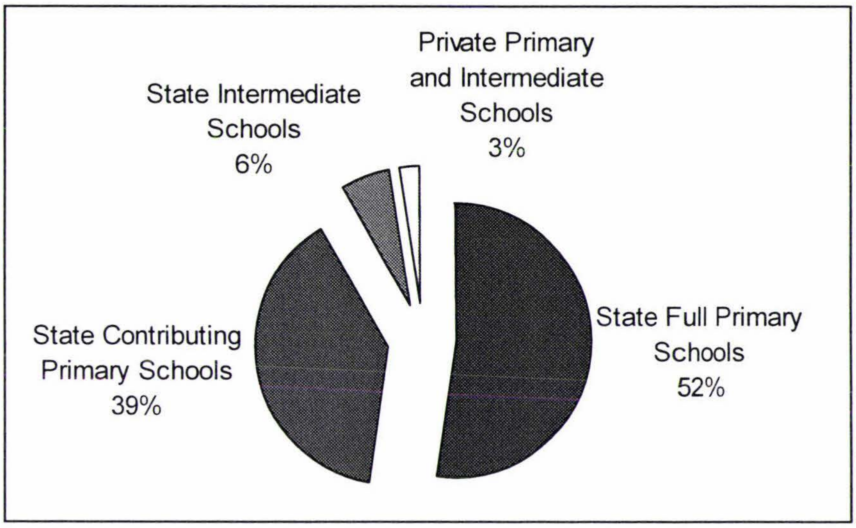
The perceived advantages and disadvantages of the existing products, detailed in Section 5.2.1.3.3, were developed by comparing the workstations against the needs of the consumer.

5.2.1.3 Results

5.2.1.3.1 Market Background

There are approximately 2300 primary and intermediate schools in New Zealand with a total of about 448 000 students attending these schools. Given below in Figure 5-15 are the proportions of primary and intermediate schools in New Zealand for the year of 1997.

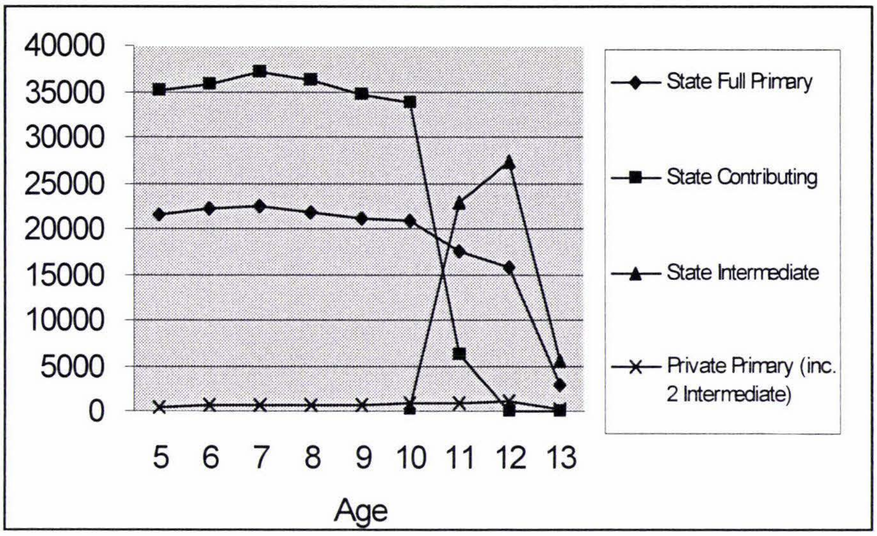
Figure 5-15 Types of Intermediate and Primary Schools in New Zealand: 1997



(Source: New Zealand Ministry of Education)

A State Contributing school is a school that only teaches students up to Year 6 (10 Years Old). A Full Primary school caters to students up to Year 8 (12 Years Old). Given below is a breakdown of the ages of the students attending these schools.

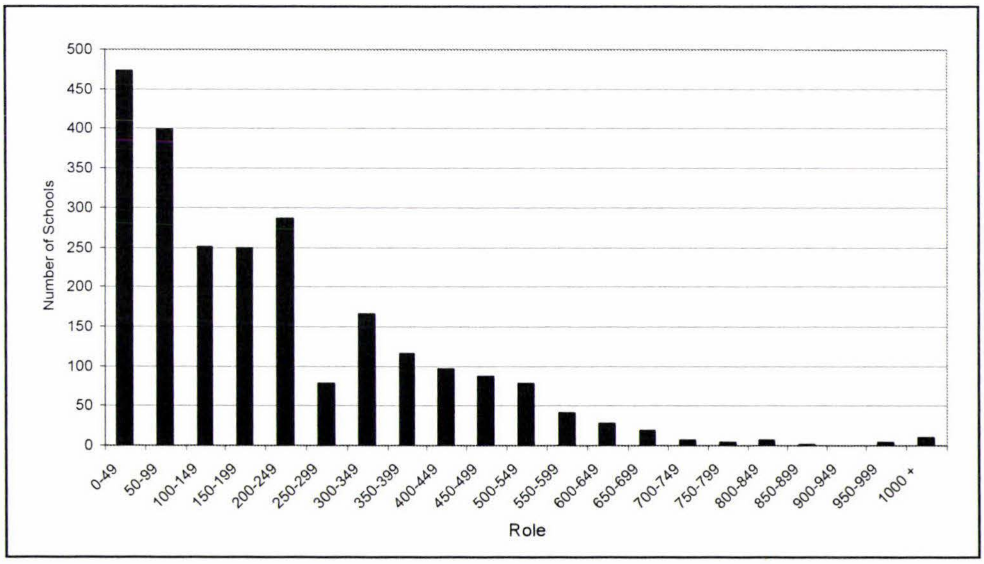
Figure 5-16 Ages of Children in Primary Schools: 1997



(Source: New Zealand Ministry of Education)

Government spending on education has remained relatively constant over the past seven years at approximately 16.5% of government spending.

Figure 5-17 School Rolls of New Zealand Schools: 1998



(Source: New Zealand Ministry of Education)

5.2.1.3.2 Competitor Analysis

This particular market is relatively new due to the recent introduction of the Technology Curriculum into primary schools. There are only a few competitor products currently in New Zealand. Provided in this section are: current New Zealand products, international products and privately made products that are designed to perform a similar task to that of the proposed mobile workstation.

Wholesale Learning Technologies – Work Bench Trolley

The trolley shown below is the only identified commercial product currently available in New Zealand. The trolley focuses on Materials technology, woodwork in particular. Refer to Section 5.2.1.2.4 to view the method by which this analysis was carried out. Product features include:

- Reversible work surface.
- Choice of two heights of trolleys.
- Bulk materials storage (620 mm in length).
- Wheel upgrade option available from castor to industrial wheels.
- Price: Standard unsealed - $495.00.
- Poly Sealed finish - $559.00.

Figure 5-18 Wholesale Learning Technology Trolley

(Source: WLT Product Brochure, 2000)

Advantages

This unit provides storage and a practical work surface for students to work on; it is reasonably priced and has some optional extras. The video taken of this unit being used in a classroom environment showed it worked well.

Disadvantages

Does not consider any of the other technology areas such as Food, Biotechnology or Electronics and Control. Castors are plastic, limiting mobility around the school. Storage of tools in tote trays creates potential for children to cut themselves. Tote trays are easily accessible to children and the contents cannot be locked away.

5.2.1.3.3 Existing Products

This section provides information on products and solutions that are related to technology education in primary schools but are not considered competitors in the marketplace. These products are either solutions that people have made up themselves or are products available in the overseas marketplace only. The purpose of including them is to help provide ideas for concepts during the next stage of development: concept generation.

<u>Hillcrest School Pahiatua</u>

Hillcrest has a specifically designed room to cater for a number of rural schools that do not have the facilities available to teach the Technology Curriculum. They have also developed mobile 'suitcases' for transporting tools to schools where it is not feasible for the students to travel to the technology rooms.

Perceived Advantages

Easy to transport and carry into any room, simple and provides the majority of tools required for Materials Technology.

Figure 5-19 Mobile Suitcases: Hillcrest School, Pahiatua

Perceived Disadvantages

Included are surfaces for doing basic sawing but nothing else, does not provide storage of consumables. Does not cater for the other areas of the Technology Curriculum.

<u>Auckland College of Education</u>

Auckland College of Education has made units to store resources used to educate student teachers. Provided below are several of these units. They are used to store the resources for all of the technology resources for teaching typical projects to students of all ages from Year 1 up to Year 8.

Figure 5-20 Auckland College of Education Mobile Units

Perceived Advantages

Auckland College of Education have produced multiple units, each concentrating on different areas of the curriculum. Non-food related units are mobile.

Perceived Disadvantages

The Food technology workstations are not designed to be moved from room to room due to their large size and weight. Storage of equipment on trolleys is messy. The perspex unit (top left), while aesthetically pleasing, is costly to manufacture. Likewise the stainless steel unit pictured on the top right is also expensive.

<u>Technology Rooms</u>

Another 'product' to consider is the technology room. Several examples of this are provided below in Figure 5-21. These rooms are specifically designed to supply all the equipment, tools, consumables and work surfaces that are required for the Technology Curriculum.

Figure 5-21 Technology Room Examples

Perceived Advantages

All the equipment and consumables can be stored in one place. The room can be set up with proper surfaces to work on. Tools can have set places and can be put away tidily.

Perceived Disadvantages

A limited number of students may work in the room at any one time, causing problems if more than one class wants to use the space at the same time. Preparing food and cutting up materials such as steel and wood in the same room can cause health problems. The cost of setting up a technology room is outside the current budget of many primary schools in New Zealand.

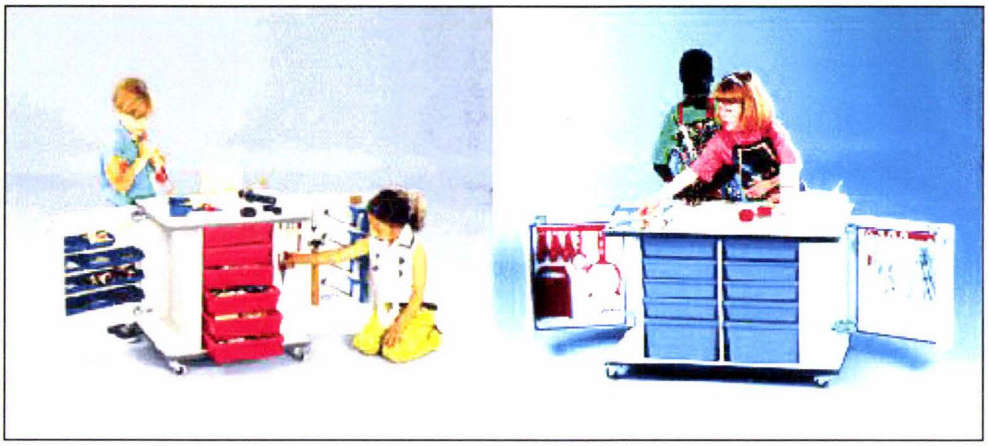
The Heron Truck System

This is an English product specifically designed for the UK market. This product could not be viewed personally, as they are only currently available in the UK. The claimed product features and images obtained from the Internet are provided below.

Product features include:

- Safe, hygienic storage options.
- Small well-designed utensils.
- Heron provide a product range that cater to the various technology areas.
- Come empty or complete with utensils and cookers.
- Units pack flat to reduce shipping costs.

Figure 5-22 Heron Technology Units



(Source: http://www.heron-educational.co.uk/)

5.2.1.4 Outcomes

The total estimated market size for this product is 2300 New Zealand schools. Each school is likely to need more than one workstation (for each of the technology areas). This is a new market area due to the recent introduction of the Technology Curriculum into New Zealand primary schools. Consequently there is currently only one major retail competitor currently in the market. There is however a lot of examples of products being made by schools and colleges of education to store the equipment needed to teach the practical component of the Technology Curriculum. An analysis of the advantages and disadvantages of the competitor products was undertaken and the information will be used to ensure the workstations designed perform better than the competition.

5.2.2 Consumer Analysis

5.2.2.1 Aim

To gather all relevant consumer information relating to this product area, in particular buyer behaviour, market segmentation and target market analysis.

5.2.2.2 Methodologies

5.2.2.2.1 Buying Behaviour of Market and Market Segmentation

- Interviews were conducted with principals.

Four school principals were approached and questioned about the method by which furniture is usually purchased within their schools.

- Interviewed with sales manager of Furnware.

  Furnware's sales manger has extensive experience in dealing with schools nation-wide and confirmed the findings from the informal interviews with several principals.

5.2.2.2.2 Target Market Analysis

- Interviewed principals from a number of schools that are different in the various categories such as size, decile rating and location in New Zealand.
- Discussed possible segments of the primary school market with sales manager who has extensive experience in dealing with this market.
- Analysed the quantitative survey conducted for trends in different school categories. For example, separate the data into groups of schools that have similar decile ratings and determine whether or not there are any differences in needs.

5.2.2.3 Results

This section outlines the relevant information relating to the consumer. The consumer for the Mobile Technology Education Workstation is primary schools in New Zealand. Factors that affect the purchase of furniture by these schools is discussed and a specific target market outlined.

5.2.2.3.1 Buyer Behaviour

Selling products to schools is different to selling through normal retail methods. This section will provide a brief outline of the typical buying processes that occur in this particular market.

Large Primary Schools (School role of approximately 100 students or more).

Large primary schools generally prepare an annual budget of all the expected expenditure in the following year. The individual teaching departments such as Physical Education, Mathematics, and Technology etc apply for a certain amount of this budget and the Board of Trustees then approves it. The school Principal and department staff then have varying degrees of influence over the spending of this funding. Some principals may wish to be notified of all spending while others may entrust staff to spend the funding as they see fit. Capital expenditure on land and buildings is also included in the budget but remains the concern of the Board of Trustees only. Funds allocated to the different departments have restrictions placed on it. Only one third of the money can be spent up to 1 April of any year, likewise, a second third is only available for spending until 30 June, at which time the final third becomes available. There is usually a budgeted amount of funding set aside for unforeseen expenditures. To obtain this money a department must table a proposition at a Board of Trustees meeting along with two quotes for the cost of the intended spending.

Small Primary Schools.

Due to the size of these schools, funding is much more limited. As a result, the Board of Trustees as well as the Principal makes the majority of the spending decisions. The spending process is basically the same as it is for larger schools except for the above differences Figure 5-17 above is a graph of the school rolls of primary schools in New Zealand.

5.2.2.4 Target Market

To ensure the needs of this market are met, an analysis of the market was completed. The purpose of this analysis was to determine if there was a particular segment of the market this product would be targeting, and if so, what aspects make it different. The results of the quantitative survey, informal interviews with both school principals and Furnware's sales manager showed that the main factor when determining needs was the size of the school.

5.2.2.4.1 Size of the school

The size of a school does appear to have an impact on the need for a Mobile Technology Education Workstation mainly due to the amount of funding received from the government. Schools with less than approximately 100 students have a limited amount of funding to spend on resources. This workstations is expected to be used by multiple classrooms and if a school does not have the students to fill more than one or two classrooms then the expenditure for that school is higher than that of larger schools. This trolley could, potentially be used to service several schools in one area and be used for parts of the year at each of the schools. This usage method has been identified as possible but potentially very difficult to cater for. The workstation design will therefore focus on schools large enough to purchase at least one workstation for themselves. The very large schools are expected to have enough funds to provide buildings or rooms dedicated to technology education and therefore will not form a part of the specific target market although some large schools could be interested in such a product. The size of schools to be targeted will therefore have schools rolls of between 100 and 250 students (approximately 800 schools, refer to Figure 5-17).

Other segment categories that were investigated to see if they had any differences in needs included Decile rating, Urban vs Rural schools, Full vs Contributing Primary Schools. Upon analysis there was no discernible difference between the different categories.

5.2.2.5 Outcomes: Target Market

From the above analysis the refined target market is as follows:

All primary schools in New Zealand with school rolls ranging from approximately 100 to 250 students that teach up to Year 6. The estimated market size is 800 schools, nation-wide. This comprises approximately one third of the total primary school market. Additional sales are expected from schools outside this market, but for the purposes of development of the product, it will endeavour to meet the needs of the market defined above.

5.2.3 Product Analysis

5.2.3.1 Aim

To gather all relevant product information relating to this product area. In particular, which technology areas require resources, what are the typical resources used for each technology area and in what environment are the resources likely to be used.

5.2.3.2 Methodologies

5.2.3.2.1 Quantitative Survey

A quantitative survey of New Zealand primary schools was used to determine the tools and equipment used for teaching the practical component of the Technology Curriculum. A free Internet survey service called inetsurvey (www.inetsurvey.com) was used to develop the survey. The survey was sent to 200 principals throughout New Zealand by email. To ensure a representative sample of New Zealand primary schools was selected, the sample of 200 was taken randomly from a list of schools throughout

New Zealand. A prize of one gas lift chair was awarded to the first participant that responded promptly to help improve response rate. Some initial feedback on the concept idea as well as resource requirements and priorities was requested. Please refer to Appendix A for a copy of the survey.

5.2.3.2.2 School Environment Study

During the school visits pictures were taken of typical school surroundings, including outdoor terrain, corridor and door configurations.

5.2.3.2.3 Target Specifications

Target specifications are the product characteristics converted into measurable units. The purpose of doing this conversion is to enable concepts to be evaluated according to measurable criteria. Provided below is an explanation of the table column headings. The results of the conversion of initial product characteristics into metrics are provided in Table 5.1.

Metric Number (Metric No.)

The metric number column is simply a reference number of the individual metrics.

Need Number (Need No.)

The need number correlates to the list of initial product characteristics given in Section 5.2.3.3.8.

Metric

The metric column of the table describes the measurement method.

Importance (Import.)

Rates on a scale of 1 to 5, the importance of the particular need. 1 being very important and 5 being not very important. These ratings will be useful when trading off between needs during concept screening.

Units

Details the units to be used to measure the metric.

Marginal Value

The acceptable range within which a concept may lie. The value '10-15 children working' relates to the number of tools required for 10-15 children to work at once.

Ideal Value

The target or ideal value. The value the product design should attempt to attain if possible.

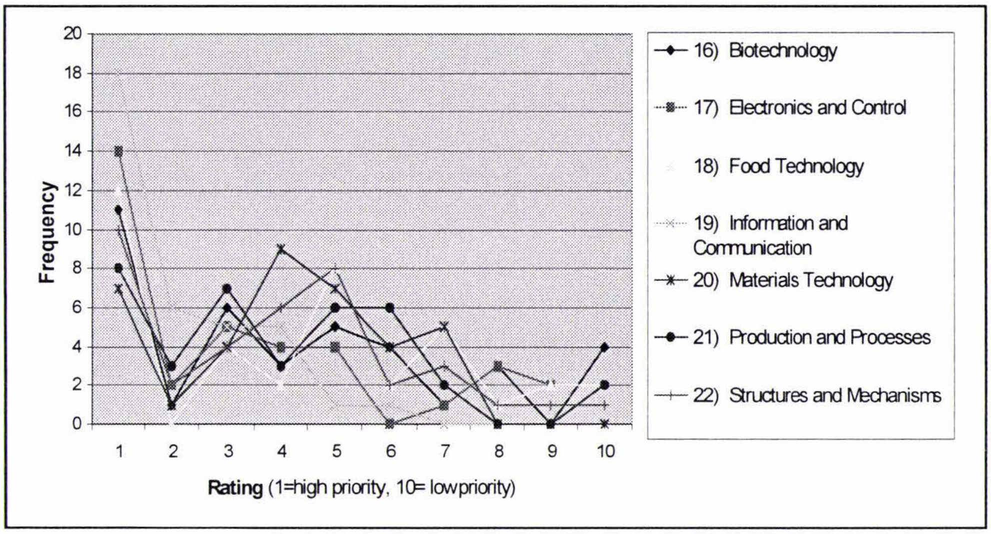
5.2.3.3 Results

Information relating specifically to the product characteristics is presented in this section. In particular, what the unit is expected to store, which areas of the Technology Curriculum are taught in primary schools and in what environment the product will be used. The initial trips to schools around New Zealand combined with the questionnaire were used to determine the most popular resources to be included on the trolley. Provided below are the results of questionnaire and school visits.

5.2.3.3.1 Priorities of Technology Areas

- 86% of respondents to the survey claimed that a product of this nature would be beneficial to their school.
- The technology areas of highest priority were, in order from highest to lowest:
    1. Information and Communication technology.
    2. Electronics and Control technology.
    3. Food technology.
- The technology areas that required the most resources over the next two years were, in order from highest to:
    1. Information and Communication technology.
    2. Electronics and Control technology.
    3. Food technology and Biotechnology equal.
- The resources used for Information and Communication technology are usually used throughout the school and so would not require a mobile workstation to store them.
- Participants selected the individual resources required for each technology area and the results were collated to determine which resources were most required.
- Resources for Materials technology, Structures and Mechanisms technology and Production and Process technology are similar and could potentially fit onto one workstation.
- Food technology and Biotechnology require similar resources and so could be put on one workstation, provided there were no health and safety issues.

Figure 5-23 Resource Priorities for the Different Technology Areas



5.2.3.3.2 Resource Requirements for Technology Areas

There are seven areas in the Technology Curriculum. To design units for all of these is a very large task. After investigating technology in schools the following areas of the curriculum will be concentrated on Electronics and Control, Food, Materials and Structures and Mechanisms. These areas are currently being taught in the majority of cases and are the areas identified as requiring storage for the equipment required to teach the practical component of the curriculum. Information and Communication has been identified, as an area that is widely taught but the resources are required and placed throughout the school and do not require a mobile storage workstation.

Provided below are lists of typical equipment used for teaching the practical component of the Technology Curriculum. Developing storage methods for this equipment forms a major section of the concept generation stage and is outlined fully later in this chapter.

5.2.3.3.3 Food Technology

Chopping boards, large bowls, small bowls, sharp knives, measuring spoon set, measuring cups, spatulas, wooden spoons, pots, sieves, potato peelers, graters, aprons, microwave, hotplate, oven, dirty dishes, water, table cloths, plates, bowls, egg beaters, electric jug.

5.2.3.3.4 Materials Technology

Hand drills, handsaws, glue guns, sewing machine, vices, drill bits, bench hooks, hammers, pliers, screwdrivers, reamers, files, shears, G clamps,

5.2.3.3.5 Structures and Mechanisms

Craft knife, glue gun, cutting mats, Lego technic, gears, pins, safety rulers.

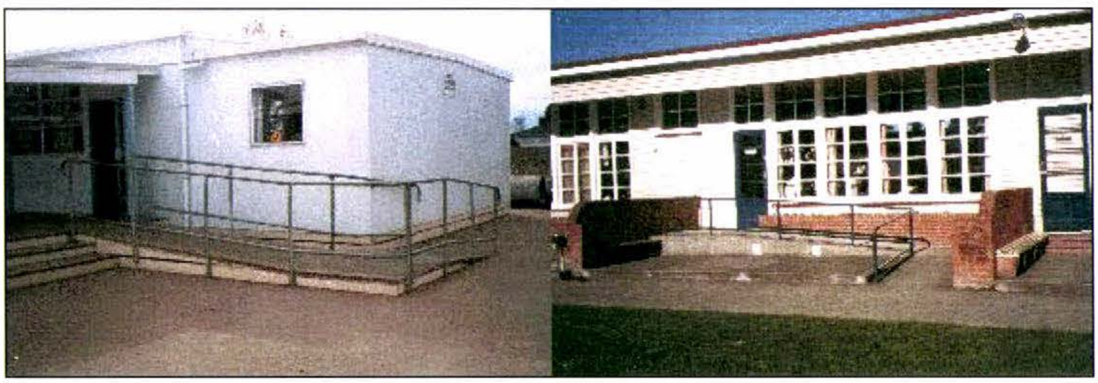
5.2.3.3.6 Electronics and Control

Batteries, wires, light bulbs, switches, pliers, screwdrivers, motors, wire connectors, resistors, diodes, wire strippers, soldering irons, solder, circuit boards, speakers, Lego dacta.

5.2.3.3.7 School Environment

Environmental factors are those factors relating to the products intended usage environment. The Mobile Technology Education Workstation will need to be moved from classroom to classroom. The most important factors to consider therefore are doorway sizes, manoeuvring in confined spaces and the type of terrain to be travelled over. The majority of schools around New Zealand are required to accommodate students with disabilities such as those in wheelchairs. This means that the Mobile Technology Education Workstation will only need to enter buildings via a ramp of some sort rather than having to be moved up and down steps.

Figure 5-24 School Environment: Examples of Ramps



A standard door is approximately 760 mm wide; the workstation must therefore not be wider than this. Consideration will also need to be made for doorsills and other small steps the workstation may need to travel over.

5.2.3.3.8 Initial Product Characteristics

From the research conducted, the initial product characteristics can be determined. These will provide guidelines in the concept development and screening stages of the product design.

1. Store equipment relating to: Electronics and Control technology, Food technology, Materials technology and Structures and Mechanisms technology.
2. Mobile, able to be moved between classrooms.
3. Must fit through doorways into classrooms.
4. Able to be manufactured at Furnware.
5. Ergonomically designed for use by 5-10 year old children.
6. Be safe to use.
7. Easy to manoeuvre around the school.
8. Appropriately priced.
9. Provide appropriate work surfaces for the tasks expected to be carried out while teaching the Technology Curriculum.

5.2.3.4 Outcomes: Target Specifications

Initial target specifications are the consumer needs converted into measurable terms. Refer to Section 5.2.3.2.3 for the methodology used to generate Table 5-3.

Table 5-3 Initial Target Specifications

Metric No.	Need Nos.	Metric	Import.	Units	Marginal Value	Ideal Value
1	1	Number of each tool stored for Food Technology	2	Number	10-15 children working	30 children working
2	1	Number of each tool stored for Electronics and Control Technology	2	Number	10-15 children working	30 children working
3	1	Number of each tool stored for Materials Technology	2	Number	10-15 children working	30 children working
4	1	Number of each tool stored for Structures and Mechanisms Technology	2	Number	10-15 children working	30 children working
5	2.6.7	Weight	4	Kg	<85	40
6	5	Height	4	mm	570<X<900	720
7	3.7	Width	1	mm	<760	<650
8	2.4.7	Length	3	mm	<1800	1200
9	7	Turning Arc	3	mm	<1200	600
10	2	Friction when pushed along floor	1	N	<250	100
11	8	Retail price	2	$	<1500	550
12	9	Top section of workstation. or included in workstation suitable for working on	3	Yes/No	Yes	Yes

5.3 Concept Generation

This section summarises the conversion of the market research findings into feasible product concepts. The process begins with a refined concept statement and initial product specifications and ends with three concepts chosen for further development.

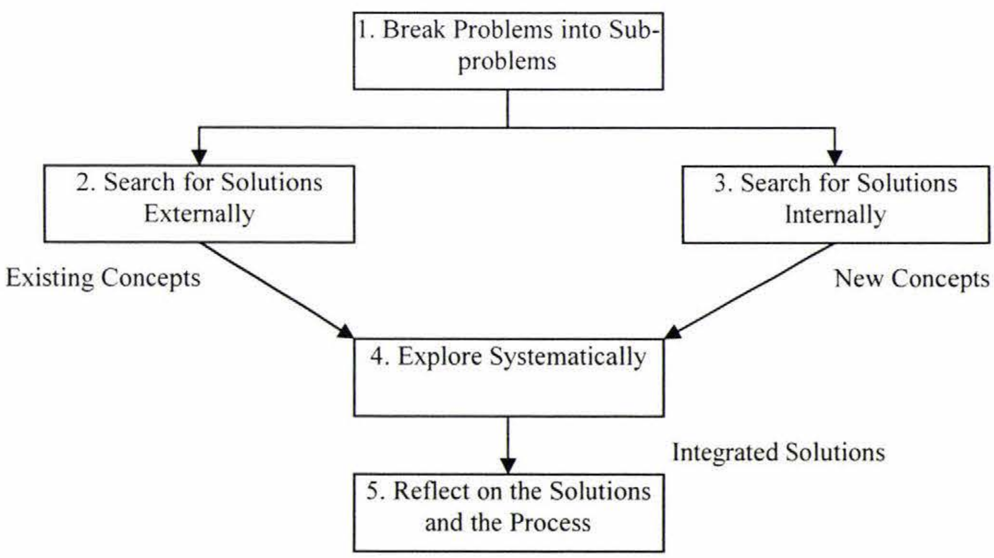
5.3.1 Aim

To produce 1-3 product concepts that meet customers needs and is viable from a manufacturing and financial perspective.

5.3.2 Methodology

To enable concepts to be developed in a logical and structured manner, a five-step methodology (Ulrich and Eppinger, 2000) will be followed. The method starts with the breakdown of the problem or task of the product into, smaller, more manageable sub-problems or tasks. The next step is to search for existing solutions to these sub-problems. If no solutions are discovered or a larger range of solutions is required, then internal searching should be conducted. This involves the use of creative techniques such as brainstorming sessions with sales and manufacturing staff. The fourth stage is the amalgamation of these solutions into concepts. Figure 5-25 outlines this process.

Figure 5-25 Concept Generation Methodology



From this task, complete product concepts will emerge. Finally reflect on the results of the process and identify the most promising concepts for further development. Also identify the areas requiring further attention. Reflection on the process is done throughout the concept generation process and not necessarily at the end.

5.3.3 Results

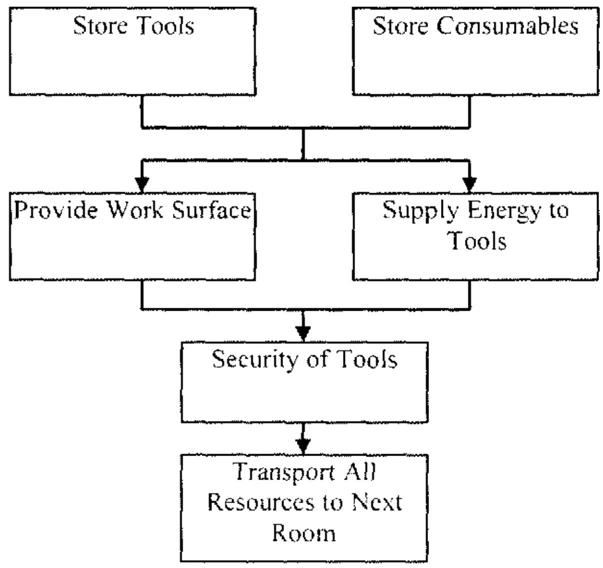
5.3.3.1 Sub-Problem Identification

For this particular type of product the best approach to decomposing the problem is to break it up in terms of the sequence of user interactions. First the tools and consumables must be stored on the unit, and then the tools are used to work the consumable materials on the work surface or surfaces. Some tools will require energy to operate. Tools then need to be put away securely. Once the tools are secure, the unit can be moved into the next room. Figure 5-26 below shows the six user interactions with the product. Using this diagram and the market information gathered, the sub-problems can be ordered in terms of importance to the consumer and then solved systematically.

The sub-problems placed in order of importance (from most important to least important) are:

1. Storage of tools.
2. Transportation of resources to next room.
3. Provide working surfaces.
4. Security of tools.
5. Store consumables.
6. Supply Energy to tools.

Figure 5-26 Sub-Problem Identification



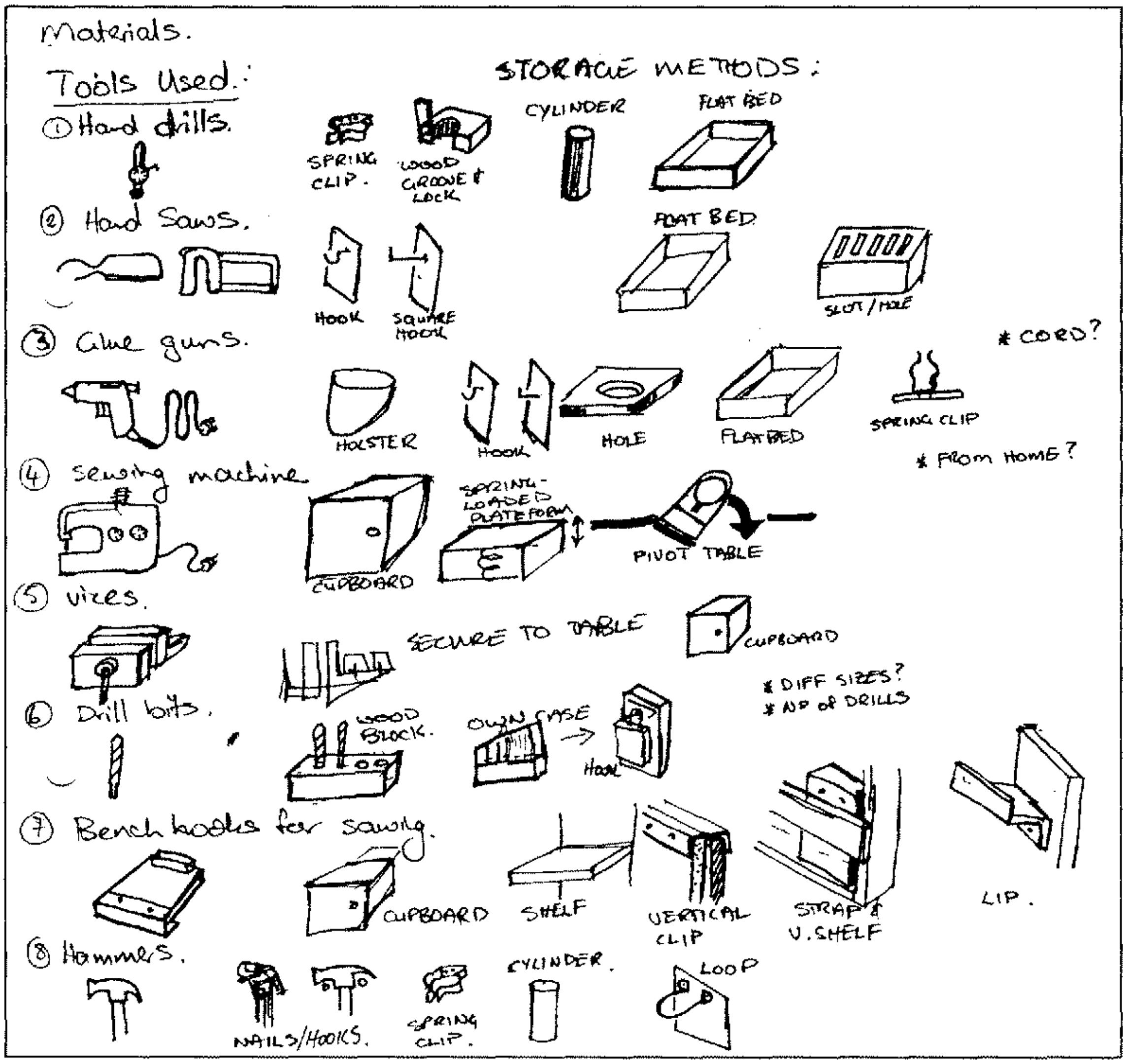
5.3.3.2 Search Externally

The second stage in the concept generation process is to search for existing solutions to the sub-problems. This process of generating concepts produces a large number of sketches, tables and ideas. Provided in this section is an example of the method used to solve the identified sub problem of storing tools for Food technology equipment. Refer to Appendix B for information relating to the other technology areas.

Sub-Problem 1: Storage of Tools

This problem has been further divided into the different Technology areas. Searching for existing methods of securing and storing tools yielded the following main methods: basic hooks, tote trays, drawers, spring clips, cupboards, and small plastic compartments that are stored either on a steel rack or on a shelf (Figure 5-27). These methods are all either already manufactured by Furnware or can be readily obtained from suppliers.

Figure 5-27 Concept Generation Sketches



Provided in Table 5-4 is a screening matrix of the equipment required for Food technology and the securing methods discovered. Each method is rated according to the following description:

1. Ideal method, the most preferred according to the criteria.
2. Acceptable method, alternative to option 1.
3. Possible method, can be stored in this way if required.
4. Impossible to store this tool by this method.

<u>Criteria for evaluating each storage method:</u>

- Tool is easily attached and well supported.

  The main purpose of the storage method is to secure the tools.
- Efficiency and cost effectiveness (weight/cost).

This is a measure of how many tools can be stored using the minimum amount of materials. The weight and cost of the unit are important to the consumer.

- Exists at Furnware already.

  Using storage methods, which are already available at Furnware, makes manufacturing of the workstations simpler.

- Tools able to be counted easily.

  Teachers must always check that all equipment is put away at the end of a class. If a storage method aids this task by making equipment easy to count, the product will be more appealing to the consumer.

Table 5-4 Food Technology Equipment

Tool	Ideal Number (Range)	Storage Method					
		Hooks	Flat bed	Spring clip	Hole	Cupboard	Individual compartments
Chopping boards	4 (2-8)	2	**1**	4	3	2	4
Big bowls	4 (2-8)	4	2	4	4	**1**	4
Small Bowls	4 (2-8)	4	2	4	4	**1**	4
Sharp knives	4 (2-8)	2	**1**	2	2	3	3
Measuring Spoons set	4 (2-8)	**1**	2	4	4	3	3
Set of Measuring cups	4 (2-8)	**1**	2	4	4	3	3
Spatulas	4 (2-8)	2	**1**	3	2	3	3
Wooden spoons	4 (2-8)	2	**1**	2	2	3	4
Pots & Lids	2 (2-4)	2	2	4	4	**1**	4
Sieves	1 (0-4)	**1**	2	3	4	3	4
Potato peelers	2 (2-8)	**1**	2	3	3	3	3
Grater	2 (0-4)	2	**1**	4	4	3	4
Aprons	30(12-30)	2	2	3	4	**1**	4
Table cloths	4 (0-6)	4	**1**	4	4	2	4
Microwave	1 (0-4)	4	4	4	4	**1**	4
Hotplate	2 (0-4)	4	**1**	4	4	2	4
Egg Beater	2 (1-4)	**1**	2	2	4	3	4
Knives & Forks	24 (24-75)	2	**1**	3	2	3	3
Plates	8 (8-30)	4	**1**	4	4	2	4
Bowls	8 (8-30)	4	**1**	4	4	2	4

5.3.3.3 Search Internally

Internal searching involves the use of creative techniques to solve problems and generate product concepts. Provided below is a sample of particular instances when creative techniques were used.

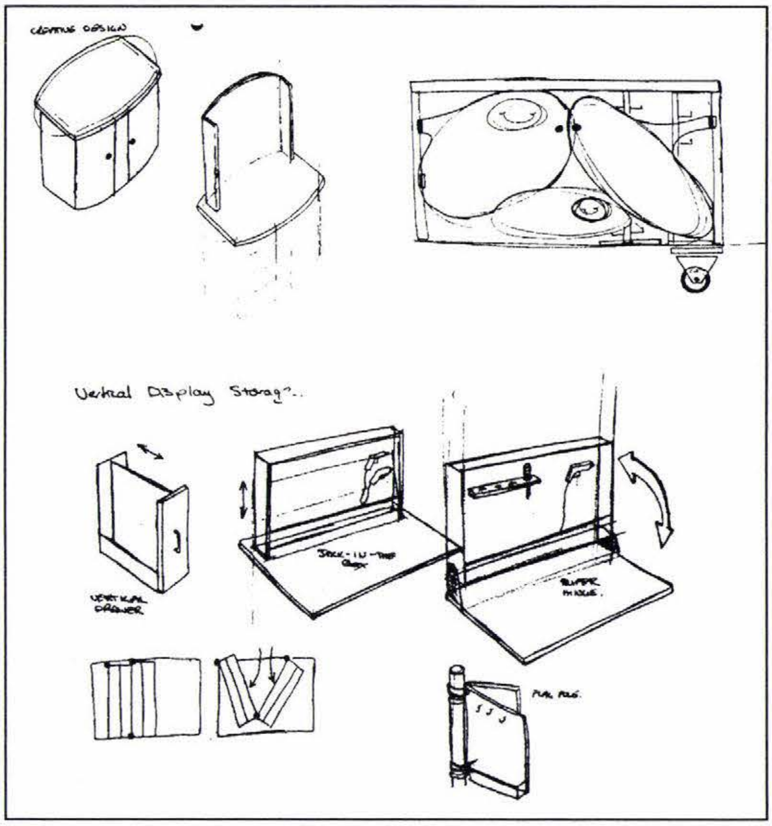
<u>Aesthetics</u>

In an attempt to improve aesthetics of the concepts and generate some new and interesting ideas for the units, sketches were drawn and new ideas developed. Provided below in Figure 5-28 are some examples of the sketches.

Security of Tools

The security of tools was also investigated. Provided below in Figure 5-28 is also an example of sketches that are attempting to find ways of securing tools that are hooked onto a vertical board.

Figure 5-28 Creative Sketch Examples



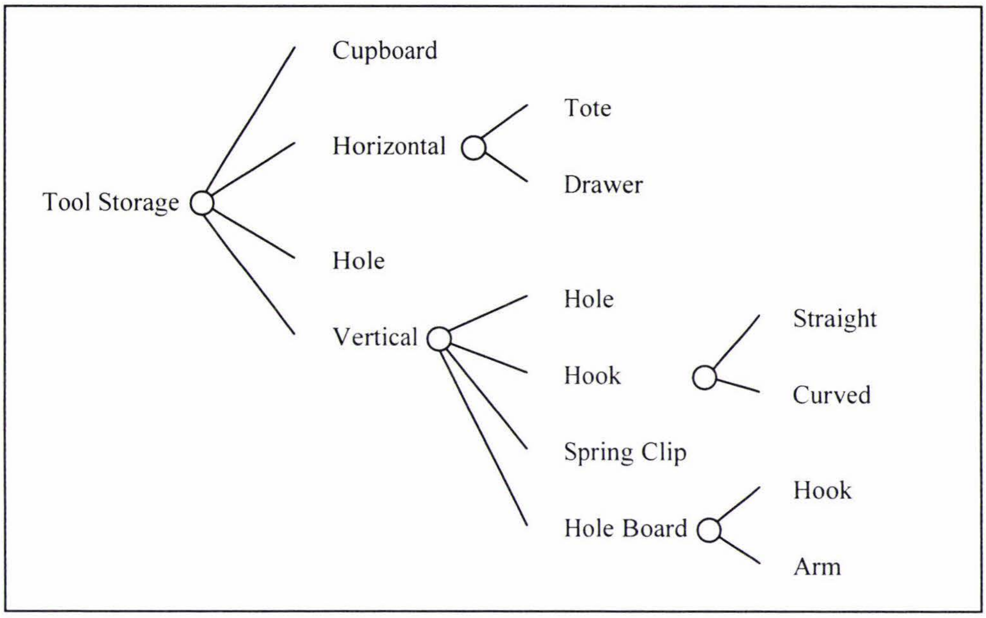
One concept of notable interest that originated from this process was the round table concept (top left of Figure 5-28). This concept provided very nice styling rated highly in the screening stage.

5.3.3.4 Explore Systematically

Exploring the ideas for solving the sub problems involves combining solutions to form concepts for solving the complete problem. A very large number of ideas have been generated and to explore every possible combination would take too long. Classification trees were used to reduce the number of interactions before exploration began. Classification trees help group solutions that are similar in some way thus reducing the total number of solutions and possible solution combinations. Each sub-problem has a set of solutions, provided below in Figure 5-29 is an example of a classification tree for tool storage. Refer to Appendix B for the classification trees for the other sub problems.

To assist the exploration of sub problem solution fragments into concept ideas, a combination table was used (Table 5-5). A combination table simply provides a visual, systematic means of exploring all the possible combinations of solutions.

Figure 5-29 Tool Storage Classification Tree



Once exploration begun using the combination table, more combinations could also be eliminated because they were obviously impossible combinations. The number of potential solutions originally started at 7x5x6x6x4x5 = 25,200. This is reduced to 7x3x5x6 = 630 using the classification trees. Further reductions upon combining concepts reduced this to 5x3x3x5 = 225.

Table 5-5 Initial Combination Table

Tool Storage	Transport to Next Room	Work Surfaces	Tool Security	Energy Source	Storage of Consumables
Cupboard	Shopping Trolley	MDF	Std Hinge	10A	
Tote	Suitcase	Solid wood	Top hinge door	10A +RCD	Hole
Drawer	Wheelbarrow	S.Steel	Bottom hinge door	Built-in Gas	Tote
Hole	Audio Visual trolley	Laminate	Slide door	Appliance + bottle	Drawer
Hook	Workshop trolley	Plastic	Std Drawer		Shelf + lip
Spring Clip		Wood Dividers	Vertical drawer		
Hole Board					

Refinements needed to be made during systematic exploration to limit the number of possible combinations. Attention needed to be focussed on the most important sub problems also. For these reasons the following refinements were made during exploration:

- The suitcase, audio-visual trolley and workshop trolley mobility ideas are functionally similar and are therefore combined.
- Energy sources are not a focus in the design at present due to the low number of tools requiring energy and the availability of mains power in schools.
- Consumables storage is a low priority and is taken out.
- Work surface materials have a low effect on design, some materials have similar characteristics.

The final combination table is shown in Table 5-6.

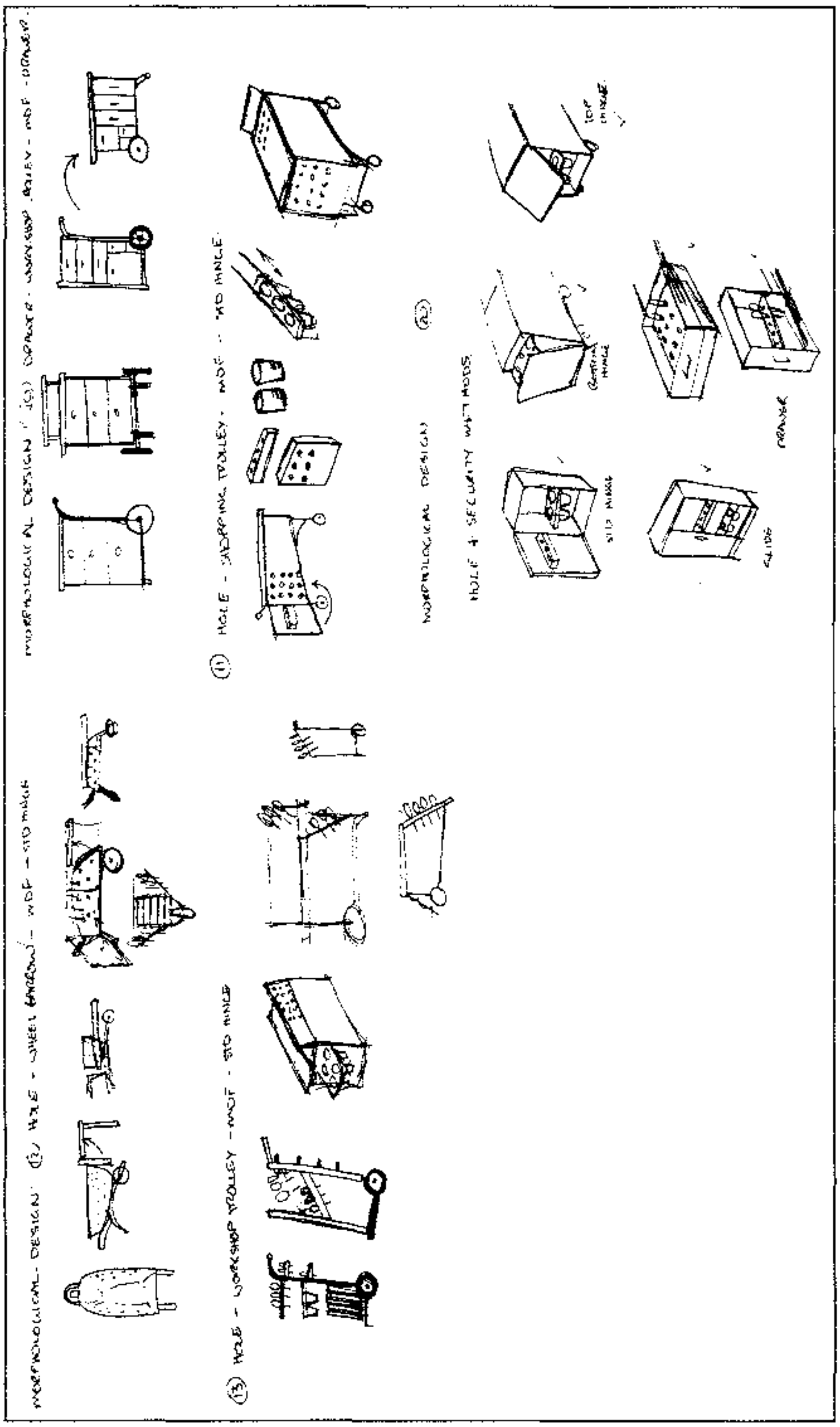
Table 5-6 Final Combination Table

Tool Storage	Transport to Nest Room	Work Surfaces	Tool Security	Energy Source	Storage of Consumables
Cupboard	Shopping Trolley	MDF	Std Hinge		
Tote			Top hinge door		
Drawer	Wheelbarrow	S.Steel	Bottom hinge door		
Hole		Laminate	Slide door		
Hook	Workshop trolley		Drawer		

The next step in generating concepts was the exploration of all the above combinations. For example: cupboard, trolley, MDF, standard hinge or tote, trolley, MDF, std hinge.

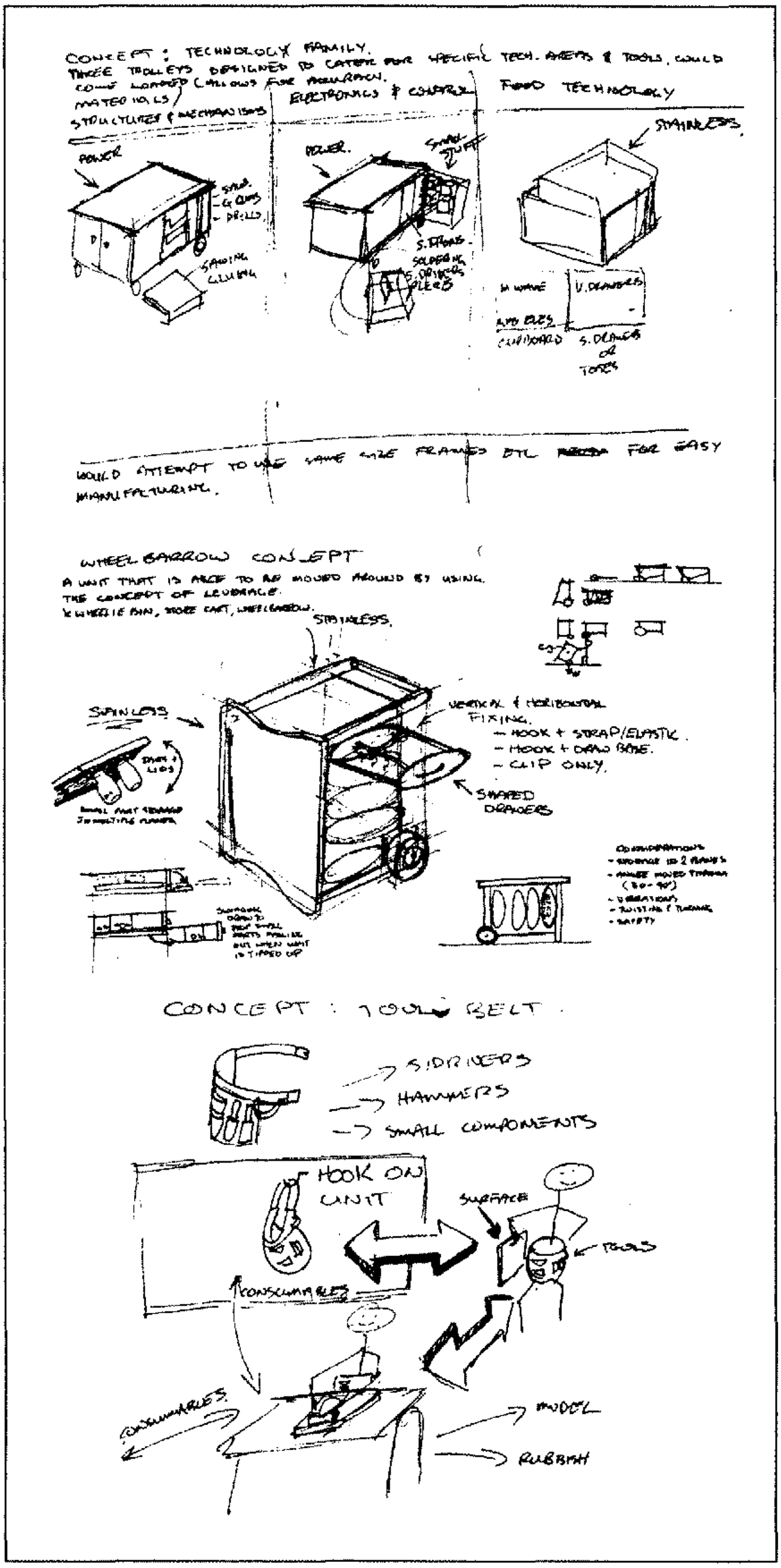
Figure 5-30 shows some examples of the combinations developed as concepts generated by systematic exploration.

Figure 5-30 Examples of Concepts Generated by Systematic Exploration



From the generation of concepts a number of different designs were developed. Seven of these were developed to a level of detail suitable for screening. Three of the concepts are provided in Figure 5-31 below.

Figure 5-31 Concept Images



5.3.3.5 Reflect on the Solutions and the Process

This was the final stage in the structured concept generation method proposed by Ulrich and Eppinger (2000). Reflection was done both during and at the end of concept development. At this stage only the initial concept development has been undertaken. These concepts will now be screened and the successful concepts will undergo a second stage of development in the next chapter: Detailed Design.

Screening

Concepts to be screened

Concept A: Family #1

Provide a basic skeleton and frame with castors. Provide a range of storage options and surface tops to cater for the four main technology areas.

Concept B: Family #2

Design 2 – 3 separate trolleys that are fixed in terms of storage and surface options.

Concept C: Workshop Trolley

A concept based on using 2 pneumatic wheels strategically placed to allow a high degree of manoeuvrability.

Concept D: Roundtable

A simple yet more aesthetic design that provides both vertical storage and general storage options. Some storage space and manufacturing cost is compromised to include these aesthetics.

Concept E: Tool Belt

Provide storage for tools in the form of a tool belt. each child can then take the tool belt and a work surface away and do work on their table.

Concept F: Trolley-Shelf System

A system where a single workstation can be loaded with a number of different 'cartridges' or storage blocks. The unused storage containers are stored on a shelving system when not in use.

Concept G: Technology Trailer

A car trailer that stores all the resource requirements for all technology areas. Designed to be used by a cluster of schools.

Screening Criterion

Each concept is rated on a scale of 1-10. 1 being very poor and 10 being excellent. The criteria selected relate to the identified needs of the customer. Criteria relating to Furnware's needs are also included.

Table 5-7 Concept Screening Table

Criteria	Concept						
	A	B	C	D	E	F	G
Ability to store Materials and S&M technology equipment	9	7	5	6	6	8	9
Ability to store E&C technology equipment	9	7	2	6	6	8	9
Ability to store Food technology equipment	9	7	3	6	2	6	9
Ease of transportation	5	5	8	5	6	5	3
Suitable work surface supplied?	8	7	5	6	6	3	7
Tools able to be secured?	7	7	5	7	8	7	5
Aesthetics	7	7	7	10	3	6	4
Company fit	9	9	5	7	1	7	1
Total	**63**	**56**	40	53	38	50	47

5.3.4 Outcomes

The outcome of this section was the decision to continue development of two concepts, Family #1 and Family #2. The Family #1 concept provided a basic skeleton and frame with castors. A range of storage options and surface tops will also be provided that caters for the four main technology areas. Consumers will be able to mix and match the options as they like. The Family #2 concept is similar to Family #1 in that a number of units will be developed but this concept will provide 2–3 separate workstations that are fixed in terms of storage and surface options. These concepts are both quite similar and development of the concepts into final products will be done in parallel for many of the technical aspects of the designs.

5.4 Summary

This chapter outlined Stage 2: Concept Generation, of the Mobile Technology Education Workstation development project. A detailed investigation into the market, consumer and product for the workstation was investigated. This information was then used to develop product concepts. A five-stage, systematic concept generation process (Ulrich and Eppinger, 2000) was used to provide structure to this task. From the concept generation, seven concepts emerged. These were screened systematically against set criteria and two were chosen for further development. They were the Family # 1 and Family # 2 concepts. These two concepts will now be developed further in Stage 3: Detailed Design.

6 Stage 3: Detailed Design

6.1 Introduction

The purpose of this chapter is to summarise the results of Stage 3: Detailed Design of the development of the Mobile Technology Education Workstation. Two concepts were selected for further development in Stage 2. This stage developed these concepts to a point where a final design can be selected and a final prototype produced that is ready for consumer and physical testing. Included at the start of the chapter is an ergonomic analysis of the proposed product. This information was used to determine which aspects of the design are influenced by human interaction. The process of developing the concepts was very iterative and at times new ideas were developed to overcome newly discovered problems before the project could proceed further. To simplify documentation of this iterative process, the chapter is broken up into stages of concept development and prototyping stages.

6.2 Ergonomic Analysis

6.2.1 Aim

To determine what aspects of the workstations' design need to consider human interactions with the product. Obtain the appropriate anthropometric information and develop possible design solutions to cater for the ergonomic considerations.

6.2.2 Methodology

1. Investigated human interactions with the workstation to determine which, if any, affect the design of the workstation.

   This investigation was done by reviewing each of the identified sub-problems individually. Basic human interactions with the workstation were identified and the particular design considerations discussed.

2. Gathered appropriate information relating to these interactions.

   Once the interactions that affect the workstations' design were identified, research into how these factors affect the design and what design elements they affect were determined. Information was gathered by interviewing users of the workstations and reviewing the appropriate anthropometric literature.

3. Developed design solutions to cater for these needs.

   The information gathered was used to design those elements of the workstation that are affected.

4. Tested solutions for feasibility and appropriateness.

   The design elements were then tested for feasibility and incorporation into the concept designs. Methods for doing this involved the use of prototyping techniques.

6.2.3 Results

6.2.3.1 Part 1: Human Interactions with the Workstation

This section is broken down into the six sub-problems identified in the beginning of the concept development stage. Each problem is reviewed for potential human interactions that require ergonomic attention.

6.2.3.1.1 Storage of Equipment

The Mobile Technology Education Workstation is predominantly a storage device. The resources required to teach the practical component of the Technology Curriculum needed to be stored away when not in use. The methods used to store equipment will need to be opened and closed easily as well as provide appropriate storage for the equipment. Furnware do not manufacture door latches and fittings therefore these will be purchased from current suppliers. The design of these fittings is outside the scope of this project and the fittings used will be assumed to be suitable for use on the workstation.

6.2.3.1.2 Transportation of Resources to Next Room

The second function of the unit is to move these resources from room to room; the workstation must therefore be mobile. The simplest and most convenient method of doing this is using industrial strength castors. They move freely, are readily available from local suppliers and strong enough to support the weight of the unit. Ergonomic factors such as ease of pushing the unit around a school need to be considered when choosing the castors. For example, larger castors can move over rough terrain easier.

6.2.3.1.3 Provide Work Surfaces

The third most important identified need is to provide work surfaces for children to work on. To do this, two methods were investigated. The first uses the top of the workstation to provide a work surface. The second uses small work surfaces stored on the workstation that can be taken away and placed on school desks to protect them. Due to the limited space available on the top of the workstation, both of these ideas were investigated. Using the top of the unit to complete practical tasks does have ergonomic implications. The main design aspect affected is the work top height. A large range of different aged children is expected to use the workstation and a large number of varied tasks are also expected to be undertaken on the workstation.

6.2.3.1.4 Security of Tools

The use of locking devices to secure tools on the workstation will need to be suitable for operation by children. Once again, Furnware do not manufacture these fittings and will need to purchase them from a supplier. The design of new securing devices is outside the scope of this project.

6.2.3.1.5 Store Consumables

Storage of consumables has the same ergonomic considerations as storage of tools.

6.2.3.1.6 Supply Energy to Tools

Supplying energy to tools is a low priority need and did not have any major ergonomic considerations.

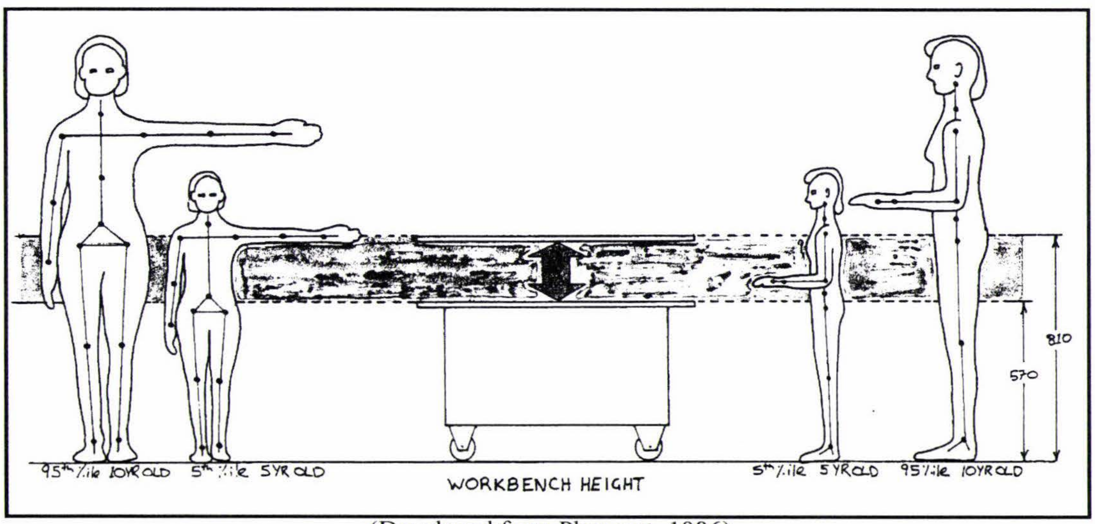
6.2.3.2 Part 2: Ergonomic Information

From the analysis of human interactions with the workstation information was gathered that would help determine what aspects of the workstation's design needed to be developed to accommodate interactions with humans. The analysis showed that the most important factor was the use of the workstation's worktop by a number of different sized children. Information relating to who will use the top is therefore outlined below.

6.2.3.2.1 Anthropometrics

A search for data relating to the sizes of New Zealand children revealed that no such information exists. The anthropometric information of British children was used as an acceptable approximation, it is estimated that New Zealand children are marginally larger than British children, but the difference is small enough to not affect design considerations based on this information. Children ranging from the ages of 5 to 10 years of age are expected to use the workstation as well as the adult teachers. Provided below are the subsequent size ranges that should be catered for. The smallest person likely to be using the workstation is a 5th percentile 5-year-old female child and the largest possible person using the workstation is a 95th percentile 10-year-old child. Provided below in Figure 6-32 are the ranges of workstation heights that suite these extremes. The heights shown illustrate the most suitable height for manipulative or general tasks (Pheasant, 1986). The tasks to be undertaken on the workstation are varied. Different tasks can be best completed at different heights. Pheasant (1986) suggests that for delicate or precise work, the height of the work surface should be 50-100 mm above elbow height and for heavy work the work surface should be 150-400 mm below the elbow height. Figure 6-32 below shows the appropriate ranges of heights for completing different tasks.

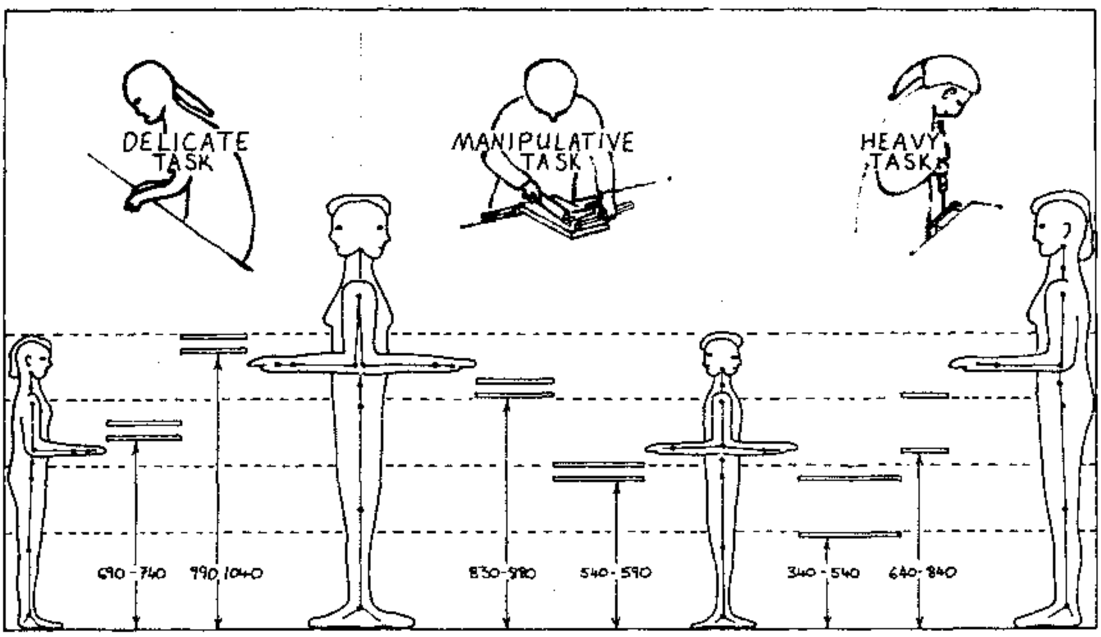
Figure 6-32 Range of Children Sizes and Appropriate Workbench Height



(Developed from Pheasant, 1986)

The large range of sizes of these users means that a compromised size of the workstation will need to be decided upon. Through interviews with lead users it was discovered that children aged 5 and 6 usually have tables and work surfaces available to work on that are suitable for doing practical work, so they do not need to work on the workstation. Likewise the teachers are not expected to be using the workstation for extended periods of time and so children aged 7 to 10 will be used as the target users.

Figure 6-33 Range of Tasks Completed On Workstation



(Developed from Pheasant. 1986)

The range of heights that suite children aged 7 to 10 and the different tasks is estimated to be between 340mm and 1040 mm. This range is very large and will severely affect the storage capacity of the unit. A compromised range of heights that will suite most child sizes and most tasks will be used instead. The target range that the workstation should be adjustable between is 590 mm and 830 mm. Ideas to make the workstation height adjustable were now considered.

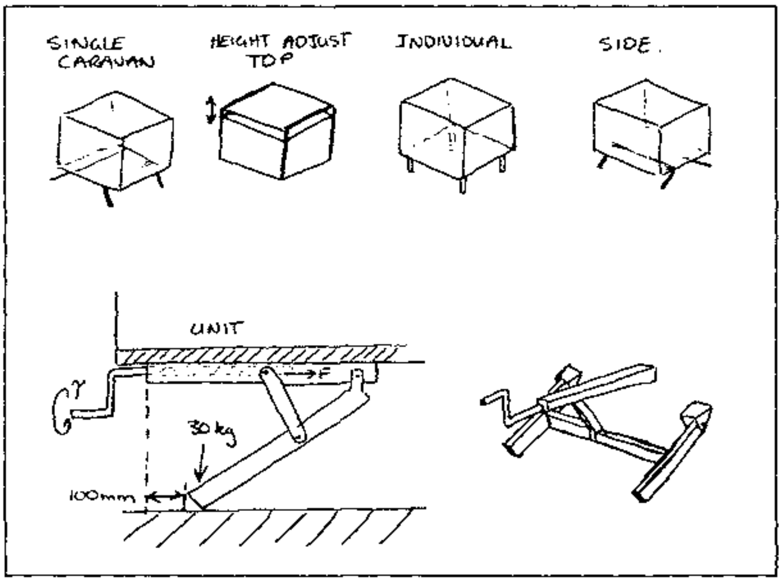
6.2.4 Outcomes: Design Solutions

To make the work surface height adjustable a number of different ideas were generated. Provided below in Figure 6-34 is a sample of them. To help screen the ideas. the steel manufacturing department was regularly consulted as the design of a height-adjustment mechanism involves the use of a mechanism made of steel. To evaluate ideas the following list of criteria was used:

- Provides a vertical range of movement of 240 mm (830 – 590).
- Costs less than $100 to purchase or make.
- Does not affect the stability of the work surface.
- Is easily and quickly adjustable.

From the range of ideas. the use of a mechanism that lifted the whole workstation was selected as most suitable (refer to Appendix B to view the screening matrix). A caravan stabiliser leg has the right amount of lift range and appeared the most suitable method of lifting the workstation. Testing the stabiliser leg involved the development of a prototype mechanism. The results of the prototyping are provided in the following section.

Figure 6-34 Examples of Work Surface Lifting Mechanisms



6.3 Prototyping: Stage 1

6.3.1 Aim

The aim of this section was to test parts of the concepts for viability. The three areas tested were height adjustment mechanism, vertical drawer design and portable work surface design.

6.3.2 Methodology

1. Produced prototyping schedule.

   The prototyping schedule outlined important information relating to the proposed prototype and helped plan the prototyping procedure by ensuring the purpose of the prototype was related to the level of approximation the prototype was be made to. Main headings included purpose, level of approximation, quantity, test plan and schedule for work to be carried out.
2. Made prototype according to schedule.

   The prototypes were then made according to the schedule. this had to fit into the production schedule at Furnware as personnel and equipment used in production needed to be used to make the prototypes.
3. Tested prototype according to schedule.

   Once the prototype is built, testing can began according to the schedule.
4. Discussed results.

   The results of testing provided information that assisted in the development of the three concepts.

6.3.3 Results

6.3.3.1 Part 1: Lifting Mechanism

6.3.3.1.1 Lifting Mechanism Prototype Schedule

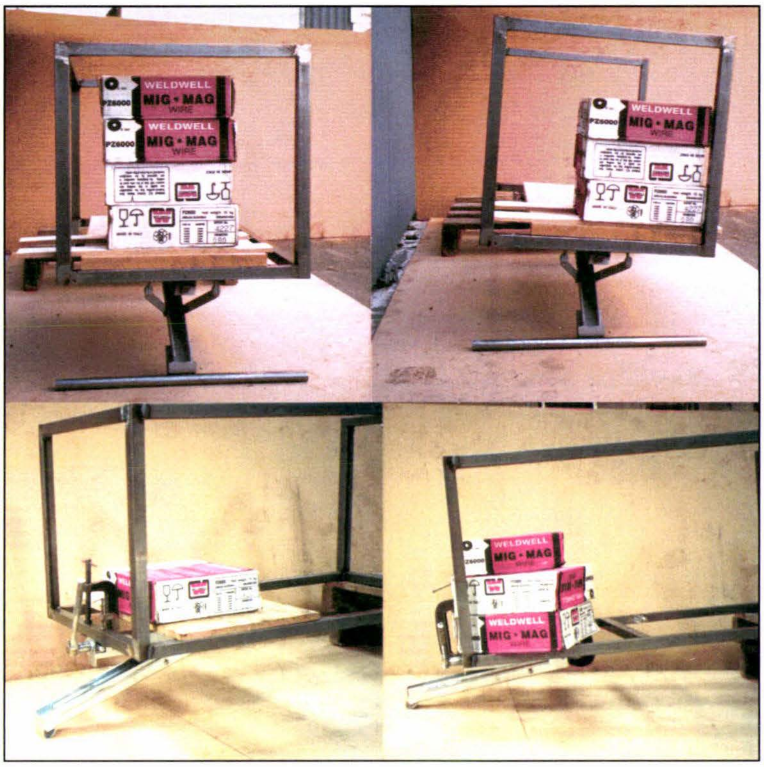
Table 6-8 Lifting Mechanism Prototype Schedule

Name of Prototype:	Workstation Lifting Mechanism
Purpose: To test lifting ability of caravan stabiliser leg To test stability of hinge mechanism To estimate cost of mechanism (Learning how mechanism will perform and potentially communicate to customer the benefits/use)	
Level of Approximation: Scale: 1:1 Material: Steel used to be same as final product Mechanism: Existing caravan mechanism, final mechanism may be made by steel department rather than purchased Aesthetics: Not same as final product	
Quantity to be built: 1 initially, 2 if modification is required	
Outline of test plan Spend 1 hour discussing options for mechanism Job card created for welding and material Production of prototype Test with varying weights: 80-140 kg to ensure mechanism has lift capacity Conduct preliminary stability tests by using mechanism at full height to saw a piece of wood or measure rocking movement when horizontal force is applied to unit. Have 'typical' users operate mechanism	
Schedule:	
Discussion	31 July 2000
Job Card produced	31 July 2000
Mechanism produced	03 August 2000
Test prototype	05 August 2000
Results	08 August 2000

6.3.3.1.2 Prototype Test Results

The first mechanism tested failed to support the weight required and had insufficient stability. A second, stronger mechanism was found and used for the second prototype. Before the stability issue was addressed the second unit was tested for strength, it passed this test. This new mechanism was configured in such a way that to use it with stabilising legs would be impossible. The height adjustment design was consequently discontinued. Provided below in Figure 6-35 is the legs and the frame used to test mechanism strength. The top two images show the first leg tested. Two problems were encountered, the leg did not support the weight at low height levels and the unit was not stable enough to work on (top right of Figure 6-35). The bottom two images show testing of the second stabilising leg, this leg could lift the weight but was still not stable enough. The frame was used in the development of the unit in later prototyping stages.

Figure 6-35 Lifting Mechanisms



6.3.3.2 Part 2: Vertical Drawer

6.3.3.2.1 Vertical Drawer Prototype Schedule

Table 6-9 Vertical Drawer Prototype Schedule

Name of Prototype:	Vertical Drawer
Purpose: To test feasibility of design Provide visual stimulus for customer opinion To investigate integration of securing methods and the method of storage (Integration of securing mechanisms and drawer design, communicate benefits of design to customers, learn if design is feasible)	
Level of Approximation: Scale: 1:1 Material: Same properties as final material Aesthetics: Not same as final product	
Quantity to be built: 1 X 200 mm single-side drawer 1 X 100 mm double sided drawer 1 X Cabinet to insert drawers 1 X 100 mm single-sided drawer	
Outline of test plan Discussion of manufacturing process, programming etc Job Card Schedule and Produce prototype Test variety of securing methods with the drawers using expected tools to be stored. Saws, drills, glue guns, soldering irons, pots, pans, rulers and drill bits etc Test stability when integrated with trolley chassis	
Schedule: Discussion Prototype made Test prototype Results	 10 August 2000 15 August 2000 16 August 2000 17 August 2000

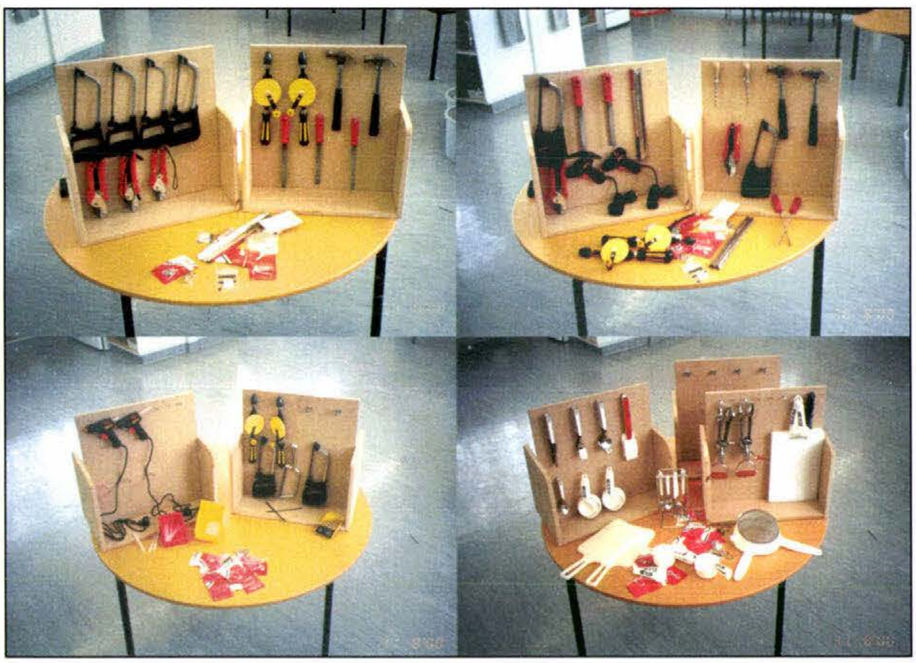
6.3.3.2.2 Vertical Drawer Prototype Results

Delays in programming meant that an interim prototype was made. Three boards, the same size as the inside dimensions of the proposed drawers were made up to progress, hanging mechanism design and arrangement. The typical tools were found at Mayfair Primary School and so several days were spent investigating hanging arrangements for all the different tools (Figure 6-36). Once the drawers were made the arrangements and best hook styles were selected. The drawers were found to work very well. The main findings were:

- Latches (either locks or clips) are required to keep the drawer firmly shut.

- Drawers can be easily removed and if handles are located the entire contents can be taken out and used away form the unit.
- A holder for the glue sticks would be a good idea.
- If the glue gun/soldering iron draw comes out, to be stable it should have two sides with equipment on.
- Non-standard drawer runners of 500 mm length are required to make the unit.
- If full access to the drawer is required, may want to use full-extension runners, these are $20 each.
- Consideration should be made as to whether or not the drawer inners need lacquering, if there is a chance that they will get wet then they will need to be.

Figure 6-36 Vertical Drawer Prototypes



6.3.3.3 Part 3: Portable Surface Development

6.3.3.3.1 Portable Surface Prototype Schedule

Table 6-10 Portable Surface Prototype Schedule

Name of Prototype:	Portable Surface Development
Purpose: To test toggle clamps, 'g' clamps and other securing methods Integration of different types of surfaces, i.e. cutting, sawing, gluing and soldering To aid idea generation for storage options Test for consumer appeal	
Level of Approximation: Scale: 1:1 Material: MDF, the expected material to be used on the final design Aesthetics: Not a major consideration	
Quantity to be built: At least four different designs will be tried so that storage of multiple surfaces can be evaluated Additional fittings will be made as required	
Outline of test plan Sketch designs , incorporate main tasks Evaluate and redesign as required Discuss manufacturing considerations with staff Evaluate and redesign Brainstorm storage options	
Schedule: Sketch designs Evaluate Make Test prototype Results	 14 September 2000 18 September 2000 20 September 2000 24 September 2000 26 September 2000

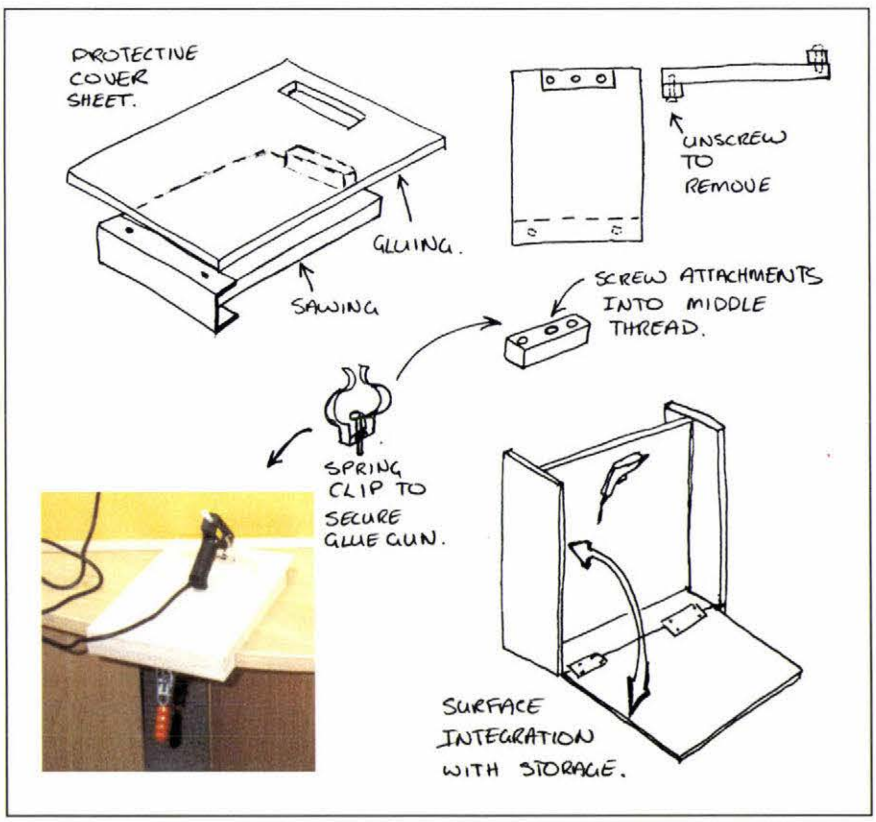
6.3.3.3.2 Portable Surface Results

- The toggle clamps worked well. They enabled children to saw without needing to hold the sawing block. A small clamp was used with a rubber tip to prevent marking desks the clamp was attached to. The clamps used could be adjusted to either 25 mm or 18 mm thick desks.
- The 'G' clamps also worked well, but because they were not integrated into the design and the children could easily lose them.
- Using locknut fittings already used at Furnware, a modular board was designed and is shown below in Figure 6-37. This design enabled the top piece of wood to be exchanged, depending on the task being completed. A piece that had a

spring clip attached to it could be used to hold a glue gun, for example. A 6 mm thick piece of MDF was used to ensure the glue did not get on the baseboard.

- A range of different size baseboards was trialed. The board wants to be as small as possible to make it easier to store, while still being large enough to work on. For sawing this is 200 mm wide by 200 mm deep. For gluing, the larger the board the better. A board the size of a standard desk being the best (450 mm wide by 400 mm deep is best).
- When tested for consumer appeal, the toggle board met with approval, when the price of $20 each was announced the idea met with some resistance.
- Storing the boards that had the toggle clamps on them proved difficult.
- Attaching the toggle boards using locknuts meant that they could be easily removed if storage was at a premium, as it is on the workstations.

Figure 6-37 Surface Prototype Development



6.3.4 Outcomes

6.3.4.1 Lifting Mechanism

The prototype testing showed that the use of a caravan stabilising leg would not be suitable for use as a height adjustment mechanism on the unit. No other feasible ideas, that met all the criteria, were discovered. The development of a height adjustment mechanism for the unit is therefore discontinued. The implications of this are that the unit may not be at optimal height for children to work at. The development of portable work surfaces that a child can take away from the unit and work on at his or her regular desk will help solve the problem of providing suitable work surfaces for the children at the appropriate height.

6.3.4.2 Vertical Drawers

The drawers performed under the conditions well and functioned as expected. Producing the drawer prototype solved many questions and their design progressed and was modified several times to ensure ease of manufacturing. If the workstation is to be made modular, small adjustments to the widths of the drawers would help reduce costs by standardising drawer dimensions to the size of standard tote trays, which are 275 mm wide.

6.3.4.3 Portable Surfaces

Several methods of integrating surfaces used for different tasks were prototyped and tested for functionality. Methods of securing sawing blocks to desks such as 'G' clamps and toggle clamps were investigated. Using toggle clamps was the most effective way of securing the sawing blocks to desks. The toggle clamps are expensive and will need to be tested further for consumer appeal. Integrating different surfaces was difficult to do without adding complexity to the designs. Using standard sawing blocks and basic pieces of 6mm MDF for gluing on was best. Several other, more complicated work surface designs were trialed such as integrating the surfaces with the drawer and using a modular works surface system (Figure 6-37). The designs chosen were simple and low-cost, making them most appropriate design for a sacrificial surface. The purpose of these surfaces is to protect school desks and any other pieces of furniture worked on. The development and testing of portable surface prototypes found that toggle clamps work well and that it is best to keep the surface designs simple and low cost.

6.4 Concept Development

6.4.1 Introduction

A review of the designs to date is provided below with the generic features such as the chassis and the workstation's overall dimensions first. The specific areas of development such as work surfaces and storage facilities are reviewed next.

6.4.1.1.1 Generic Features

Generic features are those elements of the design that apply to all of the workstations.

Chassis

The chassis that was made up to test the lifting mechanism will be used for the workstations' chassis. It is made from 31.8 mm square tube, mild steel. The chassis also includes the castors. There are three models of castors to choose from fixed, swivel and swivel-lock. The appropriate combination of castors was selected to ensure the workstation can be moved throughout the school easily, but does not move when the workstation is being used. The size of the wheels needed to be selected by compromising between ease of transport over rough terrain, height of worktop and cost.

Overall Dimensions

Height

The development of a height adjustment mechanism prototype showed that it was not feasible. The ideal height for the unit is a height between the ranges suggested for adjustment of 590 mm and 830 mm. A height somewhere in the middle of these would be the best compromise. The middle height is 720 mm. Therefore the unit height will be 720 mm.

Width

Two constants affect this dimension. The width of the unit should be as large as possible so that more students can work on the worktop and the workstation has maximum storage. The unit needs to be moved throughout the school and therefore needs to fit through doorways, which are approximately 760 mm wide. The width of the unit will therefore be 650 mm, to ensure the unit can fit through doorways with some tolerance.

Length

The length of the workstation does not have any specific constants placed on it other than to be in proportion to the height and width. Manufacturing considerations such as melteca panel size are a factor also. The overall length of the unit will be 1200 mm. This measurement is in proportion to the other dimensions and also ensures economic use of melteca sheets as the standard sheet size is 1200 mm x 2400 mm.

6.4.1.1.2 Storage of Equipment

Ideas for tool storage were found and generated for all of the tools to be used on the workstation. Two existing methods found at Furnware were the use of tote trays and the use of a basic cupboard. A new concept of using vertical drawers to store tools that are hung on hooks was developed in Stage 1 of prototyping. This idea worked well and will be incorporated into the workstation design. The integration of these storage methods into workstations that store enough equipment to keep 10-15 children working needs to be developed now. Storage of work surfaces and consumables will also need to be considered.

6.4.1.1.3 Work surface Development

Worktops

A number of different work surfaces for the workstation were investigated. These included: MDF, lacquered MDF, laminate, melteca and stainless steel. Lacquered MDF is the best worktop for Materials, Electronics and Control and Structures and Mechanisms technology work. It provides the cheapest work surface that will not swell if it gets wet. This surface is designed to be sacrificial and so is easily replaced and is cost effective. The Food technology workstation will have a stainless steel top. This top significantly adds to the cost of the workstation but is the only surface suitable for both preparing and cooking food on. Design considerations: fixing top to chassis, stainless steel top design and manufacture.

Portable Surfaces

Portable work surface design was conducted during Stage 1 of prototyping. It was decided to keep designs simple. The main factors to finalise at this stage were the storage of these surfaces and the number of surfaces required. The number of surfaces required was directly related to the expected number of tools on stored on the workstation.

6.4.2 Aim

To develop the product concepts to a level suitable for manufacture or decision to discontinue development.

6.4.3 Methodology

The methodology for developing the workstation design into a final product idea was a cyclic process of developing design components and checking that they fit with the other design components. The drawer widths must combine together to form a total width of no more than the total size of the workstation for example. The methodology followed to develop the workstation design is provided below.

1. Reviewed the past work and determine which areas require further development.
2. Investigated possible solutions.
3. Determined which fits best with other areas of the design.
4. Developed designs into final solutions.
5. Continued comparing between different design elements to ensure the workstation will function as a whole.
6. Made compromises and adjustments where necessary. If a design component clashes with another design component and a compromise is unable to be made, return to Step 3 and complete additional design work.

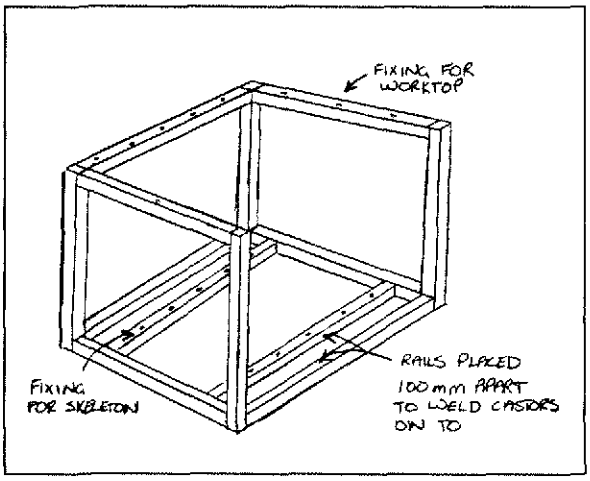
6.4.4 Results

6.4.4.1 Part 1: Generic Features

6.4.4.1.1 Chassis

A combination of two types of castors was chosen for the workstation, two fixed wheels and two swivel-lock wheels. The two fixed wheels are placed at one end and the two swivel-lock wheels are placed at the other. The fixed castors ensure the workstation can be easily pushed in a straight line, while the swivel-lock castors allow the workstation to be manoeuvred around corners and to be locked into place when children are working on the workstation. The chassis has rails welded 100 mm apart on the lower section so that the castors can be welded onto the chassis. Holes are drilled into these rails to provide fixing for the workstation cabinet skeleton. Holes are also drilled in the upper steel tube to provide fixing for the worktop. The entire frame is painted using existing painting methods. Extra holes must be drilled in each piece of steel used so that the cleaning solution used to clean the steel prior to painting can be drained out of the steel tube. Provided below in Figure 6-38 is the chassis design.

Figure 6-38 Workstation Chassis Design



6.4.4.2 Part 2: Storage of Equipment

This section outlines the development of integrated storage solutions for each of the targeted technology areas. The storage requirements for all tools were evaluated and a combination of particular and standard storage methods were combined in each of the workstations.

6.4.4.2.1 Materials and Structures and Mechanisms Technology

<u>Saw Drawer</u>

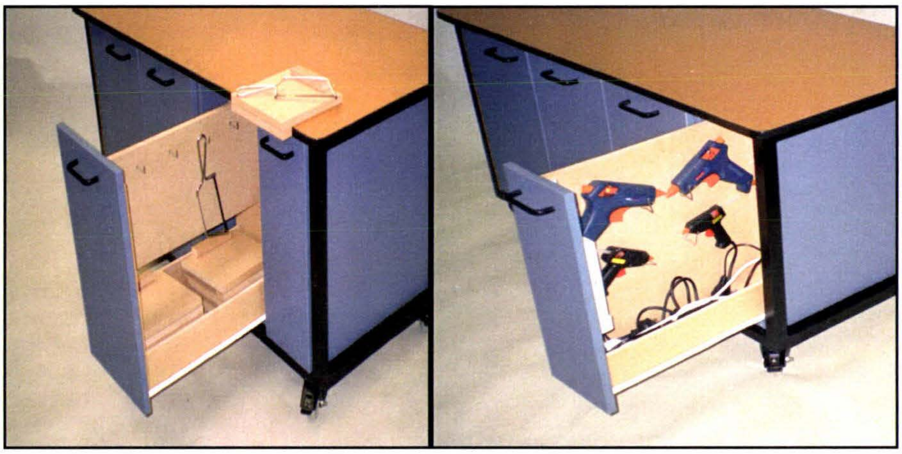
Drawer Dimensions

The overall dimensions of the drawer are 275 mm wide x 475 mm deep by 465 mm high (refer to the left image in Figure 6-39). The width chosen is the same as a standard tote tray this helped standardise the workstation dimensions. The height and depth dimensions were determined by the overall dimensions of the workstation.

Height of Side panel

The side panel[2] needed to be high enough to prevent the sawing blocks from sliding out, but low enough so that removal of the sawing blocks from the drawer was possible. The height selected was 100 mm.

Figure 6-39 Saw Drawer and Glue Gun Drawer



Middle Section Design

A simple 260 x 475 mm piece of 18 mm MDF is used for the middle section. Holes are drilled into the board 50 mm from the top and are spaced 64 mm apart. The hooks to be used are 38 mm long.

Single Vs Double Sided

The saw drawer is designed double sided. This allows saws to be hung on either side of the middle section and the drawer is large enough to store sawing blocks inside.

<u>Glue Gun Drawer</u>

Drawer Dimensions

The overall dimensions of the glue gun drawer were 210 mm wide x 475 mm deep by 465 mm high. This size is designed to fit in with the other drawers when it is included in the workstations (refer to right image of Figure 6-39).

Height of Side panel

Several different height side panels were investigated. High side panels on the side that stores the work surfaces secured the surfaces and prevented them from falling out. If large surfaces are used (400 x 450 mm) this makes removal difficult. The sides were made 100 mm high to help keep the glue gun cords from falling out of the drawer, a hook was used to secure the work surfaces in the final design.

---

[2] A side panel is the part of the drawer that prevents equipment from sliding out of the drawer.

Middle Section Design

The middle section is a full-length piece of 18 mm MDF with 3 mm holes drilled 64 mm apart across the board and in rows 50 mm apart down the board. This provides a number of storage arrangements using 38 mm square steel hooks.

Single Vs Double Sided

The drawer is double sided, one side stores the guns and the other stores the work surfaces.

General Tool Store

Drawer Dimensions

The general tool store is a drawer much the same as the glue gun drawer. The dimensions are the same to help reduce manufacturing costs by simplifying cutting of components.

Height of Side panel

The height of the side panel is also the same at 100 mm high.

Middle Section Design

The middle section is the same as the glue gun drawer; it is a simple piece of 18 mm MDF with holes drilled at the same spacing as the glue gun drawer on both sides. Included with this drawer though is a collection of 38 mm square hooks and 1" spring clips that can be arranged as the consumer wishes.

Single Vs Double Sided

The drawer is double sided to help balance the load on the drawer and increase the efficiency of storage space.

6.4.4.2.2 Electronics and Control Technology

Small Compartment Drawer

Drawer Dimensions

The small compartment drawer needed to be 275 mm wide to ensure the large plastic trays fit into the drawer (the largest is 200 mm long). All other sizes are the same as the other drawers. This width is also the same as the tote trays used at Furnware and use the same width, which simplifies manufacturing processes.

Height of Side panel

The height of the side panel is reduced to 50 mm to allow for easy access to the plastic trays.

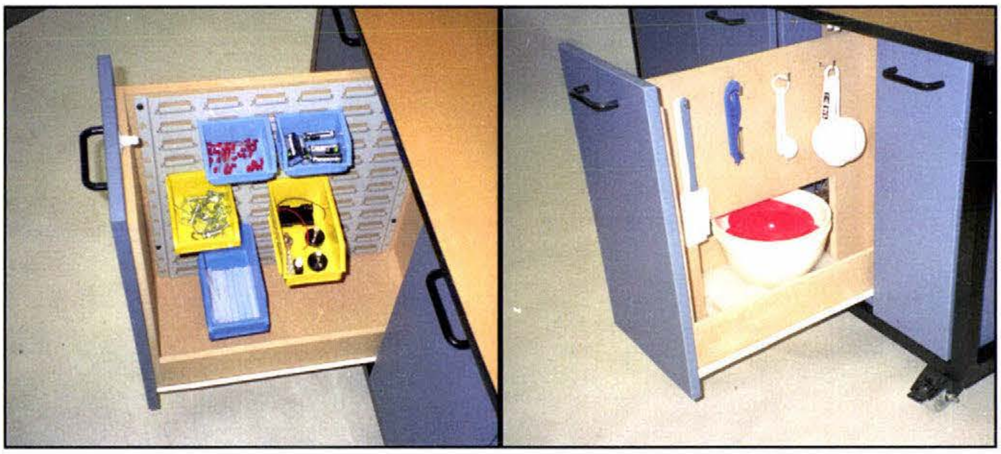
Middle Section Design

The middle section has a steel plate screwed to it that is used to secure the plastic trays on. No other fittings or holes are required on the middle section.

Single Vs Double Sided

The drawer is single sided so that the plastic trays fit into the drawer.

Figure 6-40 Small Compartment Drawer and Food Preparation Drawer



6.4.4.2.3 Food Technology

<u>Food Preparation Drawer</u>

Drawer Dimensions

The food preparation drawer was designed to store all the utensils needed to prepare food for cooking. The overall size is the same as a standard tote tray cavity like the small compartment drawer (275 mm wide).

Height of Side panel

The side panels needed to provide security to equipment but allow easy removal when needed for use. The height of 100 mm worked well for this drawer.

Middle Section Design

To include all of the equipment needed to prepare food a design for the middle section was chosen that provided the maximum amount of vertical storage but also allowed for the chopping boards and bowls. The design shown above in Figure 6-40 illustrates how a section was cut out of the middle section to allow for the bowls and chopping boards.

Single Vs Double Sided

The drawer is double sided to make the most of vertical storage.

6.4.4.3 Part 3: Work Surfaces

6.4.4.3.1 Worktops

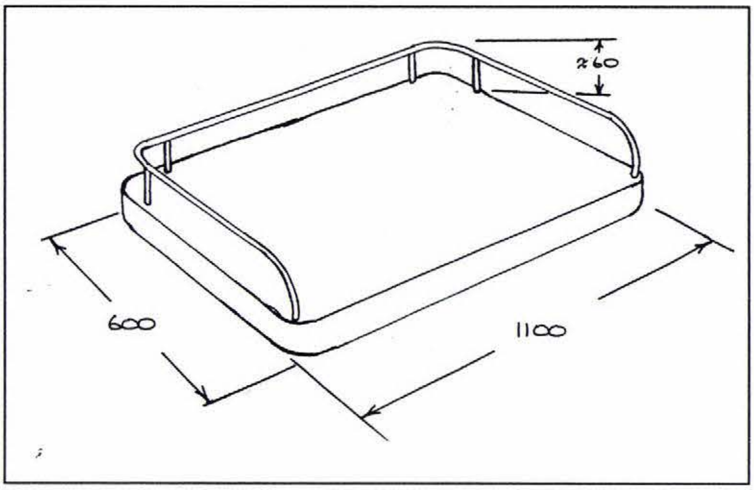
Medium Density Fibreboard Worktop

The MDF worktop needed to be made as cheaply as possible. It is going to be used as an alternative surface to standard school desks for doing practical activities on. Doing activities such as drilling and sawing on the workstation mean that it is likely to be damaged. Designing a worktop that is easily replaceable and is cheap is therefore the best option. 18 mm thick MDF panel is used because it is the cheapest material available. This is then varnished and edge banded to provide some protection. The worktop is a simple rectangular shape with 40 mm radiused edges. The rounded edges are safer than square edges. The top is a basic rectangular shape to keep costs down and also to provide a more practical top to work on, often the edge of the top will need to be used to perform a practical task, rounded edges can make this difficult.

Stainless Steel Top

A stainless steel worktop is expensive; the design of the top needs to be as simple as possible without compromising too much on function. Several different designs were developed. The simplest top would have a flat surface, square edges and no other features such as safety rails. The top would also need to be small enough to be made out of a 1200mm wide piece of stainless steel. The most functional and expensive top would have a contoured surface that incorporated a lip on the edge to prevent spillage of liquids, a safety rail to prevent items being knocked off the unit and nice, rounded edges for both aesthetic and safety reasons. Discussions with several stainless steel manufacturers led to a compromised design. The final design, shown below in Figure 6-41 has a safety rail and rounded edges for safety reasons. To reduce costs, the worktop is flat and reduced in size from the original 1200 mm to 1100mm. Reducing the size ensures the top can be cut economically from a sheet of stainless steel.

Figure 6-41 Stainless Steel Worktop



6.4.5 Outcomes

Initially the concept chosen as the one that best met customer needs was Family #1. This concept was to be presented to schools in such a way that they could effectively build up their own units by selecting any of the drawer designs for their workstation as long as they fitted into the overall size of the workstation. After discussing this idea with the sales manager at Furnware a combination of both concepts was chosen as the best to continue development. The final design provided six separate workstation models to choose from. Each model was based on the same basic dimensions, steel chassis and castors. There were two panel drawer cavities that cover all of the models to further simplify manufacturing. The differences in the models were based around the tops and the storage configurations. Each model was made of up a selected combination of vertical drawers, tote tray bays and standard cupboards. Additional parts such as vice and work surfaces were advertised as optional extras. The chosen concept is therefore more flexible than having only 2-3 fixed workstations, as in Family #2 concept, but will be marketed as six, fixed workstation models rather than as a build-your-own concept like Family #1 concept.

6.5 Summary

This chapter summarised the development of two concepts. This iterative and complex process was broken down into several stages of prototyping and concept development. Provided at the beginning of the stage was an ergonomic analysis of the workstations.

The analysis found that the most important design factor was the height of the workstation. Consequently ideas were generated to make the workstations height adjustable. The first stage of prototyping focussed on specific areas of the designs. A height adjustment mechanism was trialed. The vertical drawer idea was prototyped and portable surfaces were developed. The height adjustment mechanism did not perform as expected and development was discontinued. the vertical drawers worked well and have been incorporated into the workstations. A range of new ideas was developed and prototyped for integration of portable surfaces. The use of simple surfaces was the best idea. Finally, integrated design of the workstations was done and these will now be prototyped and tested in the final stage. Stage 4:Testing and Commercialisation.

7 Stage 4: Testing and Commercialisation

7.1 Introduction

The purpose of this chapter is to summarise Stage 4: Testing and Commercialisation of the Mobile Technology Education Workstation project. The final product design developed in Stage 3 was prototyped and tested for consumer appeal, functionality and physical integrity. From the testing, final design modifications were suggested and the final product specifications and costing presented. Finally, suggested commercialisation activities were presented. This was the final stage of the product development process used to develop the Mobile Technology Education Workstation range.

7.2 Final Prototype Development

7.2.1 Aim

To ensure developments in the workstation design function as expected. To produce a final prototype suitable for physical and consumer testing.

7.2.2 Methodology

1. Produced prototyping schedule.

   The prototyping schedule outlined important information relating to the proposed prototype. Main headings included purpose, level of approximation, quantity, test plan and schedule for work to be carried out.
2. Made prototype according to schedule.

   The prototypes were made according to the schedule, this process has to fit into the production schedule at Furnware as personnel and equipment used in production needed to be used to make the prototypes.
3. Tested prototype according to schedule.

   A comprehensive testing of the workstation was included in the next chapter. Preliminary testing was done according to the outline of test plan given in the prototyping schedule.
4. Discussed results.

The results of the testing will determine if the design is ready for commercialisation.

7.2.3 Results

7.2.3.1 Part 1: Materials Technology Prototype

7.2.3.1.1 Materials Technology Workstation Prototype Schedule

Table 7-11 Materials Technology Workstation Prototype Schedule

Name of Prototype:	**Materials Technology Prototype**
Purpose: To test the generic features of the proposed family of units. This includes the chassis, work surface, vertical drawers, castors and overall dimensions. (Integration of all parts of the product concept)	
Level of approximation: Scale: 1:1 Material: Same properties as final material Aesthetics: Same as final product	
Quantity to be built: 1 X Full-scale prototype plus all drawer options	
Outline of test plan: Discussion of manufacturing process, programming with both CAM programmer and steel design team Job card prepared Schedule and make prototype Test for functionality by storing appropriate tools in the unit, working on the unit and wheeling it around a school environment Show working prototype to key users for opinion	
Schedule: Discussion Prototype made Test prototype Results	 20 October 2000 30 October 2000 03 November 2000 10 November 2000

7.2.3.1.2 Materials Workstation Prototype Results

Generic Unit

- The top was too wide. Manoeuvring the workstation around a school environment, especially through doorways was awkward. Reducing the width down from 650 mm to 600 mm is suggested.
- An 18 mm thick top, while not a standard Furnware design, is a good idea if the surface toggle clamps are going to be used both on the workstation and on standard school desks, which are also 18 mm thick.

- Edge banding and lacquering the top significantly improved visual appeal of the workstation.
- The frame could be downsized from 31.8 mm to 25.4 mm square mild steel tube and simplified to form a chassis only. The chassis for the Food technology workstation prototype was used to test this new design.
- Two fixed wheels and two locking swivel wheels make for easy wheeling in a straight line. Manoeuvring through doorways was difficult though and all four wheels should swivel on the final design.
- The vice requires additional packing to ensure the vice is level with the worktop.

Storage

- Piano hinge is required if a door is to be placed on tote cavity and attached to steel frame, rather than using the standard door hinges.
- No tools fell off the hooks they were located on when the workstation was wheeled over rough terrain (gravel).
- Sawing blocks with toggle clamps are difficult to store and often catch when the drawers are closed.
- Needed to leave top tote tray out when a vice is attached.

7.2.3.2 Part 2: Food Technology Prototype

7.2.3.2.1 Food Technology Prototype Schedule

Table 7-12 Food Technology Prototype Schedule

Name of Prototype:	**Food Technology Prototype**
Purpose: To test the revisions made to the generic unit features. Ensure stainless steel top design works. Produce a prototype ready for consumer and physical testing.	
Level of Approximation: Scale: 1:1 Material: Same properties as final material Aesthetics: Same as final product	
Quantity to be built: 1 X Full-scale prototype	
Outline of test plan Discussion of manufacturing process, programming with both CAM programmer and steel design team Job card prepared Schedule and make prototype Ensure all components of the prototype fit together. Test structural aspects of workstation using the AS/NZ safety standard. The results of this test are provided in the following chapter. Test unit for functionality by using in mock classroom usage situation. Test for consumer appeal by questioning consumers for opinions on units	
Schedule:	
Discussion	20 November 2000
Prototype made	25 November 2000
Check prototype	27 November 2000
Results	30 November 2000

7.2.3.2.2 Food Technology Prototype Results

The majority of the test results are included in the following chapter. Included here is a review of both Financial and Manufacturing and Materials considerations. Having developed two full prototypes, the information gained from them was used to discuss whether or not the workstations' costs were on target and also raise any manufacturing details that required attention.

Manufacturing and Materials Considerations

Developing and prototyping two workstations have effectively ensured that the workstation design can be manufactured at Furnware. Provided below are some aspects that deviate from typical Furnware manufacturing processes.

- Stainless Steel Worktop

The stainless steel worktop needed to be manufactured by another company. This meant that Furnware needed to source another supplier that can produce and deliver the worktops at a competitive price and of sufficient quality.

- Vertical Drawers

  The vertical drawer design was a new development for Furnware. At present the standard drawer runners used for all other drawer have been used on the vertical drawers to keep costs low. There may be better drawer runners in the market that are better suited to this application.

- Castors

  The industrial castors used in the design were also a new component part. An existing supplier of castors and wheels stock these for a reasonable price, so this should not cause any problems.

These were the main deviations from Furnware's current manufacturing processes. For a full description of how the workstations were made, refer to Section 0.

Financial Analysis

The target retail price for the Mobile Technology Education Workstations, as specified in Table 6-1, was less than \$1500 and ideally \$550. A financial analysis of the two prototype workstations was conducted and the estimated retail prices were: Materials workstation \$ 821.00 and Food workstation \$ 1173.00. These estimates are higher than the ideal value of \$550, but within the target range of less than \$1500. The costs of the workstations and the finer points of their design are re-evaluated after testing. Details of the pricing method, including costing and mark-up percentages are commercially sensitive and could not be disclosed.

7.2.4 Outcomes

The Materials technology prototype was built according to the final dimensions outlined in Stage 3: Detailed Design. The purpose for building the prototype was to ensure that all the elements worked together as expected. The majority of the elements did work well from the testing undertaken. The workstation will be tested with the Food technology workstation for functionality and consumer appeal to ensure the Materials technology related work surfaces and storage facilities are acceptable to the consumer. A major outcome of the Materials technology prototype was that the chassis design was changed. The chassis used was simplified to reduce weight and improve storage capacity of the workstations. The chassis used for the Food technology prototype used this new design and this workstation prototype will be tested for structural integrity. If it does not pass this test, the chassis will need to be redesigned again. To reduce the costs of the workstations, the length was reduced to 1100 mm and to ensure better manoeuvrability the workstation width was reduced from 650 mm to 600 mm. The castor configuration was changed from only two swivel wheels on the Materials prototype to four on the Food technology prototype to improve manoeuvrability.

7.3 Concept Functionality Test

7.3.1 Aim

To test the workstation designs for their ability to satisfy consumer needs from a functional perspective.

7.3.2 Methodology

To test the functionality of the workstations a mock classroom usage situation was set up. A local Hastings school was approached and a test of each of the prototypes was conducted using a typical classroom environment, typical technology activity and students the appropriate age. With the co-operation of the head of the technology department at the school, two appropriate tasks were developed. The Materials Technology task involved the use of pneumatics to design and prototype a car hoist. The Food Technology project involved making hokey pokey. The children and an assistant were given instructions on what to do. A video of the children completing the tasks using the Mobile Technology Education Workstations was taken for later analysis (refer to CD at back of thesis). The methodology for testing the concepts' functionality was:

1. Contacted local school.
2. Organised and planned the appropriate technology projects.
3. Stocked workstations with equipment and set up the room, including video camera.
4. Performed the tasks with children and supervisor.
5. Reviewed the video and noted down all important findings.

7.3.3 Results

7.3.3.1.1 Test #1 – Materials Technology Workstation

The Materials technology test involved using pneumatics to design a model car hoist.

Figure 7-42 Functionality Testing of Materials Technology Workstation

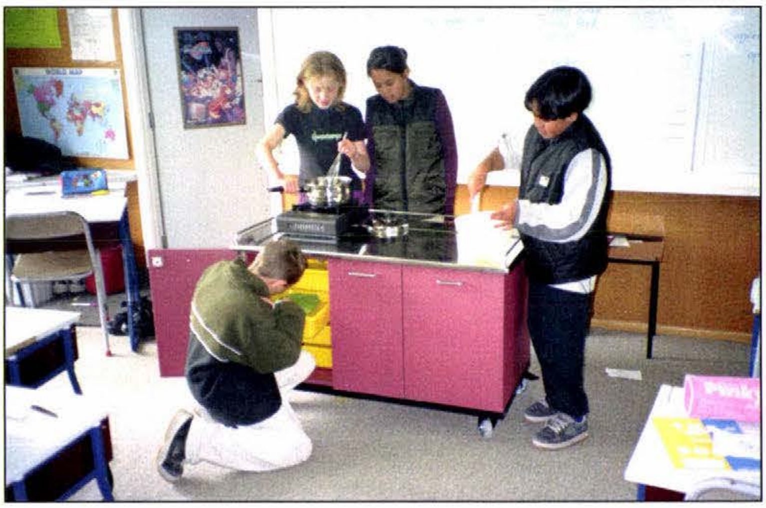
The students had to perform a number of tasks including sawing, drilling and gluing. The students worked both on the workstation and on school desks. The gluing was done using a glue gun plugged into the mains power. A 400 x 450 mm piece of 6 mm thick MDF was used to prevent glue getting on the desks. Provided below are the main findings of the test.

- The children got the drill and glue guns out of the drawers OK.
- Used the vice for the drilling, very handy.
- Labels on the drawers indicating what was inside would help children find the right tools easier without needing to repeatedly open drawers to look inside.
- Glue gun surfaces taken out of unit with a little difficulty due to the size of them
- Glue guns set up on another table nearer the power point, multiplug used. This worked well.
- Size of the surfaces great, approximately same size as desks.
- Tote trays taken out of workstation, to have better access to the materials stored in them.
- Sawing using the bench hooks done OK, needed to show children how to use properly.

7.3.3.1.2 Test # 2 – Food Technology Workstation

Testing of the Food technology workstation involved making hokey pokey. The children had to measure ingredients into a bowl. Mix all the ingredients together and then heat in a saucepan. A portable gas cooker was used on the workstation and it worked very well. Once the mixture was heated for several minutes, it was poured into a baking tray and allowed to cool. Once finished, all of the dirty utensils were loaded onto the workstation and it was moved down the hall to a kitchen, where all equipment was cleaned and put away. Provided below are the main findings of the test.

Figure 7-43 Functionality Testing of Food Technology Workstation



- Wheeling workstation down hall, bumped into doorframe, workstation fine.
- Children could open doors OK, including the door with lock.
- Unlocking and locking the door was a bit annoying if both a snap latch and lock were used would be better.
- All equipment necessary for task was stored in the workstation, except sharp knife.
- Height of workstation good, children used 9 & 10 year olds.
- All hot cooking tasks done on workstation, good to have stainless steel (heat resistant) and easy to clean.
- All dirty utensils placed on workstation after use and wheeled down to hall kitchen to be cleaned up.
- Safety rails excellent.

- Two children required to control workstation, one in front one behind. The workstation was easy to manoeuvre around classroom and hall due to castor configuration of four swivel wheels. The safety rail also acted as an excellent handle for manoeuvring the workstation.

7.3.4 Outcomes

The tests showed that the workstations worked well under normal working conditions to complete typical technology education tasks. Some areas of potential improvement were also identified. In particular changes to closing mechanisms on the doors and drawers is suggested and also the need to have four swivel castors instead of only two.

7.4 Consumer Appeal Test

7.4.1 Aim

To test the workstations for general appeal to those people who are responsible for purchase of school equipment, namely principals and technology teachers.

7.4.2 Methodology

The second consumer test was an in-depth consumer survey. Typical purchasers of the workstation such as teachers and principals were invited to view the workstations, interact with them, ask questions and watch a video of the children using the workstations in the functionality test described above. The aim of this survey was to get feedback on other aspects of the workstation such as price and aesthetics as well as the practical applications. Each participant was invited to fill out a 'Warrant of Fitness' style questionnaire. Questions were asked relating to all aspects of the workstation. The participants inspected the units and asked questions when required as they filled out the questionnaire. A total of 41 questions were asked and the results are given below. See Appendix C for a copy of the questionnaire.

7.4.3 Results

In general the workstations were very well received. The different storage options were generally all liked as were the aesthetics of the workstation and the optional extras. In particular:

1. The small compartment drawer should have the larger size plastic trays rather than the smaller trays. Trays come in a range of sizes: No. 5 (120mm x 100mm), No. 10 (165mm x 100mm) and No. 20 (200mm x 160mm). Sizes 10 and 20 were much more popular than No. 5.
2. All participants said they would include a tote bay in the workstation.
3. The single narrow drawer, while liked by the participants, was decided that a double-sided drawer was better as it made more efficient use of storage space.
4. The participants rated the stainless steel worktop highly.
5. Either 1 or 2 food preparation drawers could be included on the workstation.
6. The Food technology prototype chassis and castor configuration was preferred over the Materials technology prototype.
7. Prices estimated by participants ranged from $500 to $1000 for the Materials Technology prototype and from $1000 to $1500 for the Food technology prototype, which is within the ranges of the actual price.
8. Importance of aesthetics was rated on average a 4 on a scale of 1 to 5, one being not important and five being very important.
9. The aesthetics of the prototypes was rated on average a 5 on a scale of 1 to 5, one being very bad to five being excellent.

7.4.4 Outcomes

The feedback from participants was generally positive. Some design modifications may need to be made and certain drawer options changed to better suite consumer needs. The price and aesthetics of the workstations was positive also, indicating that the workstations are likely to sell and that further design work relating to improving aesthetics will not be necessary.

7.5 Structural Integrity

7.5.1 Aim

To ensure the workstation design is of sufficient quality and that it will be safe for both teachers and children to use.

7.5.2 Methodology

The structural integrity of the workstation was tested using the AS/NZ 4610.3:1999 Australian and New Zealand Safety Standard (Furniture - School and Educational) as a guide. The testing was carried out at Massey University using the Product Development design studio. Several tests required machinery in the Engineering laboratory also. The tests will provide valuable feedback on the structural integrity of the design.

7.5.3 Results

Physical testing of the final prototype was conducted in accordance with the AS/NZ 4610.3:1999 Australian and New Zealand Safety Standard (Furniture - School and Educational). The unit passed the majority of the tests to a sufficient level. Some areas require additional design work and are discussed below.

Table 7-13 Physical Testing Results

Safety Standard Reference (AS/NZ 4610.3)	**Description**	**Passed ✔**	**Failed ✖**
Section 3: Strength			
3.2 (Appendix A)	Initial Inspection	✔	
3.3 (Appendix B)	Vertical Static Load Test	✔	
3.4 (Appendix B)	Sustained Load Test	✔	
3.5 (Appendix C)	Overturning Damage Test		✖$_1$
3.6 (Appendix D)	Horizontal Static Load Test	✔	
3.7 (Appendix E)	Vertical Impact Test	✔	
3.8 (Appendix F)	Drop Test	✔	
3.9 (Appendix G)	Fatigue Tests		✖$_2$
Section 4: Strength of Additional Components			
4.2 (Appendix H)	Shelves and Horizontal Surfaces	✔	
4.3 (Appendix I)	Pivoted Doors	✔$_1$	
4.4 (Appendix J)	Sliding Doors	N/A	
4.5 (Appendix K)	Flaps	N/A	
4.6 (Appendix L)	Roll Fronts	N/A	
4.7 (Appendix M)	Drawers		✖$_3$
4.8 (Appendix N)	Carcass and Underframe	✔	
Section 5: Stability			
5.2 (Appendix O)	Horizontal Impact Test	✔	
5.3 (Appendix P)	Overturn Test: Unloaded	✔	
5.4 (Appendix Q)	Overturn Test: Loaded	✔	

Notes

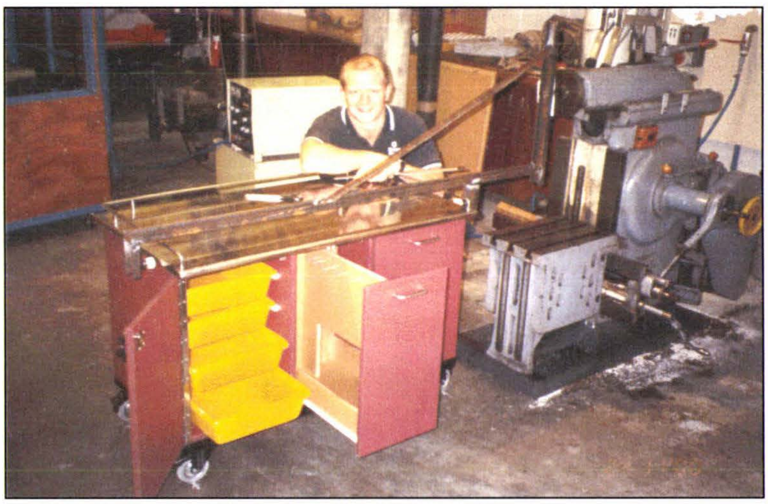
✖$_1$ The top could be attached to chassis using steel brackets to reduce the chance of the top coming away from chassis. When tipped onto back one drawer front came off the drawer inner.

✗$_2$ Cam bolts loose on inspection after 30,000 cycles of 150 N forces applied to the top front of the workstation. Some movement observed between the chassis and the skeleton.

✗$_3$ Some movement was observed in the drawer runner where attached to the cabinet. Suggest that at least four screws be used to secure the runner in the future. A reduction in tolerance between drawer and cavity may also help alleviate the problem. Plastic drawer latches lose their ability to restrain drawer over time. Suggest that a higher quality securing methods be used such as steel spring clips or push-button latches.

✓$_1$ Piano hinge used is a light gauge. Suggest that a heavier gauge be used on the final product to reduce flexing.

Figure 7-44 Physical Testing of Final Prototype



7.5.4 Outcomes

The workstation passed the majority of the physical tests. There are some areas that need to be altered if the workstation is to pass the safety standard. In particular the following design modifications are suggested:

- Increase amount of fixing between top and skeleton. Steel brackets located inside the workstation could be used to improve strength at a low increase in workstation cost and weight.
- Ensure drawer fronts are fixed to the drawer with sufficient amount of screws (at least four to six) and ensure runners are sufficiently forward in the workstation

so that the stop on the end of the runner takes the force of closing the drawer as it is designed to do.

- Cam bolts need to be tightened fully upon assembly of workstation. If Cams still come undone the workstation should be doweled and glued together. The strength requirements for these workstations are higher than Furnware's current products due to the amount of movement throughout the school this workstation is expected to experience.
- To prevent the drawer runner moving it should be secured with at least four screws and the tolerances checked between drawer and cavity. If this does not stop runner movement, then a higher grade of runner will have to be used.
- Replace plastic drawer latches with steel equivalents and retest. If this does not work, a more positive locking system such as push-button locks will need to be used.
- Increase the gauge of piano hinge from 1 mm steel to 1.4 mm steel or higher, until flexing is eliminated.

The final product specifications can now be outlined from the results of testing.

7.5.4.1 Final Product Specifications

From the consumer trials and physical testing, modifications can be made to the design to arrive at the final design. Provided in this section are the specifications of the final product. The final product consists of six different models of workstation and are outlined below.

Height: 720 mm.

Width: 600 mm.

Length: 1100 mm.

Price: Range from $706.53 to $1026.67.

Mobility: 80 mm diameter industrial strength castors type: EPRS 80. Two swivel and lock and two swivel only. The swivel and lock castors are to be located on the front side of the workstation.

Security: All storage has either doors or drawer fronts on them. The workstation comes with optional locks and standard with steel snap latches.

Work Top: Option of either stainless steel or MDF, depending on whether or not the workstation is going to be used for Food related activities or not.

Table 7-14 Mobile Technology Education Workstation Models

Storage Option	Workstation Models					
	Mats I	**Mats II**	**E&C I**	**E&C II**	**Food I**	**Food II**
Chassis	✓	✓	✓	✓	✓	✓
Skeleton I	✓	✓	✓			
Skeleton II				✓	✓	✓
Stainless Steel Top					✓	✓
MDF Top	✓	✓	✓	✓		
Standard Tote Bay	✓	✓ x2	✓		✓	✓ x2
Glue Gun Drawer	✓	✓	✓			
General Tool Store	✓	✓	✓	✓		
Saw Drawer	✓					
Small Compartment			✓	✓		
Food Preparation					✓	
Cupboard				✓	✓	✓
Retail Price	$748.28	$722.08	$797.07	$706.53	$1026.67	$986.96

7.6 Commercialisation

7.6.1 Introduction

This section summarises the commercialisation issues relating to the Mobile Technology Education Workstations. At the time of completing this report some promotional work had begun but the majority of the activities described below are plans only. Included in this section are the product strategy, marketing and launch plans and production plan.

7.6.2 Product Strategy

7.6.2.1 Product Objectives

The product objectives were set by Furnware. The Mobile Technology Education Workstation range was considered a successful product if the turnover objectives were met.

Table 7-15 Product Sales and Market Share Objectives

Year	Target turnover ($NZ)	Estimated Sales (Turnover/$831.26[3])	Estimated Market Share (Estimated Sales/ 1600[4])
1	50 000	60	4%
2	100 000	120	8%
3	150 000	180	12%

7.6.2.2 Strategic Alternative

The strategy used by Furnware for the introduction of the Mobile Technology Education Workstation range of products concentrated on providing long term profits, growth in sales and growth in market share through market development of a new product segment. The use of mobile workstations in primary schools for practical technology education is a new market in which Furnware aim to develop into a profitable sales avenue.

[3] 831.26 is the average retail price of the six units. The prices are given in Table 7-14.

[4] 1600 is the estimated market size multiplied by 2, the estimated number of workstations per customer.

7.6.2.3 Customer Targets

The target market for this product is all primary schools in New Zealand. In particular schools that have between approximately 100 and 250 students. Target market size is estimated to be 800 primary schools. Schools were expected to need, on average at least two workstations.

7.6.2.4 Competitor Targets

This market is a new market and there was only one current competitor. The commercialisation strategy therefore concentrated on developing the market segment rather than on competitors.

7.6.2.5 Core Strategy

The core sales strategy of the Mobile Technology Education Workstation was to be first to market. There was only one competitor product in this market. Due to the relative newness of the Technology Curriculum in New Zealand primary schools, this market has not yet been developed. The core strategy therefore involved reaching customers before competitors.

7.6.2.5.1 Branding

The reputation of Furnware to produce good, high quality products was also used to provide a point of differentiation to the product as well as the fact that it was developed by a university technology student.

7.6.2.5.2 Choice

The Mobile Technology Education Workstation range was comprised of six workstations, each addressing different areas of the Technology Curriculum. The consumer was given the choice of workstation that best suited their needs. This gave customers much more choice in what they buy. The main competitor only sold one type of workstation so providing six workstations gave Furnware a competitive advantage.

7.6.3 Business Strategy Fit

The new Mobile Technology Education Workstation range fitted with Furnware's business strategy because it is an educational furniture product that targeted part of the existing customer base. The workstations' fit with particular aspects of the business strategy is outlined below.

7.6.3.1 Product

This product fitted with Furnware's strategy to produce high quality, well-designed furniture as a reasonable cost. Furnware prices were often slightly higher than competitors due to the higher quality of the products sold. This workstation range was positioned accordingly.

7.6.3.2 Marketing

The Mobile Technology Education Workstation range targeted the same customers as Furnware's other products. Existing marketing channels and processes were used for this product so the Mobile Technology Education Workstation range fitted with current strategy.

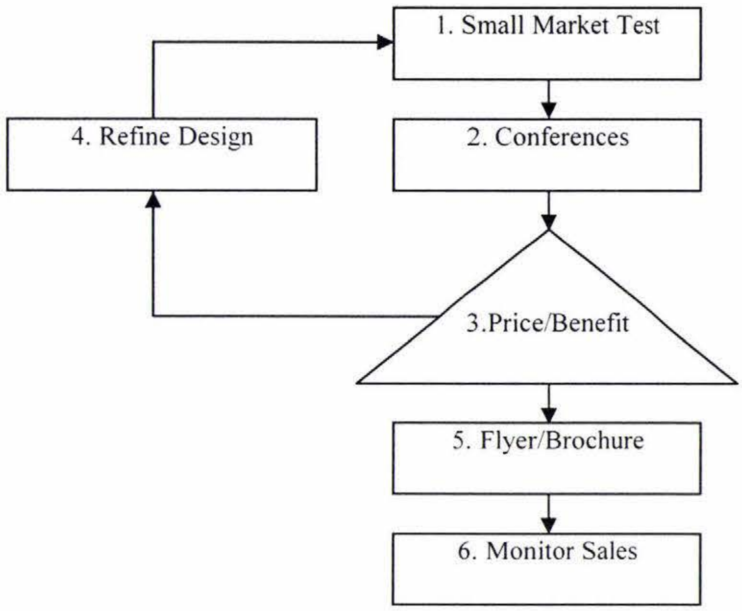
7.6.3.3 Production

The workstations do include some components that needed to be manufactured by a sub contractor. An example of this was the stainless steel work top on the Food technology workstation. The majority of the workstation was able to be manufactured using existing production processes and materials.

7.6.4 Marketing and Launch Plans

Provided below in Figure 7-45 is a flowchart of the typical marketing activities carried out at Furnware to launch a new product. The Mobile Technology Education Workstation range used the same process. A description of each of the stages and an overview of what particular plans has been undertaken for the workstation range is also provided.

Figure 7-45 Flowchart of Typical Marketing Activities Carried Out at Furnware



7.6.4.1 Small Market Test

A limited number of products are manufactured and sold to a few customers and feedback on the product is obtained. Customers can provide valuable information and suggest improvements to the product design.

7.6.4.2 Conferences

There are a number of conferences held throughout New Zealand that are suitable for getting feedback on and releasing new products. Most of these conferences are education related. The Food technology workstation prototype has already been taken to a primary school conference to gain consumer feedback.

7.6.4.3 Price/Needs Comparison

The small market test and conferences provide sufficient information about the popularity of a new product. In particular information relating to the trade-off between a product's perceived benefits and its expected retail price is gathered. This information helps decide whether of not a product is ready for full launch or whether the design needs further refinement.

7.6.4.4 Refine Design

If a new product does not receive positive feedback about both its perceived benefits and retail price further refinement maybe necessary.

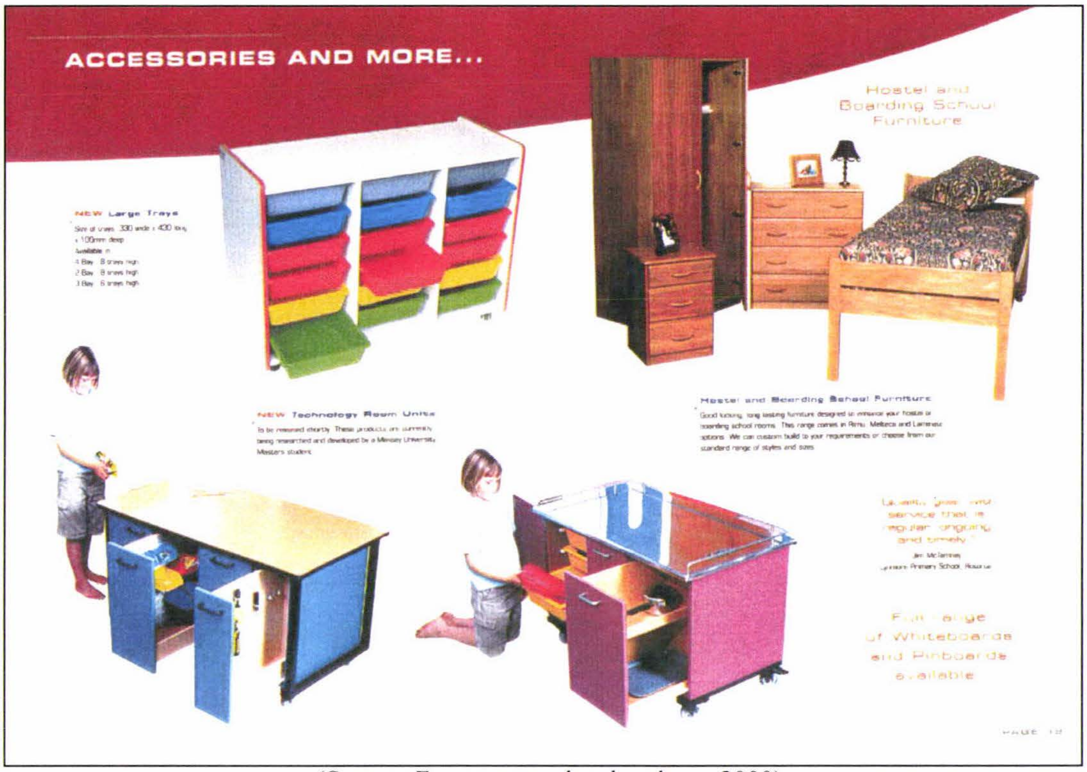
7.6.4.5 Flyer/Brochure

One of the first methods used to promote the launch of a new product at Furnware is to distribute a flyer to schools throughout New Zealand. Alternatively the new product maybe included in the Furnware product brochure. This brochure has all of Furnware's current educational products included in it. The brochure is updated annually or biannually. If a new product is launched at the same time as the brochure is updated, then the product is likely to be included in the brochure. The Mobile Technology Education Workstation range was at final prototype stage when Furnware was developing a new brochure. Consequently, to promote the new, soon to be released range, the prototypes were included in the brochure. The brochure page is provided below in Figure 7-46.

7.6.4.6 Monitor Sales

Once a product has been launched the sales are monitored to determine whether or not the new product is a success. A new product is successful if it achieves its turnover and market share objectives. Monitoring sales helps decide whether of not products should be dropped form the current product range as well.

Figure 7-46 Images of Final Prototypes in Furnware Brochure



(Source: Furnware product brochure, 2000)

7.6.5 Production Plan

There are four main production systems involved in producing the Mobile Technology Education Workstation range: panel, steel, sub-contractors and fit-up. The panel process produces all of the melteca and MDF components. This includes the drawers, drawer cavities and the MDF top of the Materials technology workstation. The steel department makes the chassis, welds the castors to it and paints it. The sub-contractors provide all those parts unable to be made by Furnware. The parts that differ from parts already brought of suppliers include stainless steel worktop, castors and latches for the drawers. Fit-up is where all components are put together. Management of the production process therefore centres on two aspects. Getting all of the components made and to fit-up at the same time and getting the workstations through fit-up to outwards goods before the shipping date. Figure 7-47 below illustrates the production process for processing solid wood parts, MDF parts and melteca parts; the workstations only have melteca and MDF parts so processing is quite simple. Figure 7-48 below illustrates the steel production process, the chassis of the workstations pass through this process.

Figure 7-47 Solid wood and Panel Processing at Furnware

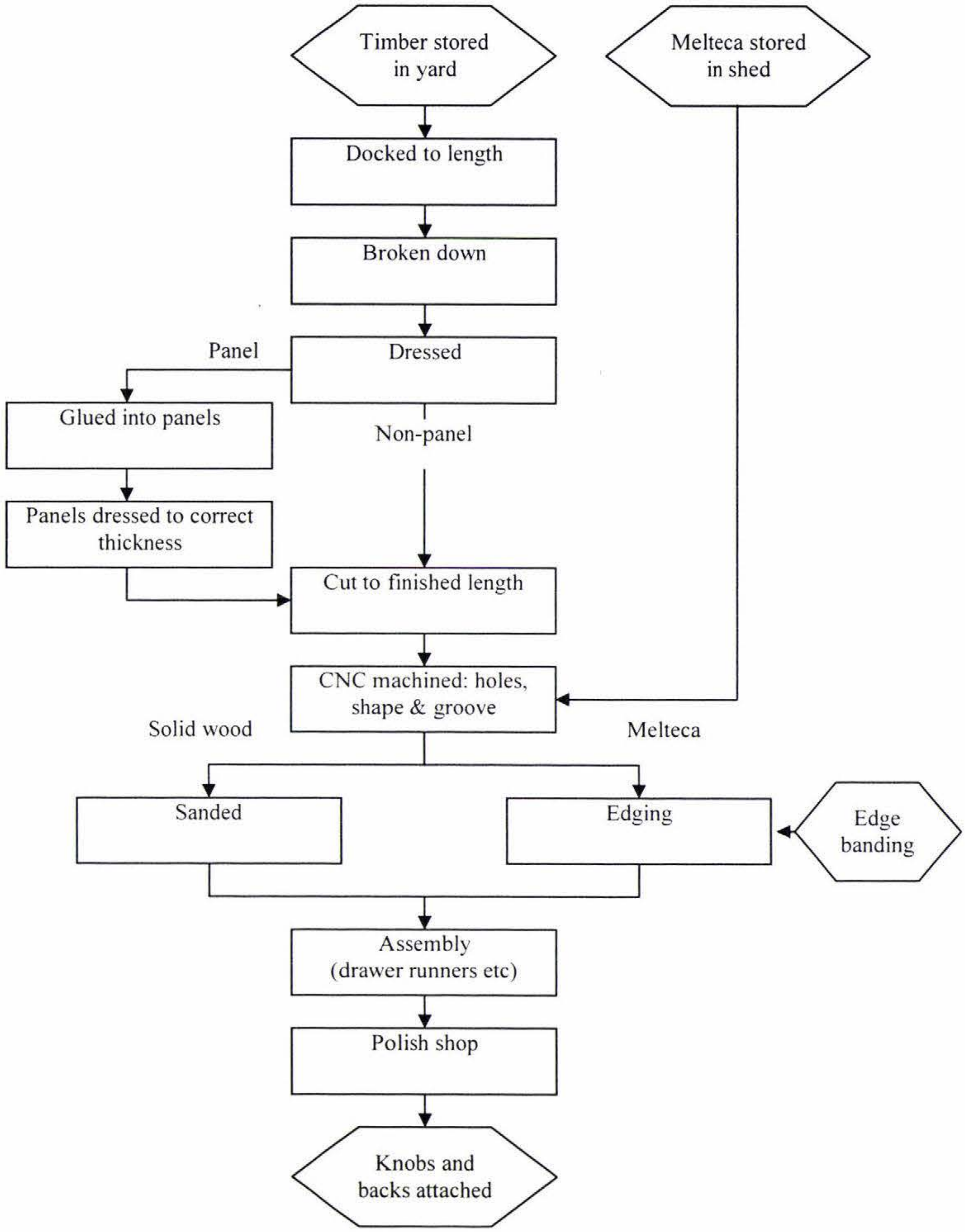
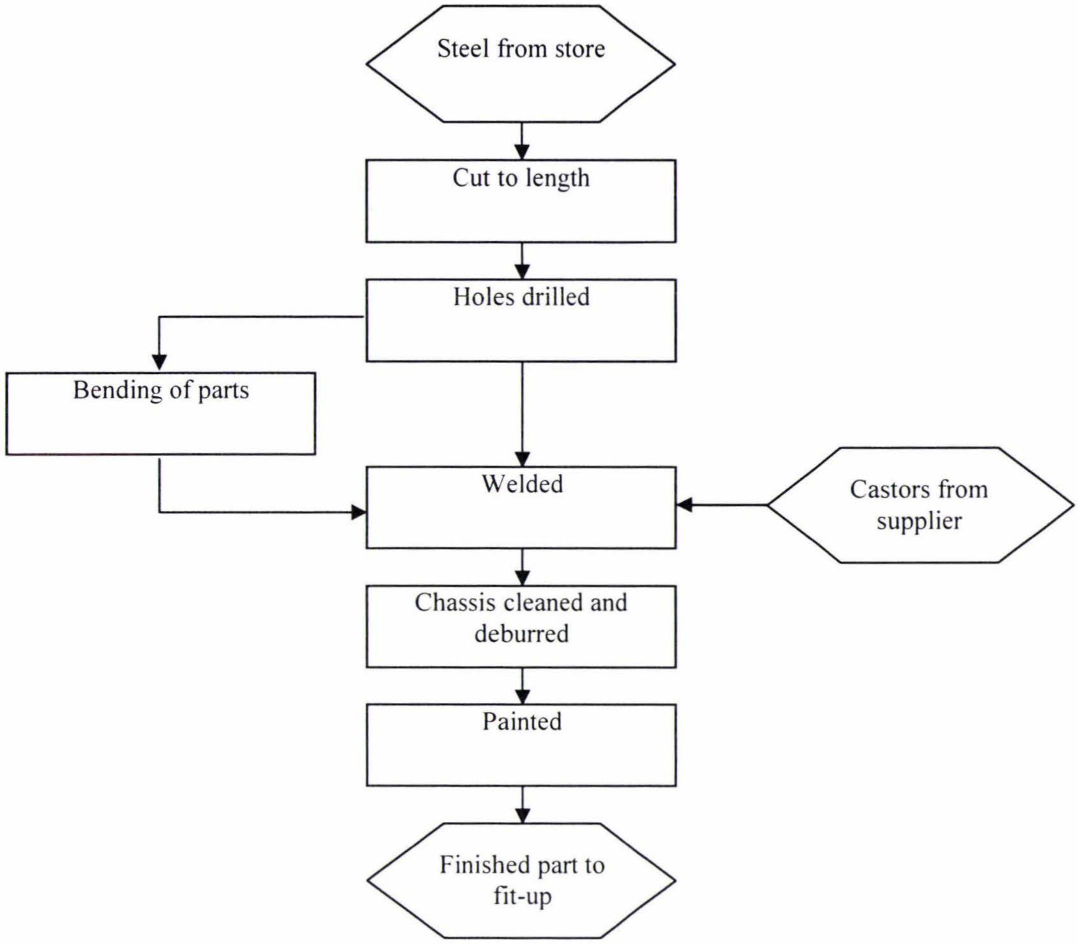


Figure 7-48 Steel Processing at Furnware



7.7 Summary

The Mobile Technology Education Workstation prototypes were tested by consumers in two ways: user trials and consumer evaluation. The user trials involved using the workstations in a mock classroom environment. The workstations functioned very well. Some potential improvements were discovered such as changes to the drawer locking mechanisms and the inclusions of labels for the drawers. Consumers were questioned in detail about the workstations and their features and much positive feedback was received. The workstations were also perceived to be worth approximately the same as their actual retail price. Aesthetics of the workstations was also well received. The workstation passed the majority of the physical tests (Safety Standard AS/NZ 4610.3:1999) as well. There are some minor areas that need to be altered if the workstation is to pass the safety standard though.

A commercialisation plan is presented in this chapter also. The product strategy provides the turnover and market share targets for the next three years. The Mobile Technology Education Workstation ranges' core sales strategy is outlined. The workstation range will be a first-to-market product that will achieve sales growth through the development of a new market segment. This product's fit with Furnware's business strategy is discussed. The workstation range, while differing in some physical aspects to the current products fits well with current product, marketing and production strategies. The marketing and launch of the workstation range will follow typical new product launch procedures used by Furnware. In particular the workstation range will be shown at conferences and included in Furnware's product brochure. Finally the production process for the workstation range was described.

8 Product Development Process Evaluation

8.1 Introduction

The purpose of this chapter is to summarise the evaluation of the product development process used do develop the workstation. The process was reviewed by stage and as a whole for possible improvements. International and national literature was reviewed to help find ways of improving the product development process at Furnware. Changes are proposed and a revised process outlined.

8.2 Methodology

1. Reviewed process by stage to determine which areas could have been done better.
   A meeting was held between the Fellow and Furnware's top management to discuss the product development project and any possible improvements that could be made.
2. Reviewed process as a whole to determine if the overall process is appropriate for Furnware.
   It was important to consider the process as a whole and how it fits with Furnware's particular operating environment as every company is different. Management issues are also an important part of product development and were discussed at the meeting with management.
3. Researched existing literature for solutions to any problems discovered.
   A search of both national and international literature relating to the specific areas of development is conducted and also in-depth research into one particular area: CAD technology is outlined in the following chapter.
4. Provided a modified product development process by combining those parts of the original process that worked well during the project and the improvements from steps 1-3.

8.3 Results

8.3.1 Part 1: Stage by Stage Evaluation

To help structure the evaluation of the product development process used to develop the workstation the evaluation was broken up into the stages of the process. Refer to Figure 3-13, page 50 for the product development process used.

8.3.1.1 Stage 0: Management Planning

8.3.1.1.1 Furnware Experience

This stage was essentially separate from the other stages in that all the tasks take place before specific product development project is started. The main sections in this stage are strategy, ideation and idea screen. There was no evidence of documented strategy identification at Furnware. Furnware did have a good ideation system in place however. The number of projects initiated by them every year is evidence of this. Idea screening was carried out by informal discussion between management and sales.

8.3.1.1.2 Discussion

The development of a strategic policy that ensures all product development projects are aligned with the company is important to successful product development (Griffin, 1997). It provides a basis from which projects can be guided. This stage was not carried out by the Fellow and is predominantly the responsibility of top management within Furnware. Furnware need to create and document clear new product strategy.

This particular project encountered problems with broad initial product definition. During the screening of ideas, a clearer definition of the product idea needed to be made. As in this research Kerr (1994) also found that New Zealand firms tended to hold informal discussion groups to decide which ideas to develop. Conversely international research identifies sharp, early product definition as a critical success factor in new product development, Cooper (1998). Clear product definition helps focus efforts on finding information most relevant to the product area, although if the new product idea is particularly innovative this task can be difficult and a redefinition is often required after a preliminary investigation is undertaken.

8.3.1.2 Stage 1: Preliminary Investigation

8.3.1.2.1 Furnware Experience

This is the first stage of an actual product development project. The main aim of this stage is to find information relating to the selected product area or areas. This information needs to be appropriate for making a selection as to which idea has the most potential. One to three vague ideas enter this stage and one researched idea that is suitable for development is the output of this stage.

A vast amount of information was collected relating to several product areas and much new information, that Furnware was not aware of, was gathered. Information such as the development of the Technology Curriculum and the number of government support documents that are available relating to this subject. Deciding on which idea to develop was done with top management involvement.

This stage was perhaps more time consuming than necessary due to the broad product definitions provided at the beginning of the stage and the lack of available knowledge within the company. The information gathered provided a lot of information relating to the product idea but perhaps not enough on the potential market size and other factors that affect Furnware's financial position such as expected price of a workstation.

8.3.1.2.2 Discussion

Focussing efforts on the exact information that is required to make informed decisions between product ideas would help reduce time taken to complete this stage. Documenting past projects and having them readily available would help future investigations by providing an information source to draw from. Product development activities should be seen as a "...knowledge creation process, which through the commercialisation of a product, ties together the knowledge base that exists as both an internal and an external resource of the company", Nagata et al. (1994). While Campbell (1998) found that many New Zealand companies were using information management systems (70% of participants) they were only moderately satisfied with them, the research also found a continued heavy reliance on informal information from customers, staff and personal experience. Furnware would benefit from a formal information system as it would help improve development time and decision making.

8.3.1.3 Stage 2: Concept Generation

8.3.1.3.1 Furnware Experience

This stage develops the chosen product idea into a product concept. To do this detailed information is gathered relating to the product area. Using this information, product concepts are generated. The concepts are then screened down to a maximum of three. These chosen concepts are developed further in the following stage.

The information gathered during the preliminary investigation provided a good base from which to start researching the chosen product area. Extensive information was gathered concerning current products and solutions that schools were using. A structured concept generation methodology from Ulrich & Eppinger (2000) assisted in providing focus to the concept generation effort. The overall product idea was broken down into more manageable sub-problems. Solutions to these sub-problems were then systematically researched.

Investigation into the classroom environment and the general methods used to teach children could have been better undertaken. Due to the relative newness of the Technology Curriculum the people who will use this type of product, the teachers, were not necessarily the most knowledgeable when it came to understanding the goals of the Technology Curriculum, especially as it involved some quite different approaches to teaching. Recognising this and concentrating research efforts on experts such as Auckland College of Education staff could have reduced the amount of time taken to gather information relating to the product design.

Once concepts were developed there could have been more consumer feedback on the ideas. Producing scale prototypes or mock-ups could have been brought into this stage to assist in communication between the development team and the consumer. This would help projects progress more quickly, reducing development time. The consumer feedback should have also included some indication of whether or not the estimated price of the workstations was acceptable, as the educational furniture market is very price sensitive.

Screening of concepts should be done with more management input. Screening of the concepts was not done with management input due to time constraints. A clearer decision point should have been used during concept development to provide focus to the development effort.

8.3.1.3.2 Discussion

This stage started with a good, detailed investigation into the product area. Perhaps more focus could have been put on the classroom environment, teaching method and target price. As in previous studies (Kerr, 1994), development tended to focus excessively on the physical aspects of the product. Kerr (1994) found that typical stages in the product development process that were missed include; detailed marketing study, business financial analysis, test marketing and pre-launch business analysis. This project required more marketing and financial information in particular. The use of consumers could have been better utilised and decisions should have been made with top management involvement, as suggested by Cooper (1998) and Earle (1999) to help improve decision making and development time.

8.3.1.4 Stage 3: Detailed Design

8.3.1.4.1 Furnware Experience

The purpose of this stage is to develop the concepts to sufficient detail where they can be manufactured into a viable product. Prototyping is used extensively in this stage to help finalise designs. Ergonomic design considerations were also discussed. The final result of this stage is a final prototype, ready for testing. Prototyping helped the project progress by illustrating whether or not a design idea was feasible or not. The use of prototype schedules (Ulrich & Eppinger, 2000) meant that the appropriate amount of planning was put into this stage and the objectives of the tasks were fully disclosed before any work was carried out.

8.3.1.4.2 Discussion

This stage and the use of prototyping could have been better integrated with concept development as well as consumer feedback. More communication between the manufacturing department and the Fellow would have helped advance the project better. Due to the late start of the project, when this stage was being completed the manufacturing staff were too busy to provide assistance. If the project had started earlier, more time would have been available for manufacturing staff to work on this project. This is also true for top management guidance and decision making throughout this stage. Using a multi-functional approach to product development has been found to improve the chance of product success, Griffin (1997). New Zealand companies often encounter problems with providing staff and resources for product development projects. Often employees cannot be spared to work on new projects, money is not available restricting the purchase of materials or equipment, and perhaps worst of all, lack of knowledge prevents necessary activities and techniques such as market research being carried out, Kerr (1994). Taking advantage of seasonal sales at Furnware would help reduce this problem. The workstation project highlighted the difficulties of completing product development activities within a small manufacturing company during moderate to busy periods of production. If possible manufacturing and management staff should be more involved in the development process of new products at Furnware. Better timing of development projects would help facilitate this.

8.3.1.5 Stage 4: Testing and Commercialisation

8.3.1.5.1 Furnware Experience

This stage tested the final design for consumer appeal, functionality and structural quality. Mock technology projects in a typical classroom environment were used to test the workstations' functionality. An in-depth survey into the workstation product was also conducted to determine fit with the consumer need and to ensure aspects other than functionality, such as aesthetics and price were acceptable.

Using the AS/NZ 4610.3:1999 school furniture safety standard as a benchmark from which to test the workstations' structural integrity provided a good reference from which to gauge the workstations quality.

The consumer evaluation could have been completed by a larger number of people to increase confidence in the positive results received. Preliminary testing at earlier stages in the development could have many advantages. This project showed positive results in the tests, with only minor design adjustments required. Future projects may not be as fortunate, if major redesign is required, then an expensive repeat of this testing process would have to be completed. The confidence of top management in consumer response on the prototypes was low. This was mainly due to the method of testing being different from the norm. Customers were invited to come and provide feedback on the workstations as well as fill out a questionnaire on the workstations. Usually Furnware relies on feedback obtained from sales representatives to determine market potential for a new product. Using the sales representatives to gather feedback is a typical method used at Furnware and should be implemented in conjunction with the questionnaire.

8.3.1.5.2 Discussion

The feedback was positive from the consumers that were questioned and only minor design changes were suggested to improve structural integrity and functionality of the workstation. More consumer feedback relating to price was required before top management was willing to invest money into full launch plans. If top management had been in involved in the project, as is what ideally occurs, confidence in the findings would have been higher. As stated in the previous section the involvement of management is important to product development projects.

8.3.2 Part 2: Overall Process Evaluation

This section provides an overall review of the product development process used to develop the Mobile Technology Education Workstations.

8.3.2.1 Product Definition

A clear product definition needs to be decided at the start of a project. If there is more than one potential product area, then a preliminary investigation needs to research the bottom line potential of all of them. A decision should then be made as to which will be developed. Before development begins, a clear product definition should be decided on. Cooper (1998) states that:

> *The ideal new product process ensures that these early stages are carried out and that the product is fully defined before the project is allowed to become a full-fledged development project.*

8.3.2.2 Development Time and Timing

The product development project took six months to complete. This length of time is acceptable for the level of detail of this project. There are advantages in shortening development time though. According to Cooper (1998), speed into the market pays off for three reasons. First into the market has a positive impact on the success rate of the product. Profitability is increased; a six-month delay can reduce profitability by one third. Speed means fewer surprises when the product is introduced into the market; the longer development time is the more changes can occur in the marketplace.

Furnware have seasonal sales and are busy between the months of October and February. Due the small size of the company and limited resources, product development projects should ideally be completed between the months of March and

September. This project started late and problems were encountered at certain stages when manufacturing and top management support was needed because of this. These timing issues would be resolved as experience in product development at Furnware improved.

8.3.2.3 Management

Management of the product development process is important (Cooper, 1998). Product development is a multidisciplinary process and requires input from many different functions within a business. Managing these interactions is important. At times during the Mobile Technology Education Workstation project top management decisions needed to be made and weren't.

8.3.2.4 Linear and Cyclic Processes

The product development process used to guide the project was predominantly a linear process. Some of the stages in the process were found to be more cyclic in nature than linear. Stages 2 and 3 (Concept Generation and Detailed Design) in particular were done more in unison than one after the other. Earle et al. (2001) states that, "...in radical innovation, there is often recycling of activities". The process developed for Furnware should attempt to show this if possible, bearing in mind that the product development process is a guide only and that a specific course of action needs to be decided for each individual project.

8.3.2.5 Formal Versus Informal Process

It is generally accepted in Product Development academia that a formal product development process is better than an informal process (Cooper, Earle and Ulrich & Eppinger). Conversely, the need for a formal process within a small company such as Furnware is less than that of a large company due to lower numbers of people and departments working on any one project, as researched by Kong (1998). The advantages of using a formal process include:

- Clear decision points.
- Documentation of past projects is available.
- Top management involvement especially at decision points.

The main advantages to using an informal process are flexibility and speed. The development team are able to decide which task to do next and complete it without the need of filling out the appropriate form or performing tasks that are predetermined in the product development process that are not important to the particular project. This flexibility also leads to shorter development time but can lead to vital stages in the development process being missed out.

Cooper (1998) suggests that a complete or thorough new product process is critical to success. He suggests that the process should also be flexible where stages can be skipped or combined, depending on the nature of the project. The use of a flexible but formal process is therefore suggested for Furnware. This ensures that documentation of past projects is available for review, projects are carried out in structured manner and also that the development team have the flexibility to skip steps as required and ensure development time is minimised.

8.4 Outcomes: Revised Process

8.4.1 Overview

Provided below is a revised process suggested for use at Furnware. The process attempts to integrate those aspects of the process used for the Mobile Technology Education Workstation development and the suggested improvements discussed above. Provided in Figure 8-49 below is the revised process. The process starts with a strategy activity as before and the initial stages remain largely unchanged. There is a second 'knowledge and leadership' stream added to the diagram to indicate the need for reporting results, creating a knowledge base of past projects and including top management in the process. The initial stages of ideation and the decision to investigate 1-3 ideas remain unchanged. The preliminary investigation remains unchanged in the process diagram although research emphasis should be concentrated more on factors that affect Furnware's financial position such as potential market size. Stages 2 and 3 of the original process have been amalgamated into one, cyclic process. The objective of this is to improve decision making and development time by better utilising prototyping and consumer feedback (testing) early in the concept generation and development phase. This cyclic series if stages also attempts to provide a more suitable process to the varying scale of development projects, from minor product modifications to innovative new product ideas. Smaller scale projects will undertake fewer cycles than larger, more complicated projects. Top management involvement is also included to ensure projects are on-track. Once a suitable product design passes management approval the project can move onto commercialisation and launch of the new product. Each of the stages is outlined in more detail below.

8.4.2 Company Knowledge and Leadership

This section of the revised process indicates the continuing development of a company knowledge base. Earle et al. (2001) highlights the importance of knowledge in Product development:

> *Knowledge is brought into the framework, and also created within the framework so that decisions can be made... In product development, the intelligent and systematic balancing of knowledge and costs is fundamental to successful product development.*

The results of a product development project both add to and can extract information from this database. This section also represents top management activities such as strategy development and decision making.

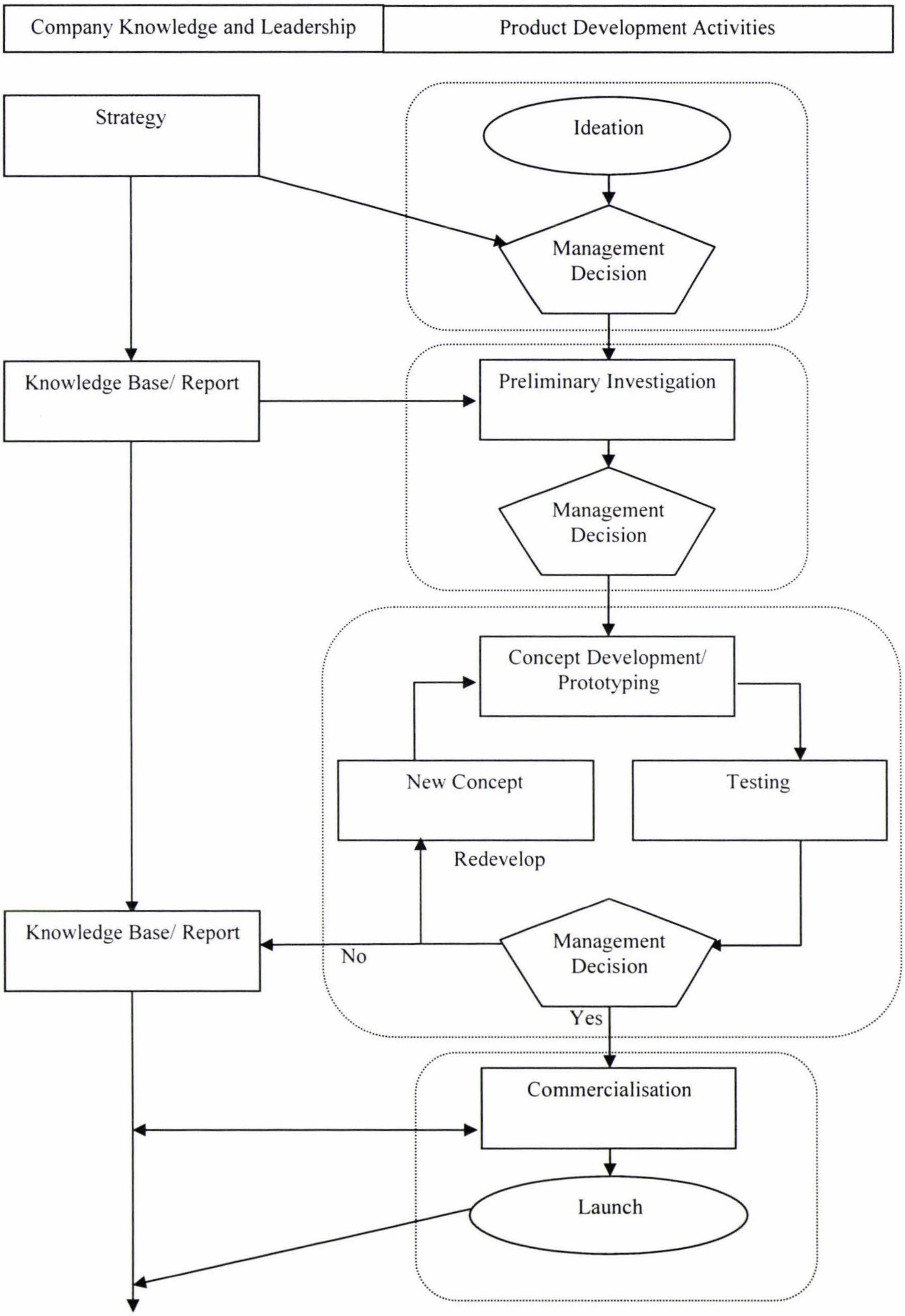
8.4.3 Ideation and Idea Selection

The product development section of the diagram begins with the gathering of new product ideas. These may come from many sources. Ideation at Furnware is done well at present. The ideas brought to the management meeting should be recorded as well as the decision on which ideas to investigate. Management decisions are based on the company product strategy. This stage remains unchanged from the original process outlined in Chapter 3 except for the recording of ideas and decisions made.

8.4.4 Preliminary Investigation

This stage remains the same as the original process except that there is information flow from the company's past projects. This should help prevent the need to redo research and thus save time. The tasks completed here should also be more focused on gathering information that affects Furnware's financial position. The management decision to either stop the project or continue is based on market potential. Investigation into consumer needs should not be neglected.

Figure 8-49 Revised Product Development Process



8.4.5 Concept Development

The third stage is an amalgamation of Stages 2 and 3 of the original process. It has been modified into a cyclic pattern to help better illustrate the actual steps taken to develop the concept. Information from the preliminary investigation provides a starting point for the concept development. From this information it is expected that sketches and ideas can be produced. These concepts can be tested by getting consumer feedback on them. Management then decides whether or not the project can move into commercialisation. Normally projects will need to complete several iterations of developing concepts and testing before the new concept is developed enough to move into commercialisation. The number of cycles will be dependent on the level of innovation of the project. Prototyping is a major tool in developing and testing ideas. A prototype may take many forms, from a reduced-scale, 'looks like' prototype to a full-scale, fully operational model. The type of prototype depends on the information required. Using a cyclic structure for this stage illustrates the iterative, constant improvement process that actually occurs during this stage. Incorporating testing as an integral part ensures that the project stays on-track with consumers' needs. The inclusion of a management decision point ensures that the project advances to the next, most appropriate stage. There are three possible alternatives for top management to choose from. One is to redevelop or continue developing the current concept into a more refined idea. The second is to move on to commercialisation of the product and the third is to discontinue the project. Even if a project is discontinued, a report of the findings, developments and reasons for discontinuing should be completed.

8.4.6 Commercialisation

The final stage of product commercialisation remains the same as described in the original process. Issues such as promotional strategies, marketing and launch issues and financial analysis are planned here and implemented through product launch. Most commercialisation techniques have been developed over time and draw on company knowledge. Six months after launch a summary report of the project should be completed and entered into the company's knowledge bank. A review of the product should also be completed at 12 months following completion. These reviews help facilitate both personal and organizational improvement in the company (Ulrich & Eppinger, 2001).

8.5 Summary

This chapter evaluated the product development process used to develop the Mobile Technology Education Workstation and provided a suggested revised process suitable for Furnware. The major changes included:

- The integration of Stages 2 and 3 into one, cyclic process.
- More emphasis on management involvement and decision making.
- Incorporation of a company knowledge bank which provides direction and information for all projects undertaken.

The changes attempt to address the areas requiring change after the Mobile Technology Education Workstation project was evaluated. In particular the main objectives of the new process are:

1. To provide a tailored product development process for Furnware.
2. To provide a structured approach that incorporates clear decision points.
3. To model the process to the actual development method (combination of cyclic and linear processes).
4. To incorporate past knowledge and experience in a structured manner and ensure each project undertaken builds this knowledge base.

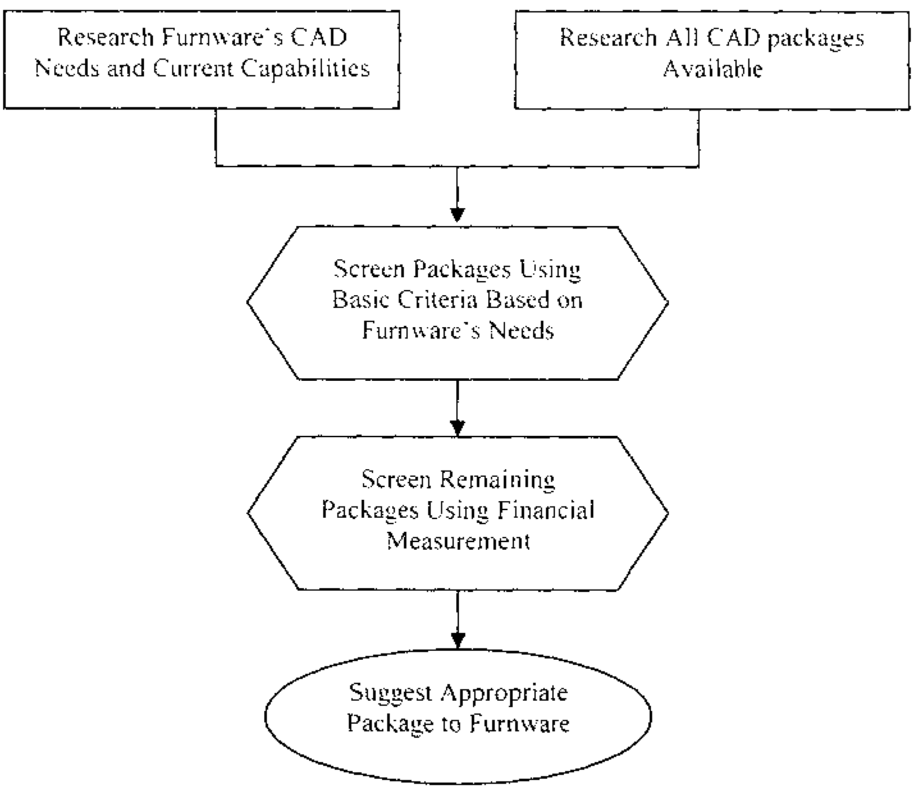
The following chapter, Chapter 9, covers the selection of CAD software that is best suited to Furnware's needs. The use of CAD technology at Furnware will help the product development process by making prototyping new products easier. CAD technology will also help current manufacturing processes by automating repetitive tasks.

9 CAD Selection

9.1 Introduction

The purpose of this chapter is to summarise the results from research into the selection of CAD software that is suitable for use at Furnware. CAD software is expected to improve both product development at Furnware and current manufacturing practices. There are three parts to this chapter. The first concentrates on understanding Furnware's CAD requirements, the second is a review of research into CAD technology and the third outlines the results of the selection process. The overall methodology for this chapter is provided in flowchart below. The methodology for each of the parts is included in the respective sections.

Figure 9-50 Overall Computer-Aided Design Software Selection Methodology



9.2 Part 1: Furnware's Needs and Current Capabilities

9.2.1 Aim

The aim of this section was to determine what Furnware would like to be able to do with a CAD software package and also what existing operations the package should then be capable of working with.

9.2.2 Methodology

Interviews were held with several key members of staff at Furnware. The manufacturing manager, CAM programmer, financial accountant and a sales representative were questioned about what the selected CAD package should be capable of doing. Each person provided valuable information relating to what criteria the CAD software should meet. The meetings were held in an informal manner with main outcomes recorded for future reference.

9.2.3 Results

This section provides background information on how Furnware would like to use CAD technology to enhance current activities. Also discussed were the current capabilities of Furnware regarding CAD and its support functions of CAM and CNC machinery. Furnware participated in a range of different design activities. These included:

- Classroom layout design.
- Design of one-off products requested by customers.
- New products designed and developed.
- Existing products redesigned and developed.

Each activity is described below, included are the specific characteristics the CAD software must include if it is to be useful.

9.2.3.1 Classroom Layout Design

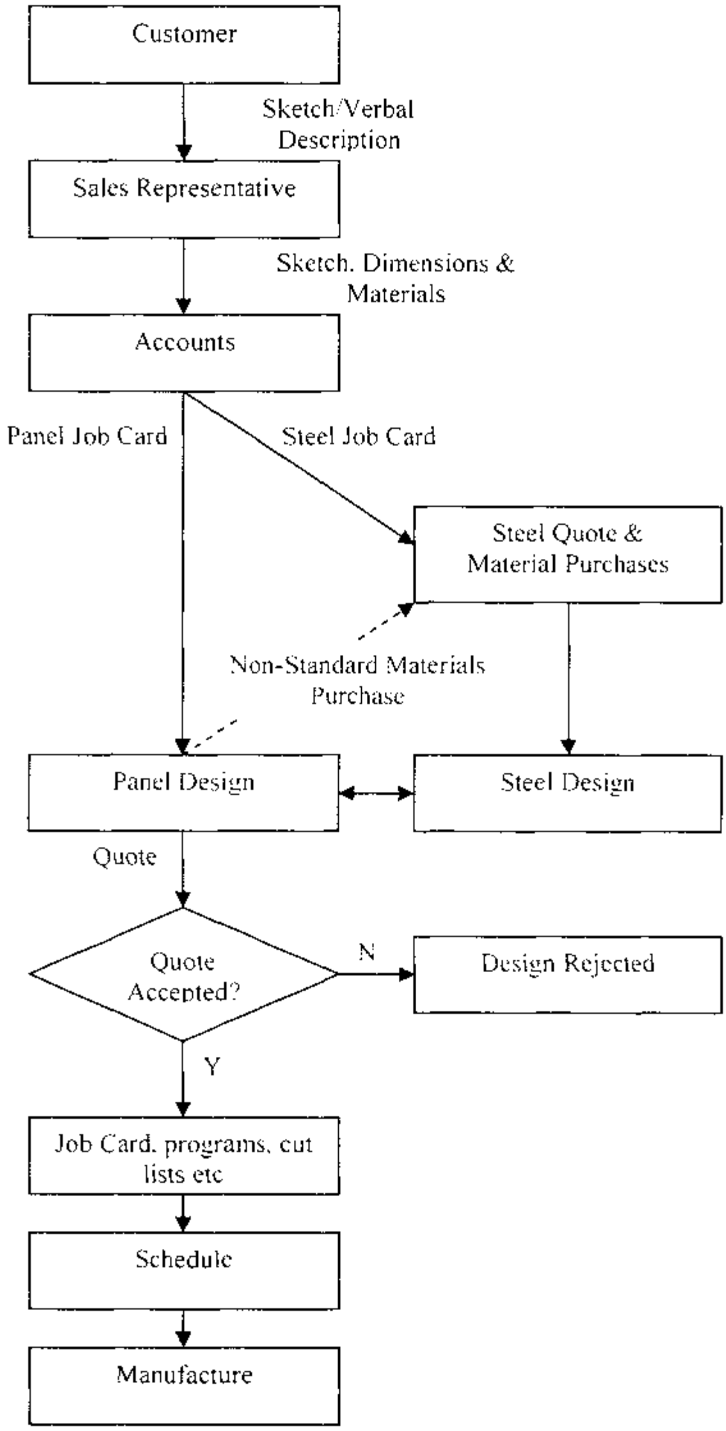
Furnware sales representatives were often faced with the challenge of producing a quote for an entire classroom set-up. This usually included student desks and seating, teacher's workstation and seating and other storage facilities (bookshelves etc). Explaining to the client exactly what the sales representative has in mind is often difficult to do accurately. Being able to produce a virtual layout of the classroom and furniture quickly and efficiently would be of great benefit to the sales representative. If a classroom layout could be drawn on computer the client could see how the room would look with the furniture proposed. Potential problems could be spotted before the actual furniture is put in place, opportunities to supply additional furniture such as storage units could also be identified. The most important advantage though would be for the client to view the colour match with the room and the furniture. The basic requirements are:

- Speed. The software must be very efficient and simple to use. Sales representatives have little time to spend drawing a model when visiting customers.
- Ability to dimension room accurately, ability to include doorways and windows.
- Ability to change wall colours and textures.
- Access to a complete library of pre-drawn Furnware products.
- Simple method of inserting furniture into classroom and locating/spacing throughout classroom.
- Changing colours of inserted products; panel, edging and steel. Be able to do this once products are in place in the CAD program.

9.2.3.2 One-off designs

One-off designs are designs that a client has requested specifically for their situation. These are designs not already produced by Furnware. Most of these products are similar to existing Furnware products in some way though. The sales representative produces a sketch with dimensions and basic features. This information is passed on to a product designer who produces a quote for the design. The client then approves this. All MDF panel work on the design is then programmed using Aspan 3.1 software and the job card, cutting lists, CNC instructions, materials requests (if required) and bill of materials are prepared before the job is entered into production. If the product involves steel components then the steel department prepares the costing, design and job cards for those components. Steel and panel work are put together in the fit-up area. The flowchart in Figure 9-51 outlines the process:

Figure 9-51 Current One-Off Design Process of Furnware Industries LTD



Key points to note

- The quote needed to be done quickly and accurately. If the job was rejected then the time is wasted in preparing a quote. The less time spent, the less time is wasted. The quote needed to be accurate to ensure a profit is made from the job and that prices were competitive.

- Division of job cards could potentially cause confusion upon product assembly of the final product.
- Deciphering both the clients and the sales representatives' drawings could sometimes be difficult. In an attempt to minimise this risk a standard form was given to the sales representatives to fill out to ensure the designers had all the appropriate information required to quote and design the product.

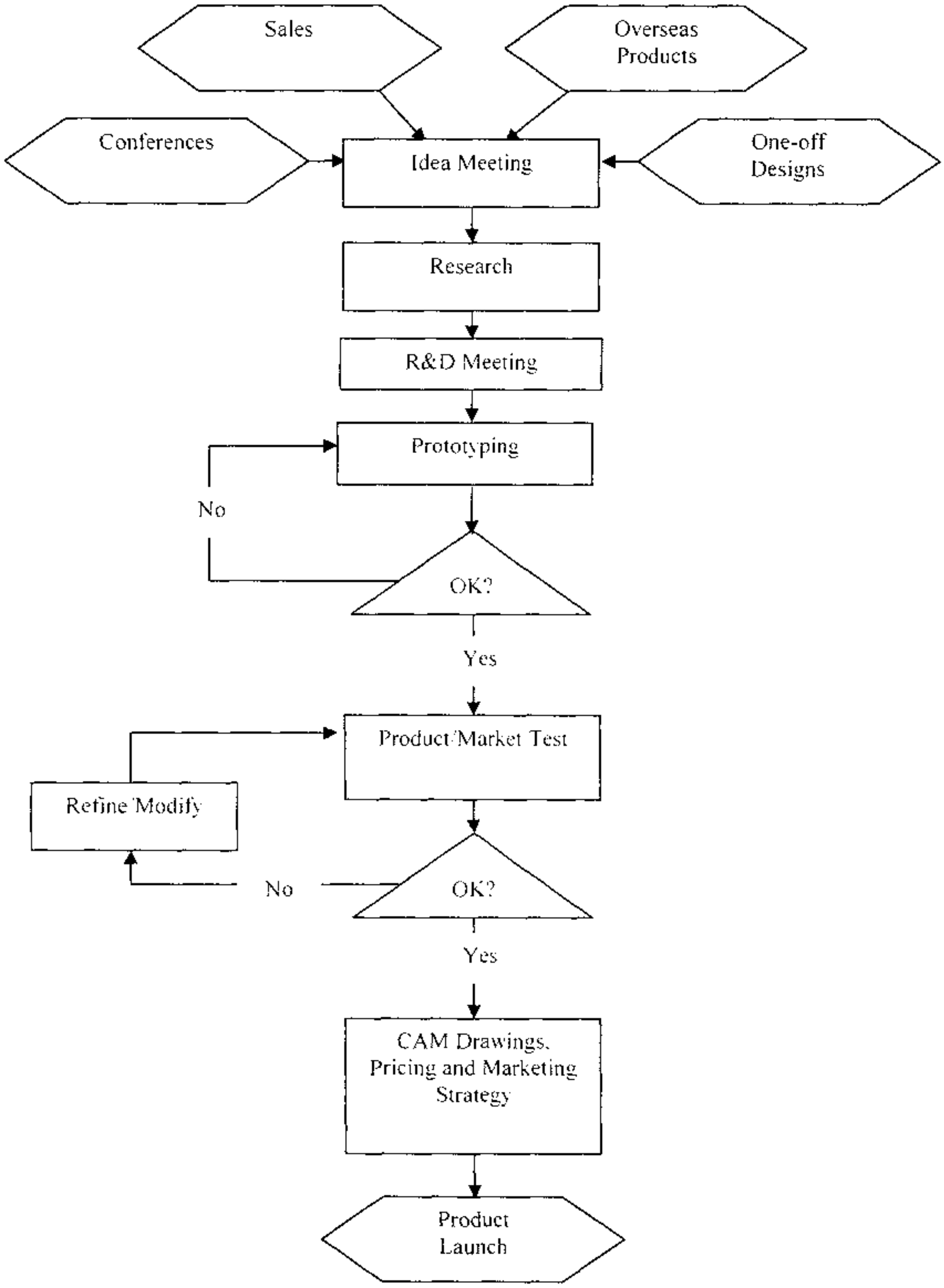
9.2.3.3 New Product Design and Development

The majority of design work carried out at Furnware had no set process to follow. Furnware is a relatively small company and so, there is usually a single person or "product champion" that is solely responsible for the new design. That person discusses issues with other members of staff as the need arises. Given below in Figure 9-52, is the typical process followed at Furnware. Much of the design work was done, using a very hands-on approach. A design was roughly sketched out and then made up using appropriate materials for the final product and at the full size of the product. This method had both advantages and disadvantages. A full-size, comprehensive prototype means that all aspects of the design could be evaluated including both functional and aesthetic aspects. The disadvantage is that, if the design requires further development and hence more prototyping, the design could become costly. The time required to prototype a full-size model could also be long, depending on the availability of production staff. There was also a need for fully rendered computer images of the new products for catalogues and showing to potential customers before the product is produced physically.

9.2.3.4 Redesign and Development of Existing Products

Redesign of a product was done on a need basis. A product may need to be made from a different material. Dimensions may need to be altered. The product may need to be redesigned so that it is collapsible. The use of current CAM technology meant that when a change was made to a product, all affected components had to be altered individually, making this a time extensive process. CAD software that automates some, if not all of this work would be beneficial to Furnware. One example of this is the use of parametric programs.

Figure 9-52 Furnware Industries Current New Product Development Process



These programs use equations to link aspects of a design such as fixing holes for two pieces of panel to the length of the side. if a new piece of furniture is made with the same design but larger. the parametric program will automatically insert extra fixing holes into the new design.

9.2.3.5 Current Capability

9.2.3.5.1 Current Software

Furnware do currently use computer software for design. Two packages are currently being used. Aspan 3.1 is used to run a point-to-point routing machine. AlphaCAM is used to run a CNC flatbed router (both programs were supplied by SANCO industries Limited).

Aspan 3.1

CAM software that was produced in 1984. This software is currently up to its seventh release (2000), making the version at Furnware obsolete. This software is no more than a 2D tool for creating machine code. The majority of subsequent manufacturing tasks done after a product has been designed, must still be completed manually.

AlphaCAM

AlphaCAM is a powerful CAM software package that was purchased by Furnware at the same time as the purchase of the CNC routing machine. AlphaCAM's strengths lie in its ability to produce both 2D and 3D parts. What it cannot do however is combine parts into assemblies or complete products. This is necessary if Furnware is going to be capable of producing fully rendered images of products, be able to test for tolerances electronically, automatically produce job quotes, Bill of Materials (BOMs), assembly instructions and a library of Furnware products.

9.2.3.5.1.1 Current Machinery

SCM Flat bed CNC Router

This machine has a 1 router, 9 drill adjustable head. The head is capable of drilling both horizontally and vertically as well as routing shapes and edge profiles. It can also router three-dimensional curves and engraves material. The machine is specifically designed to work wood. At Furnware the CNC machine is used to machine both MDF and solid wood. It is also capable of nested-based manufacturing. An advanced production method that reduces material handling by performing machining on whole sheets at once. A 2400x1200mm sheet of MDF is loaded onto the bed of the machine and the head machines a number of separate parts from that one piece without the need of first cutting sheets to approximate size.

Morbedelli Point-to-Point Router

This machine runs on numeric code generated by Aspan 3.1, it is a simple and very accurate method of cutting MDF panel to shape and inserting fixing holes. All panel must be cut down to 2 mm over the finished size before being machined on the Morbedelli machine. Panel size is limited to 900 x 1200 mm.

9.2.4 Outcomes: Furnware's CAD Requirements

After reviewing the manufacturing facilities and discussing financial constraints with Furnware management, the following base requirements were determined:

1. A return on investment within three years.
2. AlphaCAM compatible (Able to produce either DXF, DWG or IGES files).
3. Ability to design classroom layouts quickly.
4. Must provide rendered images suitable for brochure publication of assembled products.
5. Produce one-off design quotes as quickly as is currently being done.
6. Have the capability of greatly reducing job card preparation time once the quote has been accepted by automating: cut lists, bill of materials and assembly instructions.
7. Be flexible enough to design any new product using the software.
8. Good support from suppliers.

Now that a thorough understanding of what Furnware's CAD requirements are has been achieved, research into available CAD technology is discussed. This research will provide information on all CAD packages that may be of use to Furnware.

9.3 Part 2: CAD Technology Research

9.3.1 Aim

To search for all of the CAD software that may meet Furnware's needs

9.3.2 Methodology

A number of different sources were used to search for information relating to appropriate CAD software. These included: the Internet, local CAD suppliers, local businesses, Furnware staff and CAD Magazines. Initial searching was done by contacting local businesses and local CAD suppliers. More detailed searching was done using the Internet. A table of all the CAD packages found that related to Furnware's needs was generated to summarise the findings.

9.3.3 Results

A table of all CAD software packages that were found using the methodology above have been included in the table provided in Appendix D.

9.3.4 Outcomes

A large number of CAD packages were found by searching a number of different resources. The results were tabulated and are provided in Appendix D.

9.4 Part 3: *CAD Selection*

9.4.1 Aim

To select the CAD software package that best meets Furnware's needs.

9.4.2 Method

A two-stage screening process was used to determine which CAD software package is best suited to Furnware. The first stage involved comparing the CAD software packages found during Part 2: CAD Research and the needs of Furnware identified in Part 1: Furnware's Needs and Current Capabilities.

9.4.2.1 Screening Stage 1

The needs of Furnware that were found in Part 1 were converted into the screening criteria provided below. The aim of this screening stage was to sort out the CAD software packages that were most likely to suit Furnware's needs. The second stage took the selected packages and screened them thoroughly.

All software packages were screened according to the following criteria:

1. Three-dimensional drawing capability.
2. Bill of Materials production capability.
3. Cut list production capability.
4. Ability to assemble complete product.
5. Floor plan design capability.
6. Ability to design steel and panel components.

7. Support within New Zealand.

9.4.2.2 Screening Stage 2

The second stage of screening centred on the use of a Net Present Value (NPV) analysis to determine which of the three packages gave the best financial advantage to Furnware. An NPV analysis calculates the present value of a series of future cash flows. For this analysis a three-year time period was used, as a payback on investment in three years is the standard time frame for purchases at Furnware. There are a number of cash flows related to the purchase and use of CAD software. The cash flows used in this analysis were initial cost of software, hardware purchase, training costs, maintenance costs, start-up costs and savings made on manufacturing time. Of these cash flows, savings on manufacturing time was the most difficult to determine. The savings were calculated by comparing the time taken to complete tasks that CAD has an affect on and the time that it would take using each of the CAD software packages. The estimated time savings were then converted into monetary savings and added to the NPV analysis. Total monthly cash flows were then calculated for the three-year time period and the NPV determined.

9.4.3 Results

9.4.3.1 Screening Stage 1

There were three CAD packages that passed through the first stage of screening; they were CabinetVision, Pytha, and Solidworks. Each of these packages were then put thorough screening using an NPV analysis. One condition was not met by the three packages selected, which was the ability to design floor plans. During screening it was discovered that no packages provided all of Furnware's requirements and that the packages that could design the floor plans did not pass the other screening criteria. As a result of this the package selected did not meet this need. This requirement was considered less important than all of the others.

9.4.3.2 Screen Stage 2

The second stage of screening centred on a Net Present Value analysis of the three selected CAD software packages. Refer to Appendix E for the complete NPV analysis details. The NPV values were CabinetVision $23,000.03, Solidworks $17,724.34 and Pytha $81.45. Provided below are the results of the NPV analysis, sensitivity of the analysis to changes in key values used and a discussion of qualitative factors not included in the analysis.

9.4.3.2.1 CabinetVision

NPV Value: $23,00.03

Sensitivity to Changes in Calculation Values

- Time on New Job. The estimate given of 0.48 hours would need to increase to 1.80 hours before the NPV analysis would become negative. This indicated a high margin for any errors in this value.
- Rate of Return. Rate of return had negligible effect on the NPV calculation. A 10% rate of return was used in the analysis and even at 26%, the analysis would still be positive.
- Maintenance. Maintenance of the CAD software also had little effect on NPV.
- Pay Rate. As pay rate decreased the NPV decreased as well. Pay rate would need to fall from $20.00 per hour to $12.00 per hour before a negative NPV would result.
- Purchase Price. The purchase price of the software had little effect on the NPV.
- Pay Rate and Time on New Job. Pay rate and time on new job did have a combined effect but it is not too significant. If pay rate was decreased to $16.00 then the time on new job could only afford to be 1.2 hours before a negative NPV occurs.
- Rate of Return and Time on New Job. If rate of return was increased to 16% then, once again the time on new job can only afford to be 1.4 hours before a negative NPV occurs.
- Purchase Price and Time on New Job. There was no major correlation between these two values.

Qualitative Factors

- Confidence in Time on New Job Calculation. The times that were given are very fast and dependent on the software being set-up to Furnware's production process. It is also quite dependent on the level to which the new design can use existing components. Estimated level of confidence in the value given by the software supplier is 50%.

- Level of Support. The level of support provided by the retailers of CabinetVision was good. It is an Australian based company that is looking to expand into New Zealand.
- Referees. Comments made by referees consistently said that the software could do everything that they needed but that they hadn't had the time to set it up properly yet.
- Supplier. The supplier of CabinetVision keeps up with current technologies and is confident in his product.

9.4.3.2.2 Solidworks

NPV Value: $17.724.34

Sensitivity to Changes in Calculation Values

- Time on New Job. The time on new job had little effect on NPV. even if the estimated time taken of 2.50 hours extends out to 3.3 hours. the NPV would still be positive.
- Rate of Return. Rate of return also had little effect on NPV. At 26% rate of return NPV is still positive.
- Maintenance. Maintenance had little effect on NPV.
- Pay Rate. Pay rate had some effect but even if pay rate falls to $12. the NPV will still be positive.
- Purchase Price. Purchase price had little effect: even if two seats are purchased ($22.000.00) there was still a positive NPV.
- Pay Rate and Time on New Job. Both factors have little effect on NPV and the combined the effect remains negligible. Only when both were at their extreme levels of 3.2 hours and a $12 pay rate was there a negative NPV.
- Rate of Return and Time on New Job. There was no effect.
- Purchase Price and Time on New Job. If purchase price was increased to $22.000.00 then the time on new job would need to stay under 2.9 hours to avoid a negative NPV.

Qualitative Factors

- Confidence in Time on New Job Calculation. There was only approximately a 50% confidence in the times given to complete a new job. This software also requires considerable set-up and the time given was an estimate of the time taken to do the job once the software as been sufficiently set-up.

- Level of Support. The support for Solidworks is excellent, there is a retail supplier in New Zealand and those that have worked with them were satisfied with their service.
- Referees. Referees contacted were positive about the software. There was especially confidence in its ability to create anything you wanted. The time required to model one-off designs could be a problem though.
- Supplier. The Solidworks Company has been operating for sometime, as has the supplier in New Zealand so there was high confidence in the supplier.

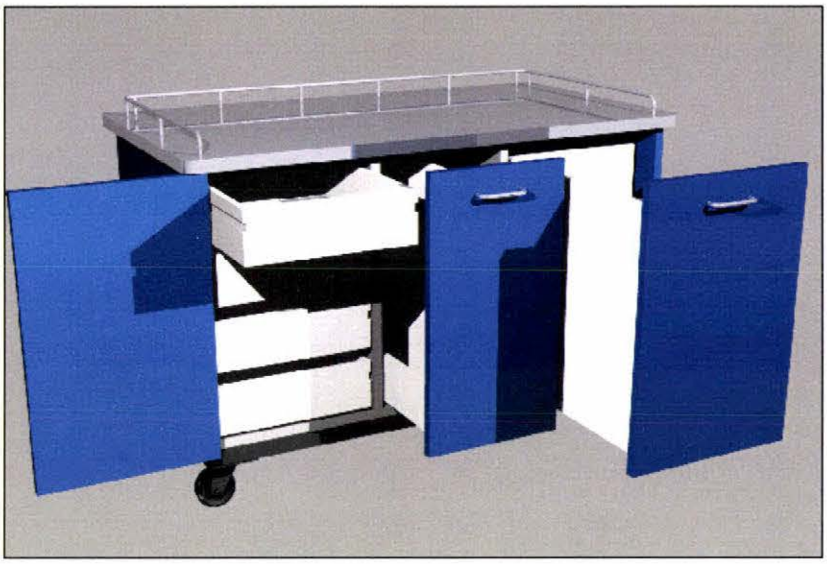
9.4.3.2.3 Pytha

NPV Value: $ 81.45

Sensitivity to Changes in Calculation Values

- Time on New Job. Time on new job would only need to be increased from 2.74 hours up to 2.8 hours before the NPV is negative. This number was therefore very important to the NPV calculation.
- Rate of Return. If rate of return increased from 10% to 12%, there would be a negative NPV.
- Maintenance. If maintenance increased to $550.00, there would also be a negative NPV.
- Pay Rate. Likewise, pay rate would only need to decrease to $18.00 before a negative NPV occurred.
- Purchase Price. Purchase price must remain under $26,000.00 for a positive NPV. This means that even if two seats were purchased, the NPV would still be positive.
- Pay Rate and Time on New Job. Both values had a large effect on NPV, combined; they also had a large effect. If pay rate increased to $26 a negative NPV would still occur at a time for new job of 3 hours.
- Rate of Return and Time on New Job. Both values had a large effect on NPV, and combined they did too. At 2.7 hours for the time on new job, return would need to stay below 14% to keep NPV positive.
- Purchase Price and Time on New Job. Purchase price had little effect so time on new job was the value that still determined if NPV remained positive.

Figure 9-53 Rendered Image of Mobile Workstation



Qualitative Factors

- Confidence in Time on New Job Calculation. The times estimated using Pytha were the highest but the confidence in the estimate given is also the highest because the tasks given to the supplier were actually carried out rather than just estimated. Figure 9-53 is a rendered image produced using the Pytha software. Estimated confidence is 90%.
- Level of Support. The closest retail supplier was based in Australia, it was quite a new company but the people were good to talk to and work with.
- Referees. All the referees contacted praised the software and claimed that it made a large difference to their work. Some had very little previous experience with the computer and were working with Pytha in a very short time.
- Supplier. Pytha is a German company and not much was known about them. The retailer in Australia was quite new and determined to stay small so that it could offer top service to its customers.

9.4.4 Outcomes: CAD Software Selection

The outcome of the NPV analysis was that all three CAD packages yielded a positive NPV indicating that purchase of any of them is a worthwhile investment. CabinetVision and Solidworks had much larger NPVs than Pytha though. The final values were CabinetVision $23,000.03, Solidworks $17,724.34 and Pytha $81.45. Based only on the NPV values CabinetVision was the most viable option to choose.

Several qualitative factors or factors that are unable to be included in the NPV analysis cast some doubt on this conclusion though. The set-up times of both CabinetVision and Solidworks mean that only an estimate of the time to model a new product could be given whereas with Pytha, the actual tasks were carried out. The Pytha calculation was accurate, but only just viable. Any slight change in a number of key values and it would not be viable (have a negative NPV).

9.5 Summary

This chapter summarised the selection of a suitable CAD software package for use at Furnware. The use of CAD technology at Furnware was expected to assist both product development activities and current manufacturing practices. The exact needs of Furnware were researched first to ensure all of the tasks the software should be capable of doing were known. Then research into all potential packages was conducted using a variety of sources ranging from the Internet to local businesses in similar trades of work. The CAD packages found were then screened through two screening stages, the first was a general screen that compared the features of the software to Furnware's needs. The second was a detailed financial analysis to determine the financial viability of the chosen packages. To do this a NPV analysis was conducted on estimated cash flows over a period of three years. Every attempt was made to include all decision criteria in the analysis to simplify the decision as to which software was most appropriate for Furnware. Unfortunately this was not possible and some qualitative factors needed to be considered.

10 Conclusions and Recommendations

10.1 Introduction

This thesis has summarised an empirical investigation into the use of product development in the furniture industry. A process was developed, based on Cooper's Stage-Gate™ process and used in the Mobile Technology Education Workstation project. The process was then evaluated and changes made to better suit the process to Furnware's situation and hopefully improve the product development there. During the revision of best practices in product development and evaluating Furnware's current manufacturing and product development activities it was found that the use of CAD technology would assist both the current manufacturing processes and product development at Furnware. Manufacturing would benefit from the automation of repetitive tasks such as preparation of Bill of Materials and assembly instructions. Consequently an analysis of available CAD technology was conducted and a selection process developed and performed. This chapter is divided into three main sections: the product development process, the Mobile Technology Education Workstation project and CAD selection.

10.2 Product Development Process

10.2.1 Conclusions

Using a combination of recognised processes, existing practices at Furnware and a review of identified best practices, a process, based on Coopers Stage-Gate™ process was developed. This process was used to develop a Mobile Technology Education Workstation range. This was then re-evaluated by the researcher and top management at Furnware to determine aspects of potential improvement . International and national literature was reviewed to help find ways of improving the product development process. A number of changes were made to the process to better suit Furnware's particular situation. The major changes included the integration of Stages 2 and 3 (Concept Generation and Detailed Design) into one, cyclic process and more emphasis on management involvement and decision-making.

10.2.2 Recommendations

The final process developed for Furnware is recommended for use on all subsequent projects. Furnware will need to continually refine their product development process, especially since this research is their first step towards implementing a structured process into the company. Furnware will first need to decide on their strategic direction. The company needs to decide the level to which they enter into product development activities. To do this will require an analysis of potential financial advantages. Will the advancements in product development activities be worthwhile from a financial perspective? It is recommended that, for a small company like Furnware the advancement of the product development process to a flexible process should be done as quickly as possible. The two iterations of product development process development conducted in this research are the first steps of many for Furnware if the company decides to improve their product development activities.

10.3 Mobile Technology Education Workstation Project

10.3.1 Conclusions

The development of the Mobile Technology Education Workstation range was done for two reasons. Firstly, to test the proposed product development process developed for Furnware and secondly to develop a new product that will improve the company's financial position. An initial broad brief meant that a lot of preliminary investigation was done first. After discussion with top management the decision to develop a Mobile Technology Education Workstation that targeted the practical component of the Technology Curriculum in primary schools was made. Detailed information relating specifically to this brief was conducted and concepts were generated. Two ideas were chosen for further development using several iterations of prototyping and concept development. The final prototypes were tested for consumer appeal and functionality. Structural testing was also done. All of which the workstations passed, with only minor changes to their design suggested.

10.3.2 Recommendations

It is recommended that the final adjustments be made to the designs and then more consumer feedback be obtained about the price and purchase intent of the workstations before full launch is made.

Several months after launch, an evaluation of the designs should be done. Research into which models are selling the most should be undertaken and a review of whether or not more or less than six workstations are needed in the range. General design elements should also be reviewed for any potential refinements to the design.

10.4 CAD Selection

10.4.1 Conclusions

The use of CAD technology at Furnware was identified as helpful to both product development at Furnware and current manufacturing processes. Research was conducted into the exact needs of Furnware and also into current CAD technology. A selection methodology was developed and used to select a CAD software package suitable for Furnware. The selection process involved two screening stages, the first quite general and the second more detailed and focussed on a Net Present Value (NPV) analysis that used the Mobile Technology Education Workstation design as an example design that the CAD software retailers had to reproduce using their software. Every attempt was made to convert all decision factors into the analysis, including purchase price, estimated timesaving, start-up costs and maintenance. The CAD software that reported the best NPV was CabinetVision. Several qualitative factors were identified as important that were unable to be included in the NPV analysis. These were referees' opinions, service from the retail supplier and confidence in times provided by suppliers.

10.4.2 Recommendations

Further discussions with the three retailers of the chosen CAD packages are recommended. The CAD package that had the highest NPV is not recommended as the best choice for Furnware due to the qualitative factors. Referees that were contacted suggested that the software was the best, but they hadn't had the time to set it up properly. This response was surprisingly common for the CabinetVision software; also, because there is considerable set-up time involved, the supplier did not actually perform the development of the example product. The referees for Solidworks were generally more positive and the supplier in New Zealand has a good reputation for providing good support. Although Pytha had the lowest NPV value, it was still positive, indicating a worthwhile investment. The referees contacted were also much more positive about the product and the supplier was the only one of the three to actually complete the example product design so confidence in the times provided by them is very high. Further discussions with the three retailers will help clarify exactly what set-up procedures are required for each software package and which is most appropriate for Furnware.

10.5 Summary

This chapter provides a summary of the conclusions and recommendations made relating to three distinct areas: the product development process at Furnware, the Mobile Technology Education Workstation product range and the selection of CAD software for use at Furnware. The product development process developed for Furnware throughout this research is suggested as a starting point from which Furnware can develop a product development process and support framework over time. The process developed attempts to align Furnware's situation with current best practices in product development. The development of the Mobile Technology Education Workstation range while done to test the product development process was also done to develop a new product for Furnware. Initial feedback from consumers is positive, as are the results of structural testing. It is recommended that minor adjustments are made to the design and more consumer feedback is done before the product is launched. CAD software packages were investigated for use at Furnware also. Using CAD technology at Furnware was found to assist both product development at Furnware and also current manufacturing processes by automating repetitive manufacturing and design tasks. A two stage screening process was developed and implemented to determine which package would best suit Furnware's needs. A NPV analysis formed the basis of this selection. Factors such as referees' opinions that could not be included in this analysis were found to have a major affect on selection.

Bibliography

Acord, T. The Importance of Product Design. *FDM Magazine*, January, 43-45.

Anon. 1995. *Technology in the New Zealand Curriculum, Curriculum Statement.* New Zealand Ministry of Education. Learning Media Limited.

Anon. 1998. *Impact 2001: Strategies for Learning with Information Technology in Schools*. Information Technology Association of New Zealand.

Benn, Cheryl & Benn, Ken. 1997. *Writing a Thesis or a Long Document Using a Wordprocessor: A Practical Guide*. Dunmore Press: Palmerston North.

Bindon, A. & Cole, P. 1992. *Teaching Design and Technology in the Primary Classroom.* Bell & Bain Ltd.: Glasgow.

Brown, K. & Charles, C. 1995. *Computers in the professional practice of design.* McGraw-Hill, Inc.: USA.

Burke. P., & Eppel. E. 1997. *Architectural Design Guidelines*. Ministry of Education: New Zealand.

Butterworth, G. & S. 1998. *Reforming Education, The New Zealand Experience: 1984-1996.* The Dunmore Printing Company Ltd.: Palmerston North.

Calantone, R., Vickery, S. and Droge, C. 1995. Business Performance and Strategic New Product Development Activities: An Empirical Investigation. *Journal of Product Innovation Management*, 1995: 12:214-223.

Cameron, A & Massey, C. 1999. *Small and Medium-sized Enterprises, A New Zealand Perspective.* Longman: New Zealand.

Campbell, H. 1999. *Knowledge creation in New Zealand Manufacturing.* Unpublished Thesis, Department of Technology, Massey University.

Cameron-Hunt, C & Corbett, L.M. 1996. *A Season of Excellence? An Overview of New Zealand Enterprise in the Nineties.* NZ Institute of Economic research Inc: Wellington.

Chazin, M. 1996. Designing Furniture Customers Want. *Upholstery Design and Manufacturing*, Nov/Dec, 16-19.

Clark, P. 1998. *Systematic Development of a High Bitumen Content Emulsion.* Massey University: Palmerston North.

Cooper, R. G. 1998. *Product Leadership. Creating and Launching Superior New Products*. Perseus Books: New York.

Corbett LM. 1990. *Manufacturing Strategies: The 1990 New Zealand Manufacturing Futures Survey.* Graduate School of Business and Government Management, Victoria University, Wellington.

Delachambre, A. 1996. *CAD Method for Industrial Assembly.* John Wiley & Sons Ltd.: West Sussex.

Dickey, 2000. *Personal Communication.*

Dunn, S. & Larson, R. 1990. *Design Technology: Children's Engineering.* The Falmer Press: Bristol.

Dunnett, Marcia. 2000. *Furniture Association of New Zealand Statement.* Furniture Association of New Zealand: Wellington.

Earle, M. & R. 1999. *Creating New Foods: The Product Developers Guide.* Chandos Publishing Ltd: Oxford.

Earle, M, Earle, R & Anderson, A. 2001. *Food Product Development.* Woodhead Publishing Limited: Cambridge.

Easton,B. 1997, February 15. *Ignoring the critics.* New Zealand Listener, p60.

Frater P, Stuart G, Rose D and Andrews G. 1995. *The New Zealand Innovation Environment.* Business and Economic Research Ltd (BERL), Wellington.

Gordon, W. 1994. *Delivering the Technology Curriculum No. 4.* Design and Technology Association: UK

Greenfield, T. 1996. *Research Methods: Guidance for Postgraduates.* Arnold: Great Britain.

Griffin, A. 1997. *Drivers of NPD Success: The 1997 PDMA Report.* Product Development Management Association - USA.

Holtz, B. (1993). *The CAD Rating Guide: A Tool for the Evaluation of Computer-Aided Design Systems*, (2nd Ed).. OnWord Press: New Mexico.

Jakobsen, M. 1995. *Development of Competitive Product Concepts, A Contribution to a Systematic Approach for Small and Medium Sized Companies.* University of Trondhiem: Norway.

Jones, T. 1997. *New Product Development: An introduction to a multifunctional process.* Butterworth-Heinemann: Oxford.

Kelsey, J. 1995. *The New Zealand experiment: A world model for structural adjustment?* Auckland: Auckland University Press with Bridget Williams Books.

Kerr, G.B. 1994. *A study of the product development practices of small manufacturing companies in New Zealand.* Unpublished Thesis, Department of Consumer Technology, Technology Department, Massey University.

Kerr, R. 1998, May 24. *Confidence crashes as spending rises.* National Business review, p26.

Kirby, H. 1997. Utilizing 3-D CAD systems. *Wood & Wood Products Journal*, Jan 1997, Volume 102, 45-47.

Kong, L. 1998. *New Product Success and Failure: Factors for New Product Success and Failure in the New Zealand Electronics Industry.* Unpublished Thesis, Department of Product Development, Massey University.

Lightford, J. 2000. *Personal Correspondence.*

McMahon, C. & Browne, J. 1998. *CADCAM, Principles, Practice and Manufacturing Management, 2nd Ed.* Addison and Wesley Longman Ltd.: USA.

Moss, M. 1992. Setting up a Resource Centre: Design & Technology Resource in a Primary School. *Primary DATA Journal*, Vol. 2, Number 1, 34-35.

Owens, Larry. J. *A Survey of Computer Use in New Zealand Schools.* The Research Bulletin No7, November 1997. Research and International Section of the Ministry of Education: New Zealand

Pheasant, S. 1986. *Bodyspace: Anthropometry, Ergonomics and Design.* Taylor and Francis: London.

Posledni, E. 1997. Function Drives Furniture Design. *FDM Magazine*, January, 34-38.

Raymond, A. 1999. Creating a Furniture Factory for the Future... and the Future is Now. *FDM Magazine*, June, 40-46.

Sampson, W. 2000. Pairing Custom and Production Work. *Cabinetmaker*, April, 12-15.

Schollum, J. 2000. *Personal Correspondence.*

Song, M., Montoya-Weiss, M. 1998. Critical Development Activities for Really New Versus Incremental Products. *Journal of Product Innovation Management*, 1998: 15: 124-135.

Souder, W.E, Buisson, D & Garrett, T. 1997. *Success through Customer-Driven New Product Development: A Comparison of U.S. and New Zealand Small Entrepreneurial High Technology Firms.* Journal of Product and Innovation Management, Volume 14, pp 459-472.

Smith, P. & Reinerstein, D. 1991. *Developing Products in half the time*. Van Nostrand Reinhold: New York.

Sulivan, C & Arso, M. 2000. *ICT in Schools 1999*. Information Technology Advisory Group (ITAG).

Swale, T. 2000. *Personal Correspondence*.

Tickle, L. 1997. *Understanding Design and Technology in Primary Schools: Cases from Teacher's Research.* The Dunmore Press Ltd.: Palmerston North.

Tickle, L. 1996. *Hands-on Technology.* Redwood Books: Wiltshire.

The Open University. 1992. *Design Principles and Practice: Block 1, An Introduction to Design.* BPCC Wheatons Ltd.: United Knigdom.

Walsh, V., Roy, R., Bruce, M. & Potter, S. 1992. *Winning by Design: Technology, Product Design and International Competitiveness*. Blackwell Publishers: Oxford.

Wang, B. 1998. *Concurrent Design of Products, Manufacturing Processes and Systems: Vol. 3*. Overseas Publishers Association: Amsterdam.

Appendix A

Internet Survey

Technology Education Workstation

Instructions: Please fill in the boxes or click on the check boxes where appropriate.

1) Name of your school:

2) Form filled out by (optional):

Product Concept: A workstation that can be easily moved between classrooms that stores the resources required to teach the areas of the technology curriculum.

3) Do you think a product like this would be beneficial to your school?

Yes

No

4) One concept idea is to provide the facilities for all the different technology areas on the one trolley. Please rate this concept from a very good idea (1) to not a good idea at all (4).

1

2

3

4

5) One other idea suggested is to provide the facilites for the different areas such as Food, Materials, Biotechnology etc, on separate trolleys. Please rate this concept from a very good idea (1) to not a good idea at all (4)

1

2

3

4

Do you have any other concept suggestions? (Perhaps a combination of different technology areas)

6) Concept 1

7) Concept 2

8) Concept 3

Please give an indication as to which technology areas are a priority in your school. Rate on a scale of 1 to 10. 1 being of very high priority and 10 being not a priority at all.

9) Biotechnology

10) Electronics and Control

11) Food Technology

12) Information and Communication

13) Materials Technology

14) Production and Processes

15) Structures and Mechanisms

Which areas require the most amount of resourcing over the next two years? Rate on a scale of 1 to 10. 1 being require resources urgently to 10, no more resources are required at all.

16) Biotechnology

17) Electronics and Control

18) Food Technology

19) Information and Communication

20) Materials Technology

21) Production and Processes

22) Structures and Mechanisms

Which tools and resources would you like to see included on the mobile workstation? Given below are some suggestions, please tick the boxes next to the items you would like to use and include any others in the space provided

23) Biotechnology

plastic bottles

sterilizing solution
fridge
pots
rubber gloves
safety masks
stirring utensils
jars
heating element
other resources?

24) Electronics and Control
soldering irons
batteries
wires
light bulbs
resisters
switches
circuit boards
diodes
buzzers
screwdrivers
magnets
microphones
LEDs
Electroflash
electronics kits
other resources?

25) Food Technology
chopping board
egg beater
electric jug
knives
forks

spoons
graters
microwave
hotplates
oven
peelers
pots/pans
seives
pot scrub
other resouces?

26) Materials Technology
samples of materials
plastic containers
hot glue guns
fabric samples
sewing machine
sandpaper
vices
chisels
hammers
MDF
other resources?

27) Information and Communication
computer
microsoft publisher
digital camera
floppy discs
light bulbs
coloured paper
felt pens
paper
cardboard

laminator
paint
other resources?

28) Production and Process Technology
paper
glue
scissors
wax
terracotta pots
wick
saucepan
ceramic clay
sandpaper
paints
brushes
other resources?

29) Structures and Mechanisms
adhesive tape
paper clips
nylon string
craft knife
cutting mats
glue gun
rubber bands
balloons
cardboard
scissors
Lego technic system
Inventa model system
other resources?

30) Any other comments?

Appendix B

Lifting Mechanisms Screening Matrix

Criteria	Caravan	Adjustable top	Individual adjustable legs	Hydraulic ram
Vertical movement of 240 mm	1	1	1	1
Estimated cost less than $100	0	1	0	-1
Stability not expected to be affected	1	0	-1	0
Is easily and quickly adjusted	1	-1	-1	1
TOTAL	**3**	1	-1	1

Appendix C

Concept Generation Results

Sub Problem Identification

For this particular type of product the best approach to decomposing the problem is to break it up in terms of the sequence of user interactions. First the tools and consumables must be stored away, then the tools are used to work the consumable materials on the work surface or surfaces. Some tools will require energy to operate. Tools then need to be put away securely. Once the tools are secure, the workstation can be moved into the next room. The sub-problems placed in order of importance (from most important to least important) are:

1. Storage of tools.
2. Transportation of resources to next room.
3. Provide working surfaces.
4. Security of tools.
5. Store consumables.
6. Supply energy to tools.

Search Externally

The process of generating concepts produces a large number of sketches, tables and ideas, provided in this section is an example of the method used to solve the identified sub problems.

This section involves finding solutions to the identified sub-problems from existing sources. Some of the sources include patents, hardware stores, existing Furnware products, storage of equipment at Furnware, existing solutions developed by schools and suppliers' catalogues. Note that the tables provided below incorporate a degree of systematic exploration (step 4). This is done to simplify the presentation of the design process carried out.

Sub-Problem 1: Storage of Tools

This problem can be further divided into the different technology areas. Provided below are Tables 1-4. They provide details relating to the resource requirements for the individual technology areas and the potential means of storing them.

Searching for existing methods of securing and storing tools yielded the following main methods: basic hooks, tote trays, drawers, spring clips, cupboards, and small plastic compartments that are stored either on a steel rack or on a shelf. These methods are all either already manufactured by Furnware or can be readily obtained from suppliers.

Provided below are tables of tools required for the four technology areas that will be targeted. Each storage method has been analyzed for appropriateness to store each tool. Each method is rated according to the following description:

1. Ideal method, the most preferred according to the criteria
2. Acceptable method, alternative option to 1
3. Possible method, can be stored in this way if required
4. Impossible to store this tool by this method.

Criteria for evaluating each storage method:

- Tool is easily attached and well supported
- Efficiency and cost effectiveness (weight/cost)
- Exists at Furnware already
- Tools able to be counted easily

Table 1 Food Technology Equipment Storage

Tool	Ideal Number (Range)	Storage Method					
		Hooks	Flat bed	Spring clip	Hole	Cupboard	Individual compartments
Chopping boards	4 (2-8)	2	1	4	3	2	4
Big bowls	4 (2-8)	4	2	4	4	1	4
Small Bowls	4 (2-8)	4	2	4	4	1	4
Sharp knives	4 (2-8)	2	1	2	2	3	3
Measuring Spoons set	4 (2-8)	1	2	4	4	3	3
Set of Measuring cups	4 (2-8)	1	2	4	4	3	3
Spatulas	4 (2-8)	2	1	3	2	3	3
Wooden spoons	4 (2-8)	2	1	2	2	3	4
Pots & Lids	2 (2-4)	2	2	4	4	1	4
Sieves	1 (0-4)	1	2	3	4	3	4
Potato peelers	2 (2-8)	1	2	3	3	3	3
Grater	2 (0-4)	2	1	4	4	3	4
Aprons	30(12-30)	2	2	3	4	1	4
Table cloths	4 (0-6)	4	1	4	4	2	4
Microwave	1 (0-4)	4	4	4	4	1	4
Hotplate	2 (0-4)	4	1	4	4	2	4
Egg Beater	2 (1-4)	1	2	2	4	3	4
Knives & Forks	24 (24-75)	2	1	3	2	3	3

Materials Technology

Table 2 Materials Technology Equipment

Tool	Ideal Number (Range)	Storage Method					
		Hooks	Flat bed	Spring clip	Hole	Cupboard	Holster
Glue gun	4 (2-8)	1	2	3	3	2	2
Hand drill	4 (4-8)	4	2	1	2	3	2
Hand saw	8 (4-12)	1	2	2	3	3	4
Sewing machine	1 (0-1)	4	4	4	4	1	4
Vices	2 (0-4)	3	1	4	4	1	4
Drill Bits	2 (0-4)	3	3	4	1	3	3
Bench Hooks	8 (4-12)	2	3	4	4	1	4
Hammers	1 (0-8)	1	2	2	3	3	2
Pliers	8 (0-8)	1	2	3	2	3	2
Screw Drivers	4 (0-8)	4	2	1	1	3	2
Reamers	4 (0-8)	4	2	1	1	3	3
Files	4 (0-8) X2	1	2	2	2	3	3
Shears	4 (0-8)	1	2	3	2	3	3
G clamps	0 (0-8)	1	2	3	3	3	3
Saw Blades	4 (2-8)	4	2	4	1	3	3
Glue Sticks	20 (10-40)	4	2	4	1	3	3

Structures and Mechanisms Technology

Provided in the table below is a list of the tools required for structures and mechanisms technology that are not required for any other area. There is some overlap in tools with this area and materials technology.

Table 3 Structures and Mechanisms Technology Equipment

Tool	Ideal Number (Range)	Storage Method					
		Hooks	Flat bed	Spring clip	Hole	Cupboard	Holster
Craft Knife	1 (0-8)	1	2	3	3	3	3
Cutting Mat	1 (0-8)	1	2	3	3	2	4
Lego Technic	4 (0-8)	4	3	4	4	1	4
Gears	20 (20-40)	3	1	4	1	3	4
Pins	40 (20-80)	4	2	4	1	3	4
Safety Rulers	4 (0-8)	1	2	4	2	3	3
Scissors	8 (4-16)	1	2	3	1	3	2

Electronics and Control Technology

Table 4 Electronics and Control Technology Equipment

Tool	Ideal Number (Range)	Storage Method					
		Hooks	Flat bed	Spring clip	Hole	Cupboard	Small Compartment
Batteries	8 (4-16)	4	2	4	3	3	1
Wires	20 (20-40)	3	2	3	3	3	1
Light Bulbs	8 (8-20)	4	2	3	3	3	1
Switches	8 (4-18)	3	2	3	3	3	1
Pliers	8 (4-12)	1	2	3	2	3	3
Screw Drivers	8 (4-16)	4	2	2	1	3	4
Motors	4 (2-8)	4	2	3	2	3	1
Wire Connectors	20 (10-30)	4	2	3	3	3	1
Resistors	40 (20-60)	4	2	3	2	3	1
Diodes	20 (10-30)	4	2	3	2	3	1
Wire Strippers	4 (2-8)	1	2	3	2	3	3
Soldering Irons	4 (0-4)	3	2	2	1	3	2
Soldering Iron Stands	4 (0-4)	3	2	4	4	1	4
Circuit Boards	8 (4-30)	3	1	4	2	2	2
Speakers	2 (2-8)	4	2	4	2	1	2
Lego Dacta	4 (0-8)	4	2	4	3	1	4
Electroflash	4 (0-8)	4	2	4	3	1	4
Screws	50 (50-300)	4	2	4	3	3	1

Sub-Problem 2: Transportation into Next Room

Generating and researching ideas for transporting the unit between rooms produced a mix of common methods such as castors and pneumatic wheels, as well as some more unusual methods such as skids, tracks and barrels.

Some other identified ideas included: golf carts, wheel chairs, wheel barrows, hospital beds, prams, scaffolding, workshop benches, audio visual equipment trolleys, shopping trolleys, small containers, suitcase and workshop trolley.

Sub-Problem 3: Provide Working Surfaces

This problem can be further divided into two basic areas: work surface type and work surface form. Different work surface materials are more appropriate to different tasks. A number of tasks undertaken by children (sawing) use tools that can cause damage to the furniture. For this reason it is desirable to provide surfaces that are either resistant to damage or sacrificial for the students to work on. The surfaces required are directly related to the tools to be used and the tasks to be completed. Reviewing the tools required for the different areas of the technology curriculum yields the following results provided in Table 5 below. The form the surfaces will take is the second area to research. The surfaces could form a part of the workstation or they could be small surfaces that are stored on the workstation and are able to be removed for use elsewhere. The focus of ideas for this section is on making a work surface that is part of the workstation, height adjustable to cater for the range of students using the workstation.

Table 5 Working Surface Types

Technology Area	Activity	Purpose of Surface	Characteristics
Materials	Sawing	Protect good surfaces Protect saw Assist in securing cut material	Easy to use Fit on workstation Cost < $15 Be easy to make
	Drilling	Protect good surfaces	Be thick enough Easy to use Cost < $ 10
	Gluing	Prevent glue contacting desks	Heat resistant Easy to clean Large enough
	Cutting	Tough surface that will not blunten knives too much	Cost efficient Light weight
	Delicate Tasks	To secure material being worked on	Able to clamp variety of materials Light weight Does not interfere with storage methods
	Hammering/ Heavy Tasks	Support material and prevent vibration	Sturdy Stable Vibration resistant
	Precision Drilling	To support drill and clamp material to be drilled	Cost Light weight Simple to use
Structures and Mechanisms	Small Parts Store	Prevent loss of Small Parts	Parts fit inside it Resistant to tipping/sliding
Electronics and Communication	Soldering	Protect desk form iron and solder	Secure soldering iron when not in use Eat resistant Stable/sturdy Store small parts
Food	Food Preparation	Provide hygienic surface to work on	Water resistant Mould resistant
	Cutting Food	Tough surface that will not blunten knives too much	Cost efficient Light weight
	Mixing Ingredients	Easy to clean up spills	Large enough for bowl etc to sit on
	Cooking	Support all equipment and be heat resistant	Hygienic Easy to clean Hard wearing
	Eating	Hygienic	Easy to clean
	Cleaning Equipment	Hold warm water and detergent	Easy to clean Heat resistant Easy to drain water

The existing methods found are outlined in Table 6 below.

Table 6 Existing Surfaces

Technology Area	Activity	Existing Solutions
Materials	Sawing	Bench hooks, vice
	Drilling	18mm thick MDF, vice
	Gluing	Newspaper, cutting mat, sawing block, 6mm thick MDF
	Cutting	Cutting mat, 6mm thick MDF
	Delicate Tasks	Vice mounted to unit, removable vice,
	Hammering/ Heavy Tasks	Heavy duty wood work top with sturdy legs. Rubberised feet
	Precision Drilling	Drill press, vice
Structures and Mechanisms	Small Parts Store	Plastic container with dividers, MDF tray, steel tray
Electronics and Communication	Soldering	MDF tray with soldering iron holder, steel tray
Food	Food Preparation	Stainless steel bench, plastic bench, laminate bench, lacquered wood bench
	Cutting Food	Plastic chopping board, wood chopping board, cutting mat
	Mixing Ingredients	Stainless steel bench with lip, lacquered bench with lip, bath,
	Cooking	Stainless steel bench, galvanized steel bench, copper bench
	Eating	Table with table cloth, stainless steel bench, lacquered wooden bench, melteca table, plastic tray
	Cleaning Equipment	Stainless steel sink, plastic bowl, bath, dishwasher

Internal searching concentrated on the development of multipurpose or better than existing surfaces. A sawing block ad a clamp and a cam attached to make it easier for children to use. The gluing surface was integrated with the sawing block in an attempt to reduce the number of surfaces required.

Sub Problem 4: Security of Tools

Some of the tools required for the technology curriculum are either dangerous or expensive. The tools are also regularly moved between classrooms. For these reasons it is necessary to secure the tools so that they do not fall from their storage position and are out of reach of children when not in use. This sub problem is very dependent on the method used to store the tools.

Table 7 Securing Methods

Storage Method	Securing Methods
Drawer	Key and lock, Bar through handles of drawers
Tote tray bay	Door and key and lock, bar and locking mechanism
Hooks and Other Vertical Storage Methods	Standard door, drawer and lock, top opening door, roller door, slide door, central pole, jack in the box, bottom opening door
Cupboard	Standard door and lock

Sub Problem 5: Energy to Tools

There are a limited number of methods available to supply energy to the tools used. Provided below in Table 8 are the common energy sources and the tools each is appropriate for.

Table 8 Energy Sources

Tools	Energy Source			
	Mains Power	**Battery**	**Gas**	**Fire**
Sewing Machine	✔			
Drills	✔	✔		
Glue Gun	✔			
Motors		✔		
Soldering Iron	✔			
Microwave	✔			
Hot Plate	✔		✔	
Oven	✔(30 A)		✔	✔
Jug	✔		✔	✔

Using a mains power supply is the most widely used and accessible energy source due to the high number of appliances using it, multiple outlets would be desirable. The incorporation of a multiplug onto the unit for example would improve ease of use. Other possible accessories are extension leads and safety devices such as Return Current Devices (RCDs).

Sub Problem 6: Storage of Consumables

This is the final sub problem and also the least vital. Tool storage takes priority over consumable storage because the majority of consumables are purchased just prior to their consumption, especially perishable food items. A similar method to that used to determine storage methods for tools was used. This consisted of four steps:

1. Identify those consumables stored most
2. Determine dependence of a tool on them (if yes then storage for them is more important)
3. Determine a number of existing storage methods
4. Score and rate according to the criteria below

Each method is rated according to the following description:

1. Ideal method, the most preferred according to the criteria
2. Acceptable method, alternative option to 1
3. Possible method, can be stored in this way if required

4. Impossible to store this tool by this method.

Criteria for evaluating each storage method:

- Consumable is easily placed in facility and does not fall out easily
- Efficiency and cost effectiveness (weight/cost)
- Exists at Furnware already

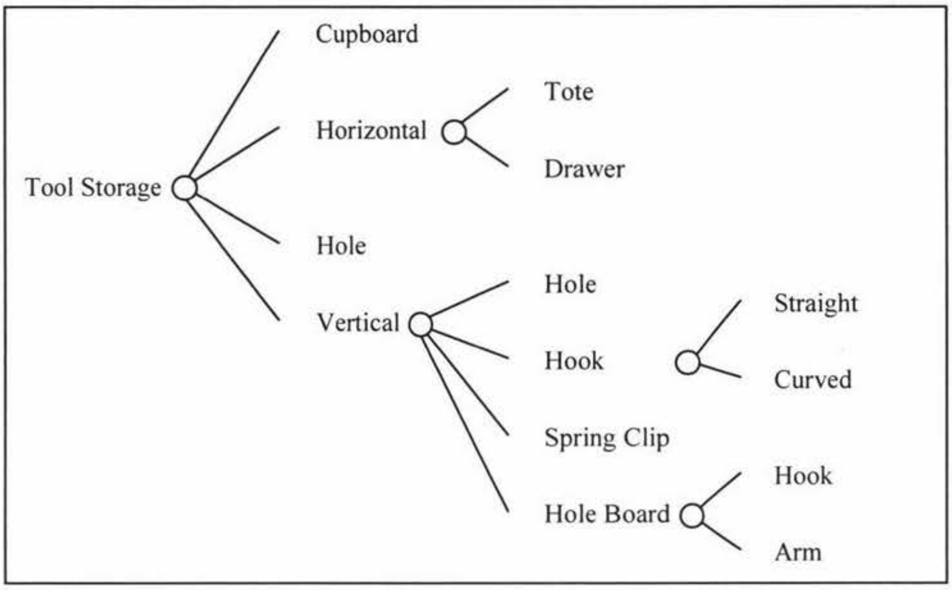
Table 9 Storage of Consumables

Consumable	Tool? (Y/N)	Storage Method				
		Flat bed	Spring clip	Hole	Cupboard	Small Compartment
Glue Sticks	Y	2	3	1	3	2
Thread	Y	2	3	3	1	2
Square Dowel	N	1	4	2	3	4
Solder	Y	2	2	3	1	2
Straws	N	1	4	2	3	3
Cardboard	N	1	4	4	2	4
Nails	Y	2	4	2	2	1
Screws	Y	2	4	2	2	1

Explore Systematically

Exploring the ideas for solving the sub problems involves combining solutions to form concepts for solving the complete problem. A very large number of ideas have been generated and to explore every possible combination would take too long. Classification trees were used to reduce the number of interactions before exploration began. Classification trees help group solutions that are similar in some way thus reducing the total number of solutions and possible solution combinations. Each sub-problem has a set of solutions, provided below in Figures 1 - 6 are the classification trees for each of them. To assist the exploration of sub problem solution fragments into concept ideas, a combination table was used. A combination table simply provides a visual systematic means of exploring all the possible combinations of solutions.

Figure 1 Tool Storage Classification Tree

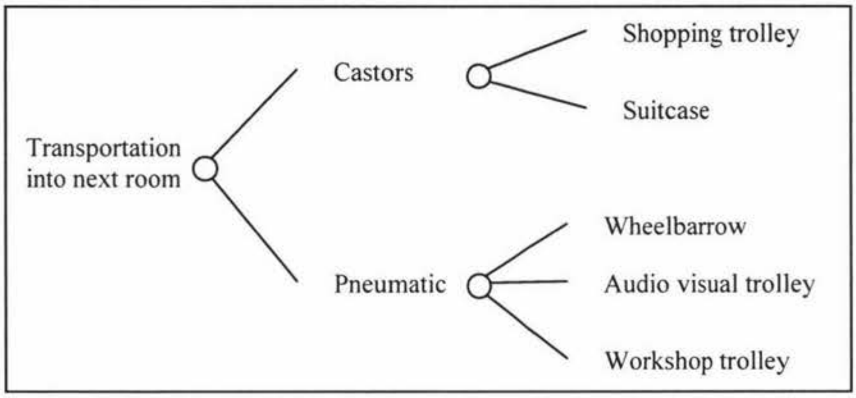


Once exploration begun, using the combination table, more combinations could also be eliminated because they were obviously impossible combinations. The number of potential solutions originally started at 7x5x6x6x4x5 = 25,200. This is reduced to 7x3x5x6 = 630 using the classification trees. Further reductions upon combining concepts reduced this to 5x3x3x5 = 225.

Sub Problem 2: Transportation into the next room

The factors that needed to be taken into consideration when screening these ideas were: Environment of use, will the method work sufficiently well to travel over cobblestones and other outdoor surfaces and down school corridors etc. Weight of workstation. The method must be able to support an estimated maximum of 80 kg. Maneuvering into classroom. Many school classroom and corridor configurations require a high degree of maneuverability of the unit to get it into the classroom. Other generic factors included durability, stability and cost.

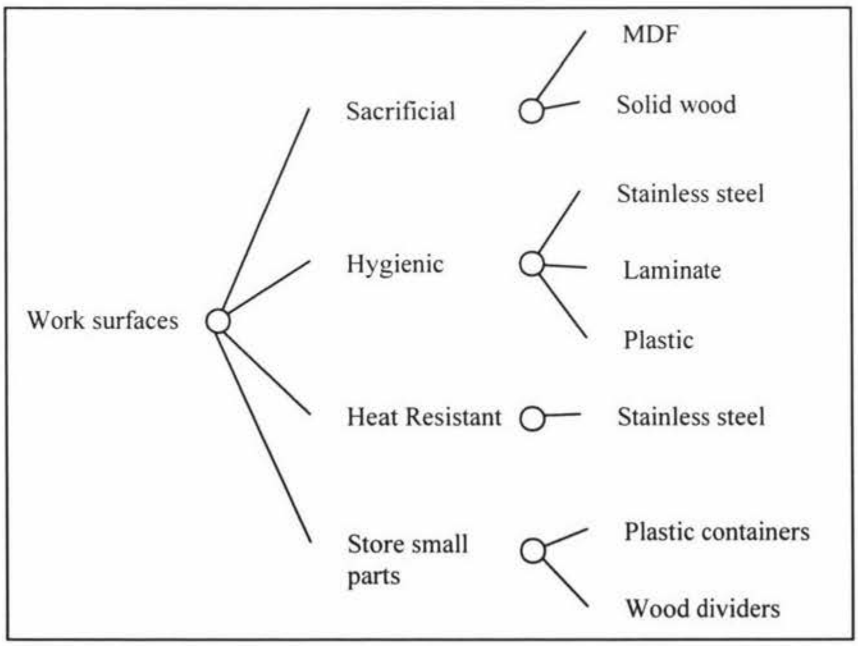
Figure 2 Transportation Classification Tree



Sub Problem 3: Work Surfaces

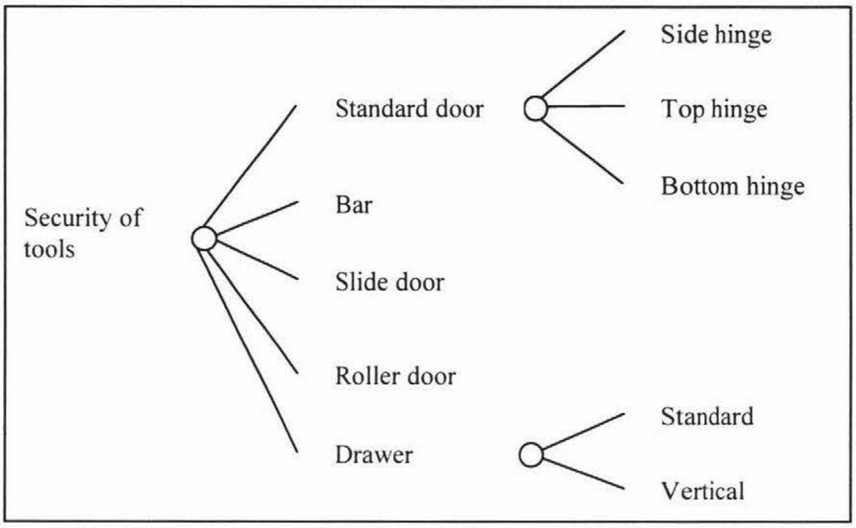
This problem was divided into two basic areas: work surface type and work surface form. The classification tree for the type of work surface is provided below. To determine which form, worktop or small surfaces stored on the unit, a series of prototypes will need to be made.

Figure 3 Work Surface Classification Tree



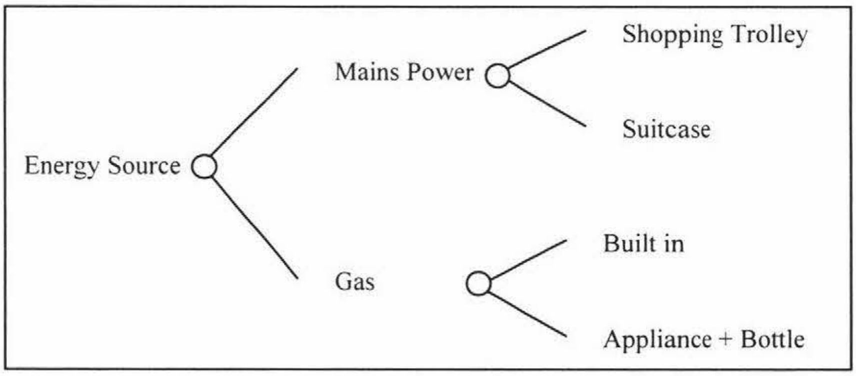
Sub Problem 4: Security of Tools

Figure 4 Tool Security Classification Tree



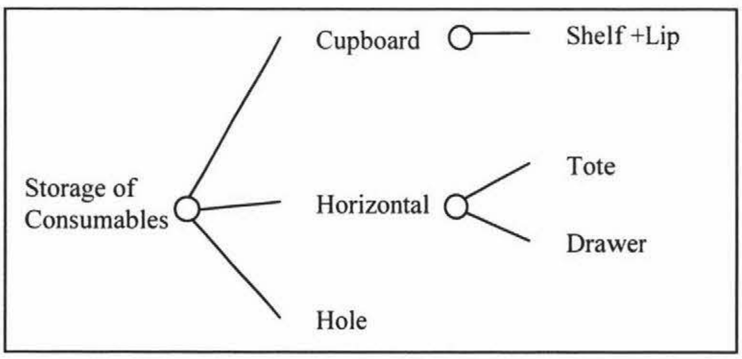
Sub Problem 5: Energy to Tools

Figure 5 Energy to Tools Classification Tree



Sub Problem 6: Storage of Consumables

Figure 6 Consumable Storage Classification Tree



Appendix D

Test Survey

Technology Workstation Review

Hello Technology Teacher

This questionnaire has been designed to gain feedback on the technology education workstation range that I have been working on. The questions on this form are designed to be filled out as you inspect, or after you have viewed the two technology workstation prototypes. Feel free to write any thoughts you have on these workstations, all of your feedback is greatly appreciated!

Basic Concept:
The proposed concept is to provide a series of different technology workstation options that include combinations of the storage and surface options presented on the prototype units. This survey is designed to ensure the right options will be used in the final designs.

Unit #1

(Blue Unit: this unit concentrates on the Materials, Structures and Mechanisms and Electronics and Control areas of the Technology Curriculum)

Worksurface

1. Do you like the lacquered customboard surface provided?

   Yes   No

2. Do you have any comments about this surface?

____

____

Tote Bay

3. Would you include a tote bay on your workstation?

   Yes   No

   If so, how many would you include?

   1   2   3

4. Would you want a door on the bay(s)?

   Yes   No

5. If yes, would you want the door(s) to be lockable?

   Yes   No

Small Compartment Drawer

(Designed to store small components such as resistors, batteries and LEDs etc)

6. Do you like this drawer idea?

   Yes   No

7. Which sizes of trays would you use?

   Small (No5)   Med (No.10)   Large(No.20)

8. Do you have any other comments about this drawer?

____

____

Saw Drawer
(Designed to store saws and sawing blocks)
9. Do you like this drawer idea?

Yes No

10. Would you want to purchase the sawing blocks with the unit?

Yes No

11. Do you have any comments about this drawer?

____

____

Glue Gun Drawer
(Stores guns, multiplug and surfaces to work on)
12. Do you like the concept of this cupboard?

Yes No

13. Would you purchase the work surfaces with the workstation?

Yes No

14. Would you purchase the multiplug with the unit?

Yes No

15. Are the work surfaces large enough?

Yes No

16. Do you have any comments about this drawer?

____

____

Toggle Boards
These boards have been designed to enable small children to better cut materials as well as provide a surface and secure mount for glue guns to help minimize mess created when using the glue guns.

17. Do you like the concept idea?

Yes No

18. Do you like the concept of using an overlay when gluing?

Yes No

19. Do you like the concept of securing the gun while not in use?

Yes No

20. The toggle clamps used on these boards cost approximately $20 each, would you purchase a set of these blocks?

Yes No

If so, how many? ______________

Narrow Drawer
(Designed to store a variety of tools such as drills, screwdrivers etc)
21. Do you think a drawer of this type is a good idea?

Yes No

22. Do you have any comments about this drawer?

____

____

Unit #2

(Pimento unit: this prototype concentrates on the Food area of the technology curriculum)

Worktop

23. Do you like the stainless steel worktop?

Yes No

24. Do you have any comments about this top?

____

____

Oversized Tote Bay

25. Would you include the tote bay in your workstation?

Yes No

26. Does it need a door?

Yes No

27. Would you want the door lockable?

Yes No

28. Would you use a gas cooker such as the one in the unit?

Yes No

Food Preparation Drawer

29. Would you include this drawer on your workstation?

Yes No

30. This drawer is designed to provide enough storage for two groups of students to prepare food. How many of these drawers would you like on the trolley?

0 1 2 3

31. Would you like this drawer to be lockable?

Yes No

32. Do you have any comments about this drawer?

____

____

Pot Drawer

33. Would you include this drawer on your workstation?

Yes No

34. Do you have any comments about this drawer?

____

____

Drawer Bank
(Not actually made as part of the prototype but expected to include three drawers, two 100 mm deep and one 200 mm deep)

35. Would you include a drawer bank on your workstation?

Yes No

Basic Cupboard and Adjustable Shelf
(Not actually made as part of the unit, expected to be about the same size as the pot drawer)
36. Would you include a standard cupboard on your unit?

Yes No

Chassis Design
The two units have slightly different chassis designs and castor configurations.
37. Which chassis frame do you think is most appropriate for this type of unit?

Unit#1 (blue) Unit #2 (pimento)

38. Which castor configuration do you prefer?

Unit#1 (blue) Unit #2 (pimento)

General Questions
39. How much would you expect to pay for units such as these?

Unit#1(Blue): Between $__________ and $__________
Unit2(Pimento): Between $__________ and $__________

40. Do you think the styling of these units is important? Please rate on a scale of 1 (not important) to 5 (very important)

1 2 3 4 5

41. Please rate the styling of the prototypes using a scale of 1 (very bad) to 5 (excellent)

Unit#1(Blue):	1	2	3	4	5
Unit2(Pimento):	1	2	3	4	5

Thank you VERY much for your time

Appendix E

Table of CAD Software

	Advanced System 3000 (1998)
PRODUCER	CamSoft
CATEGORY	CAD/CAM
SYSTEM	Win95, NT 4.0
FEATURES	Multiple viewports, extensive scanned photo-realistic tool library and job plan high-res. rendering. There are five levels of AS 3000: Level 1, Level 5, Level 10, Level 20 and Level 30. Level 5 and higher contains a mill and lathe simulator that is upgrading to 5-axis. Import/Export DXF, DWG and DNG files.
	Allplan FT 15 (1999)
PRODUCER	Nemetschek AG
CATEGORY	Architectural CAD and Modeling
SYSTEM	Win98/2000, NT 4.0, 128 MB RAM, 1 GB HD space
FEATURES	Allplan's Contex Sensitive GUI simplifies design tasks by presenting the toolbar you need when you need it. Smart Symbols elements, 3D Modeling, Visualisation, Walk-through and Animation, supports Ray-Tracing, photo-realistic rendering and Boolean operations, Parametric Radial grids, multiple views can be saved and displayed in multiple viewports, improvement in Animation, new Layout Module, new user interface with improve and enhanced program navigation. Import/Export DXF (Rel. 14), DWG (Rel. 14). Export: Data CAD, TIF. Can export Bill of Materials to Excel. Support for DGN and VRML.
	ArchiCAD 6.5 (2000)
PRODUCER	Graphisoft (Hungary)
CATEGORY	Architectural CAD
SYSTEM	Mac, Win95/98/2000, NT - 64 MB RAM, 220 MB HDD space.
FEATURES	Can calculate shadow area of a building, walk-through, can produce virtual reality scenes, Bill of Materials, Zone tool for identifying and labelling, calculates area and volume of each zone, 99 levels of undo, 600 3-D objects library, Plot Maker tool for plotting, Intelligent Cursor for aligning elements, automatic roof construction, Automatic dimensioning, parametric properties, GDL (Geometric Description Language) for defining any geometric form, Hotlinked module for external referencing. Import/Export: DXF, PICT, WMF, DWG, 3DS, Alias. Import: Top CAD. Export: Post Script, HPGL, VRML, RIB
	ArchiTECH.PC 3.0 (1998)
PRODUCER	SoftCAD Int.
CATEGORY	2D, 3D Architectural CAD
SYSTEM	Windows
FEATURES	Generates Bill of Materials, Plan and drawing production, sections, modeling, photorealistic rendering, animation, Stairs generator, terrain modeling, area and volume calculations.
	CADDS 5 version 11 (2000)
PRODUCER	PTC

CATEGORY	CAD/CAM High-End
SYSTEM	AIX, SGI, DEC Alpha, Solaris, Sun, X-Windows, HP-UX, NT 4.0 64 MB Ram, 1 GB HD space
FEATURES	Parametric modeling, explicit modeling, hybrid modeling, solids detailing, NURBs surface design, parametric multi-part design, table driven design, concurrent assembly mock-up, shading and imaging, full analysis and plastics design, piping, toolmaking. Used by Airbus Industry (Aerospatiale of France, British Aerospace, and Daimler Benz Aerospace), Land Rover, Peugeot, Fiat, etc. Import/Export: IGES, CGM, SET, STEP, Medusa, Catia, UG, SAT, STL. Import DXF, Export VRML and PostScript.
	Caddsman Modeller (1999)
PRODUCER	CADDSMAN Pty Ltd. (AU)
CATEGORY	3D Surface Modeling
SYSTEM	Win 95/98, NT 32 MB RAM, 40 MB HD space
FEATURES	Inc.: Unlimited layers, line styles, Automatic produce detailed section from the model, Photo-realistic imaging, Shadow calculation, Advanced Measurements tools for lenghts, volumes and centre of gravity, Support JPG, TIF, GIF, Software Developer Kit allows to create third part applications in C++.
	CADKEY 19 (2000)
PRODUCER	Cadkey Corp.
CATEGORY	2D, 3D CAD
SYSTEM	
FEATURES	CADKEY 19 data translation lineup now includes support of ACIS-SAT 6.2 import and export of solid models. The DWG/DXF translators offer AutoCAD 2000 file support, improved dimension and spline mapping, and a progress indicator, which visually displays the status of the translation process. New to CADKEY are the Twist Body and Stretch Body functions. The Twist Body function allows for solids, surfaces or wireframes to be twisted about an axis for any given angle. For added design flexibility, the Stretch Body function allows a specified region of a solid, surface or wireframe to be extended in either or both directions along an axis by given distances. Users can easily add other CADKEY-integrated products such as FastSURF, an advanced surface modeling program, and DRAFT-PAK, the exclusive "Machine Design Handbook for CADKEY". CADKEY POWER-PAK includes advanced modeling and detailing utilities capable of 3D assembly management with pattern file referencing and exploded assembly creation. CADKEY TRUE TEXT allows the user to create characters and text as standard CADKEY geometry using TrueType fonts. .
	CADLink 9 (2000)
PRODUCER	Graphisoft
CATEGORY	2D CAD HVAC
SYSTEM	
FEATURES	New features: - Ability to model single pipe heating systems. - Automated radiator reconnection. - Full analysis of regulating valves. - Over 2000 motors library. - 3D visualization of lighting layout - Co-ordinated bill of quantities for all services. - New browser based help system. - Integration with ArchiCAD.

	Catia ver. 5, rel. 5 (2000)
PRODUCER	Dassault Systems www.catia.ibm.com
CATEGORY	CAD/CAM/ CAE, High-End
SYSTEM	AIX, MVS, VM, X-Windows, HPUX, IBM RS/6000, SGI, Win2000
FEATURES	10 new products bring the number of CATIA V5 products to 60. New products include Product Functional Definition 2 and Product Function Optimizer 2 which incorporate Invention Machine Corporation engineering knowledge management. In the early stages of product functional description these products can help engineers in innovation, problem solving, and evaluation of alternate solutions. CATIA Version 5's knowledgeware portfolio improves. Optimization under multiple constraints is possible (similar to that in PTC's Behavioral Modeling). This release also adds a Sheetmetal Production 2 product, providing sheetmetal processes, a new 3D functional tolerancing and annotation product, a new Mold Tooling Design 2 product aids in the definition of mold tooling features, improved hybrid modeling technology and a new FEM Surface product extending meshing to surface parts. A new FreeStyle Sketch Tracer ensuring that designer 2D sketches can be captured in 3D and kept throughout the product lifecycle. CATIA Version 5 Release 5 also provides designers with enhanced productivity and flexibility in designing aesthetic shapes for consumer goods and automotive Class A surfaces.
	CDRS 2000i (1999)
PRODUCER	ICEM
CATEGORY	2D, 3D CAD
SYSTEM	NT, SGI, SUN, AIX, HP-UX 128 MB RAM, 600 MB HD space
FEATURES	Conceptual Design tool that allows you to turn your conceptual sketches or ideas into accurate surface models. Includes rendering and animation capabilities. Can create and edit curves, surfaces, support for Pro/ENGINEER, 3D Paint, CATIA, convert foreign surfaces to native CDRS data, Material and Texture editor, Light Editor, Room Editor.
	Chief architect 7 (2000)
PRODUCER	Compucon, Inc.
CATEGORY	2D, 3D CAD Architectural
SYSTEM	Windows
FEATURES	Windows-based architectural design program designed for builders, designers, and developers to create full working drawings and accurate 3D models. Features include a 3D terrain modeler, extensive texture and materials libraries, layer controls, and multiple undo. Customizable CAD symbol libraries in- clude Simpson strong-ties, windows, doors, and cabinets. Automatic roof tools feature editable roof polyline capability and boxed eaves. Photorealistic rendering includes a framing camera viewing tool.
	DataCAD Plus 9.15 (2000)
PRODUCER	Datacad LLC www.datacad.com
CATEGORY	2D, 3D Architectural
SYSTEM	Win95, Win98, NT
FEATURES	Inc.: Solid-fill hatching, 12000 symbols in 2D and 3D, multi-level undo, Plot Manager can show different versions of plans on your layout and can plott at different scales, supports Windows driver for printing, calculate the area and volume of rooms and surfaces, roof creator, import/export DWG, DXF, SMF and DC5 files.
	Deneba CAD 2.0 (1999)
PRODUCER	Deneba Systems, Inc.

CATEGORY	2D, 3D CAD
SYSTEM	Win95, NT, Mac 16 MB RAM, 40 MB HD space.
FEATURES	Based on Design Oriented Tool technology incorporates powerful 2D and 3D Boolean operations and parametric text capabilities. Open and work with multiple windows of a project to visualize it from an infinite number of vintage points. Offers Snap option, Floating Layers palette, con generate 2D floor from 3D models, Photo-realistic renderings, Automated Data Management, 2,000 2D architectural and engineering symbols and over 500 3D furniture, fixture and equipment libraries. Supports DXF, DWG (rel.14), DWF, IGES, HPGL, AI, EPS, BMP, GIF, JPG, PSD, TIF, TXT, WMF and 3DMF formats.
	Design CAD 8.0
PRODUCER	ASBC
CATEGORY	2D, 3D CAD
SYSTEM	Windows
FEATURES	3D walk-through, Internet ready e-mail support and VRML output, Anti-aliasing rendering, Animation with AVI support, 3D texture mapping, Solid Modeling, direct scanner support with vector conversion, Visual Basic and C++ support, customizable interfaces. Import/Export: DWG, DXF, IGES, and WMF.
	Eagle 11
PRODUCER	MacroVision Creative Software (Ireland)
CATEGORY	2D, 3D
SYSTEM	Windows, Win 95, NT, HPUX, AIX, SGI, Sun
FEATURES	Raster editing tools, Built-in animation for camera and target paths, C/BASIC Graphics Language, ODBC and DDE Communications, Internet support. Import/Export: DXF, DWG, IGES, SAT, MOSS, RAS, VDF, LWI.
	Euclid Quantum
PRODUCER	Matra Datavision
CATEGORY	CAD/CAM High-End
SYSTEM	Unix, NT, Win 95 - 96 MB Ram, 2 GB HDD space.
FEATURES	CAS.CADE geometry modeling Kernel, surface modeling, assembly modeling, shelling, full render capabilities, support HTML and VRML, Motif graphic user interface, Modules: EUCLID Machinist, EUCLID Analyst, EUCLID Design Manager, EUCLID Designer, 2D Drafter module integrated. Macros using C++ language. Used by: European Space Agency, Fiat, Matra Space, Bosch, Coca-Cola, Hitachi, Siemens, Villeroy & Boch, Renault, Toyota, VW, Bombardier, Elf, Nippon Steel, Stanford University, etc.
	FelixCAD 4.01 (1999)
PRODUCER	Felix CAT, Germany
CATEGORY	2D, 3D
SYSTEM	Win95, NT 32 MB RAM, 51 MB HD space.
FEATURES	Compatible with ACAD12 can edit 4 drawings at once, automatic rendering, Spline c-nd., Management tools, Digitizer support, Flisp programming language (a Lisp version), C++ programming interface kit. Import/Export: DWG, DXF, and DGN. Export WMF, FLX (native).
	Helix Design System

PRODUCER	Microcadam, Inc.
CATEGORY	CAD/CAM
SYSTEM	Win 95, NT - 32 MB RAM, 150 MB HDD space.
FEATURES	DesignBase modeling Kernel, surface modeling, assembly modeling, shelling, full rendering capabilities, Proprietary graphic interface. Bi-directional translator for IGES, STEP, Helix EDMS data manager, integrated drafting module, Sheet Metal, Kinematics Multiple Document Interface, Raster image input. Import/Export: DWG, STEP, VRML, DXF, STL, IGES.
	Imageware 10 (2000)
PRODUCER	Structural Dynamics Research Corp. (SDRC)
CATEGORY	3D Surface Modeling
SYSTEM	
FEATURES	Imageware Version 10 (V10), a major software release enabling customers to design, build, and fully inspect high-quality, free-form shaped products in less time. Imageware is advanced 3D surface modeling and verification technology solution that allows users to realize and maintain the design intent from concept through manufacturing. Consisting of three main products; Surfacer, Verdict, and Build!IT, Imageware V10 provides major benefits to the automotive, aerospace, and consumer products, and entertainment industries. · Surfacer: Award-winning, advanced surface modeling system for capturing design intent and for conducting reverse engineering functions. · Verdict: Complete, accurate and fast analysis solution. · Build!IT: Digital, product-driven process for building and inspecting assembly tooling.
	IntelliCAD 2000 (1999)
PRODUCER	Visio
CATEGORY	2D, 3D
SYSTEM	Win95, NT4.0 - 32 MB RAM, 50 MB HDD space.
FEATURES	Support AutoLisp, Visual BASIC for Applications, ADS, Raster images, ActiveX, Script records, Multiple Document Interface, unlimited Undo/Redo, limited 3D surface capabilities, Drawing Explorer browser. Uses ACIS 3D modeling engine, Photorealistic renderings, real-time pan and zoom. Import/Export DWG (rel. 14).
	LANDCADD 2000 (2000)
PRODUCER	Eagle Point
CATEGORY	Landscape CAD
SYSTEM	
FEATURES	Landscaping and irrigation design tool. Some of the new features: - Contour tool allows the user to draft in 3D proposed or existing contours. - Embedded CAD menus for AutoCAD 14/2000 - The Tree Shadow command now places shadows based on the type of plant. LAND CADD 2000 series includes Base Plan, Constructive Details, Irrigation Design, Landscape Design, Plant Database, Quantity Takeoff, Surface Modeling, Site Analysis, Site Planning, Virtual Image and Visual Landscaping. It works with AutoCAD, MicroStation, and IntelliCAD or as a stand-alone product.
	MegaCAD 3D 14.8 (1999)
PRODUCER	Megatech, Germany

CATEGORY	2D, 3D
SYSTEM	DOS, Windows, NT, Unix - 8 MB RAM
FEATURES	Dbase compatible database, thumbnail viewing of all drawings and symbols, parts list generator, over 80000 metric symbols available: Architecture, Steel Construction, Mechanical, Pneumatics/Hydraulics, and Electrical/Electronics. Based on ACIS 5.0 kernel engine. Over 170 CAD/CAM formats supported.
	MicroStation/J v7.1 (2000)
PRODUCER	Bentley Systems
CATEGORY	2D, 3D Modelling
SYSTEM	
FEATURES	New and improved features in MicroStation/J v7.1 include: Spelling checking of drawing text, Navigate Camera view control for flying through a 3D model, Streamlined dimensioning toolbox, New dimensioning tools, including symmetric dimensions; dimension chamfer; insert and delete dimension vertex; centered dimension; and reassociate dimension, Enhanced flood fill avoids shapes and text, More control over using OLE, Enhanced pen tables, Advanced visualization, Import and export ACIS models in SAT format; STEP AP214 models, Support for wheel mouse, Instant access to Bentley Web site, supports DGN, DXF, DWG (rel 14), IGES, CGM, SVF, VRML, JPG, HTML.
	MicroStation Modeler
PRODUCER	Bentley Systems
CATEGORY	2D, 3D Modelling
SYSTEM	32 MB Ram, 200 MB HDD space.
FEATURES	Assembly Modeling, Rendering, Key Frame Animation, uses ACIS 2.1 modeling and CSG methods for building up models, Motif and Windows GUI interfaces, supports OLE 2.0. Modules: MicroStation Masterpiece (rendering), ModeServer Publisher, MicroStation TeamMate 96 (data manager), MicroStation 95, MicroStation PowerDraft. Import/Export: DXF, DWG, CGM, SAT, IGES, STL, STEP, VersaCAD, etc.
	Power Shape (1999)
PRODUCER	Delcam p.l.c., Birmingham (UK)
CATEGORY	3D CAD/ CAM
SYSTEM	
FEATURES	Suitable for the shape development stager and detailed tooling design. Automatic generation of roughing and finishing paths in 3D, generation of male and female moulds, on-screen 3D simulation of the machining operation, Surface creation from curves, Dynamic surface manipulation and positioning, Object-oriented editing, Automatic core and cavity splitting, Changes identification. Includes Power MILL - a NC toolpath generation package. Import/Export: DXF, IGES, PICT, STL. Imports Catia, CV, UG, CADDS, PDGS, VDA-FS.
	Pro/DESKTOP 2000 (1999)
PRODUCER	Parametric Technology Corp.
CATEGORY	CAD/CAM
SYSTEM	Win95, NT 64 MB RAM, 40 MB HD space

FEATURES	Developed specifically for the conceptual engineers and desktop designer. Innovative 2D/3D Environment, freeform and parametric sketching, dynamically change concepts, support Word and Excel documents, Interoperability and Associatively with Pro/ENGINEER and Pro/MECHANICA, optional Photo Album module for photographic quality images, OLE support, VBA included.
	Pro/ENGINEER 2000i 2 (2000)
PRODUCER	Parametric Technology Corp.
CATEGORY	CAD/CAM/ CAE High-End
SYSTEM	64 MB RAM, 400 MB HDD space
FEATURES	Over 50 integrated modules. New modules: Pro/WEB PUBLISH - interfacing with Internet, Pro/PROCESS - for facilitating concurrent development of manufacturing process plans with the product design, Pro/ASSEMBLY - enables correct simulation of part mounting, Pro/TOOLKIT - allows to customizing the program, Pro/MANUFACTURING, Pro/PDM data management. Includes a C language API, plus simulation of gear, latches, cams and other mechanisms. Proprietary modeling Kernel. Import/Export: Catia, Cadam, ECAD, DXF, IGES, DWG, SET, STEP, CGM, STL, TIF, JPG, VDA, etc.
	PYTHA
PRODUCER	Pytha Pty Ltd
CATEGORY	3D CAD
SYSTEM	Win95
FEATURES	2D construction, advanced 3D solids and operators, technical drawings, perspectives with light sources, define materials, Import/Export: DXF, TIF and JPEG
	Revit 2 (2000)
PRODUCER	Revit Technology Co.
CATEGORY	3D Architectural
SYSTEM	
FEATURES	With release 2.0, Revit Technology is providing building design professionals with the only integrated CAD system that supports the design and documentation process from parametric massing studies through to parametric detailing. Revit 2.0 includes CostWork's square-foot-analysis model, which provides highly intelligent early-stage estimates of building costs based on customizable Designed to better define slopes and join roofs together, Revit 2.0 roofs host skylights and other roof elements
	Solid Edge 9 (2000)
PRODUCER	Unigraphics
CATEGORY	2D, 3D Solid Modeling
SYSTEM	Win95/98, NT
FEATURES	Key features of Solid Edge Version 9 include new capabilities to assist in machinery and large assembly design, web publishing tools, an engineering handbook and new utilities to assist in the migration from 2-D design techniques to 3-D solid modeling. Solid Edge Version 9 expands functionality to meet the demanding needs of machine design professionals working with very large
	SolidVision
PRODUCER	CabinetVision
CATEGORY	Cabinet making

SYSTEM	Win 95, NT
FEATURES	Photo quality renderings, graphic icon layout, custom cabinet modifications, split screen design modules, 32-bit windows application. Import/Export: DXF
	Solid Works 99
PRODUCER	SolidWorks Corp.
CATEGORY	3D CAD
SYSTEM	Win 95, NT
FEATURES	150 new capabilities. New features: Feature Palette library, Move/Resize, Dynamic Assembly Motion, Solid Works 98 Viewer. Import/Export: IGES, DXF, DWG, SAT, STL, TIF.
	Top Solid Pro
PRODUCER	Missler
CATEGORY	2D, 3D
SYSTEM	Win95, NT, Sun, HPUX, SGI, AIX, Digital
FEATURES	Top Solid is the core product of a complete range of fully integrated mechanical applications: TopCAM for machining, TopMold for injection molding, TopFold and TopPunch. Based on Parasolid kernel engine. Support XMT, IGES, DXF, DWG, Catia, JAMA, STL and VDA.
	TurboCAD Professional 6.5 (2000)
PRODUCER	IMSI
CATEGORY	2D, 3D
SYSTEM	
FEATURES	New features: ACIS solid modeling jernel version 5.3. new 3D primitives tools including Cone, Wedges, 3D Mesh, 2D Boolean tools, Join Polylines, Single Point Hatch which will calculate automatically the bounderies and create the hatch, improving Rendering, SDK programmability, Database creation control and interactivity, Paper Space, 16,000 symbols (700 in 3D). Support AutoCAD 2000 DWG/DXF, VRML, 3DS, IGES, SAT, EPS.
	Unigraphics 17 (2000)
PRODUCER	EDS Corp.
CATEGORY	CAD/ CAM/ CAE High-End
SYSTEM	64 MB RAM, 150 MB HDD space.
FEATURES	Using Unigraphics V17, manufacturing companies can capture expert knowledge in their product designs through a process called Knowledge Driven Automation (KDA). KDA builds on Unigraphics' Predictive Engineering foundation announced in September of 1999. KDA consists of capturing and recycling knowledge that exists in many forms at every stage of the product life cycle, then re-using that knowledge to dramatically enhance the design, engineering and manufacturing process. With Unigraphics V17, companies can experience KDA through two distinct methods. First, for organizations interested in creating customized, knowledge-enabled applications to address company specific processes, Unigraphics V17 introduces a new knowledge-based engineering tool called UG/Knowledge Fusion. Second, to automate standard industry processes based on KDA technology, Unigraphics V17 offers new and enhanced Process Wizards and Process Assistants. In addition to enabling KDA, Unigraphics V17 includes hundreds of enhancements that further elevate Predictive Engineering technology in the areas of industrial design, reverse engineering, product modeling, engineering analysis, manufacturing and much more. One such enhancement is a breakthrough technology called Direct Modeling eXtensions (DMX), which dramatically improves the users ability to modify solid models that lack parameters or features, as well as history-based solid models For CAD models without parameters or features, DMX enables the user to add new features as well as provides the ability

	to directly modify the model's existing faces. Another example of the enhancements in Unigraphics V17 is a powerful new finite element solving solution called UG/Structures PE. UG/Structures PE is actually a combination of three powerful solvers that work seamlessly together to solve finite element analysis (FEA) problems - from normal simulations to the most complex optimizations routines - in a fraction of the time necessary for most high-end FEA solvers.
	Vector Works 8.5
PRODUCER	Nemetschek AG
CATEGORY	2D, 3D Architectural
SYSTEM	Mac, Win 95, NT - 16 MB RAM, 19 MB HD space.
FEATURES	New features: Multiple Undo/Redo, Round Walls, Create different Wall Styles, Improved Selection tool, new 3D tools, New Roof Modeling Functionality, context sensitive menus, Resource Palette, Improved Symbol Insertion tool, better support for raster graphics: TIF, JPG, GIF, BMP, Animation and walktroughs, Reverse Translation to MiniCAD.
	Vector Works Architectural (2000)
PRODUCER	Nemetschek AG
CATEGORY	2D, 3D Architectural
SYSTEM	Mac, Win 95, NT - 16 MB RAM, 19 MB HD space.
FEATURES	Inc. Setup Assistant, Task Manager, improved ID Marker tool, Notes Manager for annotate drawings, Notation Object, Issue Manager, Improved Records and Schedules, Redline Suite tools, Smarter Architectural Objects, over 50 new Objects Libraries, Solar Animation for shadows cast calculations.
	Vellum Solids 2000 (2000)
PRODUCER	Ashlar, Inc.
CATEGORY	2D, 3D
SYSTEM	Mac, Win95, NT4.3, 128 MB RAM
FEATURES	Vellum Solids 2000, from Ashler Inc., integrates curves, surfaces, and solids into one easy to use package for engineers. It's based on ACIS kernel version 6.0. New features: Extensive curve and surface modeling tools, over 18 surface types, Local face operations which allows working independetly of how the part was constructed, tools for working with assemblies, improved user interface, support for Open GL which allows photorealistic renderings with ray-tracing, support associativity between wires, surfaces and solids, support for IGES, SAT, and DWG files, direct import from Pro/ENGINEER
	Vellum Draft 99 (1999)
PRODUCER	Ashlar, Inc.
CATEGORY	2D, 3D
SYSTEM	Win98, Mac 32 MB RAM, 25 MB HD space
FEATURES	Fully compatible with other Ashlar Vellum products, Wireframe tools, 2D parametric. User Programming Language included, Cross Platform between Windows and Mac
	Visual CADD 4.0 (2000)
PRODUCER	IMSI
CATEGORY	2D CAD
SYSTEM	Win95/98, NT4.0 16 MB RAM, 22 MB HD space
FEATURES	New features: Multiline tool, Printing Presets, improved Generic CAD/AutoCAD import/export, File Open preview window, Orthogonal Mode, Dimensioning improvements, Curved Leader & Datum command, Single Copy, Multibreaker and Divide commands. Comes with 5000 symbols in Architectural, Mechanical and Electrical libraries and 300 editable House Plans.

Appendix F

NPV Analysis of CAD software Packages

CAD Analysis: SolidWorks

		Hours		$$
	Variables			
A	Time spent on new design work/month		113.75	
C	Number of jobs able to be done currently/mth (A/B)		32.59	
J	Pay rate (/hr)		20.00	
K	Rate of return		10.00%	
L	Purchase Price (1 seat only)		11000	
	Current Situation			
	Time for Prototype II			
	Preliminary View	0.25		
	Nut thing out	0.33		
	List all panels and name	0.08		
	Programme and print out	2.00		
	Header page for programmes	0.17		
	Cutting patterns	0.25		
	Big header	0.08		
	Bill of Materials	0.33		
B	Total Time for Job (hrs)	3.49		
D	Monetary cost of job (B*J)			69.80
E	Monthly Cost (C*D)			2275.00
	Other Costs			
1	Model Stainless steel Work Top		0.00	
2	Assemble Unit in CAD		0.00	
3	Produce rendered image (8% of Jobs)		40.00	
	Time spent by Furnware staff	2.00	40.00	
M	Cost for Rendered Image		80.00	
	Monthly Cost (M * C * 8%)			208.60
4	Assembly instructions (10% of Jobs)		80.00	
	Time spent by Furnware staff	2.00	40.00	
N	Cost for Assembly Instructions		120.00	
	Monthly Cost (N * C * 10%)			391.12
F	**Current Total Monthly Cost**			2874.71
	SOLIDWORKS			
	Model Basic Cavity	0.33		
	Model Drawers and Door	0.50		
	Model Stainless steel Work Top	0.17		
	Model Chassis and Castors	0.25		
	Produce machine code for panel comps	0.00		
	Produce optimized cuting list	0.00		
	Bill of Materials	0.08		
	Produce Job Card	0.25		
	Assemble Unit in CAD	0.33		
	Produce rendered image	0.42		
	Assembly instructions	0.17		
G	Total Time for Job (hrs)	2.50		
H	Monetary cost of job (G*J)		50.00	
I	Monthly Cost (C*H)			1629.656
F-I	**Total Montly Savings**			1245.06

Notes

1,2,3&4 Costs are an estimate if work was contracted out to current designers, assumes that the only purpose of modelling parts is to create rendered image this is only required an estimated 8 % of design cases

5 A three month ramp up time has been allowed. Month1: 20%, Month 2: 50%, Month 3: 80% of full use

	Particulars	**Monthly Cashflows**									
		1	2	3	4	5	6	7	8	9	10
	Software Purchase	-7920.00	-3080.00								
	Hardware Purchase	-3000.00									
	Training Costs	-1000.00		-500.00							
	Maintenance Costs										
	Start Up Time Costs (14hrs/mth)	-280.00	-280.00	-280.00							
5	Savings made on existing tasks	249.01	622.53	996.05	1245.06	1245.06	1245.06	1245.06	1245.06	1245.06	1245.06
		-$11,950.99	-$2,737.47	$216.05	$1,245.06	$1,245.06	$1,245.06	$1,245.06	$1,245.06	$1,245.06	$1,245.06
		NPV (10%)	**$17,724.34**								

Time on new job	
	$ 17,724
2.5	17724.34
2.7	13,876.91
2.74	13,107.43
2.80	11,953.20
2.9	10,029.49
3	8,105.78
3.1	6,182.07
3.3	2,334.65

Pay Rate	
	$17,724.34
26	25,267.51
24	22,753.12
22	20,238.73
20	17,724.34
18	15,209.94
16	12,695.55
14	10,181.16
12	7,666.77

Rate of return	
	$17,724.34
8.00%	18,713.40
10.00%	17,724.34
12.00%	16,775.66
14.00%	15,865.53
16.00%	14,992.15
18.00%	14,153.85
20.00%	13,349.04
22.00%	12,576.20
24.00%	11,833.89
26.00%	11,120.74

Purchase Price	
	$17,724.34
11000	17724.34
12000	16734.89
13000	15745.45
16000	12777.13
18000	10798.25
22000	6840.49
24000	4861.61
26000	2882.73

Maintenance	
	$17,724.34
-450	18009.72
-500	17724.34
-550	17438.95
-600	17153.56
-650	16868.18
-700	16582.79
-750	16297.41
-800	16012.02

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
	-500.00						-500.00			-500.00			-500.00						-500.00			-500.00	
1245.06	1245.06	1245.06	1245.06	1245.06	1245.06	1245.06	1245.06	1245.06	1245.06	1245.06	1245.06	1245.06	1245.06	1245.06	1245.06	1245.06	1245.06	1245.06	1245.06	1245.06	1245.06	1245.06	1245.06
$1,245.06	$745.06	$1,245.06	$1,245.06	$1,245.06	$1,245.06	$1,245.06	$745.06	$1,245.06	$1,245.06	$745.06	$1,245.06	$1,245.06	$745.06	$1,245.06	$1,245.06	$1,245.06	$1,245.06	$1,245.06	$745.06	$1,245.06	$1,245.06	$745.06	$1,245.06

Pay rate	Time on new job							
$17,724.34	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2
26	25,267.51	22,766.68	20,265.86	17,765.03	15,264.21	12,763.39	10,262.56	7,761.74
24	22,753.12	20,444.66	18,136.21	15,827.76	13,519.30	11,210.85	8,902.40	6,593.94
22	20,238.73	18,122.64	16,006.56	13,890.48	11,774.40	9,658.32	7,542.23	5,426.15
20	17,724.34	15,800.62	13,876.91	11,953.20	10,029.49	8,105.78	6,182.07	4,258.36
18	15,209.94	13,478.60	11,747.26	10,015.93	8,284.59	6,553.25	4,821.91	3,090.57
16	12,695.55	11,156.59	9,617.62	8,078.65	6,539.68	5,000.71	3,461.74	1,922.77
14	10,181.16	8,834.57	7,487.97	6,141.37	4,794.77	3,448.17	2,101.58	754.98
12	7,666.77	6,512.55	5,358.32	4,204.09	3,049.87	1,895.64	741.41	-412.81

Return	Time on new job							
$17,724.34	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2
10.00%	17724.34	15800.62	13876.91	11953.20	10029.49	8105.78	6182.07	4258.36
12.00%	16775.66	14909.31	13042.95	11176.59	9310.23	7443.88	5577.52	3711.16
14.00%	15865.53	14054.23	12242.94	10431.65	8620.35	6809.06	4997.76	3186.47
16.00%	14992.15	13233.74	11475.32	9716.91	7958.50	6200.09	4441.68	2683.26
18.00%	14153.85	12446.24	10738.63	9031.01	7323.40	5615.79	3908.17	2200.56
20.00%	13349.04	11690.24	10031.44	8372.64	6713.84	5055.03	3396.23	1737.43
22.00%	12576.20	10964.32	9352.43	7740.54	6128.66	4516.77	2904.88	1292.99
24.00%	11833.89	10267.11	8700.33	7133.54	5566.76	3999.98	2433.19	866.41

Purchase Price	Time on new job							
$17,724.34	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2
11000	17724.34	15800.62	13876.91	11953.20	10029.49	8105.78	6182.07	4258.36
12000	16734.89	14811.18	12887.47	10963.76	9040.05	7116.34	5192.63	3268.92
13000	15745.45	13821.74	11898.03	9974.32	8050.61	6126.90	4203.19	2279.48
16000	12777.13	10853.42	8929.71	7006.00	5082.29	3158.58	1234.87	-688.84
18000	10798.25	8874.54	6950.83	5027.12	3103.41	1179.70	-744.01	-2667.73
22000	6840.49	4916.78	2993.07	1069.36	-854.36	-2778.07	-4701.78	-6625.49
24000	4861.61	2937.90	1014.19	-909.53	-2833.24	-4756.95	-6680.66	-8604.37
26000	2882.73	959.02	-964.70	-2888.41	-4812.12	-6735.83	-8659.54	-10583.25

35	36
	-500.00
1245.06	1245.06
$1,245.06	$745.06

CAD Analysis: CabinetVision

		Hours		$$
	Variables			
A	Time spent on new design work/month		113.75	
C	Number of jobs able to be done currently/mth (A/B)		32.59	
J	Pay rate (/hr)		20.00	
K	Rate of return		10.00%	
L	Purchase Price		45000	
	Current Situation			
	Time for Prototype II			
	Preliminary View	0.25		
	Nut thing out	0.33		
	List all panels and name	0.08		
	Programme and print out	2.00		
	Header page for programmes	0.17		
	Cutting patterns	0.25		
	Big header	0.08		
	Bill of Materials	0.33		
B	Total Time for Job (hrs)	3.49		
D	Monetary cost of job (B*J)			69.80
E	Monthly Cost (C*D)			2275.00
	Other Costs			
1	Model Stainless steel Work Top		0.00	
2	Assemble Unit in CAD		0.00	
3	Produce rendered image (8% of Jobs)		40.00	
	Time spent by Furnware staff	2.00	40.00	
M	Cost for Rendered Image		80.00	
	Monthly Cost (M * C * 8%)			208.60
4	Assembly instructions (10% of Jobs)		80.00	
	Time spent by Furnware staff	2.00	40.00	
N	Cost for Assembly Instructions		120.00	
	Monthly Cost (N * C * 10%)			391.12
F	**Current Total Monthly Cost**			2874.71
	PYTHA			
	Model Basic Cavity	0.08		
	Model Drawers and Door	0.20		
	Model Stainless steel Work Top	0.08		
	Model Chassis and Castors	0.04		
	Produce machine code for panel comps	0.01		
	Produce optimized cuting list	0.02		
	Bill of Materials	0.01		
	Produce Job Card	0.03		
	Assemble Unit in CAD	0.00		
	Produce rendered image	0.01		
	Assembly instructions	0.00		
G	Total Time for Job (hrs)	0.48		
H	Monetary cost of job (G*J)		9.54	
I	Monthly Cost (C*H)			310.9384
F-I	**Total Montly Savings**			2563.78

	Particulars	Monthly Cashflows										
		1	2	3	4	5	6	7	8	9	10	11
	Software Purchase	-32400.00	-12600.00									
	Hardware Purchase	-3000.00										
	Training Costs	-1000.00		-500.00								
	Maintenance Costs											
	Start Up Time Costs (14hrs/mth)	-280.00	-280.00	-280.00								
5	Savings made on existing tasks	512.76	1281.89	2051.02	2563.78	2563.78	2563.78	2563.78	2563.78	2563.78	2563.78	2563.78
		-$36,167.24	-$11,598.11	$1,271.02	$2,563.78	$2,563.78	$2,563.78	$2,563.78	$2,563.78	$2,563.78	$2,563.78	$2,563.78
		NPV (10%)	$23,000.03									

Time on new job	
	$ 23,000
0.48	22942.32
0.6	20,633.86
0.8	16,786.44
1.00	12,939.02
1.2	9,091.60
1.4	5,244.18
1.8	-2,450.67
2.08	-7,837.06

Pay Rate	
	$23,000.03
26	42,218.20
24	35,812.14
22	29,406.09
20	23,000.03
18	16,593.97
16	10,187.91
14	3,781.85
12	-2,624.20

Rate of return	
	$23,000.03
8.00%	25,126.68
10.00%	23,000.03
12.00%	20,962.04
14.00%	19,008.60
16.00%	17,135.81
18.00%	15,339.94
20.00%	13,617.49
22.00%	11,965.09
24.00%	10,379.58
26.00%	8,857.93

Purchase Price	
	$23,000.03
30000	37841.64
35000	32894.43
40000	27947.23
45000	23000.03
48000	20031.71
50000	18052.83
52000	16073.94
54000	14095.06

Maintenance	
	$23,000.03
-450	23285.41
-500	23000.03
-550	22714.64
-600	22429.26
-650	22143.87
-700	21858.49
-750	21573.10
-800	21287.71

Notes

1,2,3&4 Costs are an estimate if work was contracted out to current designers, assumes that the only purpose of modelling parts is to create rendered image this is only required an estimated 8 % of design cases

5 A three month ramp up time has been allowed. Month1: 20%, Month 2: 50%, Month 3: 80% of full use

12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
-500.00						-500.00			-500.00			-500.00						-500.00			-500.00	
2563.78	2563.78	2563.78	2563.78	2563.78	2563.78	2563.78	2563.78	2563.78	2563.78	2563.78	2563.78	2563.78	2563.78	2563.78	2563.78	2563.78	2563.78	2563.78	2563.78	2563.78	2563.78	2563.78
$2,063.78	$2,563.78	$2,563.78	$2,563.78	$2,563.78	$2,563.78	$2,063.78	$2,563.78	$2,563.78	$2,063.78	$2,563.78	$2,563.78	$2,063.78	$2,563.78	$2,563.78	$2,563.78	$2,563.78	$2,563.78	$2,063.78	$2,563.78	$2,563.78	$2,063.78	$2,563.78

Pay rate	Time on new job							
$23,000.03	0.48	0.6	0.8	1	1.2	1.4	1.8	2
26	42,143.18	39,142.19	34,140.54	29,138.89	24,137.24	19,135.59	9,132.30	4,130.65
24	35,742.89	32,972.75	28,355.84	23,738.93	19,122.03	14,505.12	5,271.31	654.40
22	29,342.60	26,803.31	22,571.14	18,338.98	14,106.81	9,874.65	1,410.32	-2,821.84
20	22,942.32	20,633.86	16,786.44	12,939.02	9,091.60	5,244.18	-2,450.67	-6,298.09
18	16,542.03	14,464.42	11,001.74	7,539.06	4,076.38	613.70	-6,311.66	-9,774.34
16	10,141.74	8,294.98	5,217.04	2,139.11	-938.83	-4,016.77	-10,172.65	-13,250.58
14	3,741.46	2,125.54	-567.66	-3,260.85	-5,954.05	-8,647.24	-14,033.63	-16,726.83
12	-2,658.83	-4,043.90	-6,352.36	-8,660.81	-10,969.26	-13,277.72	-17,894.62	-20,203.07

Return	Time on new job							
$23,000.03	0.48	0.6	0.8	1	1.2	1.4	1.8	2
10.00%	22942.32	20633.86	16786.44	12939.02	9091.60	5244.18	-2450.67	-6298.09
12.00%	20906.05	18666.42	14933.71	11200.99	7468.27	3735.56	-3729.87	-7462.59
14.00%	18954.26	16780.71	13158.13	9535.54	5912.95	2290.37	-4954.81	-8577.40
16.00%	17083.05	14972.96	11456.14	7939.31	4422.49	905.66	-6127.98	-9644.81
18.00%	15288.71	13239.58	9824.35	6409.12	2993.90	-421.33	-7251.78	-10667.01
20.00%	13567.72	11577.16	8259.56	4941.95	1624.35	-1693.25	-8328.46	-11646.06
22.00%	11916.73	9982.47	6758.70	3534.92	311.15	-2912.63	-9360.17	-12583.95
24.00%	10332.57	8452.44	5318.87	2185.30	-948.26	-4081.83	-10348.96	-13482.52

Purchase Price	Time on new job							
$23,000.03	0.48	0.6	0.8	1	1.2	1.4	1.8	2
30000	37783.93	35475.47	31628.05	27780.63	23933.21	20085.78	12390.94	8543.52
35000	32836.72	30528.27	26680.85	22833.43	18986.00	15138.58	7443.74	3596.32
40000	27889.52	25581.07	21733.64	17886.22	14038.80	10191.38	2496.53	-1350.89
45000	22942.32	20633.86	16786.44	12939.02	9091.60	5244.18	-2450.67	-6298.09
48000	19974.00	17665.54	13818.12	9970.70	6123.28	2275.85	-5418.99	-9266.41
50000	17995.11	15686.66	11839.24	7991.82	4144.39	296.97	-7397.87	-11245.29
52000	16016.23	13707.78	9860.36	6012.94	2165.51	-1681.91	-9376.75	-13224.17
54000	14037.35	11728.90	7881.48	4034.05	186.63	-3660.79	-11355.63	-15203.06

35	36
	-500.00
2563.78	2563.78
$2,563.78	$2,063.78

CAD Analysis: PYTHA

		Hours		$$
	Variables			
	Time spent on new design work/month		113.75	
	Number of jobs able to be done currently/mth (A/B)		32.59	
	Pay rate (/hr)		20.00	
	Rate of return		10.00%	
	Purchase Price		25000	
	Current Situation			
	Time for Prototype II			
	Preliminary View	0.25		
	Nut thing out	0.33		
	List all panels and name	0.08		
	Programme and print out	2.00		
	Header page for programmes	0.17		
	Cutting patterns	0.25		
	Big header	0.08		
	Bill of Materials	0.33		
	Total Time for Job (hrs)	3.49		
	Monetary cost of job (B*J)			69.80
	Monthly Cost (C*D)			2275.00
	Other Costs			
1	Model Stainless steel Work Top		0.00	
2	Assemble Unit in CAD		0.00	
3	Produce rendered image (8% of Jobs)		40.00	
	Time spent by Furnware staff	2.00	40.00	
	Cost for Rendered Image		80.00	
	Monthly Cost (M * C * 8%)			208.60
4	Assembly instructions (10% of Jobs)		80.00	
	Time spent by Furnware staff	2.00	40.00	
	Cost for Assembly Instructions		120.00	
	Monthly Cost (N * C * 10%)			391.12
	Current Total Monthly Cost			2874.71
	PYTHA			
	Model Basic Cavity	0.25		
	Model Drawers and Door	0.75		
	Model Stainless steel Work Top	0.17		
	Model Chassis and Castors	0.08		
	Produce machine code for panel comps	0.75		
	Produce optimized cuting list	0.17		
	Bill of Materials	0.04		
	Produce Job Card	0.08		
	Assemble Unit in CAD	0.04		
	Produce rendered image	0.08		
	Assembly instructions	0.33		
	Total Time for Job (hrs)	2.74		
	Monetary cost of job (G*J)		54.80	
	Monthly Cost (C*H)			1786.103
	Total Montly Savings			1088.61

	Particulars	Monthly Cashflows										
		1	2	3	4	5	6	7	8	9	10	11
	Software Purchase	-18000.00	-7000.00									
	Hardware Purchase	-3000.00										
	Training Costs	-1000.00		-500.00								
	Maintenance Costs											
	Start Up Time Costs											
5	Savings made on existing tasks	217.72	544.31	870.89	1088.61	1088.61	1088.61	1088.61	1088.61	1088.61	1088.61	1088.61
		-$21,782.28	-$6,455.69	$370.89	$1,088.61	$1,088.61	$1,088.61	$1,088.61	$1,088.61	$1,088.61	$1,088.61	$1,088.61
		NPV (10%)	**$81.45**									

Time on new job	
	$ 81
2.5	4698.36
2.7	850.94
2.74	81.45
2.80	-1,072.77
2.9	-2,996.49
3	-4,920.20
3.1	-6,843.91
3.3	-10,691.33

Pay Rate	
	$81.45
26	6,487.41
24	4,352.09
22	2,216.77
20	81.45
18	-2,053.87
16	-4,189.19
14	-6,324.51
12	-8,459.82

Rate of return	
	$81.45
8.00%	900.51
10.00%	81.45
12.00%	-703.08
14.00%	-1,454.67
16.00%	-2,174.84
18.00%	-2,865.03
20.00%	-3,526.60
22.00%	-4,160.86
24.00%	-4,769.04
26.00%	-5,352.30

Purchase Price	
	$81.45
22000	3049.77
24000	1070.89
25000	81.45
26000	-907.99
28000	-2886.87
30000	-4865.75
32000	-6844.63
34000	-8823.51

Maintenance	
	$81.45
-450	366.84
-500	81.45
-550	-203.93
-600	-489.32
-650	-774.71
-700	-1060.09
-750	-1345.48
-800	-1630.86

tes

1,2,3&4 Costs are an estimate if work was contracted out to current designers, assumes that the only purpose of modelling parts is to create rendered image this is only required an estimated 8 % of design cases

5 A three month ramp up time has been allowed. Month1: 20%, Month 2: 50%, Month 3: 80% of full use

12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
-500.00						-500.00			-500.00			-500.00						-500.00		
1088.61	1088.61	1088.61	1088.61	1088.61	1088.61	1088.61	1088.61	1088.61	1088.61	1088.61	1088.61	1088.61	1088.61	1088.61	1088.61	1088.61	1088.61	1088.61	1088.61	1088.61
$588.61	$1,088.61	$1,088.61	$1,088.61	$1,088.61	$1,088.61	$588.61	$1,088.61	$1,088.61	$588.61	$1,088.61	$1,088.61	$588.61	$1,088.61	$1,088.61	$1,088.61	$1,088.61	$1,088.61	$588.61	$1,088.61	$1,088.61

Pay rate	Time on new job							
$81.45	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2
26	12,489.39	9,988.56	7,487.74	4,986.92	2,486.09	-14.73	-2,515.56	-5,016.38
24	9,892.38	7,583.93	5,275.47	2,967.02	658.57	-1,649.89	-3,958.34	-6,266.79
22	7,295.37	5,179.29	3,063.20	947.12	-1,168.96	-3,285.04	-5,401.12	-7,517.21
20	4,698.36	2,774.65	850.94	-1,072.77	-2,996.49	-4,920.20	-6,843.91	-8,767.62
18	2,101.35	370.01	-1,361.33	-3,092.67	-4,824.01	-6,555.35	-8,286.69	-10,018.03
16	-495.66	-2,034.63	-3,573.60	-5,112.57	-6,651.54	-8,190.50	-9,729.47	-11,268.44
14	-3,092.67	-4,439.27	-5,785.87	-7,132.46	-8,479.06	-9,825.66	-11,172.26	-12,518.85
12	-5,689.68	-6,843.91	-7,998.13	-9,152.36	-10,306.59	-11,460.81	-12,615.04	-13,769.27

Return	Time on new job							
$81.45	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2
10.00%	4698.36	2774.65	850.94	-1072.77	-2996.49	-4920.20	-6843.91	-8767.62
12.00%	3776.18	1909.82	43.47	-1822.89	-3689.25	-5555.61	-7421.96	-9288.32
14.00%	2892.43	1081.14	-730.15	-2541.45	-4352.74	-6164.03	-7975.33	-9786.62
16.00%	2045.35	286.94	-1471.48	-3229.89	-4988.30	-6746.71	-8505.12	-10263.54
18.00%	1233.24	-474.37	-2181.99	-3889.60	-5597.21	-7304.83	-9012.44	-10720.05
20.00%	454.52	-1204.28	-2863.08	-4521.89	-6180.69	-7839.49	-9498.29	-11157.09
22.00%	-292.33	-1904.22	-3516.11	-5127.99	-6739.88	-8351.77	-9963.65	-11575.54
24.00%	-1008.76	-2575.54	-4142.32	-5709.10	-7275.89	-8842.67	-10409.45	-11976.24

Purchase Price	Time on new job							
$81.45	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2
22000	7666.68	5742.97	3819.26	1895.55	-28.16	-1951.87	-3875.59	-5799.30
24000	5687.80	3764.09	1840.38	-83.33	-2007.04	-3930.76	-5854.47	-7778.18
25000	4698.36	2774.65	850.94	-1072.77	-2996.49	-4920.20	-6843.91	-8767.62
26000	3708.92	1785.21	-138.50	-2062.21	-3985.93	-5909.64	-7833.35	-9757.06
28000	1730.04	-193.67	-2117.38	-4041.10	-5964.81	-7888.52	-9812.23	-11735.94
30000	-248.84	-2172.56	-4096.27	-6019.98	-7943.69	-9867.40	-11791.11	-13714.82
32000	-2227.73	-4151.44	-6075.15	-7998.86	-9922.57	-11846.28	-13769.99	-15693.70
34000	-4206.61	-6130.32	-8054.03	-9977.74	-11901.45	-13825.16	-15748.87	-17672.58

33	34	35	36
-500.00			-500.00
1088.61	1088.61	1088.61	1088.61
$588.61	$1,088.61	$1,088.61	$588.61