Structuring Multimedia Data to Capture Design Rationale and to Support Product Development

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Thesis submitted for the degree of
Doctor of Philosophy
of the University College London

March 2000

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ABSTRACT

Companies involved in product design face a major problem in retaining the vast amounts of data collated during the product development process. This thesis investigates how such multimedia design material can be preserved and structured to form a multimedia design rationale knowledge base for future reference or re-use by design teams. The scope of the research and the key issues are established through a study of product design and computer aided design support. The problems of eliciting tacit design knowledge, capturing design rationale and representing the resulting information in a form which is accessible to designers, are identified by a detailed field study of the product design process in a sportswear company.

Existing design rationale representations are critiqued and a design knowledge base implemented and structured using a notation based on Kunz and Rittels' 'Issue Based Information System' (IBIS), (1970) referred to as IBIS$^+$. All the data from a complete product development cycle, collated during the field study, was incorporated into the IBIS$^+$ knowledge maps. These were constructed concurrently as the design cycle progressed. The knowledge base was made available to the design team both during and after the completion of the design cycle. To test and evaluate the IBIS$^+$ notation the design team used the knowledge base to review their progress throughout the product development process. At the end of the design cycle they used it to reflect on their overall design procedure. Ways are identified in which the design process can be enhanced by capturing product design rationale. The rewards of effectively structuring multimedia product development material are shown to be substantial to design based companies, where data is primarily visual in nature, where design cycles are short, and where brand consistency is important.

Problems with a knowledge representation based on the IBIS$^+$ notation for capturing product design rationale are identified. An adapted notation, IBIS^{PDR} (Issue Based Information System Product Design Rationale) is proposed and domain specific graphical user interfaces aimed at streamlining access to the IBIS^{PDR} knowledge base in order to support domain specific design tasks are demonstrated. A task analysis comparing the usefulness of the IBIS$^+$ and the IBIS^{PDR} notations confirms the success of the alterations to the notation and the suitability of the implemented interfaces. The proposed IBIS^{PDR} notation is shown to provide an adequate base from which to structure multimedia data collated during product development and for capturing product design rationale. The notation includes elements which are to be used to consolidate the design rationale as a useful resource for future reference; then some of the limitations of capturing the entire design rationale are overcome by a formal review meeting as part of a retrospective stage at the end of the design cycle. A practical way is suggested in which IBIS^{PDR} maps from one design cycle might be used as a starting point for the following cycle, through the creation of an IBIS^{PDR} template at the end of each design cycle. It is further demonstrated how a range of domain specific graphical user interfaces connected to an IBIS^{PDR} knowledge structure, can empower the design team to access, reflect on and utilise the underlying data for specific design tasks that enhance the product design process and aid future range planning. Recommendations are made for the direction of future research in this field.

ACKNOWLEDGEMENTS

First and foremost I would like to thank my supervisor, Janet McDonnell, for being a constant source of inspiration, for her invaluable help and insightful feedback and for believing I would complete my thesis despite all my trials and tribulations over the past four years. In addition, I would like to thank my second supervisor, Philip Treleaven, not only for his support, but also for being the initial catalyst that encouraged me to embark on this research. I am grateful to EPSRC for providing funding for this work, without which it would not have been possible. I am further indebted to all the members of the product design team who participated in the field studies.

My family and friends have been a continuous source of support throughout and I owe them all a debt of gratitude. I would specifically like to thank my husband, Bob for motivating me when there seemed to be no end in sight, allowing me to make the completion of my thesis a constant priority and for coping with the absence of our baby son Henry and I, during my disappearance to a country retreat to write up this research. I must also apologise to Henry for missing his first teeth while he stayed with my parents in the final throes of completing the thesis. On that note I would like to thank my parents, not only for fetching Henry and bringing him back at a moments notice, but also for the unlimited supplies of ready cooked homemade meals to ensure that I did not starve in the pursuit of academia. Finally I would like to thank the following friends and colleagues in particular, who have all supported and encouraged me during the course of this research: Bethan Alexander, Laura Dekker, Andrew Fentem, Jane Hughes, Jean Lee, Tom Quick, June Sheard, Michael Sheard, Geoff Smith, Judy Smith, Simone Stumpf, and Lan Yin Thomas.

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CHAPTER 1:

INTRODUCTION

This chapter presents the motivations for researching how multimedia product design knowledge can usefully be structured. An overview of the research is given and the field study is introduced. The numerous benefits of design knowledge bases that capture and structure product design rationale are described. The chapter concludes with the goals and contributions of this work, the thesis hypothesis and an outline of the thesis structure.

1.1. Research Motivations

One of the major problems faced by companies involved in product design is retaining the immense amount of data collated during the product development process (Phillips and McDonnell, 1998a). This thesis explores the elicitation and structuring of multimedia product design material to create a domain specific knowledge base. Design knowledge bases of this nature would enable design orientated companies to retain and efficiently access the data collated during product range development and preserve the rationale behind the development of their products for future reference or re-use.

There exists great potential for many computer based design support tools to be developed for use within product design related industries. As outlined in chapter 2, there is a wide range of technology already available to product designers and there is also much current work under way that can be directed towards opportunities for new developments. For example, novel intelligent techniques, such as expert systems, neural networks and genetic algorithms and advanced visualisation techniques, such as virtual reality, could be utilised to provide numerous applications in the product design, development, prototyping and manufacturing processes.

Initially, the focus of this research centred generally around computerised tools to support design, but as the research progressed the need for an effective method of structuring the vast amount of product development data created during the design process became apparent and it is this that forms the focus of this thesis.

1.2. Research Overview

An in depth background study of product design and computer aided design support established the scope of the research and identified the key issues. A detailed field study of the product design process in a sportswear company was conducted to examine in depth the problems of eliciting tacit design knowledge, capturing design rationale and representing the resulting information in a form which is accessible to designers and useful for reference in their future work. Existing knowledge elicitation methods were reviewed and an analysis made of how the design critical issues relevant to the products being designed, can be elicited and then represented in a knowledge base. Extensive multimedia design data was captured during the field research using appropriate knowledge elicitation methods and the requirements of a tool to capture design rationale were identified. The potential benefits to the product design process of using computer tools to capture design rationale were explored and existing argumentation based design rationale notations scrutinised. The necessity for a more adequate structure for representing design rationale became clear.

Initially a notation referred to in this thesis as $IBIS^+$, based on Kunz and Rittels' 'Issue Based Information System' (IBIS), (1970), was chosen to organise the multimedia design data collated during an extensive field study in a sportswear company, for a range of products from a complete design cycle. The rationale for choosing $IBIS^+$ was that it most closely represented the actual deliberations that take place during design and allowed the representation to be constructed concurrently with the design meetings. The resource was used by the design team in the field study to review progress with the current season's design and to reflect on the process overall once it was completed. The designers' reactions to the tool as an information resource were scrutinised, and various issues were raised resulting from the analysis. The $IBIS^+$ structure was shown to have the potential of aiding the design team when making design decisions, allowing them useful access to their previous product development influences and supporting personal and team reflection, company knowledge management and the maintenance of brand direction. The ways in which a design team can profit from capturing product design rationale, are demonstrated and consideration given to how the identified limitations can be addressed. The need for efficient access to the underlying data became clear and consideration was given to how design tasks could be supported through the provision of suitable graphical user interfaces (GUI's) which connect to the knowledge base.

An adapted notation referred to in this thesis as IBIS^{PDR} (Issue Based Information System Product Design Rationale), encapsulating the priorities detailed by the product designers, is proposed that extends the IBIS^{+} notation. The design knowledge base constructed during the field study was restructured using the IBIS^{PDR} notation. Domain specific interface facilities to streamline the access to the underlying data are also implemented. A task analysis confirms the suitability of an IBIS^{PDR} structure for capturing product design rationale.

1.3. Capturing and Structuring Design Data

Innovation and rapid realisation of ideas is vital to designers and there is a growing demand in industry for design knowledge bases that can store extensive quantities of information and perform intelligent data retrievals and storage. As detailed later in chapter 5, many academics claim that tools to assist design based organisations to capture and retain the knowledge and reasoning behind their product design and development will greatly advantage these companies [(Conklin and Begeman, 1988), (Moran and Carroll, 1991), (Bañares-Alcántara et al, 1995), (Fischer et al, 1996), (Lee and Lai, 1996), (MacLean et al, 1991)]. However it is difficult to establish what the tangible benefits might be without empirical studies in which knowledge based resources are made available to a design team so that the value of the resource can be tested in real use situations. This thesis addresses this problem with a detailed empirical study.

1.3.1. The Requirement for a Multimedia Platform

During the design process product designers often get inspiration by looking through old designs and samples and multiple sources are used to obtain the design reference data. Much of this information forms an inherent part of the design rationale and could ideally be captured in a multimedia knowledge base. As well as including data about previous products, competitors' products, sales information and marketing directions, there may be video sequences which encapsulate the essence of the product in some way and story-boards containing pictures and samples intended to illustrate the product direction and design proposals. Various formats of data would need to be contained within a design knowledge base, including images, video clips, animation and audio clips, detailing inspirational or relevant material required by the designer during the design process. Any structuring of this knowledge clearly requires a multimedia platform where the information can be arranged in a manner that enables its role in the design decision making process to be represented. Multimedia technology enables diverse file formats to be incorporated and is suited to detailing the varying kinds of design related information required during the design process.

In addition, for a product design knowledge base to be effective the data within it must encapsulate the design issues that the designers see as being inherent in the products. The design issues surrounding a product help to make sense of the reasoning behind a design, therefore understanding and capturing the issues is an essential step towards underpinning the design rationale. An examination was conducted of how the issues relating to a design could be elicited and then represented in a knowledge base in order that the design crucial substance of the data was not lost. Knowledge elicitation usually involves extracting information in the form of words but when eliciting material from product designers it is also necessary to extract other forms, such as aesthetic and visual data. This lends further weight to the argument that a multimedia platform is an essential element of the knowledge base.

1.3.2. The Challenges and Benefits of Capturing and Structuring Design Data

There are a number of challenges to capturing and structuring design data to form a multimedia design knowledge rationale. They are identified and discussed in the thesis as areas for consideration and they include:

1. The difficulty of eliciting the tacit design knowledge which is often not expressed explicitly in design meetings.
2. The time it takes to elicit and structure comprehensive design data.
3. The financial investment required, i.e. in terms of setting up costs, equipment costs, and training costs.
4. The organisational commitment required which must come from the top down.
5. The changes required within the culture of the organisation in order that maintaining and using a multimedia design rationale becomes an established part of the design process.
6. The technical challenges of storing such vast quantities of multimedia data and retrieving it with acceptable speed.
7. The selection of a suitable method of structuring the data in order to retain the design critical elements of the rationale behind it.
8. The difficulty of quantifying and forecasting the benefits in financial terms due to their qualitative nature.
9. The problem that many of the potential benefits would not be realised until the knowledge base had been maintained over a number of design cycles.

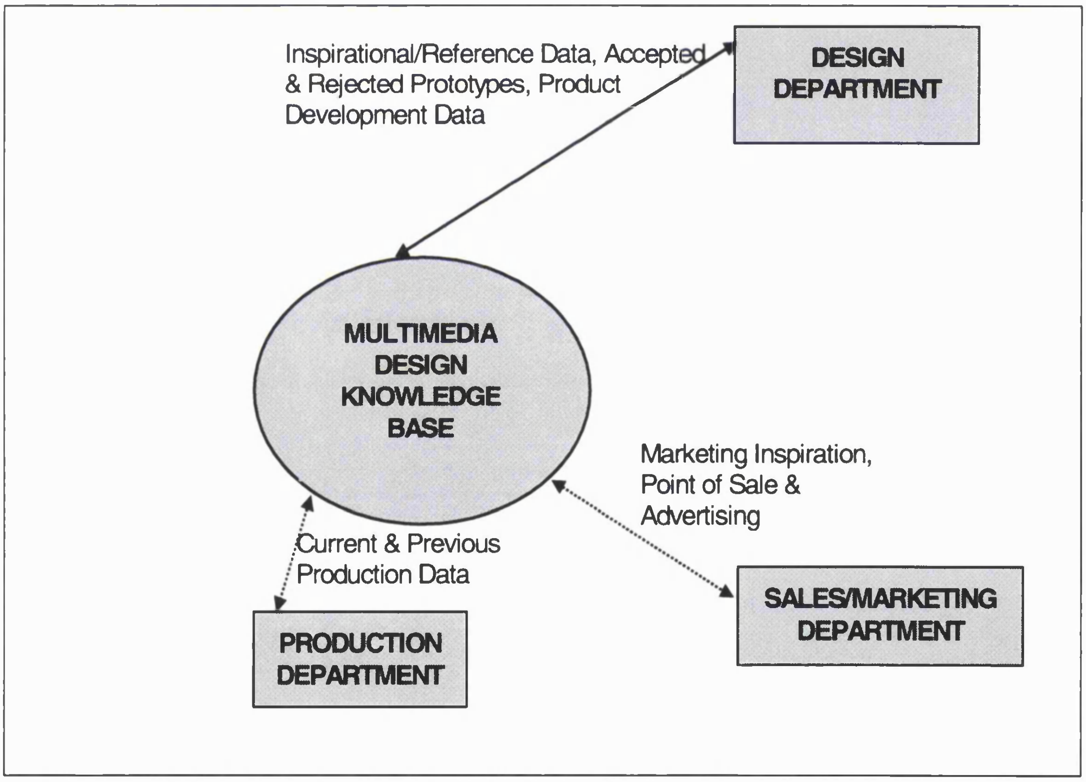
However even when taking into consideration the above challenges, this thesis asserts that they would be outweighed by the numerous benefits of suitably structured multimedia knowledge bases, which reflect the decision making process in product design, where designers use many diverse sources of material to inform and inspire their design activities (Phillips, 1997). A multimedia resource capturing the rationale behind each season's design and development would aid brands to maintain discipline when developing their products and uphold a unique and competitive position in the market place. It is envisaged that if design knowledge bases were to become part of the company culture within design orientated firms, they would grow rapidly and would mature into an increasingly invaluable source of reference and inspiration. Angela Dumas (1994) in her research on the use of metaphor in design, highlights the advantage that can be gained by ensuring that all the personnel in a design based company have a clear understanding of their corporate identity. The use of a design knowledge base should not be restricted to the design department, it should be used by a company to convey their product rationale and design values to all their personnel. The benefits of capturing and structuring design data, expanded on in this thesis, can be summarised as follows:

1. The provision of greater capacity for communication and sharing of information at different stages in the design process and to different departments.
2. The facility for new team members to quickly appraise themselves of the company's design direction and history. The damage done when key members of the design team leave, taking with them valuable product design knowledge, can be limited allowing changes in membership of the design team to be accommodated with less disruption. This is particularly important when designing branded goods where image consistency is all-important. Branded products, above all must ensure adherence to brand values.
3. The useful retention of design knowledge and expertise that is normally lost when key members leave.
4. The ability to enhance image consistency and adherence to design values, which is particularly important for branded products.
5. The provision of a source of inspiration and reference for future ranges, particularly useful where 'retro' products are being designed.
6. The provision of a resource to be tapped into by other departments as shown in figure 1.1, for example as a tool for the marketing department to provide direction for new marketing campaigns.
7. The ability to enhance the clear communication of the corporate identity, product rationale and design values throughout an organisation.

8. The facility to retain the knowledge used when constructing prototypes and thereby provide the potential to re-use this knowledge.

9. The ability to easily store and usefully access all the data used in a product development cycle, taking advantage of multimedia technology. Due to the difficulty of recording and accessing all the different types of information used during the design process, designers are given little opportunity to refer to the data utilised during their previous design work. If the design knowledge is captured and stored electronically it could be reused in years to come when designing other products or as a tool to evaluate the design process.

Figure 1.1: Organisational Interactions with a Multimedia Design Knowledge Base



1.3.3. Existing Work on Structuring Design Rationale

A body of work exists on capturing design rationale in the fields of engineering design and this is discussed further in Chapter 5, but very little has been done previously in relation to usefully structuring product design rationale. Although there are parallels between the design process in engineering and industrial product design, there are also a number of distinctions and this is elaborated in section 2.1.7 of Chapter 2. In particular the focus of product design usually leans heavily towards the ergonomic and aesthetic with much of the data used and referenced during product design being very visual. In many industrial product design domains the design cycles are also much shorter than in engineering design. Due to the fact that the design cycles are rapid, product design rationale from one cycle is more likely to have some relevance to the following development cycle than in domains where the development cycle is very extended and at the close of it most of the development rationale will be outdated. The benefits of capturing design rationale in the domain of product development, where old designs are often referred to for inspiration and design input can sometimes be recycled, are perhaps more promising but have received far less research attention.

1.4. Thesis Aims

The research aims to examine the product design process, address the problems of eliciting tacit design knowledge, capturing design rationale and structuring such knowledge in an accessible form. To explore the practicality of building and using a multimedia design knowledge base the aim of the field study was to elicit and capture the design rationale for the entire Spring/Summer 1998 product range developed by a sportswear brand (referred to in this thesis as brand X). A prototype knowledge structure was constructed, using the data collected from the field research, and based on the existing $IBIS^{+}$ notation. As discussed in section 1.2, this gave the design team from the field study a resource with which to experiment. Following an analysis and discussions with them about this experience, the notation was extended, forming the $IBIS^{PDR}$ notation, which aimed to address the limitations of the $IBIS^{+}$ notation for the practicalities of product design processes. The thesis also aims to identify the manner in which an $IBIS^{PDR}$ knowledge base used in the domain of sportswear design, should be accessed in order to enhance future design activity.

1.5. Thesis Hypothesis

The hypothesis being explored is that an appropriately structured multimedia knowledge base, incorporating domain specific graphical user interfaces, is an ideal platform for encapsulating the knowledge and issues raised during the product design process, to store design related material and enabling the capture and retention of product design rationale. Thereby enabling the current limitations faced by design orientated companies in capturing and retaining aspects of the design process to be addressed. Multimedia technology is widely available and it enables varying file formats to be used to detail design related information, such as data on previous ranges, competitors products and marketing directions. It is therefore ideally suited to storing the different types of inspirational and reference data used by product designers during the design process.

1.6. Thesis Contributions

A principal contribution to come from this thesis is the proposed IBIS^{PDR} notation, a suitably revised and extended notation underpinned by IBIS, which provides an adequate base from which to structure a useful multimedia knowledge representation of the design rationale and the data collated during product development.

The notation includes some elements which should be used retrospectively to consolidate the design rationale as a useful resource for future reference. It is established how some of the limitations of capturing the entire design rationale can be overcome by a formal review meeting as part of a retrospective stage at the end of the design cycle.

A practical way is suggested in which an IBIS^{PDR} map from one design cycle might be used as a starting point for the following cycle, through the creation of an IBIS^{PDR} template at the end of each design cycle.

It is further demonstrated how a range of graphical user interfaces, specific to fashion product design, provide access to the underlying design rationale structure to aid specific design tasks.

1.7. Thesis Structure

Table 1.1 demonstrates that the structure of this thesis is closely related to the sequence of work undertaken. Each chapter begins with a short description of the chapter contents and ends with a summary of the critical points.

Table 1.1: Research Phases

PHASE	CHAPTER
Literature/Background Research	2: Product Design and Development 3: Technology Support for Product Design and Development
Identify Suitable Methods for Eliciting the Design Knowledge	4: Design Knowledge Elicitation
Identify Suitable Structure for Initial Implementation	5: Argumentation Based Design Rationale Methodologies
Design Rationale Implementation I	6: $IBIS^{+}$ Design Knowledge Representation
Analysis, Evaluation and Recommended Improvements	7: Improving the $IBIS^{+}$ Knowledge Representation
Design Rationale Implementation II Domain Specific Graphical User Interfaces	8: $IBIS^{PDR}$ Design Knowledge Representation
Evaluation	9: Summary, Conclusions and Future Work

A short description of each of the chapters is as follows:

Chapter One: 'The Introduction', this chapter provides an insight into the thesis background and details the motivations for researching how multimedia design knowledge can usefully be structured. The field study and the concept of structuring multimedia product development information are introduced and an overview of the research is given. The numerous benefits of design knowledge bases are described. The research aims, hypothesis and contributions are also outlined and the chapter concludes with an overview of the thesis structure.

Chapter Two: 'Product Design and Development', presents an overview of product design. Important issues about design which are relevant to this thesis are introduced including: product development, product innovation, design methods, brand identity, design values, the multidisciplinary nature of design and the differences between industrial and engineering design. The nature of design problems and decision making are then explored. Consideration is given to the tacit nature of design and the potential benefits of structuring product design rationale are presented.

Chapter Three: 'Technology Support for Product Design and Development', presents an examination of how product design and development is increasingly being supported with the use of technology. A case study describes the clothing design and manufacture process and how computer aided techniques have been deployed in the clothing industry. The case study serves to illustrate the extent to which new technology has been embraced by design based industry. The potential for using multimedia knowledge bases to support product design is explored in more detail with a further case study on the impetus for multimedia textile libraries.

Chapter Four: 'Design Knowledge Elicitation', presents a clear shift in emphasis to the empirical field study of the design process which forms the central part of this research. Initially there is a brief treatment of general issues concerning knowledge elicitation but the chapter predominantly deals with the process undertaken during the knowledge elicitation stage of the field research. The depth of knowledge required to be collated in order to have useful data for a design knowledge base is illustrated. The importance is emphasised of using appropriate methods to elicit the often tacit design knowledge, such as the design values. The knowledge elicitation methods that were chosen for the field research are described and particular attention is paid to the repertory grid method. An insight is provided into the typical components of a product development range strategy and this is exemplified by the range strategy developed following the initial phase of the knowledge elicitation during the field study. Finally an overview is given of the design and marketing infrastructure elicited from the design team in order to facilitate the later construction of a more accurate representation of the design process.

Chapter Five: 'Argumentation Based Design Rationale Methodologies', discusses the motivations behind capturing and maintaining a design rationale representation. The reasons why there exists greater potential for capturing design rationale in the domain of product design as opposed to engineering design are presented. Argumentation based design rationale methodologies are introduced as a means of initially structuring the elicited design knowledge from the field research. The three predominant notations are examined: Questions, Options and Criteria (QOC), Decision Representation Language (DRL), and the Issue Based Information System (IBIS). The chapter concludes with a critique of the methodologies. IBIS is identified as providing the most suitable notation from which to construct a representation of the design process exemplified in the field study using the data collated during the knowledge elicitation stage of the field research.

Chapter Six: 'IBIS$^+$ Design Knowledge Representation', discusses how a hypertext mapping software environment was utilised to construct a representation of the design process examined in the field research. The environment used supports a graphical representation of the design rationale, allows multimedia data to be incorporated into hypertext design rationale maps and is underpinned by an IBIS based notation referred to as IBIS$^+$. An account is given of how the resulting knowledge structure was used to explore the requirements for a useful representation of the collected design knowledge. An evaluation of the design rationale representation constructed is then provided and the problems and benefits highlighted.

Chapter Seven: 'Improving the $IBIS^+$ Knowledge Representation', proposes extensions to the $IBIS^+$ knowledge structure detailed in chapter 6. Some of the identified limitations of the $IBIS^+$ notation used to construct the design rationale representation are addressed and improvements to the notation are presented, forming the adapted notation referred to as $IBIS^{PDR}$. The critical requirement is emphasised of incorporating a retrospective, reflective stage allowing the knowledge structure to be reviewed, corrected, annotated and updated in order for the design rationale to be a useful and reusable resource. Several further extensions to the $IBIS^+$ notation are proposed to be incorporated into the $IBIS^{PDR}$ notation as a critical part of this retrospective stage. The second half of the chapter provides an overview of the graphical user interfaces (GUI's) particular to the fashion product design process studied in the field research, which can be connected to the underlying design knowledge base. It is stressed that when developing GUI's for an $IBIS^{PDR}$ structure it would be essential that the domain and the purpose of the underlying data be carefully considered.

Chapter Eight: '$IBIS^{PDR}$ Design Knowledge Representation', describes how the $IBIS^+$ knowledge structure was entirely reconstructed using the $IBIS^{PDR}$ notation proposed in chapter 7, to account for the limitations in the $IBIS^+$ representation discussed in chapter 6. The graphical user interfaces (GUI's) specific to fashion product design discussed in chapter 7 were implemented to assess their effectiveness. Some of the desired navigational facilities are provided by the interface to the mapping software used to construct the $IBIS^{PDR}$ representation. In addition the $IBIS^{PDR}$ maps were made available for viewing through a web browser in order to assess the extent of any benefits that might be reaped from using this alternative environment. A relatively informal task analysis, conducted in order to explore and confirm the success of the alterations to the representation, is described. A synopsis is provided of the task analysis results and a few minor refinements are proposed.

Chapter Nine: 'Summary, Conclusions and Future Work', summarises the research and outlines the main conclusions drawn. The contributions of the thesis are presented along with some potential directions for future work.

CHAPTER 2 :

PRODUCT DESIGN AND DEVELOPMENT

This chapter presents an overview of product design. Important issues about design which are relevant to this thesis are introduced including: product development, product innovation, design methods, brand identity, design values, the multidisciplinary nature of design and the differences between industrial and engineering design. The nature of design problems and decision making are then explored. Consideration is given to the tacit nature of design and the potential benefits of structuring product design rationale are presented. The chapter concludes with a summary of the critical points.

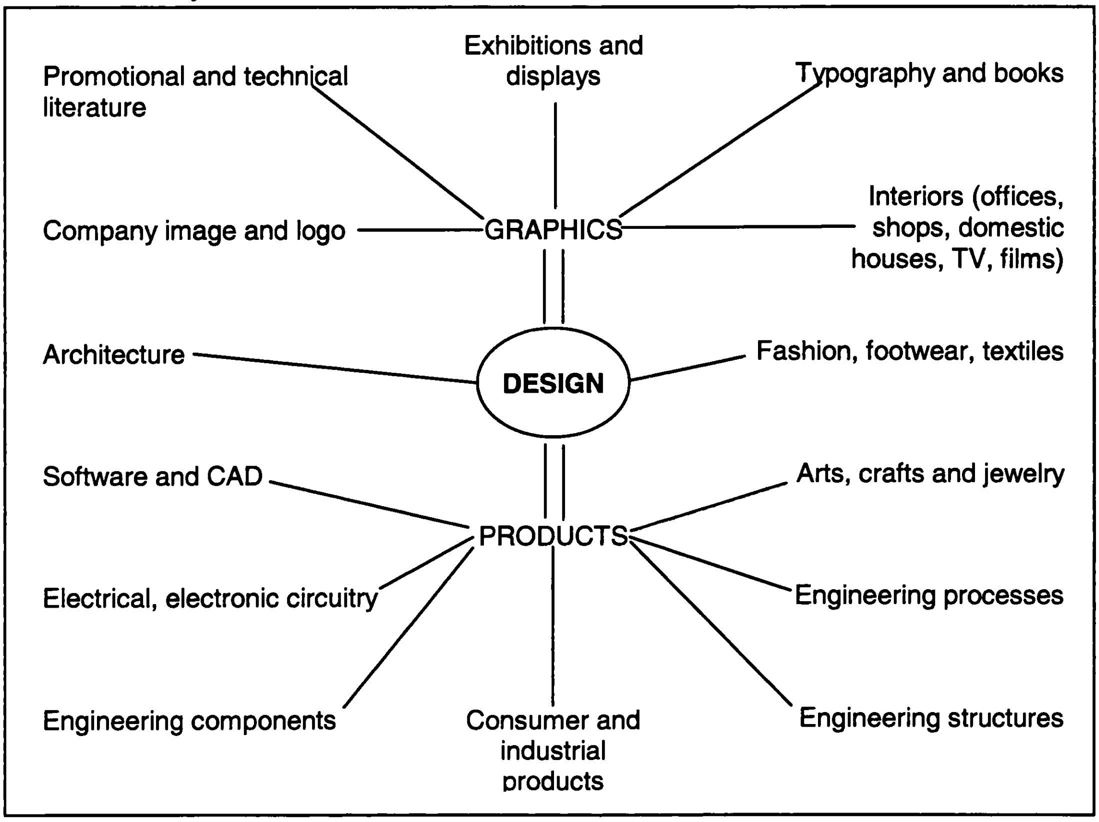
2.1. The Design and Product Development Process

2.1.1. Design and Product Development

In our day to day lives we are surrounded by consumer goods such as clothes, furniture, cars, household equipment, computers, electrical products – the list is endless. All of these products have been designed by someone, and it is easy to see that design has a vast impact on people's lives. The word 'Design' embraces many different connotations. Often it is considered to be a rather 'arty', or 'trendy' pastime, undertaken by the likes of fashion or interior designers. However, although people involved in these jobs could certainly be considered to be working with design, there is a much wider spectrum of activities encompassed by 'design', as shown in Figure 2.1 (Shirley and Henn, 1988). ' *'Design' means different things to different people. Depending on their point of view, it conjures up an image of women's fashions, designer clothing, furniture, fabrics and interior design, or even crafts. To some it embraces architecture, to others the creative side of engineering: design engineering. To very few does it suggest the activity which spans both the form and function of manufactured products – industrial design.'* (Lorenz, 1990)

Figure 2.1: The Spectrum of Design Activities

Source: Shirley and Henn (1988)



As well as encompassing ergonomic and aesthetic orientated industrial product development, designing also incorporates the complex technical and engineering aspects of creating products. Sometimes a combination of industrial and engineering designers might be involved in the development of different parts of one product. The differences between industrial and engineering design will be examined in more detail in section 2.1.8.

There are many different views on what the definition of design actually is. Walsh (1992), summarises his opinion of design quite succinctly as 'the creative visualisation of concepts, plans, and ideas and the production of sketches, models and other representations of those ideas, aimed at providing the instructions for making something which did not exist before, or which did not exist in quite that form – which might be a building, a dress, a plastic bowl, a machine, a company's logo or a pair of trainers bearing a company's logo.' (Walsh et al, 1992, p.15) Caldecote, takes a similar stance believing it consists of *' the process of converting an idea into* *information from which a product can be made. The output of the designer has traditionally been drawings and specifications, but today, these may be to a large extent replaced by magnetic tapes or discs...from which hardware can be made directly.'* (Caldecote, p.54, 1989)

Roozenburg and Eekels claim that product design *'is the process of devising and laying down the plans that are needed for the manufacturing of a product....Product design is basically devising and describing the geometry, materials and production techniques of a new product.'* (Roozenburg and Eekels, 1995, p.3) However as Cross (1994) points out designing often does not concern the creation of radically new products, but rather it involves merely modifying and improving existing products. Cross believes that the drive behind the product modifications is to satisfy one of two ends. Either the alterations will seek to increase the value of the product from the consumers' stand point or they will attempt to reduce the cost of the product to the producer (Cross, 1994). Walsh et al reaffirm that 'd*esigning often involves no technical change at all, but may simply result in a product with a different form, style, pattern or decoration – for example, a 'new' design of chair or body styling for a car......Often, designing involves incorporating new components, materials or manufacturing methods into an existing product – for example, a washing machine with micro-electronic controls or a civil airliner with a head-up display originally developed for military aircraft.'* (Walsh et al, 1992, p.26)

Walsh et al (1992) take their definition of design a stage further. They identified the '4 Cs' of design classification as being creativity, complexity, compromise and choice. *'Creativity: design requires the creation of something that has not existed before (ranging from a variation on an existing design to a completely new concept). Complexity: design involves decisions on larger numbers of parameters and variables (ranging from overall configuration and performance to components, materials, appearance and method of manufacture). Compromise: design requires balancing multiple and sometimes conflicting requirements (such as performance and cost; appearance and ease of use; materials and durability). Choice: design requires* *making choices between many possible solutions to a problem at all levels from basic concept to the smallest detail of colour or form.' (Walsh et al, 1992, p.52)*

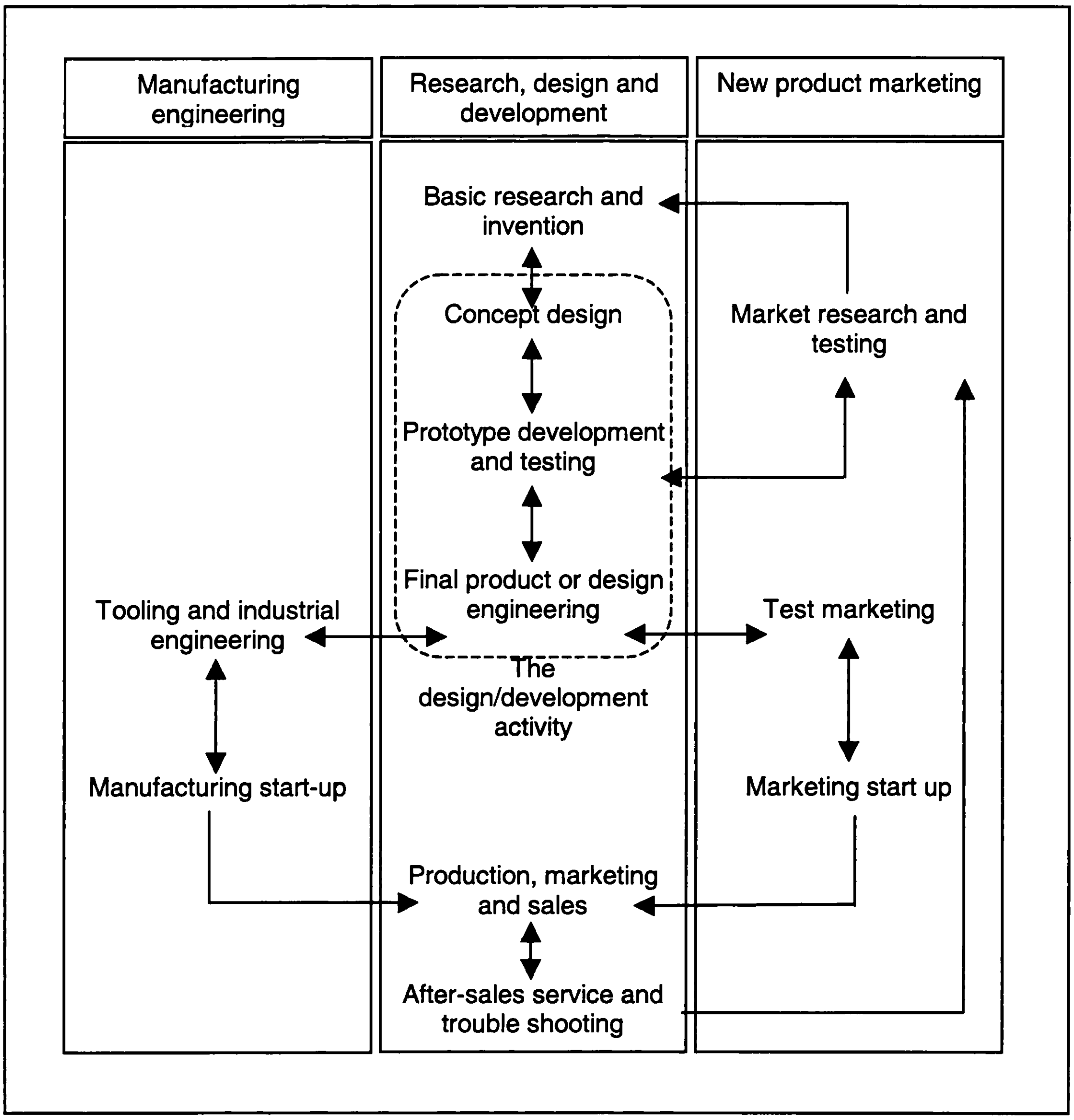
There are also widely held opinions about product design and development and how it should be defined. Roozenburg and Eekels (1995) proffer the opinion that product design is just one part of a wider, more comprehensive, umbrella activity of product development. They believe that product development not only encompasses the design of the product, but also the plans that must be produced alongside the design, for the successful production, distribution, marketing and sales of the item. The product design and development activity forming the focus of the field research in this thesis is clothing and footwear design – a dominant sub-class of industrial product design. It is therefore expected that the findings will in the main be relevant to other classes of industrial product design.

2.1.2. New Product Development and Technological Innovation

Walsh et al (1992) differentiate between new product development and technological innovation. *'The difference from technological innovation is that the 'new product' concerned might involve only changes in form, components, materials, or even just packaging, rather than changes in operating principle or technology.'* This can be demonstrated with Nike who introduced a new product line, the Nike 'Air' trainers, with the main change from the previous lines being an innovative air filled plastic component, embedded into the sole of trainers. Clearly this is a case of new product development not technological innovation because the underlying principle behind the design of the trainer as a whole remains the same, it is merely a component that has been added. The 'air' component was a novel concept first used by Dr Martens in their 'Airware' footwear. The technology used in the Dr Martens 'Airware' products was improved by an independent designer. When the new concept was presented to Adidas it was initially rejected, but it eventually took off when Nike incorporated it into Michael Jordan's basketball shoes. The important factor here is that the success of the new Nike 'Air' product class was not gained just through the addition of the new 'Air' component into the sole of their trainers but also through the care taken to adhere to the brand's identity and design values when the new component was engineered into the trainers. Additionally once launched into the market place the 'Air' technology was marketed in a manner that ensured it became an inherent part of the brand's personality. Walsh et al (1992) further emphasise that product design sits at the heart of the new product development or innovation process. This is demonstrated in Figure 2.2 (Roy and Bruce, 1984)) showing product design and development as the core of technological or industrial innovation, with manufacturing, engineering and marketing forming part of the wider activity.

Figure 2.2: The Process of Technological or Industrial Innovation

Source: Roy and Bruce (1984)



The importance of incorporating appropriate brand identities and design values into new products is elaborated on later in sections 2.1.4 and 2.1.5 and the processes and technology used by design orientated companies to ensure new products are successfully introduced varies greatly from company to company and industry to industry. However the following stages will often be incorporated:

1. The identification of a new market opportunity.

2. An assessment as to its applicability to the current portfolio of products and the brand identity.

3. The development of a commercial brief for:

    a) Design – to design the concept;

    b) Marketing – to position the concept;

    c) Operations – to source the appropriate materials and manufacturing capability;

    d) Finance - to secure the necessary cash flow;

    e) Sales – to open up the appropriate distribution channels for the new products.

A time line is then usually followed that ensures all the disciplines work concurrently to deliver the right product to the right place at the right time. More commonly the role of product and category managers is seen as all important when introducing a new product line. They are generally responsible for the creation of the commercial brief and ensuring that all departments adhere to the time lines and that the product that is produced is consistent with the brand identity and design values as well as being consistent with the commercial opportunity. Increasingly this process is much more systematic and any tools that can assist in a product being on track against its product development parameters will help. A design rationale knowledge structure of the type developed for this thesis could be exploited to communicate the development process, the time lines involved and the decision making to the various departments in a design orientated company. A computer system that prompts and raises alarms during the design and product development process, that has an innate understanding of a company's brand identity, design values and commercial requirements, would be the utopia.

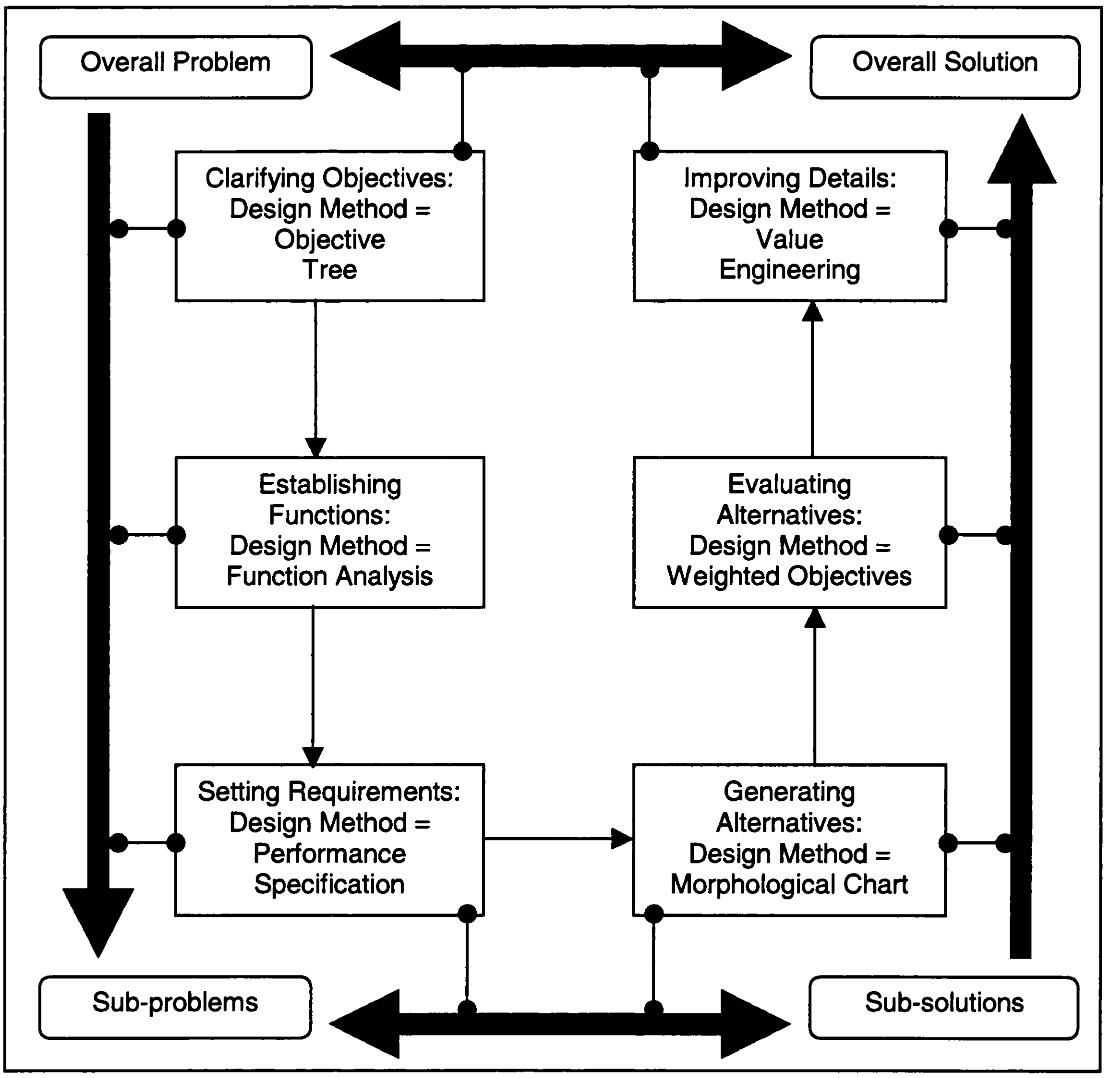
2.1.3. Design Methods

Design methods are processes, tools or techniques intended to support designing and they can be divided into two main subtypes: creative and rational. Creative methods such as brainstorming are aimed at stimulating designers to think in a more innovative manner. Rational methods consist of systematic procedures for the overall management of the design process, and of techniques to be used within such a process which help to externalise and formalise it (Cross, 1984). Some design methods consist simply of the standard traditional design techniques such as drawing. However since the early 1960's and the onset of the design methods movement many formal rational methods have been developed which do not form part of conventional design techniques. Different combinations of design methods might be used during the course of the design process. Cross (1994) demonstrates this in his design process model shown in figure 2.3, which illustrates six selected stages of the design process, the rational design method suggested as being relevant to each stage and how they relate to the design problem and solution space.

Formal design methods however have tended to focus on supporting engineering design as opposed to industrial product design. For industrial design which orientates more to the ergonomic and aesthetic, the methods are often too rigid. Many are based on weak models of the design process where in order to use the methods designing must take place by following a sequence of independent actions, each of which can be dealt with in turn. However, more sophisticated, second generation methods were later advocated (Rittel, 1972). Rittel and Weber (1984) endorsed such second generation methods, which encourage through a process of argumentation, the exploration of the problem area to be explored and the discussion of solutions by the interested parties, in order to combat the complexity of design issues. However it is asking a lot of even the most adaptable of these methods to account for the complex, messy and non-sequential nature of the industrial product design process. Rittel recommended that to be more applicable to real design situations, methods should *'emphasise investigations into the understanding of designing as an argumentative process: i.e. where to begin to develop settings and rules and procedures for the open-ending of such an argumentative process; how to understand designing as a counterplay of raising issues and dealing with them, which in turn raises new issues, and so on and so on.'* (Rittel, 1972, p.320). As discussed in section 5.1 of chapter 5, it therefore seemed appropriate to examine the three dominant argumentation based design rationale notations as a starting point when considering how to structure the design data amassed during the field study.

Figure 2.3 Six Stages of the Design Process Positioned within the Design Problem-Solution Space

Source: Cross, N., 1994, p43.



2.1.4. Brand Identity

When considering the design and product development of branded products, brand identity simply helps position a brand in the market and create the parameters against which that brand may design products, marketing and image. It basically equates to a brand's personality and is comprised of the design of the brand's products, its distribution channels, its image and marketing. It may formally be written down in the form of a strap line, brand values or a mission statement. The brand identity is a product of a brand's positioning in the market place. It should be adhered to in order to ensure the protection of that positioning. An example of a company with a strong brand identity that it utilises to protect its position in the market place is the jeans company, Diesel. In the early 1990's Levis, Lee and Wrangler dominated the jeans market. They all used the concept of originality and authenticity revolving respectively around the 'Original Jean' (Levis), the 'Original Workwear Jean' (Lee) or the 'Original Western Jean' (Wrangler). Diesel having identified the 'Original' ubiquity in the jeans market place, positioned themselves as 'Irreverent'. They created product and image that underlined their 'Irreverence', thereby creating choice and positioning in the market and becoming the fastest growing jeans brand of the early 1990's.

The most important factor of brand identity is that it allows the company to maintain an eye on the big picture. With the example of Diesel, their brand identity ensures that despite of all the creative and operative variables within the product development process at Diesel, the brand at the end of the day will be 'Irreverent'. Their position in the market place against the ubiquity of the original, Levis, Lee and Wrangler is thereby safeguarded. Ultimately the brand identity converts the reality of a market gap in to a long-term brief against which all departments in a company can work. Capturing product development rationale within a multimedia knowledge base would enhance the opportunity of maintaining consistent brand identity, enabling new and existing members of the development team to appraise themselves of previous design decisions and gain an instant and detailed insight into the brand's personality and development.

2.1.5. Design Values and Product Concepts

Design values with regard to branded products form a framework that corresponds to a brand's identity. For example, BMW uses the brand identity of 'The Ultimate Driving Machine.' The design values for a BMW are consistent with the identity: performance, efficiency, reliability, and luxury. Design values are the framework within which a designer may be creative. As long as the designer adheres to the design values then ultimately the brand identity should not be breached. As will be discussed later in chapter 5, it is therefore essential that any notation used to capture design rationale enables the design values to be retained and represented.

Design values are drawn up not to shackle the designers but to allow them to optimise their creativity within the confines of the company identity or brand. Design values are the properties inherent in a design that the designers feel are the embodiment of the product. It is important for a product development team to have a clear and unified vision of these values from the outset. Their portrayal is often done with mood or story boards depicting the values. Consistent incorporation of design values is particularly important for branded products. When properly managed in the design process, they enable the maintenance of brand identity and integrity. It is paramount for brands not to confuse their customers by diffusing the image portrayed by their products. Large corporations such as Levis and Coca Cola spend vast amounts of money in efforts to keep their brands on the right track throughout the product development process. Levis works within the parameters that it is the original jeans company with distinctly American values. However in the 1970's their product extensions involved the introduction of products types such as suits and luggage. Once in the market place the consumer quickly discerned that the products confused the brand identity and did not conform to the Levis design values. The company lost a considerable amount of market share as a result. Having returned to it's roots with the 501 jean campaign in the 1980's the company achieved unparalleled success. Consequently Levis now invest inordinate funds and time trying to ensure that all its products worldwide conform to the maxim of the 'Original Jean.'

In order to be effective design values and product concepts incorporating these values should be defined in the very early, initial concept stages of the development process. *'Before a customer unpacks a new laptop computer or sets up a high-speed packaging machine, and long before a new car rolls off the showroom floor, the product (or some early version of it) begins as an idea. Next that idea is embodied in progressively more detailed and concrete forms: ideas turn into designs, designs into drawings, drawings into blueprints, blueprints into prototypes, and so on until a finished product emerges from a factory.....it begins with the creation of a product concept.' (Clark et al, 1994, p.280)* Various techniques for enhancing the identification and communication of design values are being researched, many of which involve the use of metaphor to convey the required personality of the product. Angela Dumas's (1994) work on totem building is a good example of this, but Japanese companies have been aware of the importance of developing clear product concepts for some time (Nonaka, 1991). Clark (1994) highlights the work being under taken at Honda with the development of clear product concepts at the conceptual stages of the design process:

> *'By definition product concepts are elusive and equivocal. So it is not surprising that when key project participants are asked to relate the concept for a new vehicle, four divergent notions of value emerge. Those for whom the product concept means 'what the product does' will couch their description in terms of performance and technical functions. Others, for whom the concept means 'what the product is', will describe the car's packaging, configuration, and main component technologies. Others, for whom product concept is synonymous with 'whom the product serves', will describe target customers. Still others, reflecting their interpretation of the concept as 'what the product means to customers', will respond thematically, describing the car's character, personality, image and feel. The most powerful product concepts include all these dimensions. They are often presented as images or metaphors that can evoke many different aspects of the new product's message without compromising its essential meaning."* (Clark et al, 1994, p.281-282).

Clark (1994, p.281-282) outlines how Honda emphasise the use of powerful design concepts right from the outset of a design project. *'A rugby player in a business suit'* is the example provided as the concept used by Honda to reposition the Honda Accord with the qualities of contact, sportsmanship and gentlemanly behaviour.

The critical component when using product concepts and design values is that the image conjured up by the concept must be solid enough to enable interpretation into tangible design attributes in a finished product. Successfully shared design concepts encourage the development of products with cohesive design values by providing an enhanced design environment where complementary solutions and decisions can be toyed with. Product concepts help to push the integrity of a brand's identity and its design values against the rigors of a constantly changing market place. Product concepts allow a business to investigate either new markets or product extensions. They allow for speculation as to whether a market opportunity can be augmented to fit a company's identity and design values.

As with brand identity, maintaining a multimedia record of product development rationale would capture the design values and product concepts used during the development process, enabling the way in which they had been incorporated into the products to be scrutinsed by the product development team and communicated to future employees.

2.1.6. The Multidisciplinary Nature of Design

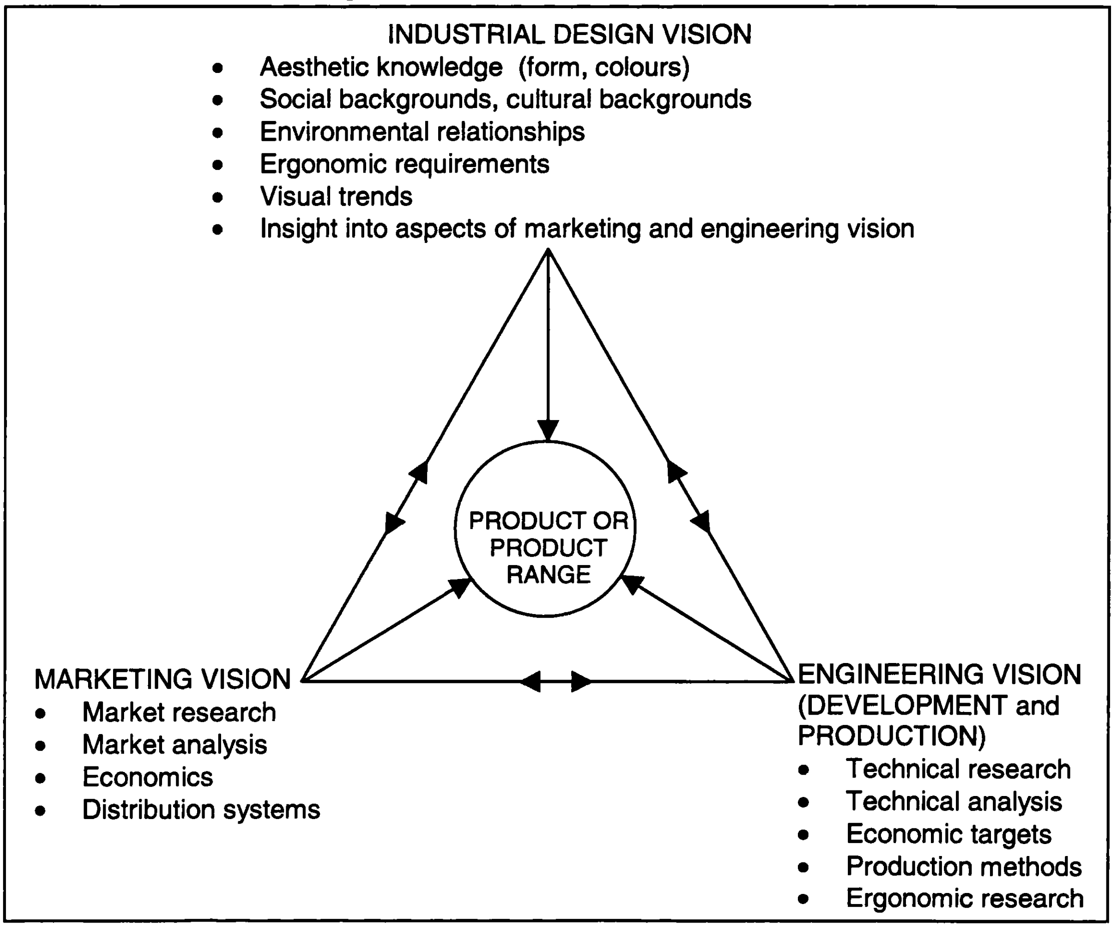
It is widely held that product design is rarely undertaken by one individual, but rather it is usually conducted under the auspices of multidisciplinary product development teams [(Leonard-Barton, 1991), (Dumas, and Mintzberg, 1991), (Roozenburg and Eekels, 1995)]. Often these design teams do not merely consist of people from the design department, but include personnel from different departments within or even external to the organisation. A design team might consist of industrial designers, engineering designers, materials sourcing technologists, marketing managers, production managers, commercial and financial managers as well as external consultants or experts in the domain. Each party will bring with them their own agenda and priorities for the design of the product. Dumas and Mintzberg (1991) categorise design as an activity conducted under a 'Design Umbrella'. They coin the phrases 'Seen Design' and 'Silent Design'. 'Seen Design' encompasses all the very specialised activities at the heart of the design process, carried out by the actual designers. 'Silent Design' consists of all the other related functions like marketing and production that connect the design manufacturing and retail processes. In other words 'Silent Design' accounts for the decisions taken by those other than the designers who are directly involved in the design process. Clearly designing is not something that takes place solely within the design department. Successful designing relies on interaction with the other departments of an organisation throughout the design process.

Conversely Lorenz (1990) emphasised that not only should other departments interact with the design department but a fully developed industrial designer should also have a valuable contribution to make to the other areas involved in product development. As shown in Figure 2.4, he identified 3 distinct product development visions: Industrial, Engineering and Marketing into each of which the designers should have a significant input, *'from ergonomics and the design of new production methods (on the engineering side of the house), to new ways of analysing markets and conducting (or interpreting) market research. It is not the mundane skills of sketching, shaping and colouring which make the industrial designer such a valuable resource, but the multifaceted ability to contribute the work of other disciplines and to stimulate, interpret and synthesize it.'* (Lorenz, p25, 1990)

The model for product development presented by Lorenz portrays the 'industrial design vision' (aesthetic knowledge, social and cultural backgrounds, ergonomic requirements) as being equally important as the 'engineering vision' (technical research, production methods) and the 'marketing vision' (market research, market analyses, distribution systems). On the basis of this a tool such as a multimedia representation of the design rationale, incorporating domain specific interface facilities might serve to enhance the communication of the design and development process and agenda throughout the departments of an organisation and ultimately lead to more focussed product development overall rather than supporting more narrowly only specific tasks that fall under the traditional umbrella of design. This underlines the extent to which a multimedia design rationale knowledge base might be utilised within a company involved in product development. Such a knowledge base could form a central reference point for an organisation to communicate many issues affecting the product development process including the timelines, the design values, the ergonomic requirements, the technical parameters and production methods and the marketing strategy. Clearly a resource of this nature would be of interest to and have an impact on a far wider audience than just the designers and could be contributed to and utilised by members of the many departments in a product development organisation including the marketing, sourcing, production, commercial and finance departments.

Figure 2.4: Product Development Visions

Source: Lorenz, C., 1990, p.25.



2.1.7. Differences Between Engineering and Industrial Product Design

As previously touched upon, this thesis focuses on capturing design rationale in the industrial product design process. Specifically the field study that underpins this research was conducted in the domain of clothing design. As shown in Shirley and Henn's (1988) diagram of design types in Figure 2.1, fashion and textiles is an archetypal part of design and it is an important class of industrial design. Section 5.1 of chapter 5 outlines that a number of notations have been developed for representing design rationale. However, in the main, previous empirical studies into the use of these notations document their application in the domain of engineering. It is therefore pertinent to examine some of the differences between the domain of engineering design and industrial product design in order to assess whether capturing industrial product design rationale might be more effective than capturing engineering design rationale.

Product design is commonly thought to encompass both engineering design and industrial design but frequently in industry a distinction is made between an industrial designer and an engineer. (Walsh et al, 1992) Industrial designers are also commonly called product designers. Their function usually envelops the ergonomic and aesthetic aspects of designing. In Moody's opinion '*Industrial design seeks to relate the hardware to the dimensions, instinctive responses, and emotional needs of the user where these are relevant requirements. Through the conscious control of form, configuration, overall appearance and detailing, industrial design is capable of conveying to the user the abstract characteristics of a product, e.g. robustness, precision.*' (Moody, 1984) Engineering designers on the other hand are thought to be more involved with the technical function of products as opposed to their visual form and aesthetic appeal. In the seminal Fielden report engineering design is defined as '*the use of scientific principles, technical information and imagination in the definition of a mechanical structure, machine or system to perform pre-specified functions with the maximum economy and efficiency.*' (DSIR, 1963)

Caldecote (1989) summarises the differences between the fields of engineering and industrial design succinctly, whilst conceding that there is often a crossover between the two domains when developing products:

> *'In complex products, such as aircraft, product development is a long and very expensive process, in which the design team is intimately involved. As we move along the spectrum of design through less complex products, such as machine tools, diesel engines, refrigerators, to toys and textiles, the paramount importance of the engineering designer in ensuring technical excellence gives place to the skills of the industrial designer, who is more concerned with ergonomics and aesthetics ....Some products (e.g. textiles) are almost entirely the prerogative of an industrial designer while other products (e.g. a submarine cable) are the sole responsibility of an engineering designer. Some products (e.g. a telephone) have approximately equal industrial and engineering design content.'* (Caldecote, p.54, 1989)

As Caldecote outlines, the type of design input required will vary considerably between different product groups. Clearly the contribution of industrial or engineering design to a product will depend on the aesthetic, ergonomic and technical requirements of the product. Some products for example may not involve the use of engineering designers and others may not require the input of industrial designers. Some on the other hand may require considerable input from both.

A number of design theorists including Walsh et al (1992), Cross (1994), Pye (1989), and Roy (1989) argue that to a certain extent, regardless of the design domain, design problems are largely similar across a wide range of industries and product types. However Roy goes on to emphasise that although it *'is true to the extent that all designing is iterative, using creativity and compromise to move from a field of possibilities to one unique solution. Nevertheless, the skill and knowledge required of different types of designer vary widely.'* (Roy et al, p.5, 1989)

The major factors when considering using design rationale capture for industrial product design is that its focus is on ergonomics and aesthetics, the design cycles are often short, and particularly in the case where a product is branded, design consistency and integrity is paramount. In clothing product design for example, a range of similar products are created season after season, there being 2 or 3 seasons each year. The significance of industrial product design cycles being short is that it means that at the start of a development cycle it is still useful for the design team to be able to refer back to the products designed and the decisions made in the previous design cycle since the majority of their aesthetic values will still be current and relevant. The design team may also wish to use the structure of the previous product range as a starting point for the following product range. In certain instances the same products from the previous cycle's range might be incorporated into the current range with only minimal, incremental changes being instigated to the design of the products. Since the design cycles are short the aesthetic trends and design influences discussed in the previous design cycle could very well still be relevant to the current design cycle, adding further weight to the argument that maintaining a design rationale in industrial product design could prove to be a very useful reference resource.

In engineering design where development cycles are often long and may last for a number of years, the benefit of being able to look back at a record of the design rationale once the cycle has finished diminishes. The reason for this is that in the space of a number of years engineering methods and technology can greatly advance and therefore at the start of a development cycle there would not necessarily be a great gain to be had from making reference to methods used at the start of the previous development cycle a number of years ago. Furthermore, in industrial product design the focus is on ergonomics and aesthetics and fashion has an important role to play. Fashion trends are famously cyclical, strengthening the argument for maintaining a design rationale in industrial product design, in order that when a fashion cycle comes full circle the design process and rationale used when the trend was previously encountered can be referred to and utilised to provide aesthetic inspiration for the current product range. This is in contrast to engineering where technical excellence is paramount and the techniques used rapidly advance and therefore there is no requirement to hark back to old methods being used in design cycles many years previously.

A final reason indicating that there is greater potential for capturing industrial product development rationale as opposed to engineering, is that due to the aesthetic focus, a design rationale knowledge base could prove particularly useful in maintaining design consistency and brand integrity. The knowledge base could be referred to in order to ensure product ranges in subsequent cycles incorporated the correct and consistent design values and could be used as a reference point for any member of personnel to appraise themselves of the aesthetic personality of the products. Much of the previous research to represent the design process by capturing design rationale using design rationale notations, has not focused on capturing the essence of the ergonomic and aesthetic considerations of industrial product design. It is worth re-examining these design rationale notations previously used mainly with engineering design and applying them to industrial product design. The amount of design re-use prevalent in industrial design suggests that there exists a greater potential benefit to capturing design rationale in industrial product design as opposed to engineering design where the data is not primarily visual in nature, the focus is on technical excellence, design cycles are long and aesthetics are of minimal importance. As will be demonstrated in section 6.4 of chapter 6, the rewards of effectively structured design rationale in industrial product design can be substantial.

2.2 Design Problems and Decision Making

2.2.1. Design Problems

Design problems are often referred to as being 'wicked' and Cross (1994) goes as far as to describe them as 'pernicious'. The reason for this being their ill defined and ill structured nature, making them extremely complex and both hard to quantify and define. At the beginning of the design process the design problem is usually poorly detailed and it requires the skill of an experienced designer to explore the problem area in an iterative manner and develop progressively improved solutions to it. Cross expands on this, talking about the design process in terms of both problem and solution spaces requiring concurrent exploration. He proffers that *'The designer makes a solution proposal and uses that to help understand what the problem 'really' is and what appropriate solutions might be like. The very first conceptualizations and representations of problem and solution are therefore critical to the kinds of searches and other procedures that will follow, and so to the final solution that will be designed'* (Cross, 1994, p.8). In a similar vein Roozenburg and Eekels (1995) cite design as a *'goal-directed thinking process by which problems are analysed, objectives are defined and adjusted, proposals for solutions are developed and the quality of those solutions is assessed'* (p.3). To accommodate the inherent complexity of design problems, Cross (1994) recounts that designers have adopted 'solution focussed' strategies where by exploring the solution area, the whole "problem" can end up being redefined. *'In order to cope with the uncertainty of ill-defined problems, the designer has to have the self confidence to define, redefine and change the problem as given, in the light of solutions that emerge in the very process of designing'* (p.18).

A dominant factor making design so complex is the multifaceted and interactive nature of design problems. *'Even when the designer has progressed well into the definition of a solution, difficulties in the problem structure may well come to light. In particular, sub-solutions can be found to be interconnected with each other in ways that imply a 'pernicious' structure to the problem, e.g. a sub-solution that resolves a particular sub-problem may create irreconcilable conflicts with other sub-problems'* (Cross, 1994, p.11). The complexity added by this 'interconnectedness' characteristic of design is further summarised by Lawson: *'Enlarging our window may well let in more light and give a better view but this will also result in more heat loss and may create greater problems of privacy. It is the very interconnectedness of all these factors which is the essence of design problems rather than the isolated factors themselves'* (Lawson, 1990, p45).

It is this 'interconnectedness' which makes design non-decomposable and is the kernel of design problems. When attempting to structure design data with the aim of capturing design rationale, whatever method is used clearly needs to be able to account for this complex, non-sequential and ill-defined nature of the design problem space.

2.2.2 Design Decisions

Throughout the many stages of the design process solutions to problems must be chosen from the various alternatives available to the design team. How certain options or solutions come to be chosen over others is the interesting point in question, particularly when considering the interconnected nature of design problems as outlined in the previous section. Clearly with product design the outcome is not apparent at the beginning. A number of potential viable designs could evolve in accordance with the decisions made. A designer may ultimately be faced with choosing the most appropriate design from a number that have been generated for one design situation. Similarly, during the procedure undertaken to arrive at those viable designs, a designer will have to identify and choose from the solutions available to various sub problems arising throughout the design process. *'Choosing between alternatives is therefore a common feature of design activity'* (Cross, 1994, p.121). In a real world design setting it is not possible to consider all the variants in turn, since the number of solutions would make an exhaustive search infeasible.

Among others, Davies and Castell (1992), discuss the consequence that taking design decisions at certain points in the design process can have on previous decisions that have been made. They call such situations '*opportunistic deviations'* and find that they are inevitable considering the complexity and ill-structured nature of design. Starr(1963) in his book on design decision theory, talks about the complexity of design problems and decisions in more detail. *'Given, a function to be performed, then, in general, a number of possible ways to achieve this goal becomes apparent. Using the language of decision theory, each of these ways or capabilities is an alternative strategy. Differences in tolerances, materials used, shape and form are just a few of the usual variants that are encountered. The decision problem is to choose the strategy which best satisfies the decision maker's objectives. If the designer does not know what objectives apply, then only by fortuitous selection can he* *succeed.....A design decision is therefore a very complex problem.' (Starr, 1963, p.2)* He highlights that a variety of considerations, including economic, political and social factors can interact with the decision procedures at a given point in time and affect the final form of a design. This explains why product classes emerge. For example chairs constitute a product class containing products with largely similar functions which may be vastly different in their design and form.

'Over the years, the methods that we employ to reach product design decisions have remained essentially unchanged. Meanwhile, the decision problems have continually grown in size. The number of usable materials, the availability of alternative production processes, the requirements for variety in size, shape and colour, the range of possible qualities as expressed in tolerance specifications and surface finishes, the number of different kinds of users - these and other factors justify the statement that the size of the decision problem has been continually increasing.' (Starr, 1963, p.3) Starr goes on to elaborate on how even for a simple problem such as whether to use plastic or metal for a particular product design many factors would need to be considered including: technological lead time, suitability, price, cost of manufacture, frequency of defects with each material, failure rates and types of failure, performance effectiveness, shipping weights and effect on shipping costs, possible varieties of colour, surface, size and shape, effect on production schedules, appearance, guaranteed period, distribution, availability, what competitors are using, what competitors products are like, how might they change them as a result of the decision taken, effects of changes in the economy, consumer taste patterns, and the impact of the companies and its competitors marketing strategies. Even when taking all of these factors into consideration, '*we succeed in merely adding a few more dimensions of reality, not in capturing the total essence of the problem.*' (Starr, 1963, p.4) Starr argues that the introduction of decision procedures are vital in product design because of the rising pressure on performance, which is increased by greater competition making the market more sensitive to small changes in design and further because as technological discoveries are made, the number of alternative paths increases. This means it is no longer possible to reach decisions without being aware of competitors strategies.

In this research the design rationale representation created as outlined in chapter 6 aims to support reflection on design decisions, based on accurate data about what was decided during the design process and on what basis. Design decisions must be taken carefully and depending on the design domain, they can be made with the help of formal decision evaluation methods or, more usually, by applying the expertise or intuition of the designer. Increasingly though companies are realising that introducing systems and methods to assist in their design decision making and to enable them to record the process for later reflection could have a positive effect on their productivity (Phillips and McDonnell (1998b). In a study of companies involved in product design Walsh et al (1992) conclude that *'the financially most successful firms were those which realised that designing a product involved making decisions on very many factors. Such firms also realised that to take these many factors into account required some way...to coordinate the inputs of managers, design and development, marketing and production staff'* (p.42). As outlined later in chapter 6, capturing multimedia design rationale in a visual hypertext map as the design process unfolds would provide a record of design decisions and enhance a design team's opportunity to examine the path to and effectiveness of their design decisions.

2.3 Representing Design Dialogue and Rationale

2.3.1. Tacit Nature of Design Dialogue

Design dialogue is the conversation pertaining to a design, undertaken by the members of a design team during the development process. The important role that design dialogue has to play in the design process is being increasingly recognised and explored, [(Cuff, 1991), (Schön, 1992)]. Dana Cuff in her study examining design meetings between an architect and client, characterises the development of the design conversation: *'First, someone lays out a starting point, after which discussion ensues about topics related to the general theme, proceeding with no immediately apparent logic. Topics are raised, dropped, ignored, reviewed, but few subjects are treated with any continuity; no issues are resolved. The speakers test whether they understand one another – whether they have made sense of their situation together.'* (Cuff, 1991, p.190) She emphasises that explicit decisions relating to the issues raised do not always get made simplistically as issue-outcome sequences, *'an issue is raised, discussed, a related issue raised, than a third, and none is decided'* (p.191) and that decisions usually come about over time *'as a series of understandings modified by new information and opinions'* (p.193).

The tacit nature of design dialogue means it is hard to completely keep track of the design process and the entirety of the designers' reasoning. However, in product design much of the unexpressed knowledge and information is contained within visual data of a multimedia nature, which, this thesis argues can be captured and usefully retained for later reference. The nature of industrial product design means that much of the tacit knowledge understood by the designers would be contained in the predominantly visual multimedia data which could be linked to a design rationale structure. Although this data may not mean anything to the untrained eye, to an experienced designer it would contain a lot of valuable information and would indeed add an expressive element to the semi-formal design rationale notations outlined in chapter 5.

2.3.2. Potential Benefits of Structuring Product Design Rationale

This research will go on to show that it is worthwhile in product design to produce as full a representation of the design rationale as possible in order to:

i) Aid and speed up the planning for the following seasons ranges;

ii) Ensure higher quality decisions are made on the new ranges on the basis of reflection on the previous design season. This thesis demonstrates that design decision making can be aided by explicitly representing design rationale in a product design domain such as sportswear, where the over-riding decisions can be split into those which are aesthetic in nature and those addressing production and technical issues. For example, a certain style may be adopted due to the design team's belief in it having the correct aesthetic values for the market and yet later prove to be a 'dog' in terms of sales. In such a situation if a design rationale representation had been constructed it could be reflected on, and the design team might question their judgement on whether they were using the correct aesthetic values for the market place with this product. Similarly it would also be useful to have a rationale of technical/production decisions. In a case where a fabric proves to be unsatisfactory, resulting in a high number of product returns, the specification and rationale for choosing that fabric could be referred to and a sensible resolution or alternative fabric chosen for future products;

iii) Provide new team members with a history of previous product development and design decisions and enable new personnel to quickly appraise themselves of the company's design direction;

iv) Help branded products to retain consistency in their brand identity. A company may retain a historical perspective on their products and design progress, thereby promoting the maintenance of design and image consistency;

v) Allow team members to analyse their own personal development;

vi) Provide an archive of previous design that will become increasingly useful with the passing of time as a resource for visual research/inspiration. Information is retained that would previously have been lost or discarded due to storage and access problems;

vii) Provide the opportunity for the re-use of design efforts and knowledge put into developing prototypes, not all of which will have gone into production;

viii) Provide a resource of inspiration and reference for marketing activities that may incorporate 'retro' designs. Many branded clothing companies such as Levis use old, archived design work from previous decades in their 'lets return to our roots' marketing activities;

2.4. Summary

This chapter has explored the 'messy' nature of the design and product development process. Section 2.1.1 provides an insight into the meaning of the word design and the spectrum of design activities. The fact that product design falls under the wider umbrella of product development is briefly discussed. It is emphasised that the product development and design activity forming the focus of the field research in this thesis is clothing and footwear product design, which is a dominant sub-class of industrial product design. Section 2.1.2 discusses the difference between new product development and technological innovation and refers to the importance of ensuring that new products encompass the identified design values. It is pointed out that designing often doesn't involve the creation of new product types but merely modifications to existing product lines. The usual stages involved in introducing new products are scrutinsed. It is stressed that a design rationale knowledge structure could play an important role in capturing and communicating the time lines and the decisions undertaken during the new product development process to various departments in a design orientated company.

Section 2.13 introduces design methods and highlights the fact that the traditional rational methods, usually used in engineering design, are often too rigid to be applicable to industrial product design. The complexity of design has been touched upon and consideration given to how even the most adaptable design methodologies cannot account for the non-sequential characteristics of the industrial product design process. However methods which encourage the exploration of a design problem and the discussion of solutions through a process of argumentation are thought to be far more flexible and suited to the 'messy' nature of product design. Examination of the 3 dominant argumentation based design rationale methodologies would therefore appear to be an appropriate starting point when considering how to structure the design data amassed during the field study.

Section 2.1.4 examines the importance of brand identity and brand positioning when undertaking design and product development of branded products. A multimedia knowledge base of product development rationale would enhance the opportunity of maintaining consistent brand identity enabling new and existing members of the development team to appraise themselves of previous design decisions and gain an instant and detailed insight into the brand's personality and development. Section 2.1.5 goes on to elaborate how design values provide a framework which corresponds to a company's or a brand's identity and provide a framework and parameters within which designers can use their creativity. The importance of developing clear product concepts, incorporating these design values at the very early conceptual stages of the development process is emphasised. When designing branded products, particular attention must be paid to maintaining brand integrity through consistent communication of the design values. As with brand identity, maintaining a multimedia record of product development rationale would capture the design values and product concepts used during the development process, enabling the way in which they had been incorporated into the products to be scrutinsed by the product development team and communicated to future employees.

Section 2.1.6 alludes to the fact commercial designing is rarely the responsibility of one person and usually takes place under the auspices of a multidisciplinary product development team consisting of personnel from many different departments within a company or even from external organisations. Product development is shown to encompass not only the design of products but also the wider activities of production, distribution, marketing and sales. Successful designing cannot take place independently and without planning to encompass these related activities. This adds weight to the argument of the necessity to develop tools which effectively communicate the design process and agenda to departments throughout an organisation, ensuring that design is not an activity conducted by designers working in solitude in an 'ivory tower'. For example systems that can alert departments about tasks remaining unfinished or late and communicate the design values and commercial requirements throughout an organisation would be invaluable. The extent to which a multimedia design rationale knowledge base might be utilised within a company involved in product development is underlined. Such a knowledge base could form a central reference point for an organisation to communicate many issues affecting the product development process including the timelines, the design values, the ergonomic requirements, the technical parameters and production methods and the marketing strategy. Clearly, a resource of this nature would be of interest and have an impact on a far wider audience than just the designers and could be contributed to and utilised by members of the many departments in a design orientated company including the marketing, sourcing, production, commercial and finance departments. Ultimately a design rationale knowledge base should enhance the communication of the development process throughout the departments of an organisation and lead to more focussed and streamlined product development.

The majority of previous research into the use of design rationale notations documents their application in the domain of engineering, where they have been found to have certain short comings. Section 2.1.7 therefore examines the differences between the domain of engineering design and that of industrial product design in order to assess whether capturing industrial product design rationale might be more effective than capturing engineering design rationale. It quickly becomes apparent that there exists greater potential benefit to capturing design rationale in industrial product design where the focus is on ergonomics and aesthetics, a lot of visual data is used containing valuable tacit knowledge, the design cycles are usually short and design consistency and integrity are paramount.

Section 2.2.1 discusses the complex, multidimensional and interconnected nature of design problems and they are shown to be non-decomposable due to their '*interconnectedness*'(Lawson, 1990, p45). When attempting to capture design rationale whatever method is used clearly needs to be able to account for this complex, non-sequential and ill-defined nature of the design problem space. Section 2.2.2 describes how throughout the design process solutions to these 'wicked' design problems must be chosen from a number of alternatives and the outcome of a design of a product is not therefore apparent from the outset. Problem setting and solving and choosing between alternatives is a common and critical feature of designing and having access to a representation of the design rationale would support designers to reflect on their design decisions and enhance the effectiveness of the design process. The design rationale representation created for this research and outlined in chapter 6 aims to support reflection on these design decisions, based on accurate data about what was decided during the design process and on what basis, providing the opportunity to examine the path and the effectiveness of the decisions.

Section 2.3.1 alludes to the important role of design dialogue in the development process and describes how much of the tacit knowledge and information used in design is contained within visual data. The tacit nature of design dialogue means it is hard to completely keep track of the design process and the entirety of the designer's reasoning. Representing design dialogue and rationale is further hindered by the fact that explicit decisions pertaining to issues raised are not always made and decisions usually emerge quite erratically over time as the design process progresses. However it is argued that in product design much of the unexpressed knowledge is contained in the visual data referred to during the development process and this can be captured in a multimedia design rationale structure and would communicate valuable information to the expert eye of a designer referring to the knowledge representation at a later stage. This reinforces the necessity for a design rationale knowledge representation to be able to store data of a multimedia nature, thereby retaining this tacit knowledge. The final section 2.3.2, lists the potential benefits of structuring product design rationale.

The next chapter goes into detail on how technology is being used to support product design and explores the potential for using multimedia knowledge bases to enhance the design process.

CHAPTER 3:

TECHNOLOGY SUPPORT FOR PRODUCT DESIGN AND DEVELOPMENT

This chapter presents an examination of how product design and development is increasingly being supported with the use of technology. A case study describes the clothing design and manufacture process and how computer aided techniques have been deployed in the clothing industry. The case study serves to illustrate the extent to which new technology has been embraced by design based industry. The potential for using multimedia knowledge bases to support product design is explored in more detail with a further case study on the impetus for multimedia textile libraries. The chapter concludes with a summary of the critical points.

3.1. Supporting the Design Process with Technology

Technology is increasingly being used to support a wide variety of design based companies enabling them to reduce product development lead times, and thereby enhancing their competitiveness. Lawson identified four potential roles for the use of computers in a design environment: *'In the 'Management Role' the computer is helping the designer to run the business......In the 'Information Processing Role', the computer is used to hold and reproduce data usually either in the form of drawings or written documents.....When we move on to the 'Solution Evaluation Role'.....the computer is being used in some way to model a proposed design, and to generate output which helps to evaluate the design.....Finally we can envisage the computer in a 'Solution Generation Role', in which the computer actually suggests either part or all of a design solution....Clearly this sort of involvement brings the computer right into the very heart of the design process itself, and is therefore much more likely to be controversial than our first role which kept the computer to a more remote management role.'* (Lawson, 1990, p.203) The design rationale knowledge representation at the heart of this research will be seen in Chapter 6 to encompasses the first three of Lawson's identified roles:

The management role – the representation supports management tasks including alerting the design team to deadlines, monitoring the effectiveness of the dynamics of the design team, and allowing individuals to reflect on their working practices;

The information processing role – the representation enables the extensive amounts of design data used during the development process to be stored electronically. However, it goes a stage further than just storing data by structuring it in a manner that the rationale and context of the design data is also retained;

The solution evaluation role – the representation is constructed concurrently with the design process and it retains the design context and rationale. It empowers designers to evaluate their actions and decisions during the design process and will have a knock on effect on the outcome of the designs.

In the following section a case study explores how computer supported design and manufacture has been deployed within the clothing industry and serves to illustrate the extent to which technology is being embraced by design orientated industry.

3.2. Case Study: Supporting Clothing Product Development with Technology

3.2.1. The Clothing Design and Manufacture Process

In order to understand how technology may fit into clothing design and production, it is necessary to look at the process in more detail. The initial stage in producing garments for the mass market often starts in the buying department. The buyers and merchandisers decide what type and style of garments should be sold and what quantities they should be sold in. Their ideas are then passed on to the design department which may be either in house or part of a garment manufacturer. In the design department, the designers translate the buyers' requirements into design drawings and working sketches of designs.

At this stage suitable fabrics for the garments will either be specifically designed by a textile designer or more usually they will be chosen from the wide range produced by the fabric manufacturers. A textile designer often works freelance, specialising in either woven or printed fabrics. As with a clothing manufacturer, a textile manufacturer does not know what the trends will be for the approaching season. A textile designer will attempt to predict what the coming season's direction will be. The cloth design can be just as important as the garment design because the quality and design of a garment's fabric is often a major selling point.

A pattern cutter or the designer, will then interpret the design drawings into a pattern and make a toile garment. From the toile, which will be made in a cheap fabric such as calico, the designer may assess if further adjustments need making before the sample machinist constructs a proper sample garment using the correct fabrics and trimmings.

Product costings will also be created in the design/sampling department before the sample garments are taken to the buying department, where further adjustments may be instigated. Calculations for the costings are made on the basis of estimated material and labour costs and historical data on the cost of previously manufactured products. The lay planner will produce a lay plan of how the pattern pieces should be laid on the fabric before cutting, in order to get the maximum usage and minimum wastage of fabric. The lay plans can then be used to estimate fabric usage per garment. Increasingly computer software is utilised to help with the construction of the estimated costings. The fabric contributes a large proportion of the overall cost of a garment and therefore it is essential that designers select a suitable fabric not only for the aesthetic design, but also for the market at which it is aimed. Having access to large knowledge bases of information on available fabrics would aid designers and buyers to make a suitable selection. When the buyers are happy with the samples they will select the ones they wish to go into the next season's range. The design department will then send the sample garments, lay plans and other production information to the manufacturer in order that the garments can go into bulk production.

When designing a garment for the mass market, the designer cannot just consider the silhouette of the product. Among other things the fabric must be carefully sourced and designed and the cost and the ability for the garment to be mass produced must also be examined. Clearly it is important that the designer is knowledgeable in and has access to all aspects of the production process. Most designers are involved in a multitude of tasks including:

- Attending buying/selection meetings;
- Supervising the sampling of their designs;
- Managing the design department;
- Attending trade and fabric fairs for inspiration;
- Meeting the production technicians and managers when problems arise in the production of a particular style;
- Making patterns for their designs;
- Developing sketches and specification drawings of their ideas;
- Conducting comparative shopping trips to view competitors products;
- Buying/Designing fabric and trimmings;
- Conducting market research;
- Keeping up to date on technical innovations with cloth and trimmings.

This has provided a brief overview of the product development process in the clothing and textile industry and there will be many parallels between this and other industrial product development domains where the process will follow a broadly similar pattern. There now follows an exploration of the extent to which technology is used to aid clothing product development.

3.2.2. Computer Supported Design and Manufacture in the Clothing Industry

Many of the processes conducted in the design department of clothing and textiles companies can be carried out with the aid of computer technology, often referred to as Computer-Aided Design or CAD. Similarly the computer technology that is used to aid the manufacturing process is alluded to as Computer-Aided Manufacturing or CAM. Information can be passed between CAD and CAM systems in order to streamline production; this is also generally known as Computer-Integrated Manufacture (CIM).

CAD/CAM systems that are currently used in the clothing and textile industry assist in a variety of tasks including improving presentation, making product development easier and quicker and enabling companies to react to trends on a quick response basis. A CAD/CAM package used by a clothing brand may comprise some or all of the following :

- A graphics package for art and design work;
- A digital sketch pad and pen used by designers to enter or alter designs directly in the computer system;
- A digitiser used to input pattern pieces into the system;
- A scanner used to input designs or patterns into the system;
- Lay planning software to assist the lay planner in maximising fabric utilisation;
- Grading software to grade the basic pattern size up and down to smaller and larger sizes;
- Plotters to plot patterns and lay plans;
- Printers for printing out art and design work and production data;
- Computer driven cutters to cut out many plies of fabric at a time;
- Production control software providing the production manager with up to date information on how the production line is running;
- Computerised sewing machines;

- Computerised pressing machines;
- Warehouse control software informing the warehouse manager of stock and storage information;

New applications that could be added to this list are constantly being developed by the larger clothing companies, in an attempt to reduce their design and development times and increase production volumes and quality. Ideally, a CAD/CAM system should provide a central database which allows users to view or modify each stage of the production process from the sketch stage down to assembly and costing information. The importance of the use of technology in product development lies in the fact it can enhance efficiency by reducing development lead times, thereby enabling companies to be the first to get particular styles into the shops and in addition it can also improve quality. CAD reduces the time lag between the design concept and the finished product, enables fashion trends to be adopted more quickly and costs minimised. Furthermore it gives companies the opportunity for mid-season replenishment and enables the strict adherence to delivery dates.

Due to the low value, high volume nature of the clothing industry, quick response is becoming essential in order for a clothing company to compete. The requirement for quick response has been a major factor influencing the development of new computer technology in the design industries. However, many traditional designers express their regret at new computer technology entering the industry. On the whole younger designers are more likely to readily adopt computer technology, whereas older designers still have difficulty adjusting, (Hardaker and Fozzard, 1995). Undoubtedly clothing companies will have to start to keep abreast of new technology in order to remain competitive. As discussed later in section 7.2 of chapter 7, it is therefore essential that design support systems and tools should be developed with more user friendly and designer orientated interfaces, in order that the designers and other personnel are not deterred from adopting new technology.

Readers unfamiliar with the history and future trends of computer supported design and manufacture in the clothing industry should refer to Appendix A, entitled 'Brief Review of Computer Supported Clothing Design and Manufacture.' Increasingly design software is being viewed as an integral part of the design process, particularly with newly trained designers entering the industry. Software developers are beginning to work more closely with clothing industry personnel when developing computerised design support systems. The developers need an in-depth understanding of the designers role in order to develop effective tools. *'It is not surprising that the majority of computer applications are in the fields of science and engineering, because many computer experts have backgrounds in the broad scientific subjects and therefore are well placed to provide useful programs to their own community."* (Aldrich, 1994).

Traditionally software engineers have had a limited understanding of the textile and clothing industry and therefore software for the industry has often not been developed to its potential or it has been incorrect for the purpose. When designing design support software, the various sectors of the clothing industry within which the software will be used, must be taken into consideration. The user interface, which dictates how the user will interact with the software, must be sympathetic to the actual practice that the piece of software is supposed to replace or complement, in order not alienate the designers.

There are numerous benefits for a company in supporting the clothing design and production process with technology. The speed with which samples and designs can be produced can be increased, productivity can also be improved and if the software has been well designed and tested, accuracy in certain tasks which are subject to human error, should be improved. Computers are far less likely that humans to make silly errors when conducting repetitive tasks. The capacity for greater communication and sharing of information between the various divisions of a company can also be enhanced. Improvements in technology should lead to an overall increase in quality of the service and product offer. Lorenz emphasises that *'the ramifications of computer-aided design and manufacture for the management of product development* *are so far reaching ... they offer the opportunity to: design and develop products more rapidly than in the past; tailor designs to target market segments much more precisely and economically; radically improve the process of design for manufacture, so that expensive and time consuming rework can be avoided; and lower the unit cost of short production runs.'* (Lorenz, p26, 1990)

On the other hand there are of course pitfalls that come with the introduction of new technology to support design. Among these are the breakdown in person to person contact in the product development process. This is a very important aspect of any business. Other pitfalls are that further advances in technology need to be made before certain areas of CAD become acceptable. For example looking at an on screen image or print out of a fabric cannot portray its texture or feel. Other problems could occur due to lack of training to correctly use the software and problems of breakdown with the newly developed technology. It would certainly be wrong to assume that in the future most of the tasks currently conducted manually by a product design team could be replaced by computer systems, thereby eliminating the functions of some personnel. New technology aimed at supporting design should be used to enhance current working practices. The skill acquired by designers over years working as part of the design team will not be able to be replaced by a computer in the foreseeable future. *'It seems reasonable to view the design of a computer aided design system as a man-machine decision making system....The real difficulty with using this approach towards computer aided design is that we understand so little of the process as practised by man that it is by no means easy to define functions.....Design problems are rarely initially explicit, and thus even the designer is unsure of the goals.'* (Lawson, 1990, p.223)

This section has used a case study to outline how computer technology is used in the clothing industry. Many uses for technology have already been found in clothing design companies and there are many applications of technology to the design process currently being researched, such as the use of artificial intelligence in design support systems. In appendix A, there is a more detailed discussion about several potential areas in which advances can be expected in the application of technology to clothing product design in the foreseeable future. The rest of this chapter focuses on the specific type of computer support tool for designers that is relevant to this thesis: design knowledge bases.

3.3. Knowledge Bases to Support Product Design

Product designers need access to a lot of reference and archive information during the design process. The variety of data designers may wish to reference includes video clips, images and information on previously manufactured designs, data for inspiration, and catalogues of available components, materials, and trimmings. Much of this data they refer to could be retained for future reference in multimedia design knowledge bases. *'It is from an organisation's knowledge base that creativity and ideas for new products will flow....Without the continual accumulation of knowledge, an organisation will be hindered in its ability to create new product ideas.'* (Trott, p143, 1998). The drawback with many existing design knowledge bases is that they do not retain the context of the design information stored within them and have complicated, ineffective interfaces that are hard to navigate. This thesis goes on to show that a multimedia knowledge representation that pays a lot of attention to the underlying structuring of the data, utilises well designed interfaces and allows intuitive retrieval of information, would have great potential for use by product designers.

In most product design rooms, old design sketches, technical drawings, material samples, etc. are archived on paper or in storage boxes, therefore a designer would have to manually wade through thousands of old files in order to retrieve this information. In reality this is impractical and old product development data is rarely looked at or used again. Multimedia knowledge bases would allow designers to look at information on previous products and maintain a record of their design deliberations. There is a vast potential for using multimedia knowledge bases in product design and these knowledge bases may vary greatly in their design and specific purpose. However besides the initial problem of collating and organizing all this data, there is also the problem of retaining its context of (original) use and these issues revolving around the structuring of design data are discussed further in chapter 5.

There is a huge body of existing work on knowledge based systems intended to support design [e.g. (Bañares-Alcántara et al, 1995), (Candy and Edmonds, 1996), (Fischer et al, 1996), (Muller et al, 1996)]. Design information systems vary greatly in their format, with the straightforward design knowledge base at one end of the spectrum, providing simple retrieval according to a known key, such as the textile library developed for the London College of Fashion (Phillips, 1997). Progressing along the scale, more sophisticated methods of querying, accessing and retrieving the information can be provided with enhanced interfaces and querying techniques such as natural language processing and image matching. Muller's (1996) work at Delft outlines an image orientated design knowledge base which stores images of prior designed products according to a typology and allows designers to use it to acquire knowledge in order to aid the development of new concepts. At the other end of the spectrum we have far more ambitious knowledge bases that aim to account for the complex and 'messy' nature of design, some of which attempt to capture the design rationale. Previous research on design knowledge bases has tended to focus on engineering design [(De La Garza et al, 1996), (Potts, 1996), (Bañares-Alcántara et al, 1995)]. For industrial design it is not extensive and the best reported research is the JANUS application to kitchen designing which is underpinned by IBIS and uses a knowledge base to enhance the appraisal of design decisions. (Fischer et al, 1996). The intention with the work for this thesis was to create a knowledge base capable of handling large volumes of multimedia design data, that retains the context with the data, structures it in a manner to provide a useful design rationale and utilises effective graphical user interfaces to enhance access to the data.

3.3.1. Case Study: The Impetus for Multimedia Textile Knowledge Bases

This case study examines the impetus that exists for constructing even a simple knowledge base for use in product design such as a multimedia textile library. It also highlights some design criteria for the knowledge representation outlined in Chapter

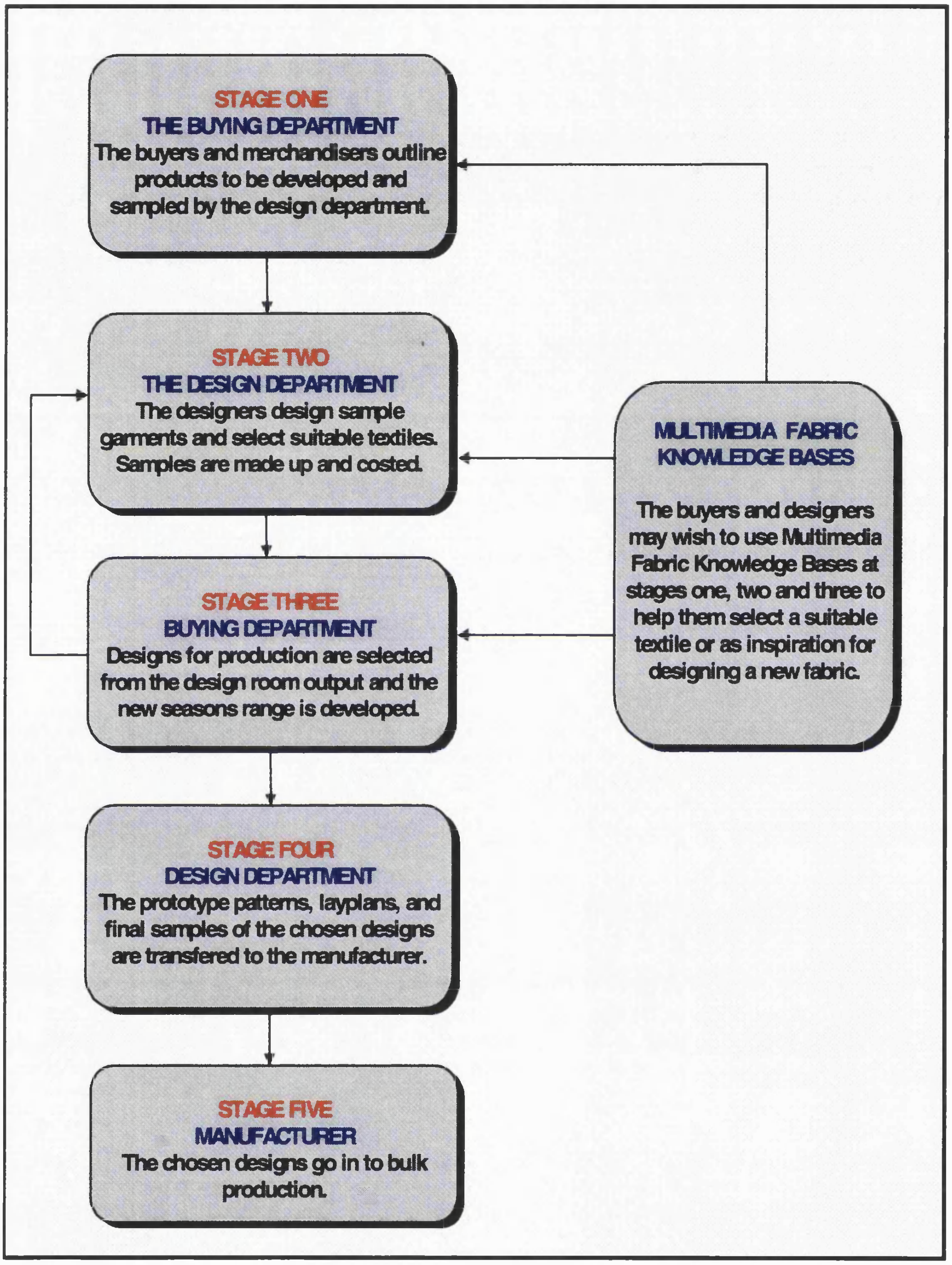
6. In this case study it becomes clear that even when developing an application as relatively superficial as a simple fabric knowledge base there are numerous aspects to be considered. Fabric knowledge bases are a specific type of multimedia knowledge base aimed at supporting textile and clothing designers. They could be used not only as a tools for inspiration, allowing designers to quickly browse through archive data on textiles, but also to search through current catalogues of fabrics available from fabric manufacturers. A Multimedia fabric knowledge base may either be stored in a static form e.g. on a CD-ROM and used purely for reference or alternatively used as a continually evolving knowledge base on a computer and regularly updated.

Multimedia Fabric Knowledge Bases in Relation to the Process of Clothing Design

In order to understand how multimedia fabric knowledge bases may support current practices in the process of garment design and production, it is first necessary to look at the role of the designer and analyse at what stage in the process a designer may need to use one. The clothing design and production process was described in section 3.2.1. Figure 3.1 summaries the process and gives an overview of the typical interaction between different departments during clothing production and the stages where multimedia fabric knowledge bases could be used, although in practice there are many more personnel and processes involved.

It would be a great benefit to both a designer or a buyer, at stages one, two and three, to be able to quickly retrieve images or video clips of fabrics that fit their desired selection criteria from either a centralised knowledge base, a CD-ROM or over the internet. The data retrieved on the textiles in the fabric knowledge base may also assist with the processing of other tasks, such as costings.

Figure 3.1: Multimedia Fabric Knowledge Bases in Relation to Clothing Production



In stage one buyers may wish to use multimedia fabric knowledge bases of archived fabrics as a reference tool when doing their research into the types of textiles they require in the coming seasons range. They may want to look up video clips and images of textile patterns and then show them to the designers to give them an idea of what they are looking for.

At stage two the designers may find it useful to use multimedia fabric knowledge bases supplied by the fabric manufacturers on CD ROM or over the internet, to search for a currently manufactured fabric that suits the selection criteria passed to them by the buyers. Alternatively if the fabric is to be specifically designed and manufactured rather than being picked from a ready made range, the designers may wish to refer to multimedia knowledge bases of fabrics either as a tool for research and inspiration or to check what fabrics have been used by the company in previous years.

At stage three of the process completed samples are passed back to the buying department. If the buyers are totally satisfied with the garments then they give them their seal of approval and they can go into production. However they may wish to specify some changes first. At this stage the buyers may still wish to alter the fabric, so a multimedia fabric knowledge base would be useful, enabling them to search for a fabric they have not used before to give the designers a closer interpretation of what the buyers are looking for. Alternatively if the sample is being rejected due to it not coming into the costing parameters then a multimedia fabric knowledge base could again be useful to search for a suitable fabric that would sufficiently alter the cost of the garment.

Implementing Multimedia Fabric Knowledge bases

A simple computerised fabric knowledge base was constructed containing images and attributes of the entire fabric library belonging to the London College of Fashion, for use as a tool by their design students (Phillips, 1997). The development criteria for this textile knowledge base can be seen in Appendix B and the user manual in Appendix C. This part of the research highlights not only the many potential benefits that can be gained from constructing a very simple knowledge base, but also some development criteria, (listed at the end of this section), that were taken into consideration later when developing the more complex and sophisticated design knowledge representation that forms the core of the field research.

The research showed that the underlying structure of the knowledge base is paramount and requires much consideration. In the fabric knowledge base created for the London College of Fashion, the requirements were quite straight forward and a simple relational database structure was used. However as expanded on in chapter 5, in order to retain design rationale and context careful structuring of the data is essential. The user interface is also critical, it dictates how the user will interact with the software and, where feasible, must be sympathetic to the actual practice that the piece of software is supposed to replace or compliment. The retrieval and storage mechanisms need to be as rapid as possible, in order not to deter the designers from using the tool. It is likewise essential that the number of screens the user must navigate through in the GUI, in order to store or retrieve textile data, be minimised allowing the users' time and patience to be preserved. Ideally a designer should be able to use the system immediately without having to read any system documentation first. The functions made available by the fabric knowledge base must be clearly displayed in order that the facilities offered are not under utilised. There are also technical considerations when developing a multimedia fabric knowledge base, such as how will the textile images be input into the knowledge base. All the technical and equipment considerations should be evaluated before development commences. A realistic assessment must be made of all the equipment that will be available, and the multimedia textile knowledge base must not be designed in a manner that would require expensive hardware that the end user is unlikely to possess.

Benefits of Multimedia Fabric Knowledge bases

Having utilised the textile knowledge base, the staff and students at the London College of Fashion pointed out further potential benefits of using multimedia fabric knowledge bases including:

- They empower designers to save time searching for and designing fabrics, freeing them to spend their time constructively on other tasks. It is clear that utilising multimedia fabric knowledge bases in industry would help reduce the time and costs involved in clothing and textile design, especially if used in conjunction with other computer aided design tools.

- They provide the capacity for greater communication and sharing of information at different stages in the product development process, not only among the design team, but also between the internal divisions of a company and with the relevant external organisations. Various divisions could be allowed access to a centralised multimedia knowledge base of fabrics via computer terminals placed in the departments.

- In a situation where a clothing company were to keep an up to date knowledge base of fabrics they had used, a new designer would be able to sit down at a terminal and view the types of textile designs the company had previously utilised. If the designer were considering producing a floral skirt, all the floral textiles used previously, could be retrieved from the knowledge base and viewed. This could be useful to the designer, either by providing them with inspiration for floral textiles or enabling them to be sure that a garment was not created that was too similar to one manufactured in the previous season.

- Multimedia fabric knowledge bases that are interactive, utilise well designed interfaces and allow intuitive retrieval of textile information, could have further implications for retrieval of information over the Internet. Textile weavers and printers could put their new season's range on-line and update them regularly in order that potential customers could have immediate access to information and images of the textiles they produce. This ability to remotely access large multimedia fabric knowledge bases via the internet, could considerably alter the way designers and textile producers work together in the future. To date, the full range of textiles manufactured by textile producers are largely inaccessible to design departments, with the manufacturers often being based in another country. Weavers will send out sample cards with small swatches of their new seasons fabrics, but if a designer wishes to view the whole range they would need to travel to the weavers headquarters or go to textile trade fairs. The ability to view the ranges remotely through a multimedia knowledge base over the internet, or on a CD ROM, overcomes the geographical problem, thereby saving the designer a considerable amount of time. It would also allow other personnel, such as design assistants, who may not have been given the chance to travel to the textile producers, the opportunity to view all their fabrics. In a situation where a textile weaver has produced many fabrics, a multimedia knowledge base that has been well indexed, would also save the user time when searching for fabrics with particular properties.

- With the potential of putting the knowledge bases on the internet or CD ROM, textile knowledge bases need no longer to have their access limited by geographical location. The issue of multimedia fabric knowledge bases overcoming the problems of viewing inaccessible textiles is further highlighted with the case of fragile fabrics that can easily be damaged. Antique fabrics are often very delicate and can be damaged by light, moisture in the atmosphere or acid on the surface of human hands. Such fabrics are often archived away and are completely inaccessible to most people. A multimedia knowledge base would be ideal in this sort of situation, allowing images and video clips of the archived fabrics to be stored on a CD ROM or computer and viewed without any damage being caused to the delicate fabrics.

- As opposed to a traditional manual textile library, the new multimedia knowledge bases will consist of electronic data that cannot only be viewed and interpreted but also manipulated. This presents the opportunity to plug other hidden interfaces into the knowledge base which can perform certain useful actions and assist with further processing of the data. An example of such an interface might be a piece of software developed for costing garments. This software could be knowledgeable about the necessary costing heuristics, thereby allowing it to communicate with the fabric knowledge base and calculate what the fabric cost for a garment would be after seam allowances, wastage etc. had been accounted for. Alternatively, once a fabric had been retrieved from a knowledge base, it could potentially be transposed onto 3D models in a virtual catwalk show, allowing users to assess and interpret the fabric's suitability for a particular garment design.

- Alongside overcoming access and geographical location difficulties and fragility of fabrics, multimedia fabric knowledge bases would also improve communication between textile producers and clothing manufacturers. They would facilitate seamless communication between involved parties and enable the integration of the fabric knowledge bases into existing systems. The aim for the future should be to link multimedia fabric knowledge bases into integrated clothing design systems. It is not hard to envisage some of the benefits of such integration. A designer might then be enabled to conduct such tasks as retrieving a desired fabric from a multimedia design knowledge base, and immediately viewing the fabric imposed on a three dimensional image of a garment design that they had previously constructed using CAD software, before having a sample directly constructed on a linked computerised production line.

It is clear from the above that capturing multimedia data on fabrics in a simple electronic knowledge base provides designers with numerous advantages during the design process. It is easy to envisage how many more benefits could be gained by extending this to capturing the complete design rationale along side multimedia data on other elements used during the design process such as trimmings, and design drawings.

Multimedia Fabric Knowledge Bases Challenges

Having utilised the textile knowledge base, the staff and students at the London College of Fashion also pointed out various different kinds of barriers including cultural, psychological, organisational, knowledge elicitation and technical obstacles that would need to be overcome or addressed in order to successfully introduce multimedia fabric knowledge bases as a standard design support tool including:

- Traditionally it has not been part of textile and clothing designers culture to adopt the use of computer technology in their working practices. This is gradually changing but it is however surprising how many design departments still do not possess any computers whatsoever. A change is required to overcome the psychological barriers that many designers posses to using computer technology and to alter the typical clothing designers perception of computers as machines which stifle creativity.

- Organisational changes may also be required if the use of multimedia fabric knowledge bases is to be widely adopted among mass market clothing designers. It is unlikely that computers will be in the design department if they have not already been introduced into the other departments within a clothing company. Considerable investment will often be needed to install appropriate computer systems throughout an organisation. Appropriate staff training would also have to be given, in order to ensure the systems were exploited efficiently.

- Other personnel in a company may wish to use a multimedia fabric knowledge base alongside the designers. For example, the staff in the costing department may want to look up an appropriate fabric price when doing rough costing estimates for garments. Consequently the textile knowledge bases would have to be designed in a fashion that people from multi-disciplinary backgrounds would find easy to use.

- Technical limitations and challenges would need consideration and addressing, such as the problem that looking at an image or video clip of a fabric on a VDU cannot effectively portray its tactile qualities.

- Understanding the process clothing designers go through when choosing fabrics and eliciting this knowledge from them presents a further challenge. The importance of using appropriate knowledge elicitation techniques is explored further in Chapter 4.

- The structure of a fabric knowledge base and what it might consist of, would require careful examination. It would be very difficult to design a generic textile knowledge base that could be used across the industry, because terminology and methods of working can vary quite widely in differing sectors. The purpose of a multimedia textile knowledge base would have to be clear at the outset in order that the specific needs could be met of the sector it was to be used in. It is not realistic to think that clothing designers right across the industry will use computer aided design support tools such as multimedia textile knowledge bases in the same manner. Clothing designers working at the couture end of the clothing market work in a very different manner from those working designing clothes for the high street. At the high end of the market, garments can cost thousands of pounds each and therefore greater amounts of time and money can be lavished on creating and designing fabrics specifically for each individual garment. A designer working in this area is likely to conjure up images of the fabrics they require in their mind and then have those fabrics specifically woven. Therefore their predominant use for a multimedia knowledge base might be as tools for design research or inspiration. On the other hand, a designer working in the middle or lower end of the market, where many garments will be made out of the same fabric and each garment is required to fit into a strict costing, could find multimedia fabric knowledge bases to be most useful when searching for fabrics with suitable specifications.

It became evident in this study that it is critical not to just consider how multimedia knowledge bases may support the current working practices of product designers but also to explore how technology may enable new ways of working. Changes instigated through the use of multimedia knowledge bases will be dramatic in the future, not only enabling the whole product development process to be speeded up, but also facilitating different methods of working. Multimedia fabric knowledge bases may actually change some of the designers work practices and provide them with numerous additional facilities to manual textile repositories. Where some tasks may be altered by the introduction of multimedia fabric knowledge bases, others may be made entirely redundant. It is important not to restrict ourselves by thinking of them merely as a direct electronic replacement for the old methods of working.

In summary this research into textile knowledge bases highlighted not only the many potential benefits and challenges posed by constructing a very simple design knowledge base, but also the following development criteria which were taken in to consideration later when developing the more complex design knowledge structure to capture product design rationale collated during the field study:

1. The underlying structure of the knowledge base is paramount and the purpose requires careful consideration before embarking on construction. Chapter 5 reflects in detail on a suitable underlying structure for the design rationale knowledge base constructed to structure the data collated in the field study.

2. A design knowledge base must facilitate ease of access to the information contained within it, be simple to navigate and have a graphical user interface that makes the functionality of the knowledge base as visible as possible, is sympathetic to the task at hand and compliments the domain. Section 7.2 of chapter 7 examines in detail the issues surrounding the GUI requirements for the design rationale knowledge structure built as a result of the field study.

3. When developing design support tools there is the further challenge of encouraging design teams to use the software so it becomes an inherent part of the designers psyche and is adopted for everyday use as part of the design process. To aid this, design knowledge bases should be developed with close consultation of the personnel that will be using them. The design rationale representation constructed to structure the knowledge elicited in the field study was built with constant consultation and feedback from the members of the design team involved.

4. Technical considerations should also be accounted for, such as problems of efficiently inputting multimedia data and finding an appropriate storage medium to account for the large file sizes of video and image files. However this was outside the scope of this research when constructing the design rationale knowledge base that forms the focus of the field study.

3.4. Summary

The first part of this chapter is dedicated to showing how technology is increasingly being used to support product development. Section 3.1 describes how computers are utilised to enhance a wide variety of tasks within companies involved in product design and development. It then elaborates on how a design rationale knowledge representation could be used within three of the potential roles for the use of computers in a design environment identified by Lawson (1990).

The second part of this chapter in section 3.2 provides a case study that explores how computer supported design and manufacture has been deployed within the specific industrial product design domain of the clothing industry. It serves to illustrate the extent to which technology is being embraced by companies involved in product design and development. Section 3.2.1, the first part of the case study provides an overview of the clothing design and manufacture process in order to facilitate the reader to comprehend how and at what stages technology may be utilised in clothing design and production. Section 3.2.2, the second part of the case study goes on to give an outline of CAD/CAM in the clothing industry and it explores the benefits and pitfalls of the introduction of such technology.

The final part of this chapter focuses on the potential in product design for using design knowledge bases. Section 3.3 provides an introduction to this specific type of computer support tool for designers that is relevant to this thesis: knowledge bases to support product design. The extensive body of work and wide variety of knowledge based systems intended to support design is alluded to. It is emphasised that the intention with the work for this thesis was to create a knowledge base capable of handling large volumes of multimedia design data that retains the context with the data, structures it in a manner to provide a useful design rationale and utilises effective graphical user interfaces to enhance access to the data.

In section 3.3.1 a case study exemplifies the impetus that exists for constructing an elementary knowledge base for use in product design such as a multimedia textile library. It serves to demonstrate how even a simple knowledge base can enhance product design in many ways. The potential benefits and challenges posed when constructing a very simple design knowledge base of this type are listed along with some development criteria to be taken into consideration later when developing the more complex design rationale structure to capture the product design rationale during the field study.

The next chapter focuses on knowledge elicitation methods and the process whereby the design knowledge in the field research was elicited is outlined. A case study illustrates the depth of knowledge required to be collated by the knowledge engineer in order to have useful data for a design knowledge base.

CHAPTER 4:

FIELD STUDY DESIGN KNOWLEDGE ELICITATION

This chapter presents a clear shift in emphasis to the empirical field study of the design process which forms the central part of this research. Initially there is a brief treatment of general issues concerning knowledge elicitation but the chapter predominantly deals with the process undertaken during the knowledge elicitation stage of the field research. The depth of knowledge required to be collated in order to have useful data for a design knowledge base is illustrated. The importance is emphasised of using appropriate methods to elicit the often tacit design knowledge, such as the design values. The knowledge elicitation methods that were chosen for the field research are described and particular attention is paid to the repertory grid method. An insight is provided into the typical components of a product development range strategy and this is exemplified by the range strategy developed following the initial phase of the knowledge elicitation during the field study. Finally an overview is given of the design and marketing infrastructure elicited from the design team in order to facilitate the later construction of a more accurate representation of the design process. The chapter concludes with a summary of the critical points.

4.1. Design Knowledge Elicitation

In order for a design knowledge base to be developed, there is clearly a requirement for an empirical study of the design process and elicitation of expert knowledge from experienced personnel in product development. McGraw and Westphal emphasise the importance of using experts as opposed to novices when conducting knowledge elicitation, '*for not only have experts stored more information, but they have organised it into more structurally and hierarchically meaningful patterns than have novices.*' (McGraw and Westphal, 1990, p.57). In view of this, in depth field research was conducted with an American sportswear brand (referred to in the rest of this thesis as brand X), in order to elicit detailed data during the design process, from an experienced product design team. This field research is outlined in section 4.2

Appropriate knowledge elicitation tools and techniques must be selected in order to extract as much tacit knowledge from designers as possible. Elicited design data forms the backbone of a product design knowledge base. Design knowledge elicitation is a pre-requisite to the construction of a design knowledge base and clearly once a structure for a design knowledge base has been established then knowledge must be continually elicited and added to the knowledge base in order to maintain it. A member of the design team, already immersed in the design process would be an ideal candidate to collate the information for the knowledge base. They would be able to effectively identify the appropriate data to be structured within the knowledge base and would be less likely to have to interject or interrupt the flow of the design meetings in order to elicit the knowledge than an independent knowledge engineer, unfamiliar with the design process.

To construct an effective knowledge base approaches to knowledge elicitation are required that help to define the design values held by the design team, since as emphasised in section 2.1.5 of chapter 2, values play an important role in a design's justification and rationale. The values held by the designer, or the company the designer works for underpin the aesthetic and semiotic aspects of a product's design. Branded products in particular require a platform that ensures discipline and adherence to brand values. A brand knowledge base that structures the design rationale and encompasses the brand values would help maintain a unique and competitive position in the market. A product design is not arrived at by following a pre-defined, hierarchical process, step by step, or by simply examining all the functional and non-functional requirements and constraints. As alluded to in chapter 2, the design process is far more complex than this. Furthermore, with product design there is always a trade off, not all the requirements can be satisfied to the full and consideration needs to be given to how designers subconsciously confer weightings to the requirements according to their importance and effect on the end design. The design process can't be understood by simply examining the design requirements and constraints. The principal challenge lies in appreciating and eliciting the designers' values, knowledge and the issues they see as being critical to the design of the product.

4.2. Field Research Design Knowledge Elicitation

Figure 4.1 shows the process undertaken in the field research. Initially appropriate knowledge elicitation tools and methods were chosen and these are outlined in section 4.2.1 Subsequently the design values and relevant design knowledge were elicited from the design team based on their views of the brand and its previous ranges. As expanded on in section 4.2.2, the design team found that conducting repertory grid exercises was a particularly useful practice at the outset of the development cycle. It enabled them to form a concrete and cohesive brand strategy which is described in section 4.2.3 and verify that they all held the same or similar belief systems in respect of the product ranges. Following this elicitation of the design values and discussions with the design team, a range strategy and explicit range plans for each of the ranges were produced before the design and development process commenced. The details of the individual range plans can be seen in appendix D. A range strategy of the type described in section 4.2.3 would ordinarily be produced at the outset of each new development season, but the design team felt that this strategy had been enhanced by the prior knowledge elicitation exercises conducted. The business and market environment were also taken into consideration during the formation of the strategy. The new product range was then developed and as will be elaborated on in chapter 6 the design rationale and the data resulting from this was structured into a design rationale knowledge base that was iteratively referred to and updated throughout the design process.

An overview of the design and marketing infrastructure is given in section 4.2.4. This information was elicited from the design team to provide an insight into the mechanics of the design process within brand X, in order that the design knowledge gleaned once the development process commenced was more comprehensible to the knowledge engineer facilitating accurate structuring of the design rationale. As outlined in section 4.2.1, once the development process had begun in earnest only knowledge elicitation techniques that did not interrupt the flow of the design process, such as observation and recording of design meetings, were utilised.

It was intended that ultimately the knowledge base would store and structure all the information utilised during the development process, relating to every element of the products' development from their design to their marketing strategy. Data of varying type would be stored including technical and design drawings not only of final products that were sent into production but also of prototypes developed to a certain point and then for one reason or another discarded. Information on why the prototypes in question were not used could be stored along with the rest of their design and development information. It would enable the design department to track progress, in terms of their product and marketing design, season by season and to easily demonstrate the evolution of products.

Figure 4.2 demonstrates the variety of data that the design team highlighted would ideally be contained in their product design knowledge base. It includes points of reference to the inspiration behind the products and their marketing and also data on their competitors' products. As touched on in section of 1.3.1 of chapter 1, the knowledge base needed to be developed on a multi-media platform to enable text files, image files, video clips, audio clips and animation to be stored. Multimedia technology enables diverse file formats to be incorporated and is suited to detailing the varying kinds of design related information required during the design process. Much of the data contained in the knowledge base would be visual, by nature of the fact that designing garments is a very visual activity. The images and data within it would need to capture the design issues that the designers/experts see as being inherent in the products. This adds further weight to the argument that extensive knowledge elicitation would need to be conducted in order for the end results to be effective. It was envisaged that the knowledge base would grow rapidly and would become an increasingly invaluable source of reference and inspiration. The tool's use would not need to be restricted to the design department and a direct benefit of it would be that it could be used to ensure that all departments have a clear understanding of the design process and product values.

Certain challenges presented themselves during the knowledge elicitation stage of the research. Initially there was difficulty in obtaining data from designers, a lot of the large companies involved in product design are reluctant to part with information about their design process. A further challenge was searching for the most effective method of eliciting the issues that the designers saw as being critical to the products design. Much of the rationale behind the designs was implicit and could not be easily expressed by the designers. The methods chosen are elaborated on in the following section.

Figure 4.1: Eliciting Design Knowledge To Enhance Range Development

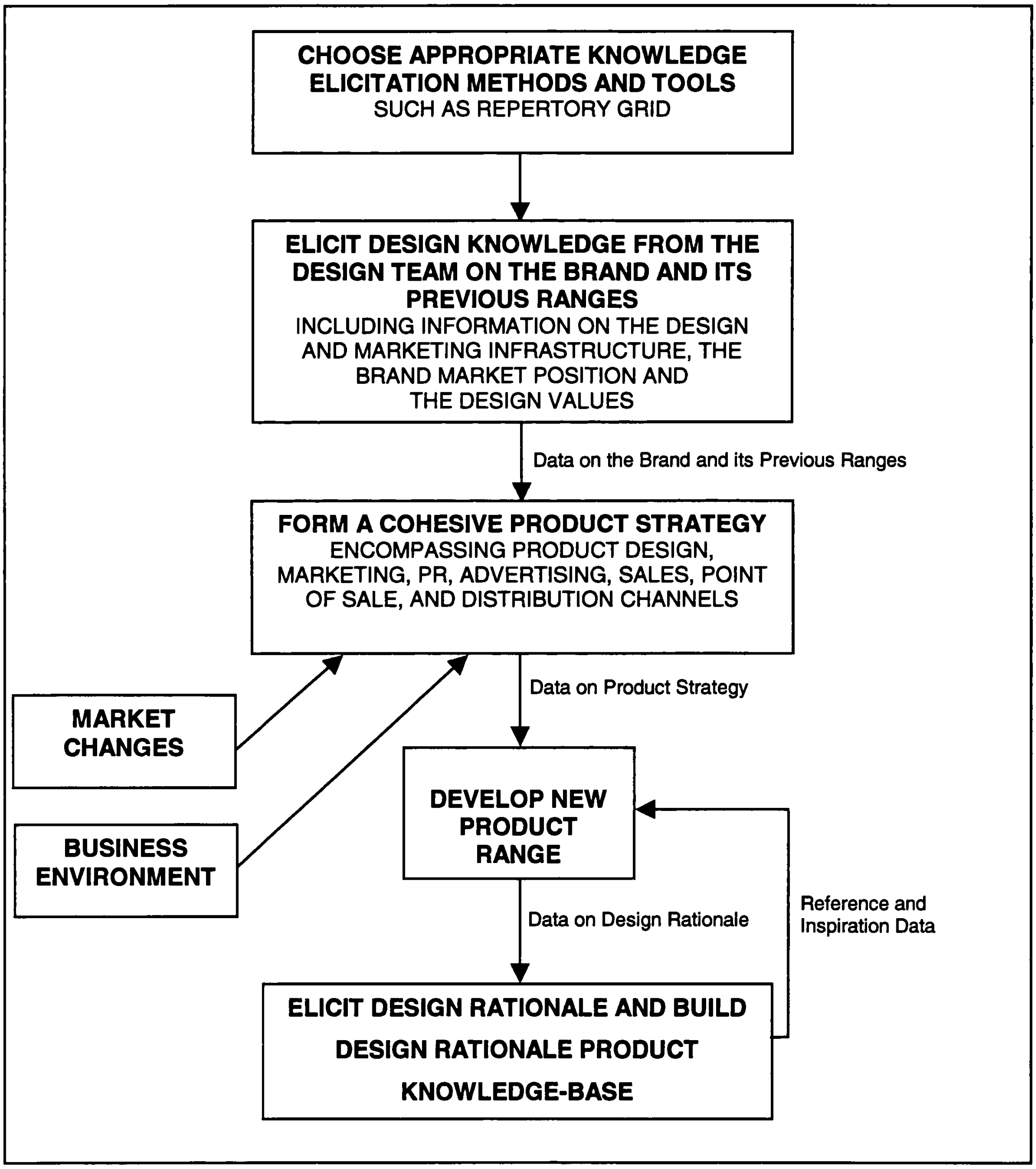
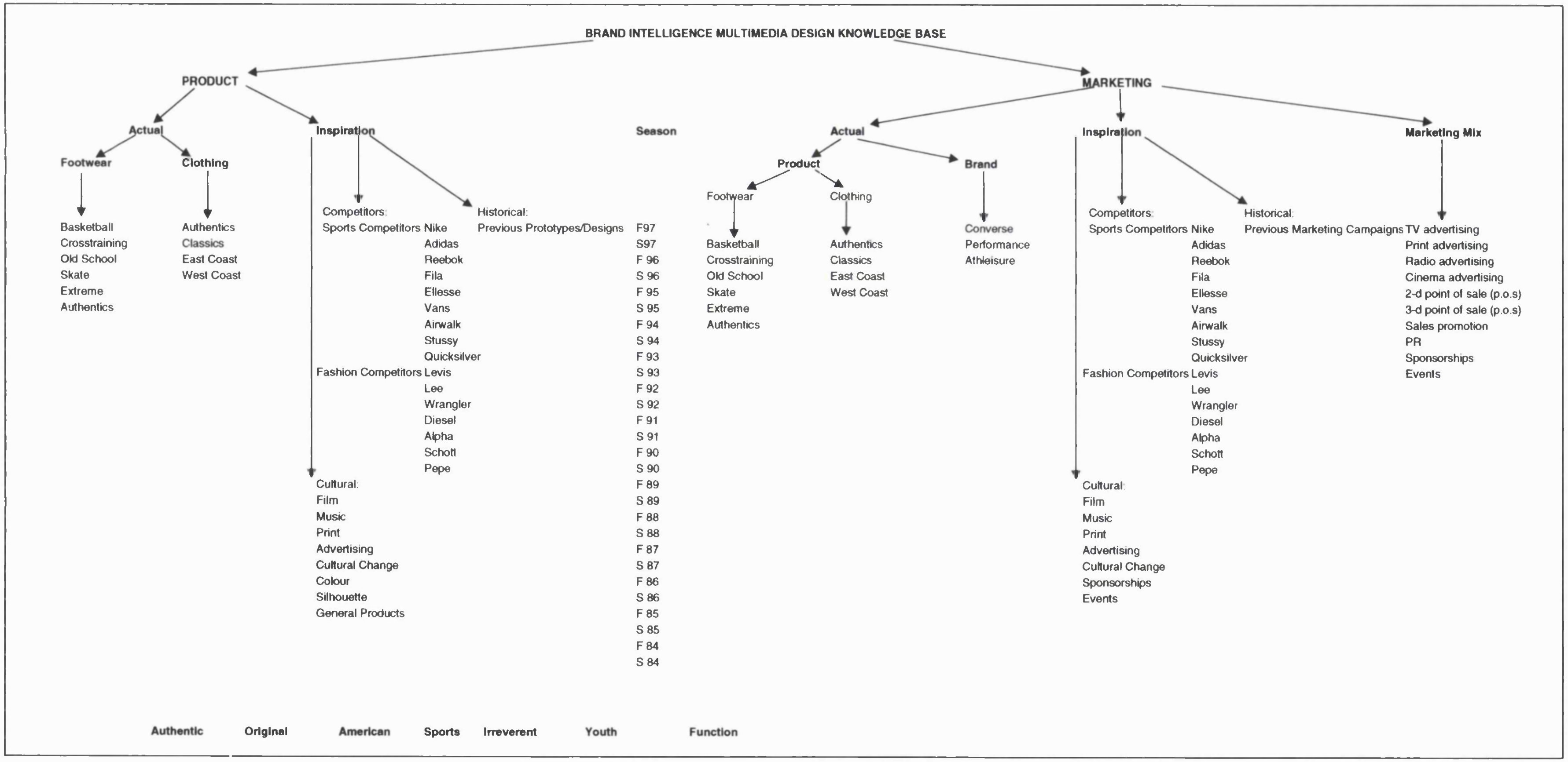


Figure 4.2: Potential Information Genres to be Incorporated in a Product Design Knowledge Base



4.2.1. Knowledge Elicitation Methods Used in the Field Study

Neale, in his review of knowledge acquisition methodologies, provides a concise appraisal of the various knowledge acquisition and elicitation techniques, (Neale, 1988). The primary techniques that were suited to the field study were structured and unstructured interviews, repertory grid analysis, observation and audio recording of all the design meetings. It was felt that the combination of these methods would provide the knowledge engineer with an in depth understanding of the mechanics of the design process within the company, give insight into the design values held by their design team and cause minimal disruption to their working practices while providing a vast and rich source of data.

The initial aim was to extract as much knowledge as possible about the brand as a whole and the overview of the design and marketing infrastructure in section 4.2.4 is a result of this. Structured and informal interviews were conducted with the European marketing director, the product development team and the external graphic design agencies. Their product portfolio includes trainers, clothing, watches and accessories and it became apparent that it would be more appropriate to focus on one part of their product range for the more detailed knowledge elicitation exercises. Four new clothing ranges were being introduced into their European market: Authentics, Classics, East Coast and West Coast. These ranges were used as the focus of the knowledge elicitation research in the field study. Subsequently repertory grid exercises were conducted and this is elaborated on in section 4.2.3. This enabled the values the design team held about the brand and it's market positioning to be elicited.

Once the Spring/Summer 1998 range development process commenced it was followed in detail and where location allowed, the range development meetings were attended for one whole product development cycle (5 months). The meetings were observed and all the discussions transcribed and any documentation resulting from or used during the meetings, including any visual references and notes, were collated. During the formal design meetings, care was taken not to distort their flow by interrupting or interjecting with questions. However outside of these meetings further knowledge was gleaned from the design team by conducting structured and semistructured interviews both with individuals and the team as a group, in order to gain a deeper insight into the design process and collect enhanced data. A schedule of the design meetings and formal interviews can be seen in appendix E. The construction of a knowledge base using an IBIS notation to structure the data, commenced as soon as the design process began and this is described in more detail in chapter 6. Doing this enabled the design team to refer to the knowledge structure as the design season progressed and reassess their design goals and objectives. The knowledge structure evolved with the progress of the design process and became an increasingly useful resource for the designers.

4.2.2. Repertory Grid Exercises

Kelly developed the repertory grid theory in the 1950's. Fransella and Bannister in their manual on repertory grid technique state that, '*Kelly devised repertory grid technique as a method for exploring personal construct systems. It is an attempt to stand in others' shoes, to see their world as they see it, to understand their situation, their concerns.' (Fransella and Bannister, 1977).* The repertory grid provides a basis for extracting the views or values that people hold about an entity or entities and can be used to model expertise. *'The repertory grid was an instrument designed by Kelly to bypass cognitive defences and give access to a person's underlying construction system by asking the person to compare and contrast relevant examples (significant people in the person's life in the original application). This use of relevant examples has also been important in the application of repertory grids to expertise modelling.*' (Gaines and Shaw, 1993). Before the design process commenced repertory grid exercises were conducted using software that enabled the results to be graphically plotted relatively quickly. Manual elicitation of the results would have been an extremely time consuming process. Gaines and Shaw emphasise that, '*repertory grid methodologies are difficult to undertake manually as they require feedback and management from the elicitor while at the same time attempting to avoid inter-personal interactions that would distort the elicitee's conceptual structures. Hence the advent of the personal computer in the mid-1970s and its evolution into the graphic workstations of the 1980s has been very significant for the practical application of the approach.*' (Gaines and Shaw, 1993).

In the field study repertory grid exercises were conducted with the design team to elicit the predominant design values the design team held about brand X and assess where the design team saw the positioning of the four product ranges in relation to these values. The result of these exercises are demonstrated in figure 4.3 and 4.4. Other repertory grid exercises were also conducted to elicit and verify the brand's market position in relation to its competitors and the results can be seen in figure 4.5 and 4.6.

There were two main advantages to conducting the repertory grid exercises. Firstly they provided a tool to draw out the brand values the design team thought should be inherent in the product range and assess whether the product development team all held the same values about the products they were designing. This was important since the data within the knowledge base would be gleaned from all the members of the product development team and if there were discrepancies between the *design* values held by the different members, it might account for inconsistencies in the information collected. Secondly, from the knowledge engineer's point of view, going through the repertory grid exercises was a good precursor to attending the design meetings and collecting the design rationale data. Conducting the repertory grid exercise on both the brand values and market positioning facilitated a more in depth understanding of the company's design strategy and market, which made the content of the design meetings at a later date, easier to comprehend. Gaines and Shaw reinforce the value of using the repertory grid in the early stages of the knowledge elicitation process: '*The grid is the starting point for analysis and refinement, not necessarily in itself a conceptual structure, but rather a set of data that must be accounted for by any conceptual structure developed.*' (Gaines and Shaw, 1993)

Figure 4.3: Repertory Grid - The Product Ranges' Positioning in Relation to the Brand Values

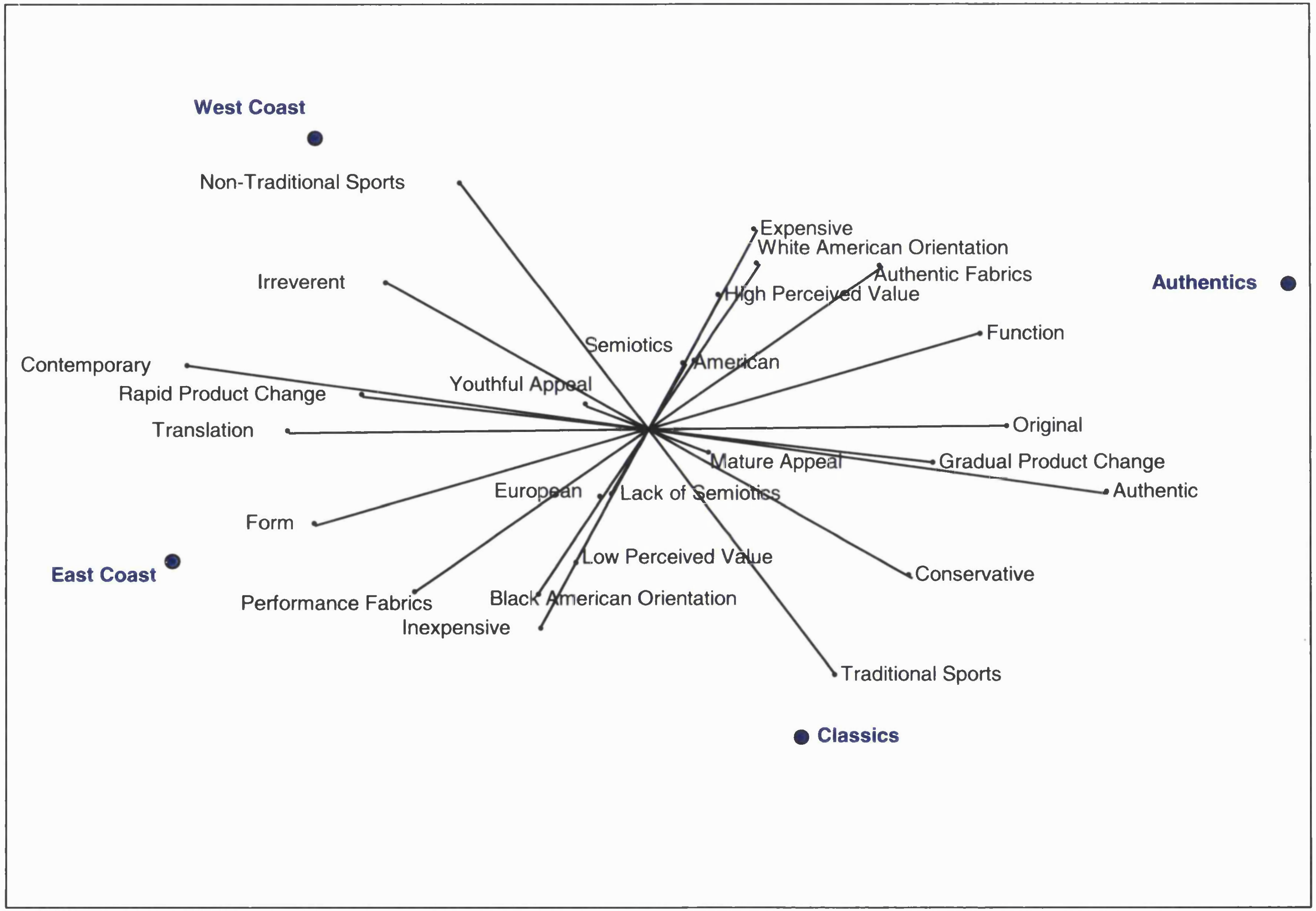


Figure 4.4: Eliciting the Positioning of the Product Ranges in Relation to the Brand Values

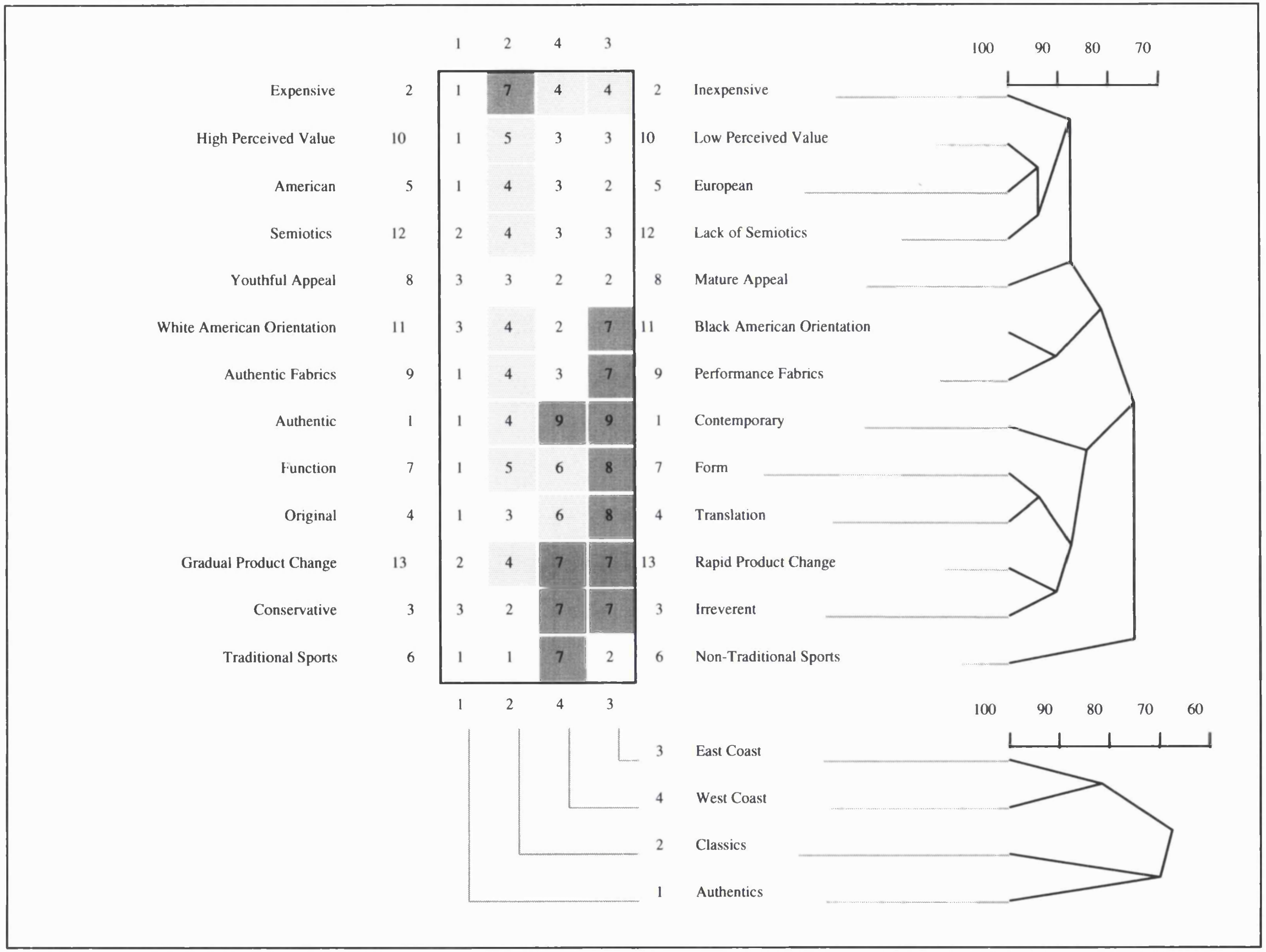


Figure 4.5: Repertory Grid – The Brand's Market Position in Relation to its Competitors

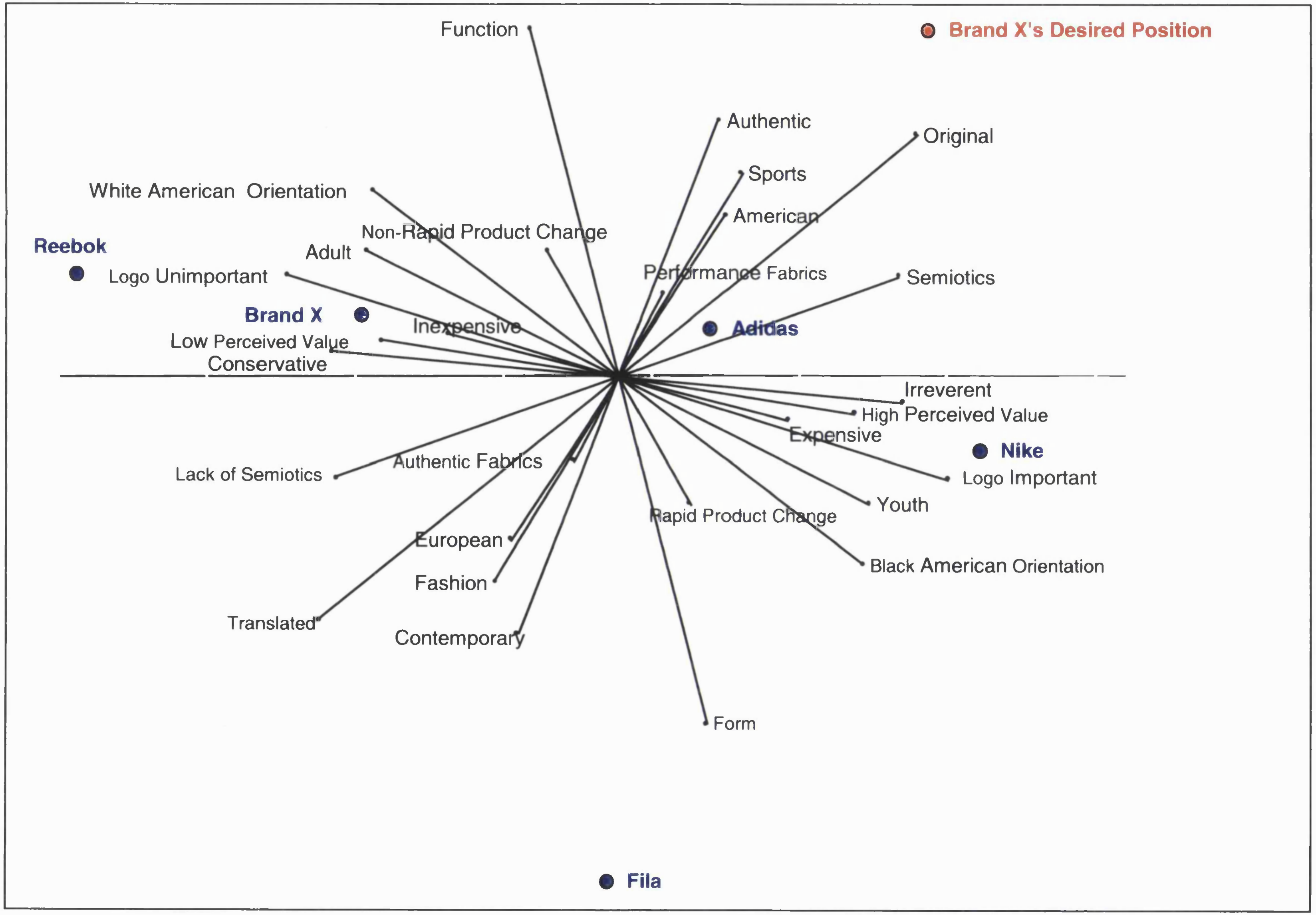
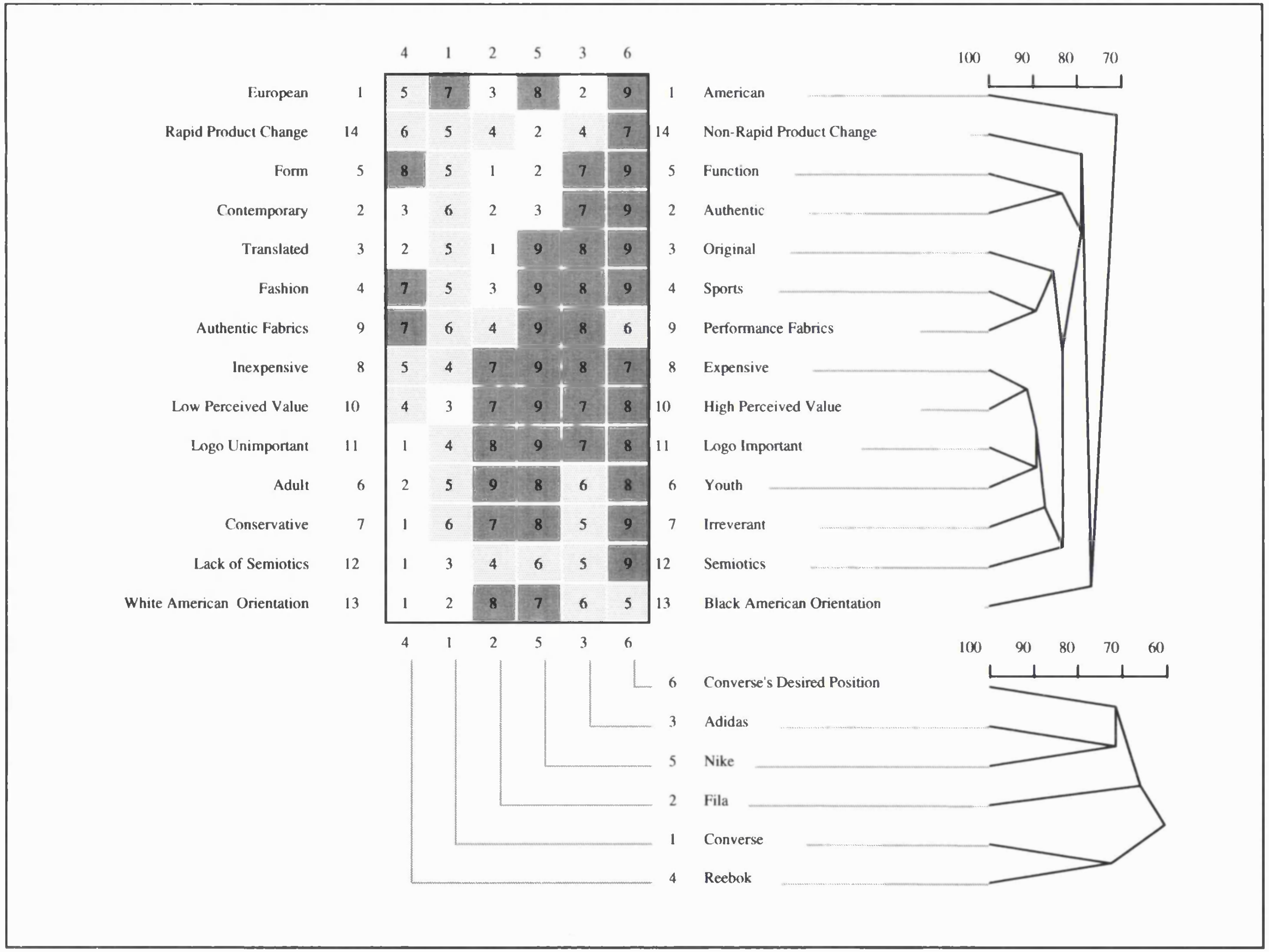


Figure 4.6: Eliciting The Brand's Market Position in Relation to its Competitors



4.2.3. Range Strategy

A range strategy in clothing product development would typically include a mission statement, range objectives, and a range plan. A range strategy would ordinarily be produced at the outset of each new development cycle, but the design team in the field study felt that their strategy had been enhanced by the prior knowledge elicitation exercises conducted. As elaborated on in the previous section, the design team found that conducting repertory grid exercises was a particularly useful practice at the outset of the development cycle. It enabled them to form a more concrete and cohesive brand strategy and range plan and verify that they all held the same or similar belief systems in respect of the product ranges. Following this elicitation of the design values and discussions with the design team, a range strategy was produced before the design and development process commenced.

A mission statement provides a design team with the overall goal and focus for the range to be developed. In the field study the mission statement was as follows:

> Mission Statement
>
> The MISSION 2000 in respect to the European Clothing ranges is to: *'Build a clothing brand that is instantly recognisable, and a distinct alternative to major competitors.'* The brand must become firmly positioned as the authentic, original American sports brand, a true alternative to the competition in terms of product, marketing and service. The aim is to clarify and focus the marketing and product resources to engineer a platform from which the brand can emerge as the original, authentic, American, sports brand in the eyes of not only the retailer, but also the consumer. Opinion leading cultural and fashion trends must be interpreted as early as possible and presented to the market place faster than in competitors' products. The new clothing ranges must marry the rich heritage of American sportswear to the existing brand values.

Before commencing a new development cycle a design team must also appraise themselves of the current status of the company or brand. In the field study the design team called this 'The Reality':

> The Reality
>
> The brand is an American sportswear company with a heritage in basketball. The product offering is competitive but not a true alternative to the competition. The marketing strategies are comparable but by no means better than the competition.

Range objectives are used to break down the overall mission statement into manageable aims which the ranges must account for and rules to which the ranges must adhere. In the field study the range objectives were defined as follows:

> Range Objectives
>
> - The ranges must assist the brand to become the alternative brand to the sum of their competitors;
> - The cultural and fashion trends of both west coast and east coast American urban culture, must be addressed by the new ranges;
> - The ranges must address the commercial and competitive needs of the market;
> - The ranges must address the differing positioning requirements of the brand and at the same time maintain a balance between the collections;
> - The ranges must be innovative and not simply be copies of competitors' products. A successful branded clothing line cannot be launched by manufacturing staple products such as plain T-shirts and putting the brand's logos on them. Neither would it be successful if they simply tried to copy their competitors;
> - The designers need to concentrate on the perceived values within the range and build inherent semiotic values into the fabric, construction, branding and styling. Each product within the ranges must exhibit two constant

semiotic details, other than the logo, that will identify the garment as being a product belonging to this particular brand;

- The ranges must represent all that is authentic and original within American sport;
- The ranges must only exhibit the three core logos in their pure form;
- The ranges must only use the colours red, white and blue in the logos unless they use a totally black logo;
- As much perceived value as possible must be built into the ranges.
- Long term growth in each market for the clothing ranges must be ensured.
- Strong retail partnerships must be developed and an integrity adopted when choosing distribution channels.
- Marketing campaigns and programs must be devised to ensure there is a consumer demand for the products. These marketing programs should be specifically defined through the core values of the Authentics range and go in to great detail about the authenticity of the products' design and styling etc..

Once the mission statement, current state of the brand and the range objectives have been defined by a design team a more detailed range plan can be drawn up containing information and direction for each product to be developed. The specific range plan for each of the ranges that were developed during the field study can be seen in more detail in Appendix D but a brief over of the four ranges, Authentics, Classics, East Coast, and West Coast is as follows:

Authentics Range

This range must pay absolute homage to original, authentic, American products in terms of styling, fabric, construction, colours and logo application. The objective is for it to be the Levi's of the Sportswear industry. This is to be the premium collection, acting as the signature for the brand's clothing line and carrying the advertising for all the ranges.

Classics Range

This range must be the "take - down" version of the Authentics range, coming in at a lower price point. It should form a basic collection of sportswear garments, with fewer products than in the Authentics range. It must embody wholly the brand values. However, the governing factor throughout is the price and competitiveness. The Classics range is a diffused version of the Authentics range outlined above.

West Coast Range

This range must have its roots in west coast American culture and at its core must be the west coast lifestyle. The range must endeavor not to be a cliché of the west coast culture, but rather to take only that which is authentic and original from within it. The range is required to strike a balance between commercial volume and brand image.

East Coast Range

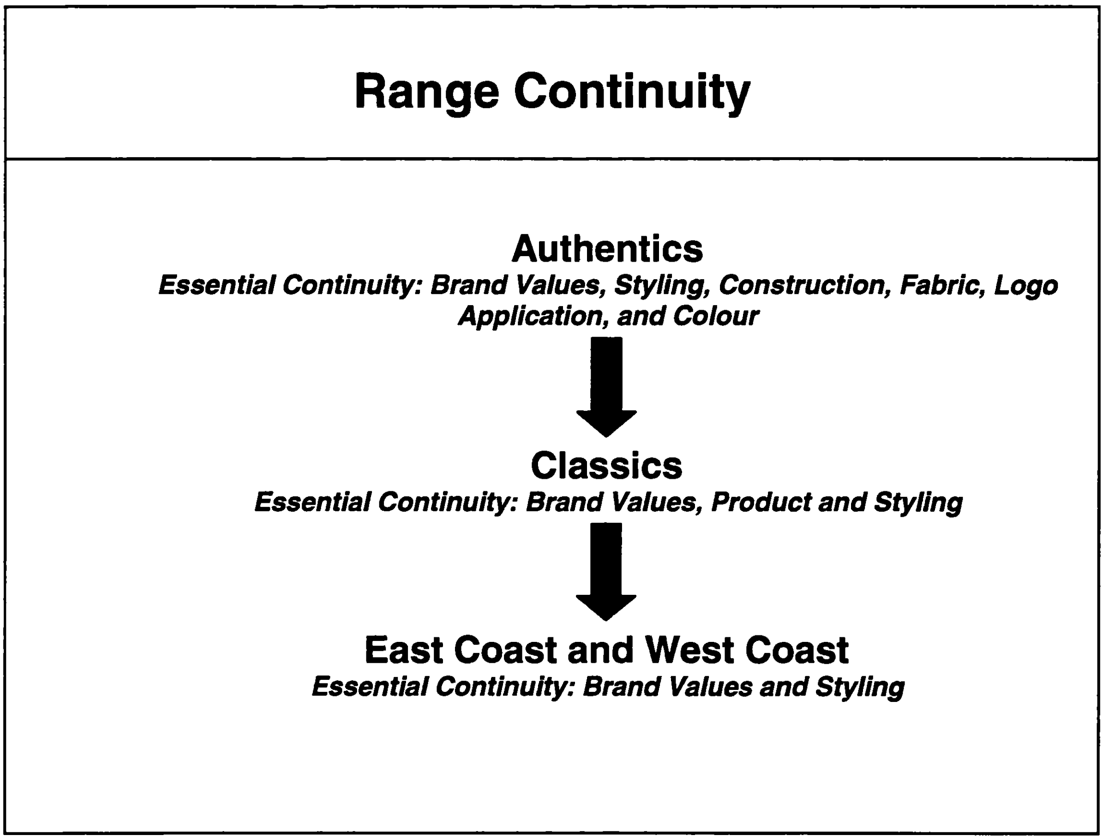
This range must have its roots in east coast American culture and encompass the east coast lifestyle. It must endeavor not to become a cliché of the east coast American culture, but rather to take only that which is authentic and original from within it. The range must strike a balance between commercial volume and brand image.

Range continuity is further factor that is critical when developing a new product range and which must be accounted for in any range strategy produced by a design company. This is particularly true where brands are concerned since as discussed in section 2.1.4 of chapter 2, it is essential to maintain integrity and a strong identity with branded products. The design team in the field study developed the following guidelines for continuity in their ranges and it is exemplified diagrammatically in Figure 4.7:

Range Continuity

The Authentics range is to change the least from season to season, incorporating only incremental changes, and retaining continuity each year in terms of its product, styling, construction, fabric, logo application and colour details. Similarly the Classics range is to only incorporate incremental changes and always maintain continuity in terms of its product and styling. The East and West Coast ranges need to encompass more dramatic changes but it is still considered to be essential that continuity is maintained in terms of the general styling and that the inherent range values are not lost.

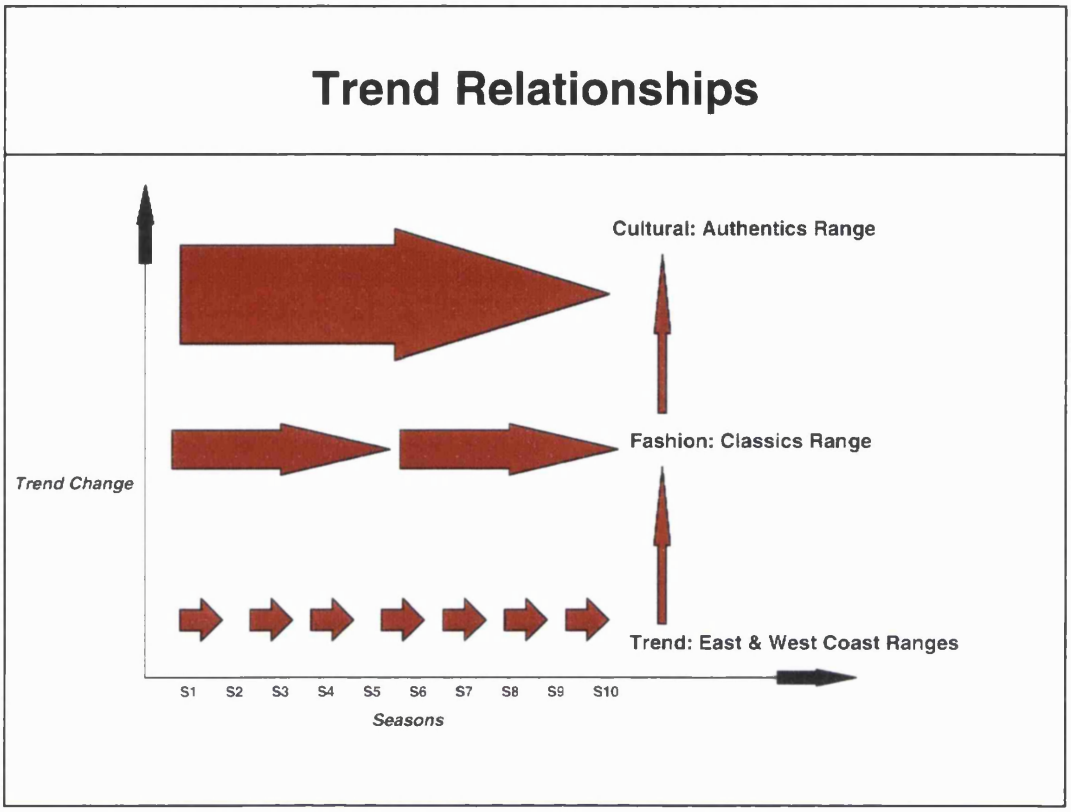
Figure 4.7: Range Continuity for the Ranges in the Field Study



A further consideration that product designers must account for in their range strategy is the relationship of changes in trends and fashion to the products, particularly for ranges which carry over for a number of seasons incorporating just a few incremental changes. In the field study the design team developed the following guidelines for trend susceptibility in their ranges and this is exemplified diagrammatically in Figure 4.8:

> Trend Relationships
>
> The Authentics range should be the least susceptible to changes in fashion or trends, taking its influences from authentic, historical sportswear products. Changes to this range as seasons progress should be minimal and the range will be influenced by cultural changes.
>
> The Classics range should be susceptible to changes in fashion but not to changes in trends. A trend would normally only last for one season, as opposed to a fashion which may last for two or three seasons.
>
> The East and West Coast ranges should be susceptible to changes in trends allowing the aesthetics of the ranges to change quite dramatically from season to season, although the core values of the range must not be compromised.

Figure 4.8: Trend Relationships for the Ranges in the Field Study



4.2.4. The Design and Marketing Infrastructure

The mechanics of the design and marketing infrastructure for brand X was elicited from the design team before the start of the design process. Its purpose was to provide the knowledge engineer with an understanding of the design and marketing processes in the company, in order that the design knowledge gleaned once the development process commenced was more comprehensible, thereby facilitating accurate structuring of the design rationale. The remainder of this section provides a summary of the information elicited on brand X's infrastructure. It serves to illustrate the extent of the roles typically involved in product development. Not all product design companies would be structured identically to this but many follow broadly similar lines. If carefully implemented and managed, a design rationale knowledge base would be a useful reference point for the personnel involved throughout the infrastructure, but training would be essential in order that it was clear how to refer to and update it.

The Design and Marketing Infrastructure at Brand X

In clothing, the design and production is handled by a product manager but sourced externally by a licensee who would control the production aspects of the product development process. The licensee manufacturing the clothing then owns the inventory but the brand sell and distribute the products in return for a sales commission and a royalty for the use of the brand name. The clothing is licensed out on a regional basis, i.e. there is a pan European clothing licensee in Denmark, who is supervised by the European non footwear product manager. The same applies for the United States, the South Pacific and South America. Once the broad strategy has been finalised internally, the designers at the clothing licensee are briefed on the product requirements and the frequent meetings with them are usually very informal . They always have their own product manager and often designers or consultants from either the licensee or external agencies are at product development meetings. Sometimes additional members from either side attend the meetings. The main product development meetings are held according to a pre agreed critical path, but sometimes meetings take place off the cuff whenever the unexpected occurs.

Manufacturers in Copenhagen, Portugal and China are used for the clothing production. There are two seasons a year called 'Fall' and 'Spring' and development for each starts eighteen months in advance. The sources of inspiration for the products changes over time but include competitors ranges, film, technological change, fabric changes, television, music, fashion, cultural change, and design rich product domains such as cars. The designers collate the visual influences along with the marketing manager and the designers from the other agencies. This is usually an informal process with no real defined procedures. Products from recent ranges are generally only referred back to when designing the new ranges if they have had a tremendous sell through. However in some of the ranges there is a lot of demand for really old styling from the fifties and sixties. These designs are researched and then re-worked for the modern market. In clothing the Authentics range is based on original American sportswear. The ability to look at old designs, in particular patterns, colour, logo application, construction techniques, and fabric, is important for all the ranges. However for the Authentics range it is essential that authenticity is retained as far as possible in the styling, so old products manufactured by the company in the fifties are purchased from vintage clothing dealers. Competitors' products are also examined, particularly the retro ones, for design influences. Further styling inspiration is not usually taken from direct competitors, but from less direct and more opinion leading competitors further up the diffusion life cycle, in order to translate their influences into products for the mass market.

As shown in Figure 4.9, the marketing director decides in conjunction with the category managers and senior vice president of marketing, the overall strategic direction of the brand. The marketing manager is then briefed on the marketing requirements for the forthcoming season. All elements of the marketing mix need to be considered in the brief. Specific market opportunities are catered for with special makes. During the design process the retailers and sales men from all over the world will preview the range to ensure its global suitability. Once a prototype range has been developed it is then shown to the sales force and key retailers before any final changes are made. The predominant European design and marketing personnel can be seen in Figure 4.10.

Figure 4.9: Personnel Involved in Forming the Product and Marketing Strategies

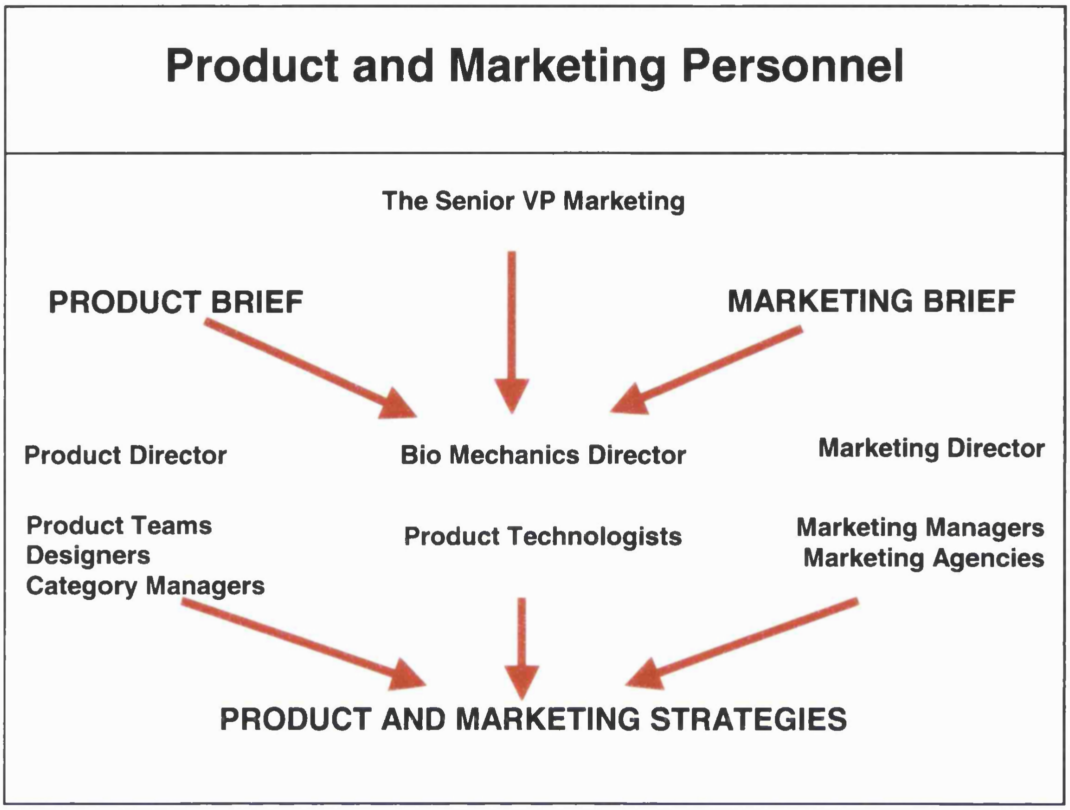
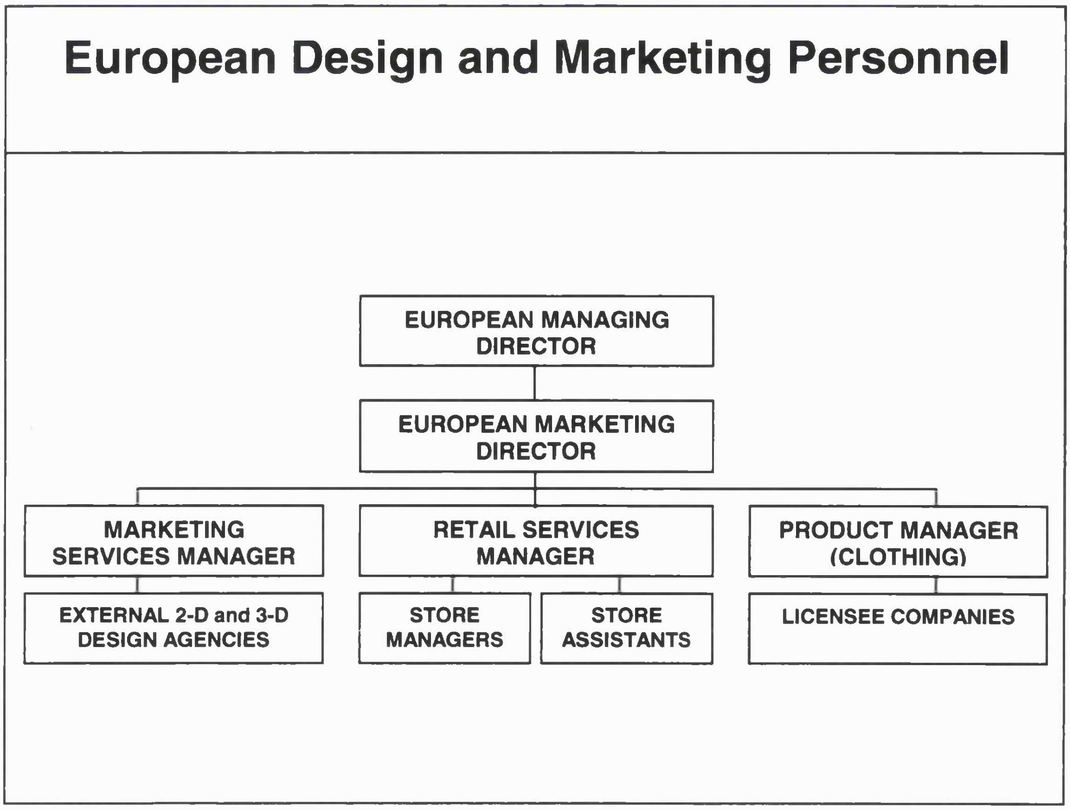


Figure 4.10: European Design and Marketing Personnel



A description of each of the main roles involved with developing the products is as follows:

Product/Category Managers

The product or category managers control the product ranges. They are responsible for identifying market gaps and the weak and strong sellers from the previous season. They work with the buyers from the key retail accounts who provide their preferences for the forth-coming season. The category managers also cross reference the range against any strong marketing opportunities to ascertain whether there are any additional product opportunities.

Key Account Buyers

The buyers from the key retail accounts give their opinion on the general design and brand direction for the entire range. Sometimes they require specific styling or colour details on certain products, and these are classed as "special make ups" and would be given to the account exclusively in return for a large order. Retailers use this aspect of the design process to gain exclusive products in order to differentiate themselves on the high street.

Marketing Managers

The marketing managers brief the category managers on the overall strategic direction of the brand for the forthcoming season. They define the values of the brand, within which the category or product managers need to work. The category managers then start to develop the range plan which must satisfy the demands of the retailers and the marketing managers and will be applied across all the price points. In turn the designers are then briefed by the category managers so they can design the products, collaborating with the bio-mechanics director and production engineer.

Designers

The designers develop the aesthetics of the products, choosing all the materials and designing the style to fit in with the range plan and objectives.

Bio-Mechanics Directors

The bio mechanics directors ensure that the products are fit for their purpose, e.g. basketball. Bearing in mind that some basketball players are seven foot tall and can weigh seventeen stone, the products must incorporate the best technology to ensure they perform well under extreme pressures.

External Agencies

For all of the external agencies involved in the design process, as shown in Table 4.1, the marketing manager directly briefs the account handler or the designer from the agency on the creative issues. No promotion ever goes ahead without the full approval of the retail marketing manager and the brand marketing manager or marketing director. Once the broad strategy has been finalised the 2-D agencies are briefed on how to develop the packaging and the 3-D agencies on how to develop point of sale. Once the first round prototypes of both footwear and clothing has been developed, the packaging and point of sale must be finalised. At this stage the advertising must be developed and it must be ready in order to show the retailers the full product support package of the packaging, point of sale and the advertising at the trade shows. At a later stage the promotions and media agencies will be involved, when the products are closer to being launched in the consumer market place.

Table 4.1: Types of Outside Agencies Used

Company Type	Company Contacts
PR Agency	Account Handler
Ad Agency	Account Manager Creative Director Creatives
Media Agency	Account Manager Media Buyer/Media Strategist
3 -D Design	Account Manager Designers
Promotions	Account Manager Creatives
2 - D Designer	Designer

4.3. Summary

This chapter introduced the design knowledge elicitation undertaken in the field study. Section 4.1 gives a brief introduction to the necessity for an empirical study of the design process and elicitation of knowledge from personnel immersed in the product development process in order to create an effective design rationale knowledge base. Section 4.2 outlines the detailed field research conducted with an American sportswear brand referred to in the rest of this thesis as brand X for reasons of commercial sensitivity. The process undertaken during the knowledge elicitation stage of the field study to elicit the design knowledge that underpins the knowledge representation referred to in chapter 6 is described. The potential information genres that could be incorporated into a product development knowledge base are also introduced. The importance is emphasised of eliciting the tacit design knowledge, not usually explicitly expressed by designers, such as the design values.

The appropriate knowledge elicitation methods that were chosen for the field research are elaborated on in section 4.2.1. The extent of the field study conducted deserves emphasis. Every formal design meeting was attended for a whole product development cycle and design knowledge elicited with regard to the four product ranges under development during that time. A schedule and transcripts of these meetings can be seen in appendices E and F. Conducting such extensive field research enabled a depth of understanding of the design process within brand X that otherwise would not have been possible. It facilitated the later structuring of a design rationale representation rich in design knowledge and that proved a realistic testing ground from which to assess the requirement of a more useful design rationale knowledge base. Section 4.2.2 pays particular attention to the repertory grid exercises conducted with brand X to extract and verify the values the design team saw as being inherent in the brand and assess where the design team saw the positioning of the four product ranges in relation to these values. The repertory grid was also shown to be a valuable tool for providing the knowledge engineer with a more in depth understanding of the brand identity and market position.

Section 4.2.3 provides an insight into how a range strategy might typically be broken down into a mission statement, range objectives and a range plan. This is exemplified by the range strategy from the field study developed following the initial phase of the knowledge elicitation. The design team from brand X emphasised that the strategy was enhanced by the prior knowledge elicitation exercises conducted. The importance of the concepts of range continuity and trend relationships are also underlined. In the final section 4.2.4 a summary is provided of the information elicited on the design and marketing infrastructure within brand X. The purpose of eliciting this information on the infrastructure was to facilitate the accurate structuring of the design rationale at a later stage.

The next chapter discusses the motivations behind capturing design rationale. It introduces argumentation based design rationale methodologies as a means of structuring the elicited design knowledge from the field study.

CHAPTER 5:

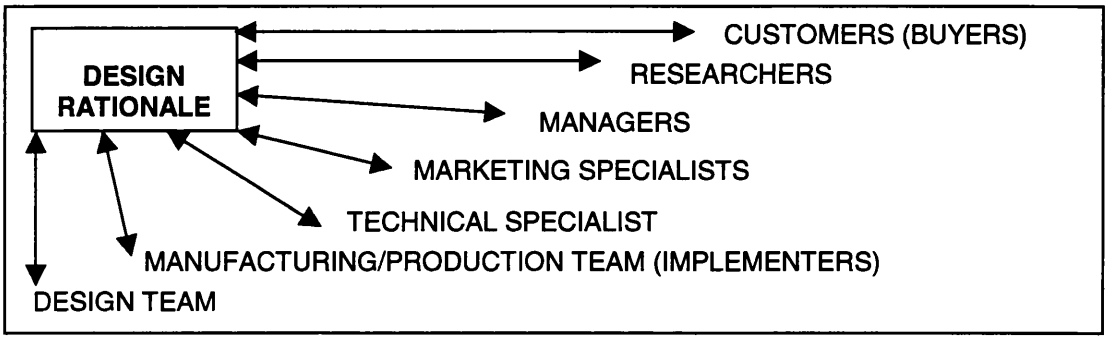
ARGUMENTATION BASED DESIGN RATIONALE METHODOLOGIES

This chapter discusses the motivations behind capturing and maintaining a design rationale representation. The reasons why there exists greater potential for capturing design rationale in the domain of product design as opposed to engineering design are presented. Argumentation based design rationale methodologies are introduced as a means of initially structuring the elicited design knowledge from the field research. The three predominant notations are examined: Questions, Options and Criteria (QOC), Decision Representation Language (DRL), and the Issue Based Information System (IBIS). The chapter concludes with a critique of the methodologies. IBIS is identified as providing the most suitable notation from which to construct a representation of the design process exemplified in the field study using the data collated during the knowledge elicitation stage of the field research. The chapter concludes with a summary of the critical points.

5.1. Representing Design Rationale

Maintaining a design rationale encompasses capturing the reasoning behind a product's design and development. Bañares-Alcántara et al argue that '*Design rationale encompasses the justifications supporting the decisions of a designer or group of designers. Keeping and using the rationale in a design is an important requirement for directed and relevant design support.*' (Bañares-Alcántara et al, 1995, p.196) The benefits of capturing design rationale have been cited as including: leading to a better understanding of the design space and of the issues involved, to provide a basis for documentation, communication, learning, justification, traceability, computational support, artifact re-design, re-use of design knowledge, verification of goals being fulfilled, and to enable current and future reflection on the design, thereby supporting the future design decision making process [(Lee and Lai, 1992), (Fischer et al., 1991), (MacLean et al., 1991)]. Moran and Carroll (1991) reinforce that capturing design rationale enables designers to reflect on their reasoning at different stages in the design process, facilitates communication of the design rationale to others, and enables the design knowledge to be reused or reflected upon in future design projects. Some personnel that could make use of a design rationale can be seen in Figure 5.1, and include members of the design team, the production team, the marketing department and also the customers.

Figure 5.1: Contributors to and Users of Design Rationale



This stage in the research involved conducting an analysis of the most suitable method to construct a design rationale representation during the product design process. The ultimate aim was to develop a knowledge structure that could effectively capture design rationale over a period of time and encapsulate the justification behind product development, providing context to the multimedia material that is a by product of the product design process. The intention was to empower designers to track their product and marketing design progress, season by season and make visible the evolution of the products. In chapter 2, the often tacit nature of product design knowledge is discussed. A chief consideration when capturing design rationale is attempting to encapsulate an implicit process and this tacit knowledge as an explicit representation. Before starting to collect data and document in detail a whole design cycle, notations and methodologies on how to structure the initial knowledge representation were considered.

A body of research exists on capturing design rationale in the field of engineering design [(Bañares-Alcántara, et al, 1995), (Brice and Johns, 1999), (De La Garza et al, 1996) and (Lee, 1991)], using argumentation based notations, but as noted by

Shipman and McCall (1996) capturing design rationale has not generally been successful in practice. However very little has been done previously in relation to capturing the essence of the ergonomic and aesthetic considerations of industrial product design and usefully structuring product design rationale. As discussed in detail in section 2.1.7 of chapter 2, although there are parallels between the design process in engineering and industrial product design, there are also a number of distinctions. It is worth re-examining the design rationale notations previously used mainly with engineering design with a view to applying them in the domain of industrial product design. The amount of design re-use prevalent in industrial design suggests that there exists a greater potential benefit to capturing design rationale in industrial product design as opposed to engineering design where the data is not primarily visual in nature, the focus is on technical excellence, design cycles are long and aesthetics are of minimal importance. This thesis asserts that capturing industrial product design rationale has greater potential than capturing engineering design rationale for the following reasons:

- The focus of product design is on ergonomic and aesthetic issues and much of the data used and referenced during product design is very visual. In product design fashion has an important role to play and fashion trends are cyclical. Maintaining a design rationale would ensure that when a fashion cycle comes full circle the design process and rationale used when the trend was previously encountered could be referred to and utilised to provide aesthetic inspiration for the current product range. This is in contrast to engineering where technical excellence is paramount and the techniques used rapidly advance and therefore there is no requirement to hark back to old methods being used in design cycles many years previously.

- In many industrial product design domains the design cycles are much shorter than in engineering design. Since the design cycles are short the aesthetic trends and design influences discussed in the previous design cycle are more likely to hold some relevance to the current design cycle than in domains where the development cycle is very extended and at the close of it most of the development rationale will be outdated. In product design old designs can be referred to for inspiration and design input can sometimes be recycled. In certain instances the same products from the previous cycle's range might be incorporated into the current range with only minimal, incremental changes being instigated to the design of the products. In engineering design the development cycles are often long and may last for a number of years, the benefit of being able to look back at a record of the design rationale once the cycle has finished diminishes. The reason for this is that in the space of a number of years engineering methods and technology can greatly advance and therefore at the start of a development cycle there would not necessarily be a great gain to be had from making reference to methods used at the start of the previous development cycle a number of years ago.

- In the case where a product is branded, design consistency and integrity is paramount. Due to the aesthetic focus of product design, a design rationale knowledge base could prove particularly useful in maintaining design consistency and brand integrity. A knowledge base could be referred to in order to ensure product ranges in subsequent cycles incorporated the correct and consistent design values and could be used as a reference point for any member of personnel to appraise themselves of the aesthetic personality of the products.

As discussed in section 2.1.3 of chapter 2, Rittel and Weber (1984) endorsed second generation design methodologies which encourage exploration of a design problem through a process of argumentation in order to address the complexity of design issues. Existing design rationale notations are based on a model of argumentation and it therefore seemed appropriate to consider the three dominant argumentation based design rationale methodologies as a starting point for structuring the design knowledge elicited during the field research. The three methodologies scrutinsed were the Issue Based Information System (IBIS), Questions Option and Criteria (QOC) and

Decision Representation Language (DRL). Section 5.5 reveals why a notation underpinned by IBIS was eventually chosen to structure the elicited design data.

5.2. Issue Based Information System (IBIS)

Much of the current research on capturing design rationale is based on variations of the more broadly applicable Issue Based Information System (IBIS), first described by Kunz and Rittel (1970). IBIS stems from an argumentation based model of problem solving and is intended to '*guide the identification, structuring and settling of issues raised by problem solving groups, and provides information pertinent to the discourse.*'(Kunz and Rittel, 1970, p.1) Its original purpose was as a system to characterise, order, and resolve questions raised by co-operative groups of people in administrative government agencies and provide relevant information for the discussion. It was intended to facilitate the organisation and structuring of complex problems and decision processes within organisations, in order that a plan for a solution could be arrived at. Problem solving typically involves deliberation between members of a group, who each have their own expertise and perspectives. A feeling of agreement and a strategy emerges from the deliberation, along with resolutions to the issues at hand.

IBIS offers a solid structure with which to explore the deliberation between group members. The legal moves in an IBIS structure can be seen in figure 5.2. The essential elements are issues, positions, and arguments. Issues are questions that require a resolution and an IBIS dialogue always starts with a root issue. The positions are ideas that proffer possible solutions to issues. The arguments are statements which either support or object to the positions. IBIS also incorporates the following relationship types which link the issues, positions and arguments in a hierarchical structure with the main issue at the root: Positions may *Respond to* Issues; Arguments may *Support* Positions; Arguments may *Object to* Positions; Issues may *Generalise* other Issues; Issues may *Specialise* other Issues; Issues may *Replace* other Issues; Issues may *Question* other Issues, Positions or Arguments; Issues may Be *Suggested by* other Issues, Positions or Arguments.

Through the process of issues being put forward, positions relating to them being stated and deliberation of the positions, a topic is explored and the participants gain an enhanced understanding of the issues. Kunz and Rittel (1970) emphasised that during the process there would be several different types of information being exchanged including a) between the members of the group, b) with the experts used, and c) with reference documentation to support the issues raised. With the more traditional documentation systems, the major problem was that they did not retain any of the structure of the deliberation between the members of a group or the working procedures followed and they did not provide the ability to compare similar issues that may have arisen before. IBIS attempts to combat this lack of expressiveness found in the more traditional systems by making the discussions explicit. Furthermore, using IBIS should actually enhance the whole problem solving process, ensuring that as many avenues as possible are stated, explored and fully considered. IBIS can also be used to demonstrate a snapshot of the state of play of the deliberation between the group at any one moment.

Figure 5.2: Legal moves in IBIS

Source: Conklin and Begeman, 1988, p.305

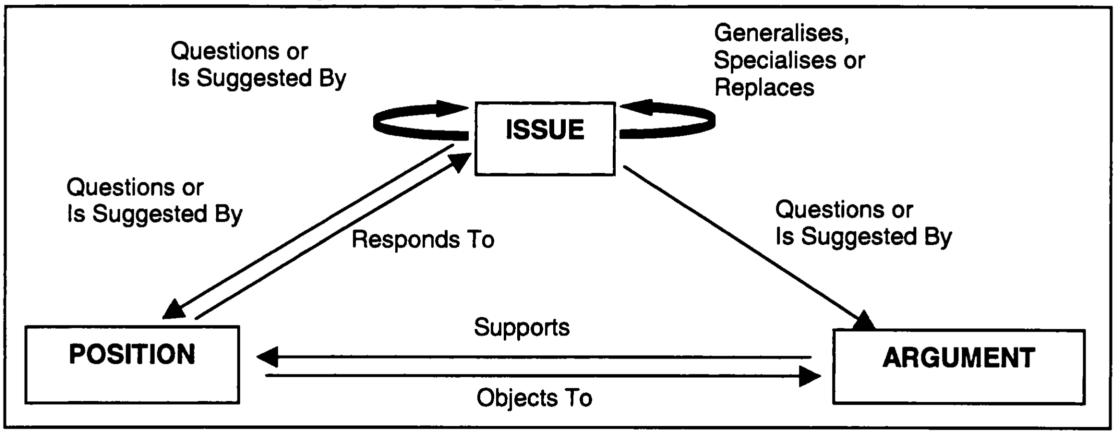
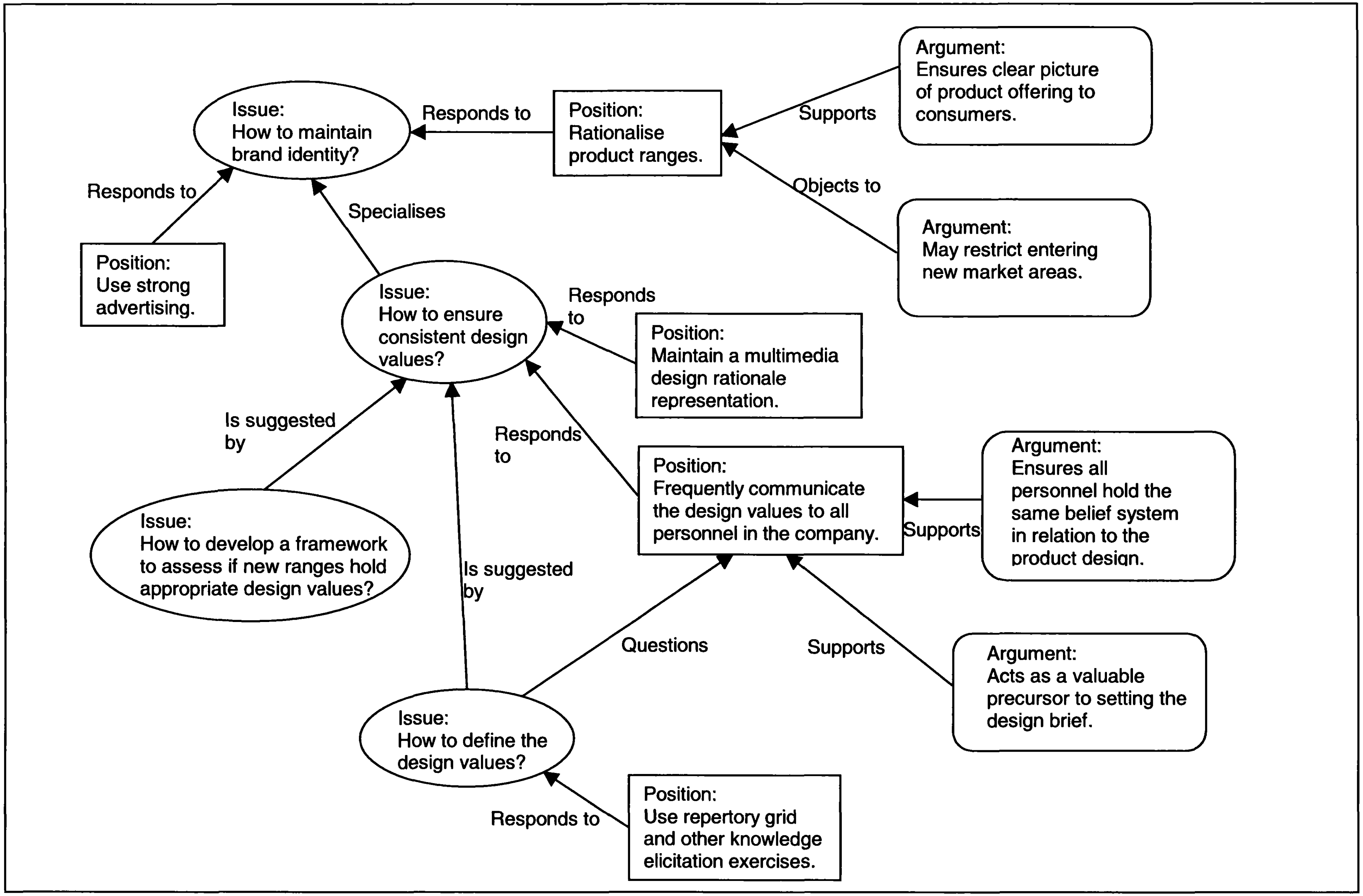


Figure 5.3 uses the IBIS notation to elaborate some of the issues centering on maintaining brand identity and the role of design values as discussed in sections 2.1.5 and 2.1.6 of Chapter 2. It serves to demonstrate the basic dynamics of the IBIS notation. The same example is executed later with the other two notations discussed in sections 5.3. and 5..4.

Figure 5.3: A Segment of an IBIS Dialogue

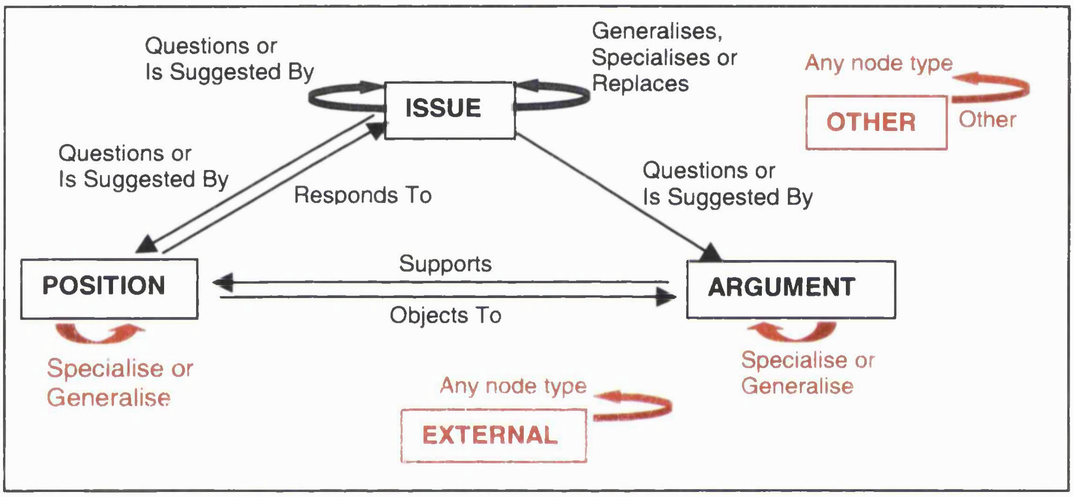


As outlined earlier, IBIS is intended to organise the process of handling problems in ill-structured domains, modeled in terms of an argumentation structure. In section 2.2 of chapter 2 the product design process was indeed shown to be such an ill structured domain, where issues do not lend themselves to a sequential approach to problem solving. Previous investigations into the usefulness of IBIS to structure product design rationale have focussed on engineering design domains. Its application to the context of design deliberation, takes the form of a network representation of the various alternatives that are considered in response to issues and the arguments for and against the positions (Moran and Carroll, 1991). Often the understanding of design problems evolves as the solution is worked on. *'IBIS attempts to capture the issues that arise in the course of design deliberation, along with the various positions (or alternatives) that are raised in response to issues and the arguments for and against the positions. Keeping track of such a network supports the recall of decisions and their rationale. This makes the decisions more understandable to designers at a later time and exposes them to reflection and reconsideration.'*(Moran and Carroll, 1991, p.198) IBIS supports the representation of a complex network of issues, positions relating to them and their justifications. In a design conversation certain issues may be touched on briefly and then remain unresolved or explored. It requires the skill and knowledge of a designer to filter the critical issues in the network from the mundane.

Conklin and Begeman (1988) proposed several extension to the IBIS method in their hypertext 'graphical IBIS' (gIBIS), as demonstrated in figure 5.4. The gIBIS tool was developed to capture design deliberations and uses a graphical window to enable hypertext networks of the gIBIS nodes and links to be constructed and navigated. It utilises IBIS as the underlying notation but incorporates additional node types and uses colour hypertext maps to facilitate the construction and navigation of IBIS networks. An additional, more generic node and link type, 'Other', is incorporated in gIBIS as an option to be used where difficulty is being experienced with the ridgity of the IBIS framework. An External node type is also proposed in order to contain links to external files, such as briefs, sketches, meeting minutes. Further flexibility is added in gIBIS by allowing positions to specialise or generalise other positions and likewise arguments. The ability to create submaps as an entity is also incorporated into the graphical tool Conklin and Begeman used to build their gIBIS networks. These submaps may be moved about or aggregated and made into a single node with the facility to be expanded to the full map as desired by the user. Within this node a marker is provided to flag whether or not a resolution had been reached for the issue at the root of the submap. This can be contrasted with IBIS which does not signal issue resolution.

Figure 5.4: Legal moves in gIBIS

Source: Conklin and Begeman, 1988, p.305



Two main categories of use were identified for the gIBIS tool: a) as an isolated hypertext tool for structured thinking and design; and b) as a vehicle for structured communication (Conklin and Begeman, 1998). Conklin and Begeman concluded that there is a close correlation between some of the cognitive structures and processes of design and the node and link types that compose IBIS. However they also identify shortcomings that require addressing, namely the lack of a node type for goals and requirements, the lack of support for denoting a decision or consensus for issues and the ability to link data on artefacts to the decisions that led to them.

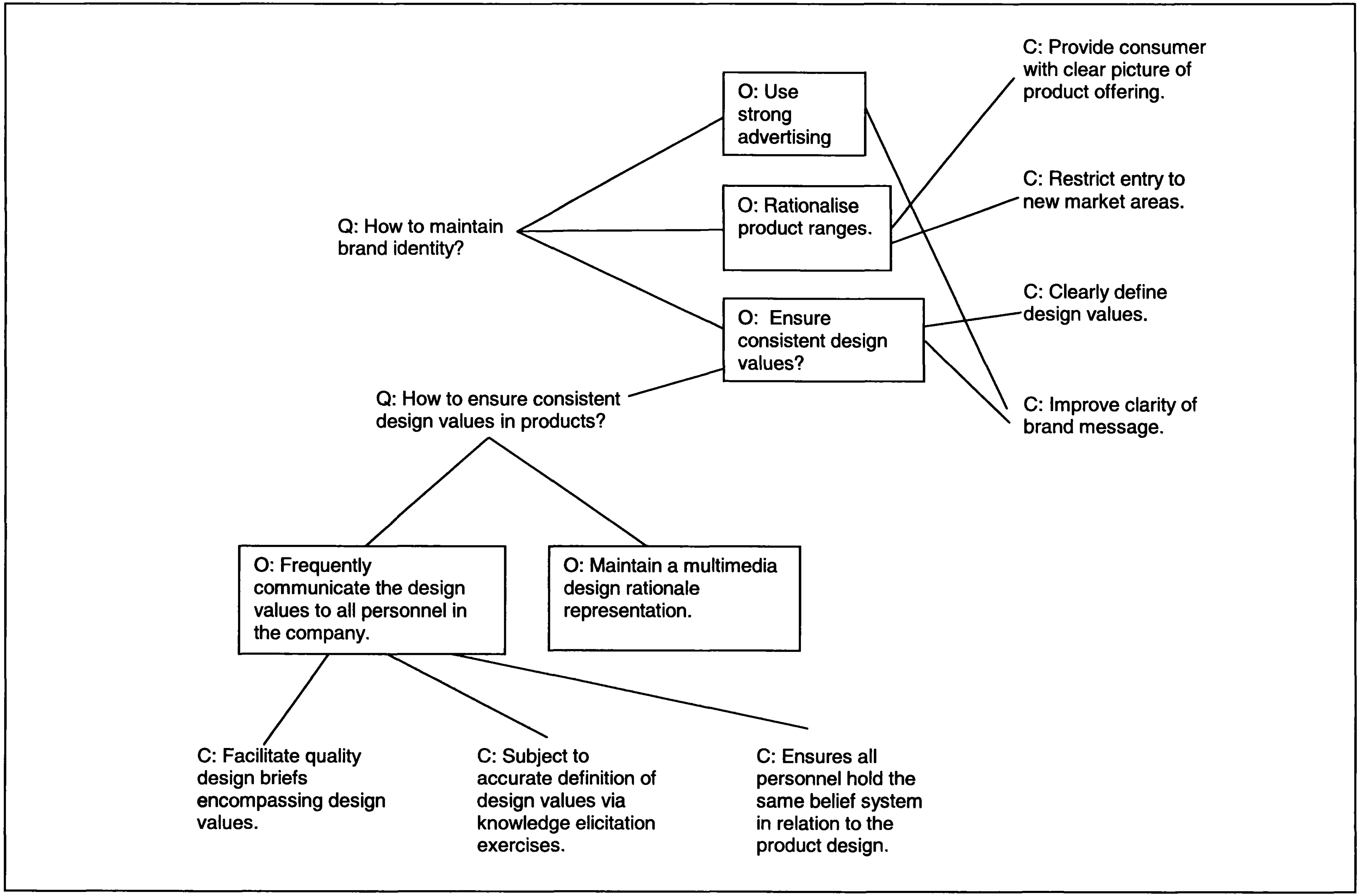
5.3. Questions Options And Criteria

Another methodology considered when deciding how to structure the design data was Questions, Options and Criteria (QOC) developed by MacLean et al (1991). QOC focuses on a breadth first exploration of the space of alternative options available to the designer along with the criteria reinforcing each option . It can be used to conduct a design space analysis and to construct a representation of it as a co-product of the design process and which must itself be created as a separate entity. It is based on the idea that a particular design is one which exists in a space of design possibilities. Hence an analysis of the design space justifies why a design will emerge in the form it does from among the many potential alternatives. The essential elements of the QOC notation are the '*questions*', which are the key issues relating to a design space and these correlate to the 'i*ssues*' in IBIS based notations; the '*options*', which are the possible solutions to those 'q*uestions*' and can be loosely mapped to the '*positions*' in IBIS based notations; and the '*criteria*', which allow the '*options*' to be compared and appraised and can be mapped to a certain extent to the '*arguments*' in IBIS notations.

Since QOC enforces a rigid structure on how design options are generated and assessed, it is not suited to creating a record the design deliberations per se as they naturally arise, but rather to construct an explicit representation of the potential design space that surrounds an object. It is claimed that using QOC enables a designer to make their decision by referring to all the options available, weighing up the relative effects of their criteria to arrive at the most appropriate solution. It focuses on the comparison of all possible options as opposed to IBIS which represents the evaluation of a particular option as suggested by the designer. MacLean et al (1991) emphasise the fact that a QOC representation must be 'carefully crafted' itself and created along with the design specification. This makes it a potentially intrusive method on the designers' time. The merit of conducting a design space analysis is that it provides a designer with a detailed and complete analysis of the design alternatives. MacLean et al argue that creating a design space analysis '*will repay the investment in its creation by supporting both the original process of design and subsequent work on redesign and reuse by a) providing an explicit representation to aid reasoning about the design and about the consequences of changes to it and b)serving as a vehicle for* *communication, for example among members of the design team or among the original designers and later maintainers of a system.*'(MacLean et al, 1991, p.55) Although there are clearly advantages to making all possible design options and their criteria explicit, it is simply not feasible to spend the amount of time required to do this in a commercial design environment. Certainly in most industrial product design domains, the time factor and the pressure to reduce lead times would be prohibitive to such analysis. However in a situation where a design team was experiencing difficulty resolving a certain aspect of a design there is an argument for using the QOC structure to expand the number of avenues being considered for the particular problem more fully in order to find a more suitable solution.

Figure 5.5 uses the QOC notation to elaborate some of the issues centering on maintaining brand identity and the role of design values as discussed in sections 2.1.5 and 2.1.6 of Chapter 2. It represents the same dialogue as that shown in Figure 5.3 to demonstrate the IBIS notation. However figure 5.5 only serves to demonstrate the basic dynamics of the QOC notation and does not represent a full QOC analysis since due to the difficulty of trying to enumerate all the possible options and their criteria only a couple of options are presented.

Figure 5.5: A Segment of a QOC Dialogue



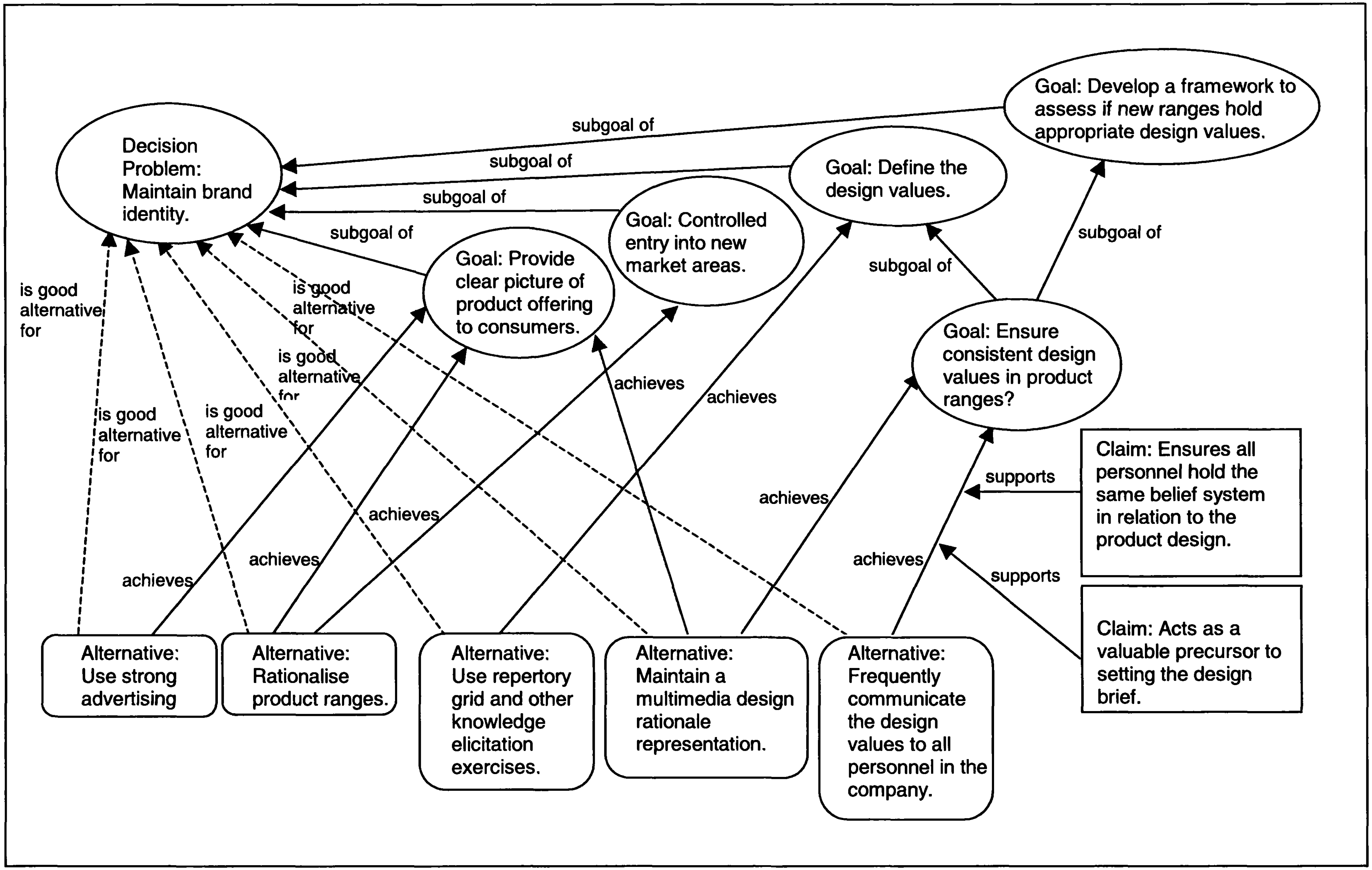
5.4. Decision Representation Language

The third methodology considered for structuring the design data was Decision Representation Language (DRL), developed by Lee and Lai (1996). DRL is primarily a model for capturing decision making and evaluating the alternatives available in relation to specific goals. Section 2.2 of chapter 2, expands on the complexity of design decision making and the necessity to introduce systems to aid decision management. Lee and Lai intended that DRL would demonstrate a design's progress, the options considered, and the assessments leading to the choice of one option over another.

DRL provides a framework that explicitly differentiates five elements of space: criteria, alternatives, arguments, evaluations, and issue. These elements of space collectively form the design space and each holds certain aspects of data pertaining to the design. Any option put forward relating to the decision problem at hand is called an alternative and alternatives can be evaluated by drawing on the arguments associated with them. Using the criteria space arguments can be grouped and weighted enabling changes in the significance of an alternative to be dealt with. The criteria form the goals and may be linked to other criteria forming subgoals. The alternative space can be connected to the criteria space through the goals that each alternative achieves from the criteria space. The arguments either for or against the alternatives form the argument space and can be linked to these by 'achieves' or 'claim' connections between the alternative space and the criteria space. The 'achieves' claims can be advocated or disputed by other claims. The issue space demonstrates how decisions are linked and interrelated and shows the dependencies between them. Alternatives are evaluated by considering how all the subgoals interact and by assessing the 'achieves' claims. What emerges is a very complex network which enables the alternatives to be weighted and evaluated. In contrast with QOC which focuses very much on making all the possible options and their criteria explicit, DRL places far more emphasis on evaluating the alternatives against a set of goals and capturing decisions resulting from the evaluation.

DRL is the most complex of the three design rationale methodologies to be considered and as elaborated on further in the following section this complexity was the predominant factor rendering it inappropriate for the purposes of structuring the design knowledge collated during the knowledge elicitation stage of the research. Figure 5.6 uses the DRL notation in a simplistic manner to elaborate some of the issues centering on the problem of maintaining brand identity and the role of design values as discussed in sections 2.1.5 and 2.1.6 of Chapter 2. It represents the same dialogue as that shown in Figure 5.3 and 5.5 to demonstrate the IBIS and QOC notations respectively.

Figure 5.6: A Segment of a DRL Dialogue



5.5. A Notation for the Knowledge Structure

All of the above notations use an argumentation based approach to represent a design rationale. However, the manner in which they are intended to aid the design process varies and they each place a slightly different emphasis on the elements of the rationale they capture. IBIS provides a methodology which governs how design dialogue should be conducted and structured. QOC focuses on eliciting all the design options and their criteria for careful consideration by the design team in order to optimise the final form of the design. DRL centers on decision management and evaluation of the alternatives in relation to specific goals.

Having considered the three methodologies it was decided that an IBIS based notation would provide the most suitable staring point for structuring the design data to be amassed during the product design process. IBIS allows parties involved in the design process to partake in discussions with a view to the resolution of the design problem at hand (Conklin and Begeman, 1988). Important data and knowledge utilised by the respective parties can be incorporated into an IBIS type structure. IBIS categorises all the main problems to be addressed within the design situation as issues. Each issue may have various positions held by the members involved, that directly relate to it and attempt to resolve the issue. There is no limit to how many positions an issue may have. In turn each position may have arguments for and against the idea being upheld and again there is no limit to how many arguments each position may have.

As outlined in section 5.2 the IBIS method is based on the principle that problem solving involves a dialogue between relevant parties. A plan of action emerges as each member draws on their expertise and puts forward their ideas, positions and arguments, to explore the topic at hand. The suitability of utilising the IBIS model to capture design rationale is reinforced by Dana Cuff's (1991) characterisation of design dialogue in Section 2.3.1 of Chapter 2 in which she describes how design decisions usually come about over time *'as a series of understandings modified by new information and opinions'* (Cuff, 1991, p. 193). IBIS provides a concrete structure within which the interested parties can hold their problem solving conversation, enabling key elements of the dialogue to be understood and supporting the emergence of a common understanding. The original aim of IBIS was therefore to enforce a structured manner in which to address and frame an issue that required resolving. However, the way the IBIS notation was used to construct the knowledge representation in this research differed in that it was not used as a tool to commence and explore a design discussion. Rather a commercial design process was observed in action and the notation was used to structure and record the deliberation as it happened but not to interfere or shape the design discourse away from its usual path. Out of the three considered methodologies IBIS provided the only notation that would most closely capture the dialogue of the design process allowing it to be easily structured in real time without being distorted. However as will be discussed in chapter 6, certain aspects of the design rationale were not well represented and the IBIS notation requires additions to provide an adequate representation of the design deliberations in (clothing) product design.

The reason IBIS provides the flexibility to fairly closely represent natural design discourse is it was designed to enable its users to control and steer the path taken through the design process. A practical constraint on capturing design rationale during product design is to cause minimal disturbance to the design process. Clearly QOC in contrast could not have been used to represent the natural discourse of a design dialogue because the enforced breadth first structure of its notation is too far removed from the natural course of design dialogue. It requires all possible design options to be made explicit and explored and this is clearly not done in a commercial design environment where lead times are paramount.

Although at first glimpse the QOC notation appears to be just another way of structuring the IBIS theory, there are some critical differences which add weight to the argument that IBIS is more suitable for constructing the knowledge representation of the design process. Firstly QOC's '*criteria*' and IBIS's '*arguments*' differ in that the '*arguments*' are positions for and against the ideas raised and '*criteria*' is not explicitly used in the IBIS notation, but rather is implicitly referred to by the '*arguments*'. Using the QOC notation would require all the criteria for the design position being discussed to be made explicit, even where they may actually be superfluous for the design process, i.e. where they do not, in practice, influence a design decision, or because they are obvious to the parties involved in the discussion. The IBIS notation not only requires less effort to construct but also it does not deviate far from the usual design discourse and provides a more natural representation of the design rationale. It allows issues and their arguments to be presented as they are discussed and does not artificially force the designer to be explicit about criteria that they would otherwise have not paid any attention to. Fischer et al affirm this, '*A truly complete account of the reasoning relevant to design decisions is neither possible nor desirable. It is not possible because some design decisions and the associated reasoning are made implicitly by construction and are not available to conscious thinking. Some of the rationale must be reconstructed after design decisions have been made. Many design issues are trivial; their resolution is obvious to the competent designer, or the design issue is not very relevant to the overall quality of the designed artifact. Accounting for all reasoning is not desirable because it would divert too many resources from designing itself.*' (Fischer et al, 1996, p.270) The '*issues*' and '*ideas/positions*' used in IBIS can centre on any discussion which arises during the design process, whereas the '*questions*' posed and '*criteria*' offered when using QOC have to focus specifically on a design option since the aim is to structure the design space. However there could be some benefit to be gained from using IBIS and QOC together to complement each other. For example once IBIS has been used to construct a map of the design rationale, QOC could be used to expand on areas where there were deficiencies in the design discussions, forming a sort of SWOT analysis on elements of the rationale.

Lee and Lai point out some of the limitations of IBIS and highlight that in IBIS '*Arguments cannot directly respond to other arguments. Therefore a query such as "Show me all the arguments that respond to this argument" cannot be computed.*' (Lee and Lai, 1996) Their main criticism of IBIS is that it provides a less explicit representation than DRL, this is not to say that the same information can't be inferred from it, but that IBIS doesn't provide all the constructs to make the necessary information explicit in the structure. In particular and in contrast with QOC and DRL, IBIS does not use the constructs of criteria and goals explicitly in its representation but goals may be implicitly referred to in IBIS by framing them as issues and criteria implicitly referred to by framing them as arguments.

The main limitation in the scope of Lee and Lai's (1996) DRL for our purposes is that it is primarily a model for capturing decision making and it does not capture certain critical aspects of product design rationale. This was a deciding factor making DRL an unsuitable starting point for representing the design knowledge. Lee and Lai themselves emphasise the importance of choosing the correct representation for the situation in which it is to be used. If the representation is hard to is use and construct then the users are unlikely to be motivated by it and no benefit will be reaped from it. It was felt that besides being extremely complex to construct, Lee and Lai's DRL model, focussed too heavily purely on the decision making process. Although as discussed in section 2.2.2 of Chapter 2 making decisions is an essential element of the design process it is not the only factor that needed to be considered when capturing design rationale. In a real product design setting, although decisions on small details are reached, they are often a by product of the exploration of ideas and reflections on wider issues. Creating a representation using DRL, is also an extremely time consuming process and unnatural in sequence involving the design team being very explicit about all alternatives. This consideration was a further inhibiting factor in terms of considering using the notation for capturing design rationale as the product design process (naturally) proceeds. Moran and Carroll warn against the limitations of constraining models of rationale. "*Formal capture techniques, that is those that produce formal representations of rationale, constrain expression to a pre-specified set of categories and relationships; and thus many aspects of design are not captured.*" (Moran and Carroll, 1996) However, sometimes a certain formality is good to encourage reflection. Certainly a positive underpinning of DRL is '*the philosophy that the vocabulary should be extended to tailor the task in hand and that is better to provide a method for extending the vocabulary as needed rather than to provide constructs that may not be useful in general.*' (Lee and Lai, 1996)

When considering the wide variety of domains within which we may want to capture product design rationale, much of what needs to be captured can be represented by a generic design rationale notation, but it is the graphical user interface and the manner in which the record of design will be accessed and made use of that may need to be domain specific. This is expanded on in more detail in chapter seven and is graphically demonstrated in Figure 7.1. Moran and Carroll reinforce the fact that '*useful design tools need to be domain specific, but many of the principles behind the tools are generic.*' (Moran and Carroll, 1996, p.198)

5.6. Summary

Section 5.1 discusses the potential benefits and motivations behind capturing and maintaining a design rationale representation. Attention is drawn to the fact that most previous empirical studies using argumentation based design rationale notations have focussed on the domain of engineering. Capturing design rationale has not widely been adopted by the engineering community and the reasons why capturing industrial product design rationale has greater potential than capturing engineering design rationale are presented. The conclusion is reached that the amount of design re-use prevalent in industrial design suggests that there exists a greater potential benefit to capturing design rationale in industrial product design, where design cycles are short, aesthetics are important and the data is primarily visual in nature, as opposed to engineering design. The suitability of exploring argumentation based design rationale methodologies as a starting point for structuring the design data elicited during the field research is reinforced by Rittel and Weber (1984) who endorsed methodologies which encourage exploration of a design problem through a process of argumentation in order to address the complexity of design problems.

Section 5.2 provides an overview of the Issue Based Information System (IBIS) notation and a segment of an IBIS dialogue is presented to demonstrate the dynamics of the notation. Conklin and Begeman's graphical gIBIS tool is introduced which enables hypertext IBIS networks to be constructed. Section 5.3 provides an overview of the Questions Options and Criteria (QOC) notation and a segment of a QOC dialogue is presented to demonstrate the dynamics of the notation. Section 5.4 provides an overview of the Decision Representation Language (DRL) notation and a segment of a DRL dialogue is presented to demonstrate the dynamics of the notation.

Finally section 5.5 critiques the methodologies in relation to their suitability for the purposes of this research. An argument is provided supporting the IBIS notation as being the most appropriate starting point to structure the design data to be amassed during the field research due to the simplicity of its representation and the ability of the model to represent the natural process of product design. An IBIS like approach presents a fairly natural way of structuring a design rationale since it allows issues and their arguments to be presented as they are discussed and does not artificially force the designers to be explicit about criteria to which they would not otherwise have paid any attention. Moran and Carroll confirm that the critical advantage of the IBIS model is that it '*is geared to capturing deliberation as it happens*,'(Moran and Carroll, 1991, p.198) thereby not requiring the rationale to be constructed as a separate part of the development process.

The next chapter the focuses on how a representation of the design process examined in the field research was constructed using multimedia hypertext design rationale maps, underpinned by the IBIS notation. An evaluation of the design rationale representation constructed is then provided.

CHAPTER 6:

IBIS$^+$ DESIGN KNOWLEDGE REPRESENTATION

This chapter discusses how a hypertext mapping software environment was utilised to construct a representation of the design process examined in the field research. The environment used supports a graphical representation of the design rationale, allows multimedia data to be incorporated into hypertext design rationale maps and is underpinned by an IBIS based notation referred to as IBIS$^+$. An account is given of how the resulting knowledge structure was used to explore the requirements for a useful representation of the collected design knowledge. An evaluation of the design rationale representation constructed is then provided and the problems and benefits highlighted. The chapter concludes with a summary of the critical points.

6.1. Constructing the Design Rationale Representation

The data elicited as the design process was observed during the field research needed to be structured in order to facilitate the exploration of the requirements for a useful representation of the collected design knowledge. An existing hypertext mapping software environment[1] was utilised that supported a graphical representation of the design rationale and allowed the multimedia data to be linked to the maps. The notation used by the software is underpinned by IBIS and the tool was not dissimilar to the gIBIS system outlined by Conklin and Begeman (1988) and referred to in section 5.2 of chapter 5. The original IBIS concept developed by Kunz and Rittel (1970) was meant to aid the exploration of issues and their potential resolutions. As argued in section 5.4 of chapter 5, the basic elements of the IBIS methodology appear to provide a suitable starting point to structuring the complex design issues encountered during the product design process, capturing the deliberation as it occurs and retaining the rationale behind decisions. The mapping tool incorporates a slightly extended version of the IBIS notation which for clarity is referred to as IBIS$^+$ in the rest of this thesis.

[1] Questmap version 3.1

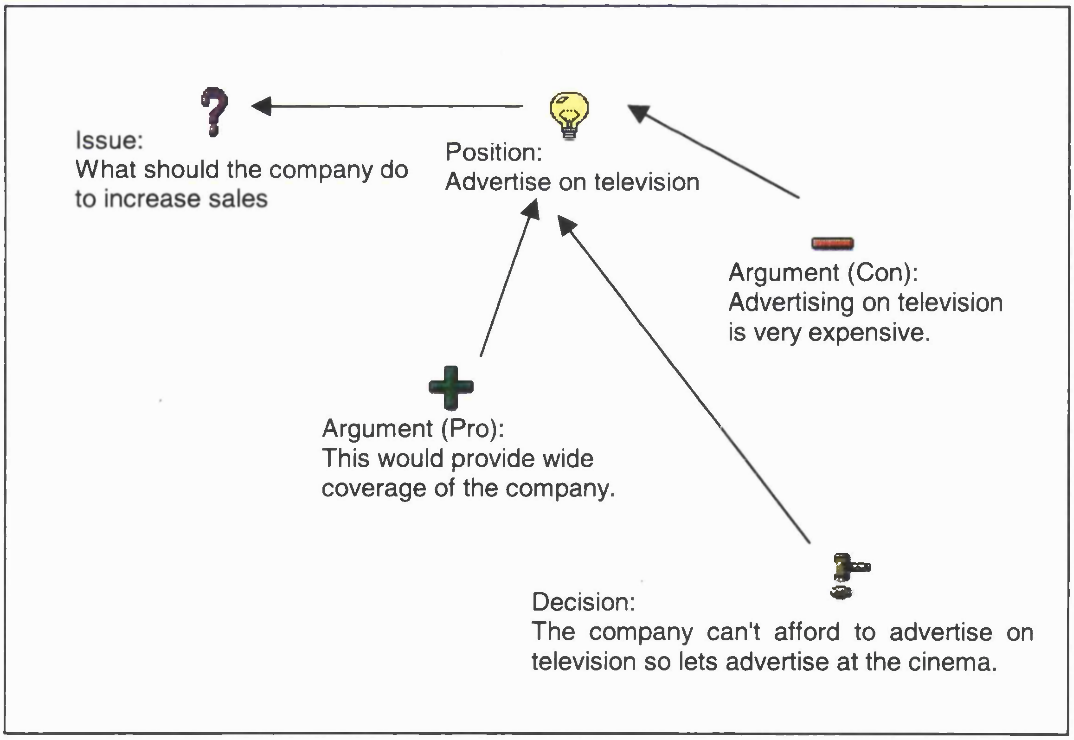
Detailed knowledge elicitation was conducted as outlined in Chapter 4, to capture the design rationale for a Spring/Summer 1998 product range for an American sportswear company. As a vehicle for investigation, to scrutinize the requirements for a useful representation of design knowledge, the IBIS$^+$ tool was used to create a representation of the design process followed in the field study as the design dialogue unfolded. The IBIS$^+$ representation provided an initial basis from which to explore the real problems of design rationale in the field of product design. The initial aim of the knowledge representation was to store all the information relating to the products being designed and to capture the decisions relating to their development. The goal was to establish the requirements for an adequate design rationale notation for product design and to identify the ways in which it might support the product design process by making the resource available for use by the design team. The IBIS$^+$ tool had the advantage that it allowed files of various formats to be linked into it providing the flexibility of being able to interface multimedia data. The resulting structured collection of data was installed on the computers belonging to the design team incrementally as it was being constructed. An analysis was then conducted to assess its effectiveness and limitations.

6.1.1. IBIS$^+$ Maps

The mapping software used enables IBIS$^+$ maps to be constructed in order to provide a graphical representation of the dialogue. A hypertext type structure of different nodes and link types is utilised to denote the main IBIS$^+$ elements on the maps. The maps consist of IBIS$^+$ nodes and links to demonstrate the relationship between the nodes. The nodes can also be linked to other map views or files of various formats which can be launched directly from the maps by clicking the nodes. A node is a data object in a hypertext database and operates as the junction between links or other objects. A hypertext node may also have content, either in a simple form such as a text or a more complex form, such as code to launch another application. A link is the connecting mechanism between two nodes and can also be used to define the type of relationship that exists between the two nodes. Each individual map created is classed as a view and predominantly addresses a certain topic. Fragments of the IBIS$^+$ knowledge structure maps constructed to represent the design discourse can be seen in appendix F.

The fundamental components of the IBIS$^+$ maps follow the IBIS methodology in that the nodes represent issues, positions about how to address the issues and arguments for and against the positions as shown in Figure 6.1. The issues require a resolution and the position proffer possible solutions to the issues. Arguments can either be for or against a position. These components are linked by relationships between one another. Positions always responds to an issue, while an argument (pro/con) either supports or objects to a position. In addition, the notation allows issues to be directly linked to other issues and positions to be linked to other positions. (This latter extension to IBIS was originally proposed by Conklin and Begeman (1988)). A decision node type is also incorporated into the notation which can be linked to issues or positions, this too is an extension of the original IBIS notation. Each node can contain some explanatory text and can be connected to other reference files launched directly from the nodes, such as other IBIS$^+$ maps, graphic, video or audio files.

Figure 6.1: Fragment of an IBIS$^+$ Map Dialogue



The following is a description of the node types that may be incorporated into the IBIS$^+$ maps:

Topics 

A topic may be defined as the problem area being explored and it should describe the broad issue that is under scrutiny. *'Topics...serve as a crude organisation principle for denoting the foci of concern.'*(Kunz and Rittel, 1970) For example in the field research the topic is 'Developing The Spring/Summer 1998 Clothing Range.' The whole discussion revolved around this subject. In the IBIS$^+$ maps constructed during the field research the topic is the first issue on the first map, and since the maps are constructed in a tree like structure, all branches eventually lead back to this issue. Topics are denoted by a question mark node as shown above.

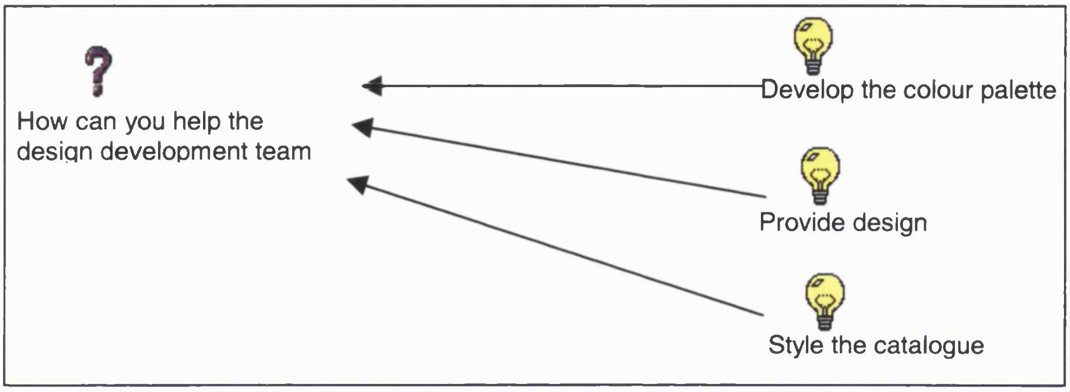
Issues 

Issues are the questions raised specific to the topic and sub-topics that arise, questioning how the topics might be approached. Kunz and Rittel (1970) described them as *'the organisational "atoms" of IBIS-type systems.'* The Issues require exploration in order to address the overall problem. Each IBIS$^+$ map begins with an issue. Throughout the conversation, new issues may be created as needed. Issues when raised may or may not be settled through the deliberation process. In the IBIS$^+$ notation used by the software utilised to construct the maps in the field study the issues are represented by a question mark.

Positions 

Positions may be described as the ideas put forward by members of the team in order to resolve the issues. A position responds to an issue and outlines one possibility for a resolution. *'Positions are developed by utilising particular information from the problem environment and from other cases claimed to be similar.'*(Kunz and Rittel, 1970) *'To each issue a logically closed set of possible positions or an open list of possible positions may be assigned.'*(Kunz and Rittel, 1970) Positions are represented in the maps constructed during the field research by light bulb nodes. An example is shown on the segment of a map illustrated in Figure 6.2, which explores the role of a clothing stylist. It starts off with the issue, 'How can you help the design team', from which stem several factual positions raised by the stylist concerned, demonstrating where he saw his role within the product development team.

Figure 6.2: Using an IBIS$^+$ Map to Explore Issues and Positions



Arguments

Arguments are posed by members of the group, and may either support (pro) or oppose (con) a position that has arisen during the discourse. Argument nodes respond to positions and assert a belief about the position, held by a member of the group. The process whereby members put forward their positions on certain issues may continue until a solution is reached through convincing the rest of the team by using the strongest arguments. In the IBIS$^+$ notation arguments for a particular issue are denoted by a plus node and arguments against a particular issue are denoted by a minus node.

The IBIS$^+$ software used to build the maps in the field research includes the following elements which are not part of the original IBIS notation presented by Kunz and Rittel.(1970):

Views 

View nodes denote that the currently open map view is connected to another map view. The view may be launched by clicking on the map view node. View nodes are denoted on the maps as miniature IBIS$^+$ maps icons.

Decisions 

A decision node is used to indicate when a decision pertaining to a position has been reached. When a decision relating to an issue is reached it is denoted on the maps by linking a decision node to the position being upheld or disregarded. Decision nodes are represented on the maps by a mallet icon.

Notes 

Notes can be connected to any other node types on the maps, and can contain textual information pertinent to the node they are connected to. Notes nodes are denoted by a notebook icon.

References 

Reference nodes can be connected to any nodes on the maps and represent an object, whether it be a document, graphic, video etc. In other words reference nodes launch files containing pertinent reference information related to the node they link to. They allow external files to be included in the discourse. Reference nodes can be linked to any other node type and are denoted by a book or will display the icon of the file type to which they point.

Relationships

The relationship types in table 6.1 are incorporated into the IBIS$^+$ notation and are denoted on the maps by different coloured links:

Table 6.1: IBIS$^+$ Relationship Types

The Responds to link, a black arrow, connects a position node to an issue node and is used to indicate that the idea offers an answer to the issue posed by the issue icon.	
The Supports link, a green arrow, connects a pro argument node to a position node and indicates that the pro node favours the stance taken by the position node.	
The Objects to link, a bright red arrow, connects a con argument node to a position node and indicates that the argument node opposes the stance taken by the position node.	
The Challenges link, a dark red arrow, connects an issue node to another issue node, position, argument, or view node and indicates that the issue node questions the validity, assumptions or pertinence of the node to which it is attached.	
The Specialises link, a dark green arrow, connects an issue to another issue, a position to another position, or an argument to an argument and indicates that the node refines, or further focuses, the node to which it is attached.	
The Expands on link, a blue arrow, connects an issue to another issue, position, argument or view node and indicates that the issue node asks a question about a specific detail implied by the node to which it is linked.	
The Related to link, a magenta arrow, connects a reference node to an issue, position, argument, or other reference node, and a view node to reference, note or another view and indicates that the node from which it originates contains information pertinent to the node to which it is attached.	
The About link, a dark cyan arrow, connects a note node to any other node, a view node to an issue, position, or argument node, and an issue node to a reference, or note node and indicates that the node from which it originates contains information relevant to the node to which it is attached. The About link is a general purpose link that shows only the broadest relationship between nodes.	
The Resolves link, a grey arrow, connects a decision node to an issue node and indicates that a decision has been made concerning the issue according to the line of reasoning and other notations listed in the decision node contents.	

6.1.2. The Requirement for a Comprehensive Knowledge Structure

The knowledge representation that was constructed using this IBIS^+ mapping tool was installed on the product manager's computer and an analysis conducted to assess its effectiveness and what kind of interface such a tool should incorporate. It was therefore essential when constructing the representation that it should be comprehensive and include a full season of design data in order to make the research credible. The reason for this is that in order to gain quality reflection and responses on the knowledge representation from the designers, it needed above all to be realistically complex, capturing as much knowledge as possible within it, thereby making it useful in a real design setting and facilitating the detection of its limitations.

The IBIS^+ knowledge structure contained approximately 200 image files, 4 video files, 2 audio files, and 30,000 words of design meeting transcripts. It consisted of 13 IBIS^+ maps containing 480 nodes and 471 links. The names of the different node types and the totals of the nodes and links contained within the 13 IBIS maps of the knowledge structure can be seen in Table 6.2. The brief context of each meeting and formal interview can be seen in Table 6.3. and more detail about the attendees and dates can be seen in the schedule of design meetings in appendix E.

Table 6.2: Totals of the Different Node and Link Types Within the Decision Maps

Node Types	**Totals**
Issues	14
Positions	134
Arguments	30
Decisions	71
References	201
Notes	17
Map views	13
Total Nodes	**480**
Total Links	**471**

Table 6.3: The Purpose of each Design Meeting and Interview

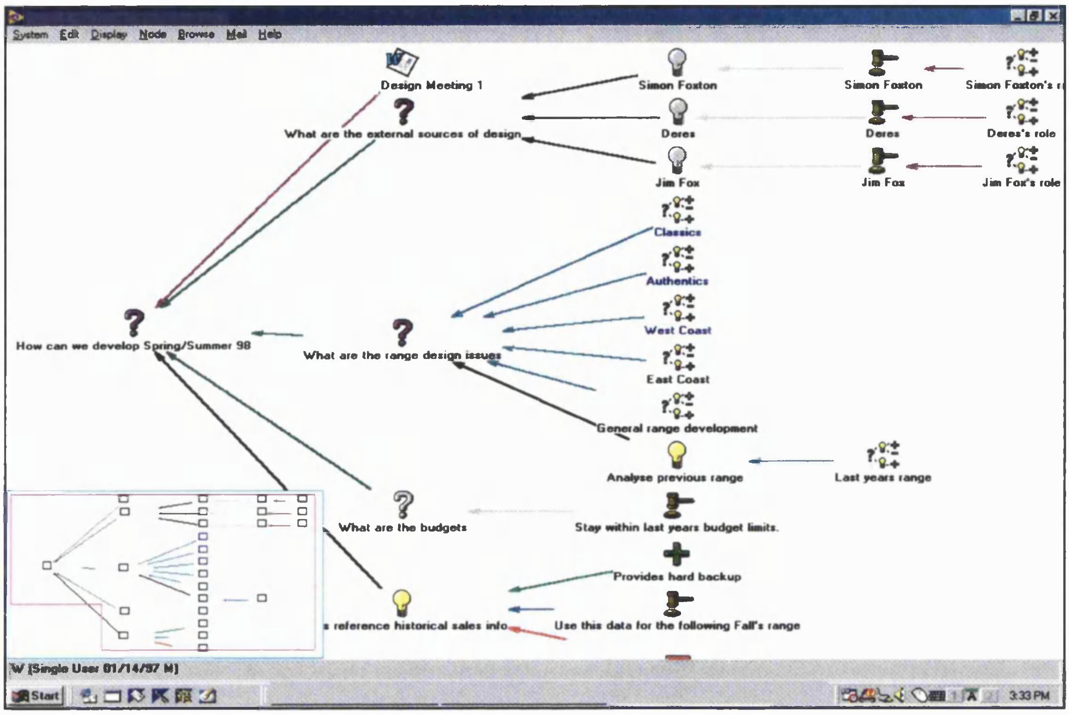
	Meeting Context
1	FORMAL DESIGN MEETING: Hold an initial discussion about the points that need to be taken into account when developing the Spring/Summer 1998 clothing range.
2	FORMAL DESIGN MEETING: Review the main points that need to be taken into account when developing the Spring/Summer 1998 clothing range, with the stylist.
3	FORMAL DESIGN MEETING: Enable the stylist to make comments on the previous clothing range and to decide what stage would need to be reached by the beginning of January when a meeting with the clothing manufacturer would be held.
4	FORMAL DESIGN MEETING: Go over the main points that need to be taken into account when developing the Spring/Summer 1998 clothing range with the manufacturer and decide when the prototype samples and master collection would be delivered.
5	FORMAL DESIGN MEETING: Have a brainstorming session with the external sources of design input.
6	FORMAL DESIGN MEETING: Go through everything that was presented by the external sources of design at the previous meeting and start to pull the range into shape. Decisions need to be made around the colour palette and also on which styles should be immediately discarded. The sketches of the range assembled so far need to be scrutinised and unwanted styles thrown out.
7	FORMAL DESIGN MEETING: Finalise the designs with the designer at the manufacturer so that she can transfer them to sketch form on the CAD system.
8	FORMAL DESIGN MEETING: Finalise the range before samples are made.
9	FORMAL DESIGN MEETING: View the samples for the whole range.
10	INTERVIEW: Obtain detailed feedback on the $IBIS^+$ knowledge structure that the design team had been given access to throughout the design process and to acquire further design data that needed to be input into the structure.
11	MEETING: Install the finished version of the $IBIS^+$ knowledge structure.
12	INTERVIEW: Establish feedback and reflections on the $IBIS^+$ knowledge structure now that it had been installed at the company for 1 month and to ascertain what changes would be required to make it a useful tool for the representation of design rationale.
13	INTERVIEW: Establish further feedback and reflections on the $IBIS^+$ knowledge structure and to ascertain what changes would be required to make it a useful tool for the representation of design rationale from a product managers point of view.

To achieve the necessary complexity and detail a complete product development season was followed. All of the formal design meetings were attended where location allowed, observed and fully transcribed and informal interviews were conducted with the design team at the end of each design meeting to assess their opinion of the usefulness of the knowledge structure as it evolved. Any visual or multimedia data referred to during the meetings would be structured into the $IBIS^+$ knowledge maps.

Further visits and interviews were conducted with members of the product development team to collect other background material that had not been gleaned in the formal design meetings and to obtain feedback on the value of the $IBIS^+$ knowledge structure and to assess its effectiveness.

Showing the designers an insubstantial prototypical representation, comprising a small quantity of data to which they find it difficult to relate and asking them both to imagine a realistic, substantial set of useful data and to conjecture how they might make use of it, is asking too much. In order to gain quality reflection and responses from the designers, the maps needed above all to be realistically complex, capturing as much knowledge as possible, thereby making them relevant in the real design setting and facilitating the detection of their limitations. It was therefore essential that the representation should be comprehensive and include a full season of design data in order to make the findings credible. A segment of one of the $IBIS^+$ knowledge maps can be seen in figure 6.3 and further examples demonstrating the multimedia nature of some of the data contained within the maps can be seen later in this chapter in figures 6.4, 6.5, and 6.6. Appendix F entitled, 'Fragments of the $IBIS^+$ Knowledge Structure Maps' provides more examples demonstrating the richness of the data structured within the knowledge maps.

Figure 6.3: A Segment of the IBIS+ Knowledge Maps



6.2. Problems Encountered with the IBIS+ Representation

A number of difficulties were encountered when constructing the IBIS+ representation. The overriding problem proved to be the sheer quantity of data that required structuring. However a smaller set of data could not have been used when constructing the representation since it would not have provided the foundation for a high quality of feedback on the knowledge structure.

The intention was to structure the data from each meeting in real time as the meeting progressed. However this was not always possible due to the speed at which the meetings were conducted. It was imperative not to interrupt the flow of the design meetings by interjecting or asking the design team to wait while the structure was updated. Therefore the meetings were audio recorded as well as being observed and a transcript of the entire meeting would be created directly after it. The transcripts were then used to complete any gaps in the structure that had not been completed during the meeting due to lack of time. The transcripts were also linked to the relevant nodes in the structure in order that they could be referred back to by the design team at a later date if required. Obviously creating these transcripts of the entire meetings was a very time consuming process, as was trawling through all the transcripts to locate the relevant issues, positions, arguments and decisions. Some of the data in the transcripts was inappropriate for inclusion in the structure, for example discussions about what the design team did at the weekend etc. Only data relevant to the design of the product range was incorporated.

A further significant difficulty arose from ambiguity in the data. For example, sometimes the members of the design team would contradict themselves saying one thing one day and the opposite the next. When this occurred further questioning was required external to the main design meetings to clarify the ambiguity. It was essential to maintain channels of contact open with the personnel involved in the field research. Problems were increased by the fact that some meetings could not be attended since they were conducted abroad. These meetings (formal design meetings number 4 and 7 in the schedule of meetings in appendix E) were recorded and members of the design team who attended them collected any relevant data. For these meetings it was sometimes difficult to decipher what was being referred to or talked about on the audio tapes, particularly if the discussion involved several visuals.

6.3. Evaluation of the IBIS$^+$ Representation

Following each formal design meeting the design rationale knowledge representation would be updated. It was on the beginning of the agenda for each formal design meeting to discuss the latest additions to the knowledge representation and how useful it had been to the design team since the last meeting. The designers used the design rationale as it was being constructed during the design season, to reflect on what they had stated they would achieve at the initial meetings and to identify what decisions had for various reasons fallen by the wayside. At the end of the design season when the IBIS$^+$ maps were completed the product design team experimented with the complete representation for several weeks. Then a detailed analysis of their reflections and opinions was conducted based on the feedback obtained from the design team at the beginning and end of each formal design meeting and in the structured interviews conducted (meetings 10, 11, 12 and 13 in the schedule of meetings in appendix E).

One of the major comments was that it would be extremely useful for the current design rationale to be used as a template to start building the next season's range. However the maps editor was not at an advanced enough stage for the designers to be able to develop a template for themselves. There were many other important findings from the analysis of the designers' experience with using the $IBIS^+$ maps. These concerned weaknesses in the $IBIS^+$ notation; how to support reflection during and after the design process; interface requirements – ways of presenting data from the maps for specific purposes and direct benefits to the design team and the company of retaining knowledge used during the design process over a succession of design cycles.

The limitations of the $IBIS^+$ notation led to a complete restructuring of the material collected for the whole design season. The adaptation of the notation and its extension to cope with the realities of the product design process are described in detail in chapter 7.

Capturing Design Rationale In Its Entirety

Concern was voiced regarding the impossibility of capturing all the design decisions despite the fact that as far as possible all the formal design meetings had been attended. It might be expected that all important decisions would be shared or discussed in the formal design meetings, however, this is clearly not always the case. For example design issues may be discussed between a sub group of the design team on the way to meetings or in other non scheduled discussions. Furthermore, urgency sometimes dictates that decisions have to be made outside of formal meetings. This may sometimes mean that there is no time to consult and inform the rest of the design team about some of the decisions made. This is an inevitable limitation of any attempt to capture real decision making. On a related issue Fischer has pointed out that, '*a truly complete account of the reasoning relevant to design decisions is neither* *possible nor desirable. It is not possible because some design decisions and the associated reasoning are made implicitly by construction and are not available to conscious thinking. Some of the rationale must be reconstructed after design decisions have been made. Many design issues are trivial; their resolution is obvious to the competent designer, or the design issue is not very relevant to the overall quality of the designed artifact. Accounting for all reasoning is not desirable because it would divert too many resources from designing itself.*' (Fischer et al, 1996)

These are practical constraints which need to be addressed. These shortcomings and their resolutions will be discussed in more depth in the next chapter. As detailed further in chapter 7, many of these inherent limitations can be overcome to some extent by holding a session for reflection at the end of the design process during which the decision structure is reviewed, corrected, annotated and rationalised in order for the knowledge representation to be of value for future reference. In the field study it was shown that this task does not need to take more than a couple of hours and ensures the design rationale structure is up to date. In itself this session would be useful as a review for the design team of the design process and the goals that had or had not been achieved. It is also a useful exercise to ensure that the design rationale structure accurately reflects the important outcomes of the design process.

It was also clear that the maps would contain more detailed and accurate knowledge had they been created by the product development team themselves, as opposed to a knowledge engineer. Then, however the product design team would need to find the time and the motivation to do this, it certainly was not feasible with the tools we were using to structure the data from the design meetings. This is an area that requires further investigation.

There are also questions to be addressed over the amount of tacit knowledge that is brought to bear on understanding the rationale as it has been recorded. With visual data such as story boards and inspiration videos it will not be obvious to a lay person what is being conveyed, this is part of the skill the designer and the unexpressed culture and context within which the team operates effectively. Where there is a debate on a specific visual and aesthetic issue, it must be considered that the data will be looked at in an historical context in the future. For example, if there is a discussion involving the use of particular fabric types, investment in clarification such as the inclusion of visual illustrations will demonstrate what the fabrics look like, and what their different types and applications are at that time. Cultural perspectives of the time must be added to the data in order for it to retain its meaning in future years. Identifying exactly what will be needed is ultimately impossible. However practical, experienced designers can probably make intelligent guesses which will help their successors. The remaining issues raised about the decision structure fell into the following categories:

Extending the IBIS Method

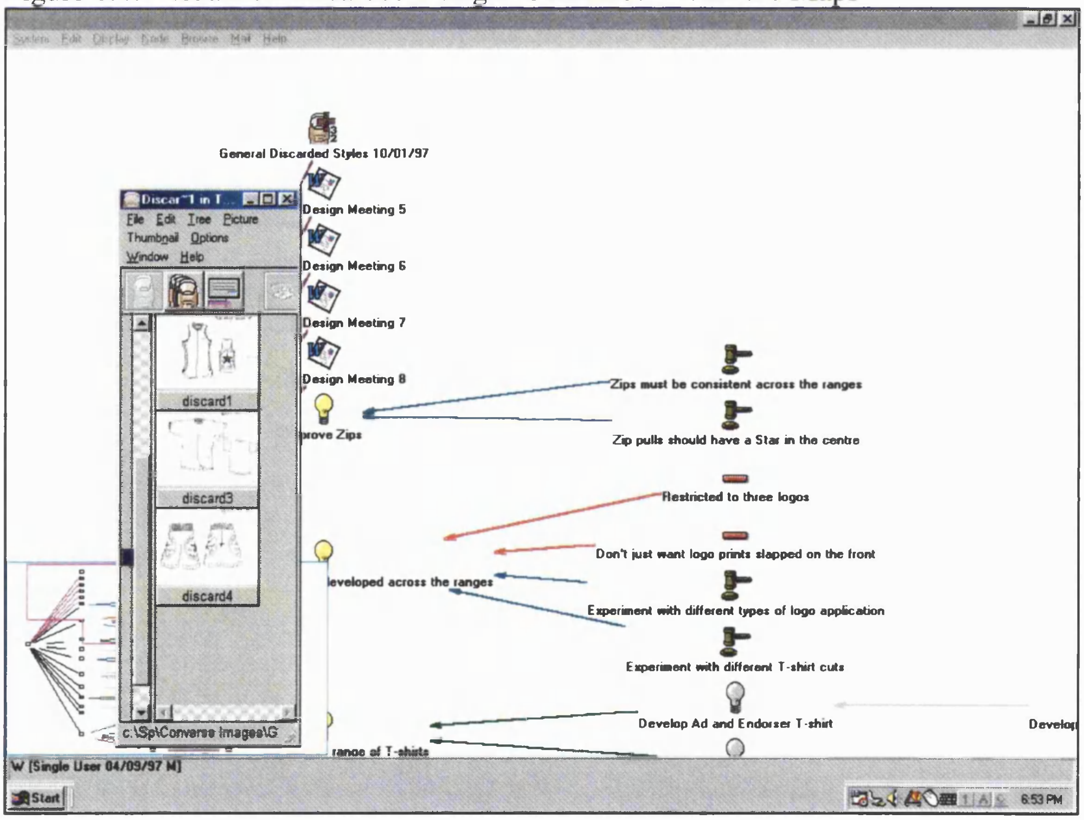
These were issues that were raised due to limitations within the IBIS methodology or the interpretation of IBIS embedded in the software used to construct the maps. Some of these issues are addressed in chapter 7 by making extensions to the IBIS method, adding new node types and altering the notation and through the addition of a reflective stage at the end of the design process as previously outlined.

Supporting Reflection/Decision Making

Several issues were raised concerning the capability of the tool to support reflection on the design process, which in turn would have an impact on the design decision making in the next season's product development meetings. It quickly became apparent that there was a requirement for the knowledge structure to be used not only as a record of the design rationale but also to enhance strategic planning and to provide a starting point for the following season's design cycle.

A particularly useful aspect was thought to be the use of the knowledge structure as a reflective tool to enable the design team to review the previous range development process and to highlight where goals had been achieved. The design rationale maps sparked debate within the design team as to why certain issues had remained unresolved or had fallen by the wayside. Figure 6.4 shows how visuals of products that are discarded from the range at an early stage are retained within the multimedia maps in order that the designers may refer back to them at a later date. The design team were given access to the knowledge structure as it was being built, and while the design process was still ongoing. They noted that it was useful to use the maps to see what goals had been achieved and identify what had been accomplished and what had not, even before the design process had been completed. The knowledge structure provided an insight into the reasoning behind certain decisions being made and allowed the identification of the issues that were lost during the design process. The design team also noted that it would be a useful historical record, as over time catalogues and samples get mislaid. Many claims are made about the importance of recording the design process, but in the field of product design little research has been conducted to substantiate this.

Figure 6.4: Visuals of Discarded Designs Contained within the Maps



Graphical User Interface Requirements

These issues were in the main domain specific and could be resolved through the redesign of the graphical user interface and through the addition of improved interface navigation facilities.

Functional Requirements

Some of the issues raised centred around the requirement of additional functions within the tool such as spell checkers, word search engines and image searching/matching facilities. A search engine would be very useful to do keyword searches on the contents of the nodes. An image matching/searching facility would also be beneficial when considering that over a period of time a very large number of images would be stored in the maps.

Poor Use of the Representation

These were issues raised that would not have occurred if the representation had been constructed by the design team themselves as opposed to a knowledge engineer. This is due to the fact that it is hard for the knowledge engineer to become totally immersed in the design process and have an entirely complete comprehension of the ideal way to categorise the maps and issues to suit the needs of the designers. This problem would be overcome if a member of the design team was charged with structuring the design rationale.

A practical restriction of doing research was further highlighted by that fact that clearly the maps would contain more detailed and accurate knowledge had they been created by the product development team themselves, as opposed to a knowledge engineer. The problem here would be convincing the product design team to find the time and the motivation to do it and this is an area that requires further investigation. A change in attitude would be required within the organisation. The tool would need to be available to all members of the design team at all times, maybe over an intranet, so new Positions could be added as they occurred. This would ensure the maps were as comprehensive as possible and fewer retrospective additions would need to be made at a later date. It also emerged from the discussions with the design team that it would be useful to have the photo's of the final garments and the whole marketing package, including point of sale and advertising added to the map. This would require an input in terms of time but could be done as part of the reflective stage.

Obviously the rationale within the knowledge structure would only make total sense to a user knowledgeable about that particular domain and field of expertise. With visual data such as story boards and inspiration videos it may not be obvious to a lay person what they are conveying and it may take the skill and mind of a designer to understand the tacit knowledge within it. Where there is a debate on a specific visual and aesthetic issue, it must be considered that the data will be looked at in an historical context in the future. For example, if there is a discussion involving the use of particular fabric types, visual illustrations could be included to demonstrate what the fabrics look like and what their different types and applications are at that time. Where necessary cultural perspectives of the time must be added to the data in order for it to retain its full meaning in future years. An inherent limitation of attempting to capture the design rationale in this manner is that it doesn't account for the fact that, in order to fully relate the reasoning behind a design, the design narratives, innate data, and cultural aspects of the design would also have to be accounted for.

6.4. Direct Benefits of the IBIS$^+$ Representation

Certain direct benefits of the knowledge representation were identified. A summary of these benefits presented in an anecdotal style, can be seen in figure 8.22 in chapter 8, entitled 'Viewpoint: The Design Team's Perspective.' The initial reaction to the knowledge structure was how well it graphically demonstrated the work conducted. Perhaps the most stark benefit was when a key member of the design team left the company, the newly recruited member of the team was able to use the structure to appraise themselves of the design process and the decisions that had been undertaken in the development season before he joined. the resource demonstrated how through collating the design rationale The dangers to a brand of losing its direction in terms of brand image are particularly critical and this could be avoided. It was also stated that the resource would be a good tool for reflecting on personal development, by allowing individuals to raise their awareness of their own decision making process and thereby further develop their expertise. It further enabled the design team to reflect on how well the external design consultants had fulfilled their roles and how critical they were to the process. Clearly the resource could be used to aid the team to become efficient with their external interactions.

It became clear to the product development team, having experimented with the resource, that once the design rationale had been captured over a few seasons the benefits would become more significant. For example, after a number of cycles' data had been collected, it was envisaged that savings might be reaped on paying for external specialist information, such as on 'retro' design data from vintage clothing experts, that once captured should not need to brought in from outside.

Having experimented with the resource, it became clear to the product development team that once the design rationale had been captured over a few seasons the benefits would become more significant. The work identified many positive benefits from constructing as full a representation as possible of the design rationale. These included:

- Aiding and speeding up the planning for the following cycle's ranges. As discussed in section 3.2.3 of chapter 3, any resource which enables clothing companies to reduce design and production lead times and implement quick response and thereby the opportunity for mid season replenishment in reaction to sales would be invaluable;
- Ensuring higher quality decisions are made on the new ranges on the basis of reflection on the previous design season;
- Providing new team members with a history of previous product development and design decisions;
- Helping branded products to retain consistency in their brand identity;
- Allowing team members to analyse their own personal development;

- Providing an archive of previous design that will become increasingly useful with the passing of time as a resource for visual research/inspiration;
- Providing a resource for marketing activities that may incorporate 'retro' designs. Many branded clothing companies such as Levis use old, archived design work from previous decades in their 'lets return to our roots' marketing activities;
- Aiding quality reflection on both aesthetic and technical decisions. It is useful to explicitly represent design rationale in those product design domains where the over-riding decisions may be split into those which are aesthetic in nature and those addressing production/technical concerns. For example, a certain style may be adopted due to the design team's belief in it having the correct aesthetic values for the market and yet later prove to be a 'dog' in terms of sales. In such a situation if a design rationale representation had been constructed it might lead the design team to question their judgement on whether they were using the correct aesthetic values for the market place with this product. Similarly it would also be useful to have a rationale of technical/production decisions. In a case where a fabric proves to be unsatisfactory, resulting in a high number of product returns, the specification and rationale for choosing that fabric could be referred to when seeking a sensible resolution.

Ideally the design rationale would not be built by one person and then presented at the beginning of each meeting as it was in our work. Is should be constructed as an integral part of the design meetings by all members of the design team. Members of the team should be allowed to view or add to the rationale at any time and it should be used as a reference point during meetings for the team to reappraise goals and objectives. The nature of product design means that much of the tacit knowledge understood by the designers would be contained in the predominantly visual multimedia data linked to the design rationale structure. Although this data may not mean anything to the untrained eye, to an experienced designer it conveys a lot of valuable information and adds an expressive new dimension to formal design rationale notations. In clothing product design in particular, a range of similar products are created season after season, and there are two or three seasons each year. The amount of design re-use prevalent means that it appears to be much more practical to justify the effort of capturing design rationale in this sort of domain than in engineering design domains. In product design much implicit knowledge is visual data of a multimedia nature, which this thesis claims can be usefully retained for later reference by setting it in context in a design rationale map structure. Figures 6.5 and 6.6 demonstrate the potential for capturing tacit knowledge by including visual data within the design rationale maps.

Figure 6.5: A Clip from one of the Inspiration Videos Contained within the Maps

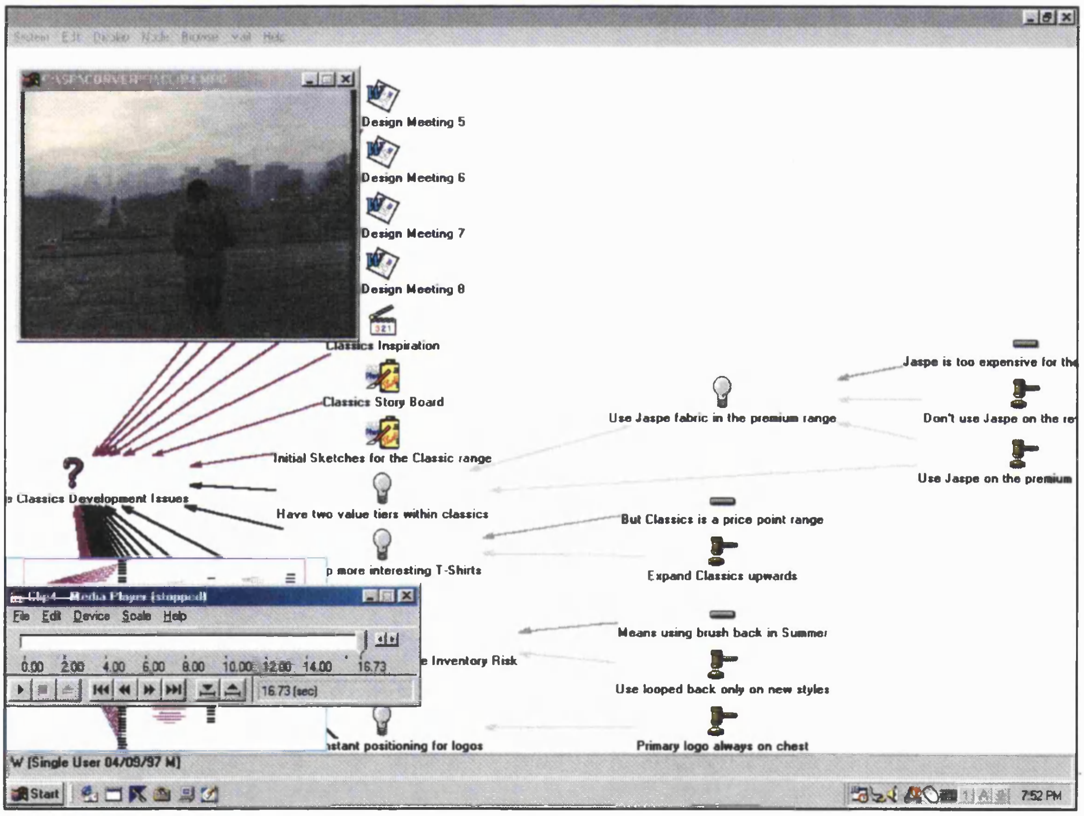
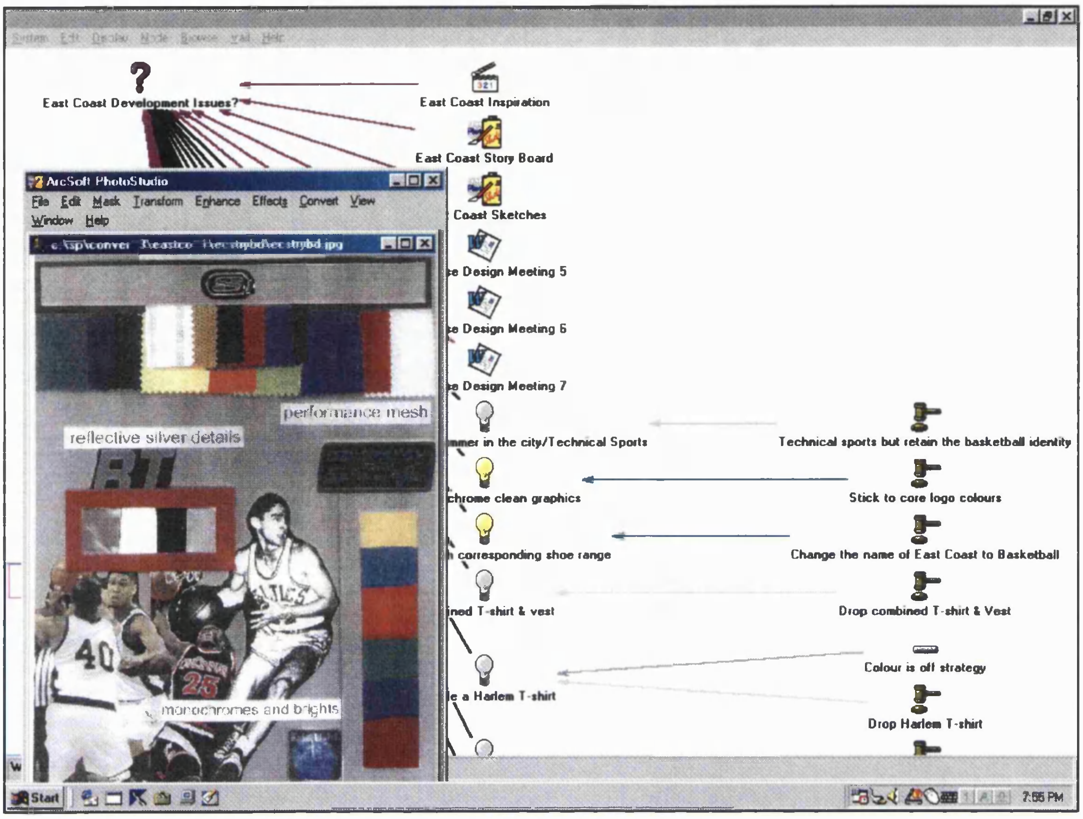


Figure 6.6: A Visual Design Story Board within One of the Maps



6.5. Summary

This chapter outlines how a hypertext mapping software environment was utilised in order to structure the data elicited during the field research and explore the requirements for a useful representation of the collected design knowledge. The mapping tool used supported a graphical representation of design rationale and allowed multimedia data to be linked to the maps. It incorporated a slightly extended version of the IBIS notation which for clarity is referred to as IBIS$^+$. Section 6.1.1 describes the elements and dynamics of the IBIS$^+$ notation used to construct the design rationale maps. Section 6.1.2 then goes on to illustrate the depth of the data structured and the requirement when constructing the representation that it should be comprehensive and include a full season of design data in order to make the research credible. The reason for this is in order to gain quality reflection and responses on the knowledge representation from the designers, it needed to constructed from their own design deliberations, be realistically complex, and be as complete and accurate as possible, thereby making it useful in a real design setting and facilitating the detection of its limitations. This facilitated the identification of how the $IBIS^+$ notation needs to be extended to be able to express practical design decision making in a competitive commercial setting and this will be expanded on further in chapter 7. It highlighted how many of the inevitable inadequacies of trying to capture design rationale during the design process can be overcome by taking a relatively small amount of time to reflect on the design process and tidy up the record retrospectively. It has led to many useful insights, which will be referred to in chapter 7, into how information from such a knowledge structure can be presented to designers to support their work.

Section 6.2 expands on the problems encountered when constructing the $IBIS^+$ maps, namely the sheer quantity of data requiring structuring, the time required to construct the design rationale and the potential ambiguity in the elicited data. Section 6.3 provides an evaluation of the design rationale structure following feedback from the design team. From this analysis there were some clear limitations which needed to be overcome if an effective tool for capturing design rationale was to be developed and these are addressed in chapter 7. Section 6.4 goes on to outline the many direct benefits identified by the designers of maintaining a design rationale. The initial reaction of the design team to the design rationale maps was how well they graphically demonstrated the work conducted and the processes and decisions undertaken during the product development cycle. Having experimented with the resource, it became clear to the product development team that once the design rationale had been captured over a few seasons the benefits would become more significant. The work identified many positive benefits from constructing as full a representation as possible of the design rationale. More research is required in order to assess the feasibility of a design-oriented company allocating adequate resources into retaining product development rationale over a substantial period of time. Nevertheless, it is apparent from the research that if a company invests the time and money into capturing design rationale, they may be rewarded with a resource that will not only enhance their design decision making process and provide a more structured approach to their product design, but when collated over a number of design seasons, it can further be used to support their overall strategic planning.

In the next chapter the limitations of the IBIS$^+$ notation used to construct the design rationale representation are addressed and an improved notation is presented. The importance is underlined of providing graphical user interfaces that support product designers to utilise the underlying data.

CHAPTER 7:

IMPROVING THE IBIS+ KNOWLEDGE REPRESENTATION

In this chapter extensions to the IBIS+ knowledge structure detailed in chapter 6 are proposed. Some of the identified limitations of the IBIS+ notation used to construct the design rationale representation are addressed and improvements to the notation are presented, forming the adapted notation referred to as IBIS^{PDR}. The critical requirement is emphasised of incorporating a retrospective, reflective stage allowing the knowledge structure to be reviewed, corrected, annotated and updated in order for the design rationale to be a useful and reusable resource. Several further extensions to the IBIS+ notation are proposed to be incorporated into the IBIS^{PDR} notation as a critical part of this retrospective stage. The second half of the chapter provides an overview of the graphical user interfaces (GUI's) particular to the fashion product design process studied in the field research, which can be connected to the underlying design knowledge base. It is stressed that when developing GUI's for an IBIS^{PDR} structure it would be essential that the domain and the purpose of the underlying data be carefully considered. The chapter concludes with a summary of the critical points.

7.1. Enhancing the Design Knowledge Structure

The IBIS+ maps of the design process described in chapter 6 were constructed concurrently with the design process and presented to the design team in order that they could use and reflect on them as the design process unfolded. To achieve the necessary complexity and detail a complete product development cycle was followed. All of the formal design meetings were attended where location allowed, observed and fully transcribed and informal interviews were conducted with the design team at the end of each design meeting to assess their opinion of the usefulness of the knowledge structure as it evolved. Any visual or multimedia data referred to during the meetings was structured into the IBIS+ knowledge maps. Further visits and interviews were conducted with members of the product development team to collect other background material that had not been gleaned in the formal design meetings and to obtain feedback on the value of the IBIS+ knowledge structure and to assess its effectiveness. The brief context of each meeting and formal interview was outlined in Table 6.3. in chapter 6.

Following each formal design meeting the design rationale knowledge representation would be updated. It was on the beginning of the agenda for each formal design meeting to discuss the latest additions to the knowledge representation and how useful it had been to the design team since the last meeting. The designers used the design rationale as it was being constructed during the design cycle, to reflect on what they had stated they would achieve at the initial meetings and to identify what decisions had for various reasons fallen by the wayside. At the end of the design cycle when the $IBIS^+$ maps were completed the product design team experimented with the complete representation for several weeks.

A detailed analysis of the design team's reflections and opinions was conducted based on the feedback obtained at the beginning and end of each formal design meeting and in the structured interviews conducted (meetings 10, 11, 12 and 13 in the schedule of meetings in appendix E). Certain issues raised suggested that for the maps to most accurately and adequately reflect the design process it would be pertinent for them to be constructed by someone entirely immersed and conversant with the design process at hand – e.g. a member of the design team. Certain mis-representations in the knowledge structure would not have occurred if the maps had been constructed by a member of the design team. They were due to a limited comprehension of the ideal way to structure the design process into separate components to suit the needs of the designers. This was illustrated by a designer's comment that an entirely separate map should have been created for the logo development, in order that it would be possible to show the development or modernisation of the logos from cycle to cycle. The designers also required a separate map for colour palette development, instead of including it as part of the general range development map.

Other issues were raised due to limitations with the $IBIS^+$ notation used, which dictated that the rationale be mapped in terms of nodes associating questions, positions, arguments for and against, and decisions. The resulting approach to tackling the weaknesses identified has two main aspects. The first involves alterations to the notation to make the representation richer and more suited to representing industrial product design and this is described in section 7.1.1. Some of these additions to the notation would be used retrospectively once the design process was complete.

The second involves the introduction of a distinct retrospective, reflective stage which follows on from the end of the design process, during which the maps are in effect "tidied up" to make them valuable for future reference. Conducting this reflective stage would enable the maps to be used to create a template to aid planning and decision making for the following cycles design process and this is detailed in section 7.1.2. Other researchers have alluded to the benefit of learning by reflecting on past experiences, (Wheelwright & Clark, 1992). However the chances of doing this are greatly enhanced by maintaining an accurate record of the design process, since if a design team doesn't have a design rationale to reflect on and learn from they are likely to reconstruct it inaccurately in their minds. '*Getting at the fundamental sources of problems in the development process, is unlikely to occur naturally. Because the development process is so complex and involves so many different people in different groups, and because the issues cut across groups, departments, functions and organisations, learning is likely to require careful systematic effort*', (Wheelwright and Clark, 1992, p.287).

7.1.1. Addressing the Limitations of the IBIS$^+$ Notation

The limitations of the IBIS$^+$ notation for constructing a design rationale representation were identified in the previous chapter through designers reflecting on the IBIS$^+$ maps. These limitations now needed to be addressed and a more adequate design rationale representation devised. The adapted notation devised is referred to in this thesis as IBIS^{PDR} (Issue Based Information System Product Design Rationale). In order to make the structure richer, possible extensions to the IBIS$^+$ method needed to be explored by incorporating additional categories, subtypes, relations or issue interdependencies where necessary. Other researchers have suggested this sort of strategy. Fischer reinforced the idea that '*the IBIS method should be modified to* *emphasise relevance to (i.e., serving) the task at hand.*' (Fischer et al, 1996) It was critical though to guard against the model becoming too complex rendering representations based on it difficult to learn and time consuming for a user to construct. Conklin and Burgess-Yakemovic (1996), have already noted that '*in fact the issue of the trade-off between the expressive power of the design rationale notation and its ease of use is one of the central problems of the design rationale field.*' Furthermore loosening of the $IBIS^+$ notation was considered, in order that the user does not have to rigidly stick to categorising all their discussions into issues, positions and arguments. For example allowance could be made for annotation. This might entail allowing designers to annotate positions or decisions within the structure, giving such flexibility as indicating which nodes have formed the key influences on the range.

The suggested alterations to the $IBIS^+$ notation to form the $IBIS^{PDR}$ notation are as follows:

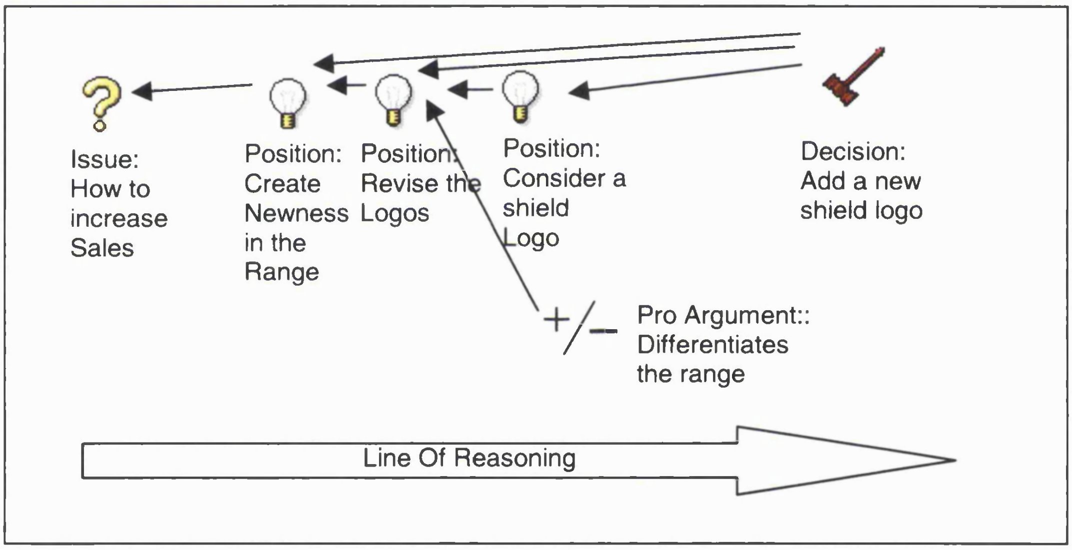
Use Only One Link Type

Using the multiple relationship types provided by the $IBIS^+$ notation is confusing to quickly decipher by glancing at the different coloured links on the maps. It was consequently suggested that only one generic link type should be used, simply denoting that one node is relevant to another, the nature of the links being implied by the types of nodes it connects. This is an example of de-formalisation of the notation.

Create The New Node Type, 'Resolution'

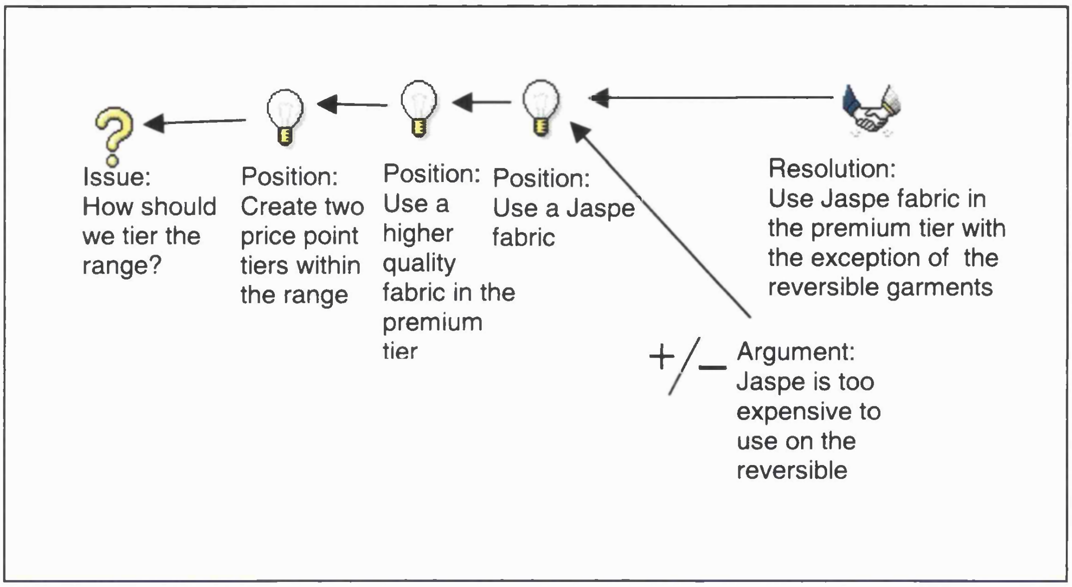
The representation as it stood required decisions to be concluded very cleanly, and fully resolve all the issues and positions along the development path. In practice this does not happen and so in certain places the maps mislead the user into thinking all the issues in a line of development have been addressed, when in actual fact they have not. Sometimes there is a very complete representation of the line of reasoning, which leads directly to a full resolution of all the issues and positions in the line. At other times, a decision may be made that only partially addresses the line of reasoning, and the representation must be able to show this. Where a decision node appeared on the maps it was not clear whether all the positions or just some of the positions along the line of reasoning had been solved by the decision. One possibility considered was to connect the decision node to all the position nodes along the line of reasoning (L.O.R.) that it resolves, and then alter the colour of the position nodes to visually indicate that they were resolved, as shown in Figure 7.1. This would involve linking all decision nodes to all the position nodes on the line of reasoning in the map that they relate to, as opposed to just the position node created at the time that specific decision was made.

Figure 7.1: Linking Decision Nodes to all the Position Nodes in the L.O.R



The problem here though would be that the linear structure of the maps would be lost and they would also become increasingly complicated and confusing to look at. The solution was to introduce a new node, called ‘Resolution’. 'Decision' nodes would still be used when only part of the line of reasoning was being addressed. 'Resolution' nodes would be used when the whole of the line of reasoning was being addressed and all the positions in that line had been solved by that particular resolution, as demonstrated in Figure 7.2. The positions in a line of reasoning to which a resolution node is attached should be greyed out to denote that all the positions are addressed. Obviously, when constructing the map a user must decide whether a decision reached solves the whole line of reasoning, or just part of it, before selecting either the decision or resolution node type.

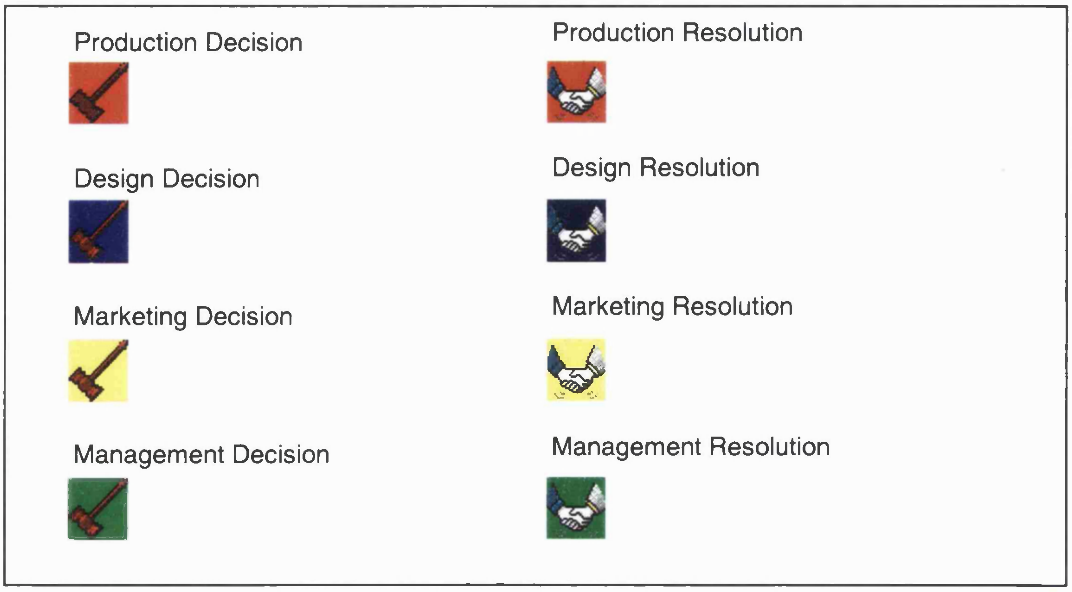
Figure 7.2: Adding the New Node Type: Resolution



Create New Domain Specific Decision & Resolution Nodes

It is often important to be able to identify the stakeholders responsible for making a specific decision. In the field research the design team were concerned about the fact that it was not possible to assess by glancing at the map from what stance the decisions were being made. They were keen to differentiate decisions according to which department or perspective they were coming from (e.g. Marketing, Sales, Management, Production, Design). This is addressed by introducing the domain specific decision and resolution nodes shown in Figure 7.3, each department being identified by a different colour.

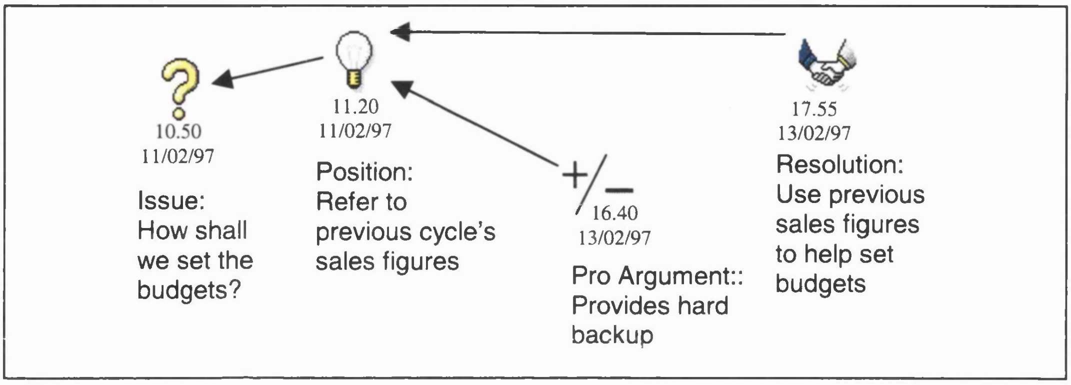
Figure 7.3: Colour Coded Decision and Resolution Nodes



Time And Date Stamp All The Nodes

It was also clear that some temporal aspect to the representation would be valuable so that when reflecting on the design process it would be possible to see in what sort of time frame decisions were made. Furthermore, it would be useful to utilise the knowledge maps to assess whether targets are being reached within the expected time frame. A simple scheme seems adequate for product design which as described in chapter 2, has relatively short design cycles. An effective solution for these purposes is to time and date stamp all the nodes as shown in Figure 7.4, which enables members of the design team to check how they are progressing against the timelines that they set themselves at the outset of the development cycle and to see which discussions came before or after others.

Figure 7.4: Time and Date Stamped Nodes



7.1.2. Retrospective Additions to the IBIS+ Notation

Wheelwright and Clark (1992) emphasised the importance in product design of reflection on a good quality record of the development process. '*In the context of product and process development, learning from experience means learning from development projects. But organisational learning is not a natural outcome of development projects ....In some instances, for example, the outcomes of interest are only evident at the conclusion of the project. Thus, while symptoms and potential causes may be observed by individuals at various points along the development path, systematic investigation requires observation of the outcomes, followed by an analysis that looks back to find the underlying causes...Natural incentives in the organisation favor pressing forward to the next project. Without concerted effort and focussed attention on learning from the project that has just been completed, it is unlikely that engineers, marketers or manufacturers will naturally devote time and energy to yesterday's problems. Most companies learn very little from their development experience. Those that do understand the power in improvement have developed tools and methods to help people individually and collectively gain insight and understanding and focus energy and attention on the problem of learning*', (Wheelwright and Clark, 1992, p.285).

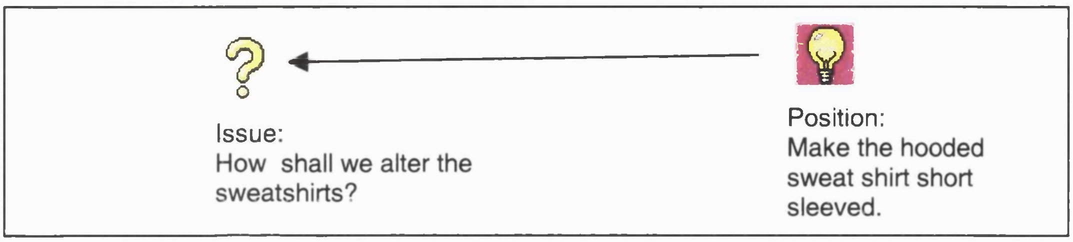
There was further evidence in the field research, supporting the need for the incorporation of a retrospective, reflective stage, that would allow the design rationale structure to be reviewed, corrected, annotated and updated in order for the status of the knowledge representation to be accurately maintained. It would also be a useful exercise to refresh the memories of the design team about the process that had been followed and highlight issues that had been brought up but that remained unresolved. 'F*or example, the problem of unresolved issues showing up very late in a development program....we need to understand how a problem that surfaced early in the program could have remained unresolved all the way through the prototyping process. This deeper question focuses on the organisational processes and involves many different departments and individuals. Learning about that kind of problem will require systematic effort*', (Wheelwright and Clark, 1992, p.289)

Several extensions to the $IBIS^{+}$ notation, which are outlined in this section, have been incorporated into the $IBIS^{PDR}$ notation as part of this retrospective phase. A quick test during the field research showed that conducting this reflective process to update the $IBIS^{+}$ maps of the design cycle captured, incorporating these retrospective additions to the notation, only took two hours. It ensured that the design rationale structure was up to date and provided the design team with the opportunity to address some of the incompletenesses in the record of the design rationale in order to make it useful at a later stage. The design team emphasised the fact that they had found it useful to reflect on the design rationale structure not only during its construction, but also while conducting this updating exercise in order that they could then confidently refer to it further at a later date. The retrospective additions to the $IBIS^{PDR}$ notation are described in the remainder of this section.

Link the Key Position and Decision Nodes to Image Files of the Final Products

Until construction of knowledge maps becomes an integral part of product design culture there would be limitations in the information that users could gain through a quick glimpse at design rationale maps. It would be important to ensure that once the final products are determined they are clearly and directly linked back to the initial positions to which they relate. The ability to hyperlink between position nodes and the final products that they related to would be an essential facility. The simplest way of achieving this is to hyperlink retrospectively the key positions nodes to graphics files of the end product they affected. Such a link from a position node can be shown by colour-coding which alerts the user to a retrospectively added association, as shown in Figure 7.5. For example if the node were to be shaded pink, the user would know that a hyperlink existed to an image of the finished product relating to it.

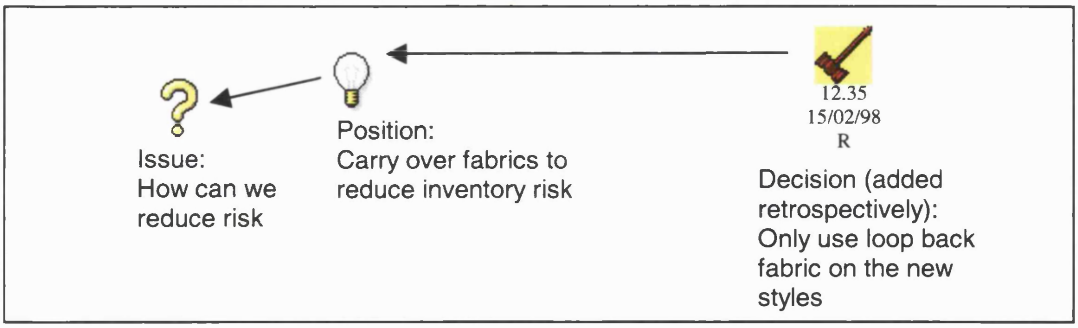
Figure 7.5: Colour Shaded Position Node Denoting a Hyperlink to the Finished Product



Add An 'R' Flag To Retrospective Decision Nodes

Another interesting observation, which comes from carefully recording what actually goes on during design meetings, is that many of the positions which are raised appear to remain unresolved. During retrospective editing, decision nodes that are omitted from the maps need to be added and connected to the positions to which they relate. This would prevent confusion when users refer to the knowledge maps at a later stage. For example the maps might otherwise incorrectly portray that some positions had not been resolved and decisions had not been made, when actually they were eventually addressed and had merely been swept aside temporarily in the need to get on with other more pressing concerns. Once again colour coding might be used to differentiate nodes added retrospectively from those added during the design process. However, since colour coding is already used to identify different decision making groups it is proposed that all these "tidying" up operations that take place retrospectively should be flagged as such by adding an "R" flag to any node added at the retrospective stage, as in Figure 7.6. Further support for utilising an 'R' flag instead of further colour coding comes in section 8.2 of chapter 8. A task analysis conducted with the design team using an $IBIS^{PDR}$ representation of the design process, demonstrated the extent to which colour coding can prove confusing to the users if not used sparingly.

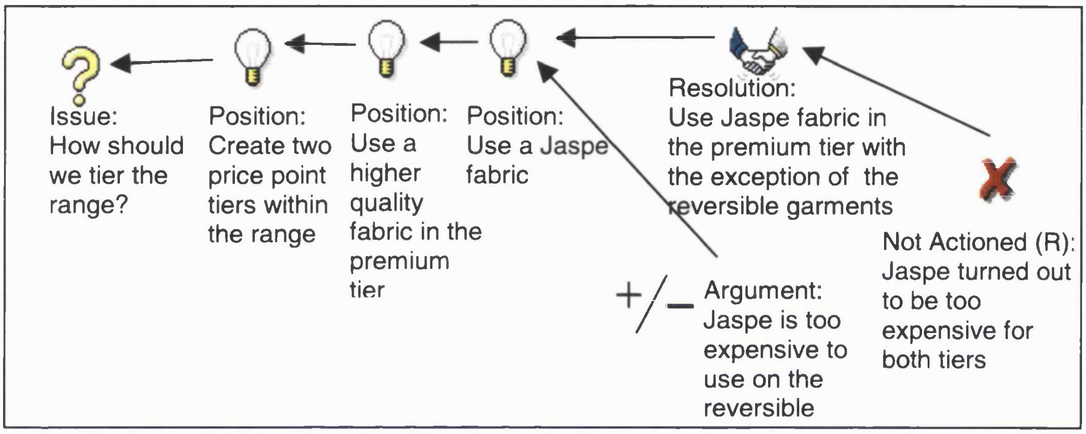
Figure 7.6: Adding an 'R' Flag to Retrospective Nodes



Utilise A New Node Type, 'Not Actioned'

A method is also required of denoting that certain decisions hadn't been implemented even though they had been discussed during the design deliberations. A new node type called 'Not Actioned', linked to decision nodes is proposed. This is to be used to annotate the map at the end of the design cycle, as shown in Figure 7.7, ensuring the information on the map contributes to the completeness of the map as a record of the design process. Text should be added to the node explaining why it was not actioned. If this node type is not connected to a decision node it can be assumed that it was actioned. Where position nodes don't have decisions or resolution nodes linked to them they could be added retrospectively as shown in figure 7.6, in order that it does not appear that they were not actioned.

Figure 7.7: Adding the New Retrospective Node Type – Not Actioned



7.1.3. Utilising the Design Rationale as a Template and to Support Reflection and Decision Making

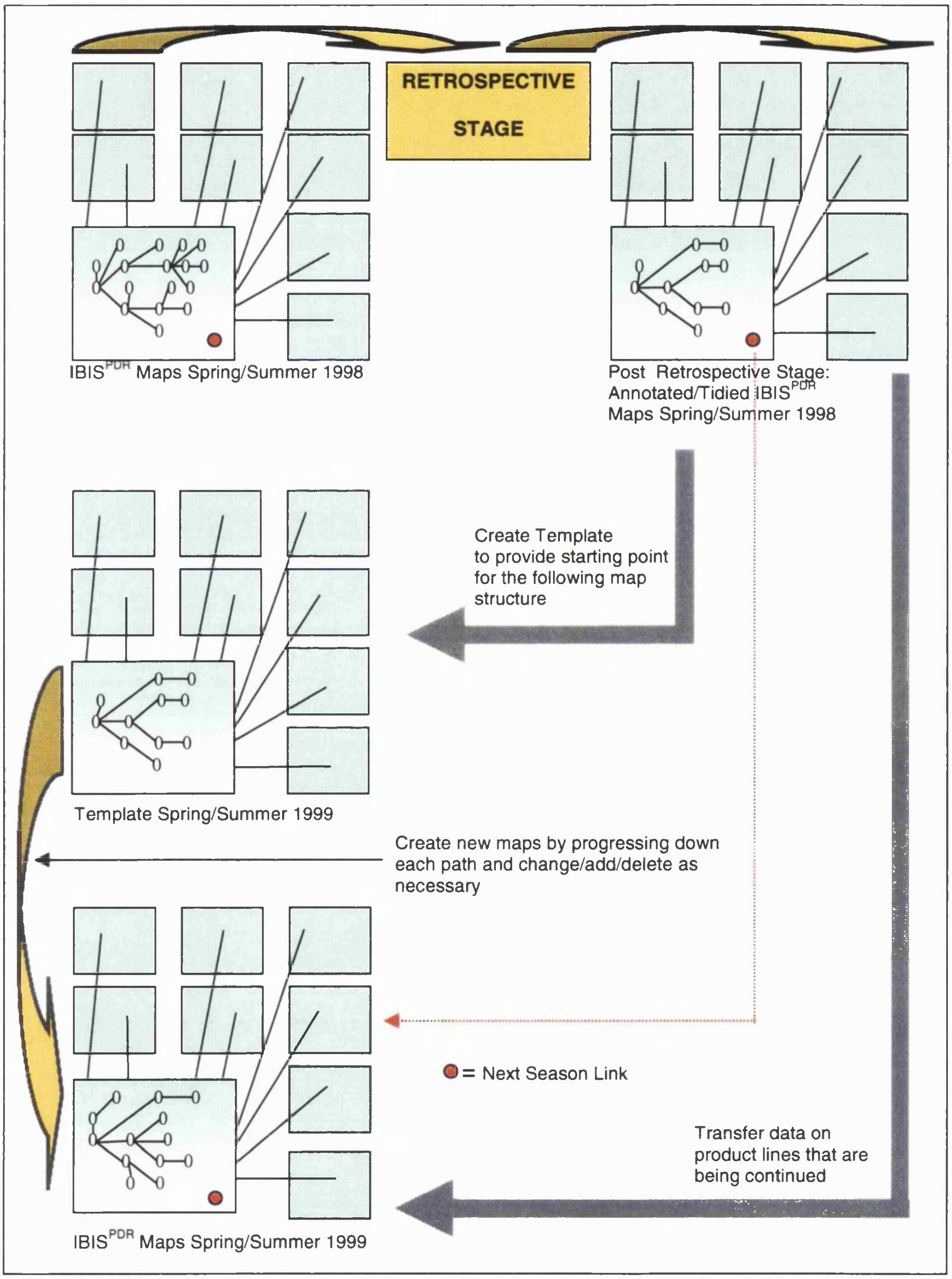
Companies involved in product design are becoming increasingly aware of the benefits to be gained from encouraging reflection on the design process (Phillips and McDonnell, 1998c). An $IBIS^{PDR}$ representation would offer the potential to support reflection on product design rationale, which in turn could impact on the decision making in subsequent product development cycles. The importance of introducing procedures that streamline design decision making in order to maintain competitive advantage in product design is underlined in section 2.2.2 of chapter 2.

In the field research the $IBIS^{+}$ design rationale maps provided a useful starting point for the next cycle's range planning. They enabled a review to be quickly conducted of the goals identified at the beginning of the previous cycle and a new set of goals to be drawn up for the coming cycle. The $IBIS^{+}$ maps sparked debate within the design team as to why certain issues had remained unresolved or had fallen by the way side. By providing access to an IBIS^{PDR} knowledge representation constructed concurrently, while the design process is still ongoing, the ability is provided to assess what goals have been achieved and identify what has been accomplished and what has not, even before the design process is complete.

It quickly became apparent that there was a requirement for the design rationale maps to be used not only as a record of the design process, but also to create a template to provide a starting point and support strategic planning and design decision making for the following season's design cycle. The decision structure in a product design environment would not change entirely from one development cycle to the next. Some of the design decision structure would be unique in each cycle, but a relationship would exist with the structure from the previous development cycle. A parallel may be drawn here with timetables, which are rarely identical year on year, but there is often some structure that can be carried over.

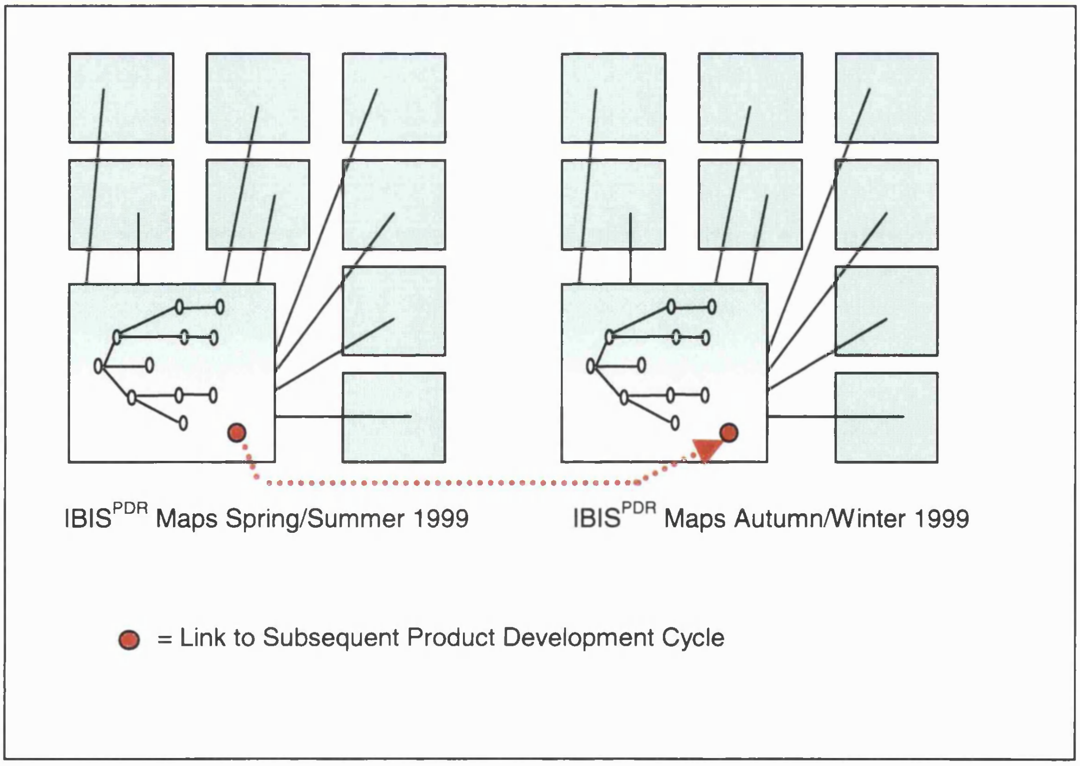
Design rationale maps from a current product development cycle could be used as a template for the next cycle's maps, in order to provide a starting point and to reduce the work of constructing the next cycle's design rationale. A set of the maps could be used initially to identify a model path for the product development. From this a template could be created to form a basis for the following cycle's maps. The design team in the field study emphasised that this would make the knowledge base a very useful tool for design/product managers and it would speed up and enhance the following cycle's range planning. However, a reflective stage would be required first, in order to 'tidy up' and annotate the maps with decisions not made explicit in the design meetings. The benefit of having a retrospective stage, to ensure the design rationale maps provide as complete a representation of the design rationale as possible, was elaborated on in section 7.1.2 of this chapter. This retrospective stage would be a modest task, although it would need to be done as soon as possible at the end of the design process. It would be an essential pre-cursor to creating an accurate and useful template. The design rationale maps would then provide invaluable support for the strategic planning and decision making at the start of the following season's design cycle. Figure 7.8 demonstrates how a template can be created after a reflective stage at the completion of a development cycle.

Figure 7.8: Retrospective Stage Adjustments Followed by Template Creation



In product design, decision making would be further enhanced through the ability to link successive IBIS^{PDR} representations. This would facilitate a product development team to trace the design rationale back over a number of cycles. Every time a design cycle is completed a link to the next cycle's map should be added as demonstrated in Figure 7.9. This is reinforced by the field research where one reason preventing all the rationale being captured in the maps was that many of the design scenarios understood by the design team, stemmed from previous cycle's development. Over a period of time these omissions could be overcome to some extent by linking in seasonal progression. Exploration of the decision structure through a number of cycles would give an understanding of previous design scenarios and decisions. If the decision structure were then to be explored in depth for a number of cycles, an understanding of the previous design scenarios and decisions could be gleaned from the structure, making the maps' contents' progressively more understandable to a user and reducing the effort required to construct a design rationale for a new cycle.

Figure 7.9: Linking from One Cycle's Knowledge Structure to the Next



7.2. The Graphical User Interface Requirements

In the first part of this section the Graphical User Interface (GUI) requirements particular to the fashion product design process studied in the field research are outlined. Although these interface requirements have been developed with a specific domain in mind, as discussed in chapter 2, industrial product design domains follow a broadly similar development pattern and it is likely that similar GUI's could be utilised in other product design domains. However when developing GUI's for an $IBIS^{PDR}$ structure, it would be essential that the domain and the purpose of the required access to the underlying data be carefully considered, in order that the most appropriate GUI's could be developed. Many of the interface issues raised with regard to the $IBIS^{+}$ maps during the field research could be resolved through the addition of improved map navigation facilities. The requirements for certain interface facilities link to the issue of supporting reflection and decision making, such as the ability to view a product range in a gallery alongside a whiteboard area where images could be annotated or altered. In the second half of this section the requirement for enhanced navigational facilities within the interface to the maps is outlined.

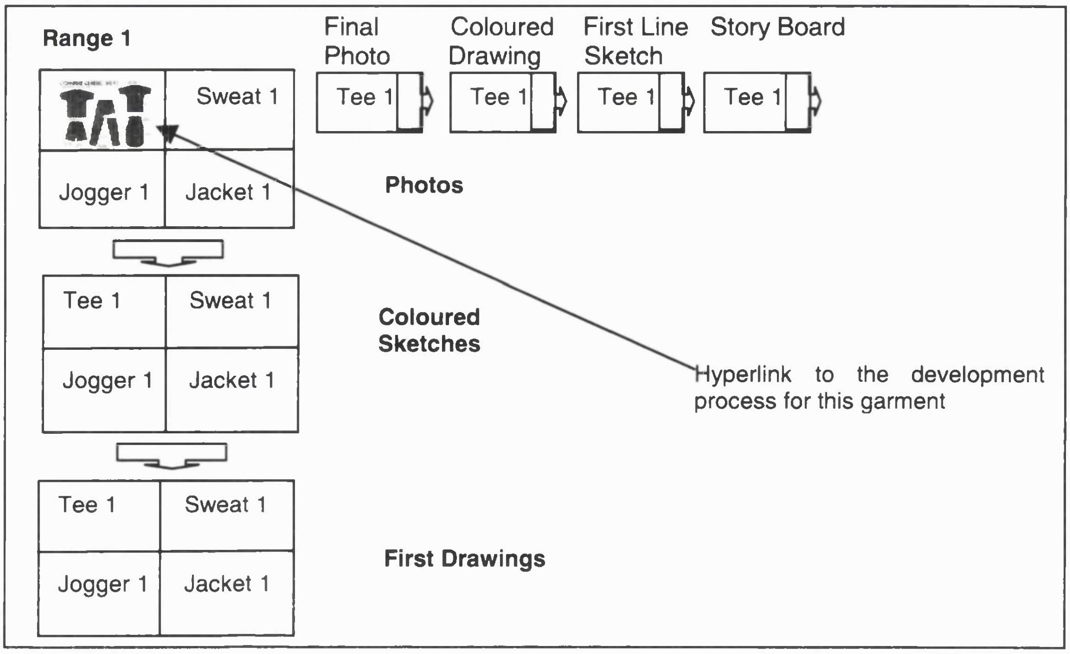
7.2.1 Graphical User Interfaces Particular to Fashion Product Design

Suitable, domain specific ways of presenting the information from the maps are discussed in this section and are referred to in this chapter and in section 8.2.1 of chapter 8 as views 1-4:

View 1 - Viewing Stages of Product Evolution from Final Product to Initial Concept

As a source of reference data allowing historical exploration and as a decision making tool for a design team in years to come, the $IBIS^{+}$ maps are presented with the final products as the leaf nodes in the decision networks that the maps represent. For use as a historical resource it is more natural and in keeping with the usual manner of working, to view the final products and then to be able to back track through the decision making process in reverse, to see the evolution of the products from the original inspiration. A specific interface that retrieves data from the knowledge maps could facilitate this. Graphics from each range could be viewed together or in categories of the various stage of product development, e.g. final photos, coloured sketches, and line drawings. A display could be provided of the lines of development starting from the leaf nodes on the maps, so that any particular product can be taken individually and all the images along its development path can be viewed starting with the final photo of the finished product, as demonstrated in Figure 7.10. Slides shows of images would enhance the tool, for example, a user might be focussing on logo design and would be enabled to view a slide show that flashes up the initial sketch ideas and the working drawings of the logos in their order of development. As discussed in section 2.1.7 of chapter 2 the significance of industrial product design cycles being short is that it means that at the start of a development cycle it is still useful for the design team to be able to refer back to the products designed in the previous design cycle, as the majority of their aesthetic values will still be current. Since the design cycles are short, the aesthetic trends and design influences in the previous design cycle could very well still be relevant to the current design cycle. Presenting the data to a design team utilising a more intuitive interface such as the one demonstrated in figure 7.10, that mimics the manner in which they would naturally structure and wish to view the images, would facilitate reflection on the product's visual development and enable a quick assessment of it's relevance to the development cycle in hand.

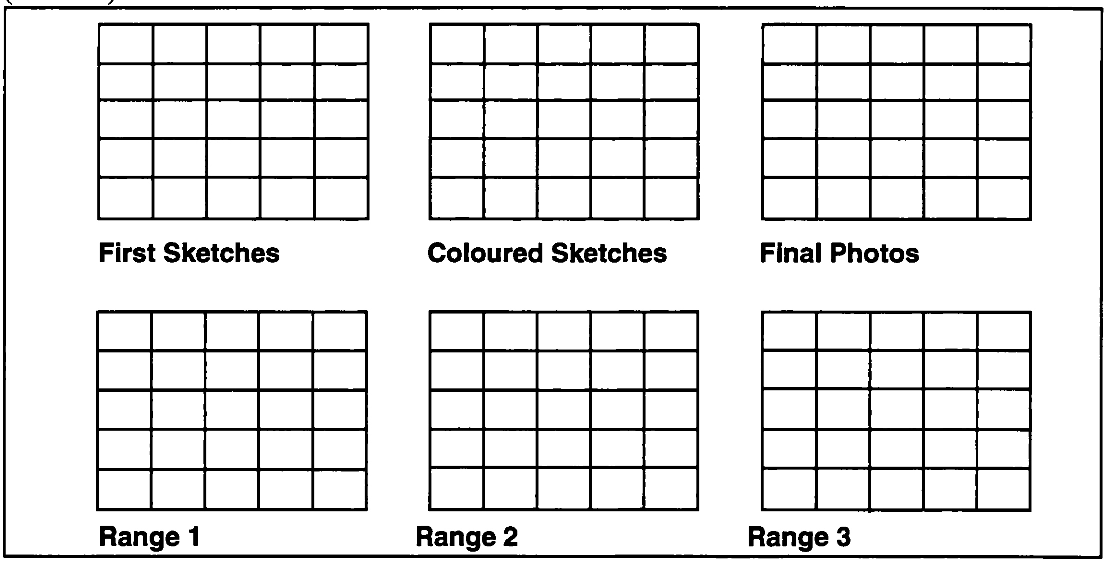
Figure 7.10: Displaying Lines of Product Evolution from Final Product to Initial Concept (View 1)



View 2 - Viewing Individual Ranges and Stages of Range Development in Image Galleries

In fashion product design there are typically three main stages of visual development during the design process, all of which have physical outcomes: 1. Initial sketches, 2. Colour sketches, 3. Final photographed samples. These visual stages would also typically occur in most other industrial product design domains. As discussed in chapter 4, in product development several ranges are typically developed along side one another in any product development cycle within a company. It is therefore natural for members of a product design team to want to view the products from particular ranges together. An ideal way to view the all of the products from each stage and in each range together, would be to provide a gallery displaying thumbnail size graphics of the product images, as illustrated by Figure 7.11.

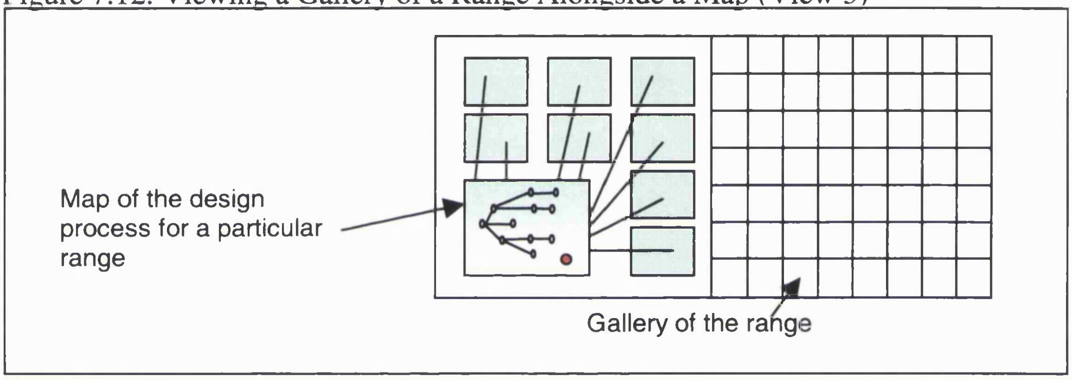
Figure 7.11. Viewing Ranges and Stages of Range Development in Image Galleries (View 2)



View 3 - Viewing an Image Gallery of a Range Alongside Design Rationale Maps

When looking at the maps of particular ranges it should also be possible to have a gallery view of the range down the right hand side of the map screen, enabling users to relate to the products as they are discussed or even access their evolution, as shown in Figure 7.12. In the field study the product manager commented that it would be very helpful if sales information was directly linked to the range data which in turn would enhance the strategic decision making process. For example when looking at a garment from a particular range, if the sales data could be called up, the product development team would be able to see at a glance how successful the garment was. An image gallery where the top 20 best selling garments could be viewed alongside their sales figures and similarly the bottom 20 worst selling garments could be viewed, would also aid reflection on product sales. Having this information so readily to hand would affect the development of the coming cycle's range. In fashion product design sales figures are routinely referred to but this would make the process a lot easier and give a quick visual reference of what had sold well and what hadn't.

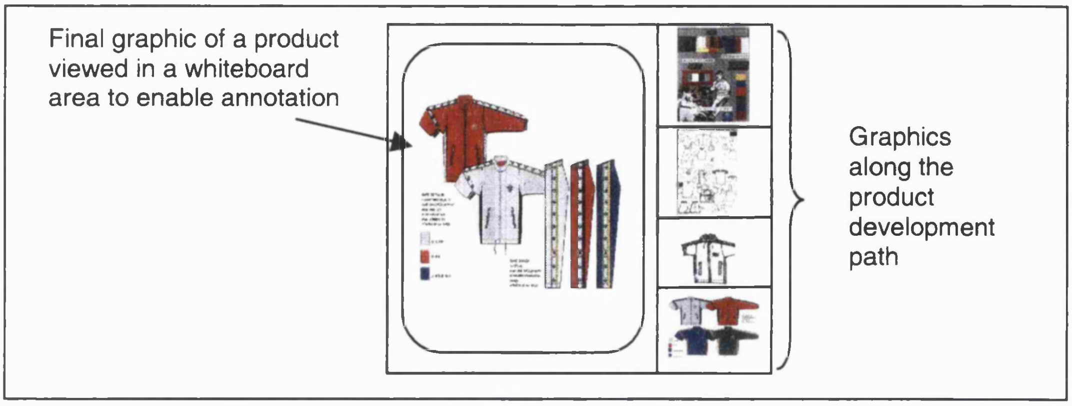
Figure 7.12. Viewing a Gallery of a Range Alongside a Map (View 3)



View 4 - Viewing Product Images in a Whiteboard Area for Annotation with Thumbnails Graphics of the Entire Product Evolution or Product Range Along Side the Whiteboard Screen

Viewing an image of a particular product in a whiteboard area where it could be annotated with information by members of the design team for later reflection, would provide another useful GUI. It would be further beneficial to have the facility to view all the other graphics in the line of visual evolution for the particular product at the same time. For example, when viewing a final photograph of a finished product in the whiteboard screen, thumbnail images could be provided down one side of the interface, displaying the range story board, the initial sketches, the working drawings and then final colour drawings, to enable the evolution of the product to be seen instantly as seen in Figure 7.13. This would facilitate users being able to visually trace back from the final outcome of the design process for a particular product.

Figure 7.13: Viewing Images from a Range Alongside a Whiteboard (View 4)



7.2.2 Navigational and General Interface Issues

The field study raised navigational issues which required addressing in the IBIS$^+$ representation that was constructed. Most of these were due to limitations in the interface of the mapping software used to construct the maps and could be resolved through the provision of the well documented overview, zoom, and detail on demand navigational facilities within the interface (Shneiderman, B. 1998). The IBIS$^+$ maps were found hard to navigate because of the inability to scale the maps to a desired size. A zoom facility that enabled the user to resize the view of the maps, forward and backward browse buttons to quickly scan through previous map views and scroll bars along the sides of the maps would resolve this. Tools familiar from other software packages, such as a find and replace facility, were identified as being potentially very useful as the knowledge base grew, as was a spell checking facility. With regard to the map layout of the IBIS$^+$ maps, some of the members of the design team felt they would also like to have the flexibility to view the structure in a list view as well as a map view as demonstrated in Figure 7.14.

Figure 7.14: Viewing the Decision Structure in a List View

POSITION
  Argument
  Argument
  Decision
POSITION
  Argument
  Argument
  Decision

Instead of:

POSITION ← Argument
← Argument
← Decision

It is critical that appropriate navigational facilities are provided within the interface of a design rationale knowledge base, that are intuitive for potential users to navigate, otherwise it could prevent the knowledge base being used as an integral part of the design process.

7.3. Summary

This chapter outlines how following the evaluation in Chapter 6 of the $IBIS^+$ knowledge representation constructed during the field research, extensions to the $IBIS^+$ notation are proposed.

Section 7.1. describes how the design team in the field research reflected on and experimented with the $IBIS^+$ representation, not only as it was being constructed concurrently with the design process, but also when it was completed at the end of the design cycle. A detailed analysis of their experiences of using the representation was then conducted as outlined in chapter 6. Certain issues raised require the $IBIS^+$ notation to be suitably adapted for representing industrial product design rationale. The second approach proposed for tackling the weaknesses within the $IBIS^+$ representation, is to introduce a distinct retrospective, reflective stage, following on from the end of the design process, to tidy up the design rationale maps and provide a more complete representation. The benefit of learning by reflecting on an accurate record of the design rationale is alluded to. Conducting this reflective stage would further enable the maps to be used to create a template to aid planning and decision making for the following cycles design process.

Section 7.1.1 outlines the proposed extensions to the $IBIS^+$ notation to form the adapted notation referred to as $IBIS^{PDR}$ (Issue Based Information System Product Design Rationale). Following this, section 7.1.2 emphasises the importance of being able to reflect on as complete a representation of the design rationale as possible. The requirement is described for the incorporation of a reflective stage that would allow the design rationale structure to be reviewed, corrected, annotated and updated.

Several further extensions to the $IBIS^+$ notation are proposed to be incorporated into the $IBIS^{PDR}$ notation as a critical part of this retrospective, reflective stage.

Section 7.1.3 introduces the importance of procedures that streamline design decision making in order to maintain competitive advantage in a product design environment. It is proposed that $IBIS^{PDR}$ maps could be used to create a template to support strategic planning and design decision making for subsequent design cycles. The knowledge structure would then become an invaluable range planning tool. It is further proposed that design reflection and decision making could be enhanced by linking successive $IBIS^{PDR}$ representations, facilitating the tracing back of the design rationale over a number of cycles and promoting the understanding of previous design scenarios and decisions.

Section 7.2 provides an overview of the GUI's particular to the fashion product design process studied in the field research, which can be connected to the underlying design knowledge base. These were identified as a consequence of exploring the $IBIS^+$ representation during the field study. It is stressed that when developing a GUI for an $IBIS^{PDR}$ structure it would be essential that the domain and the purpose of the underlying data be carefully considered.

Figure 7.15 summarises the improvements recommended in this chapter to the $IBIS^+$ knowledge structure outlined in chapter 6. It demonstrates the progression of the $IBIS^{PDR}$ notation. It shows how the $IBIS^{PDR}$ notation extends the $IBIS^+$ notation in order to provide a more suitable representation for capturing design rationale in a industrial product design environment. It also demonstrates how through the process of exploring improvements to the $IBIS^+$ notation in the field research, ideas were developed for GUI's specific to fashion/product design. Such GUI's could be utilised with $IBIS^{PDR}$ knowledge maps to streamline access to the underlying data.

The next chapter describes how the $IBIS^+$ knowledge representation developed during the field research was reconstructed using the $IBIS^{PDR}$ notation outlined in this chapter. A review of the $IBIS^{PDR}$ design knowledge representation is then presented, following a task analysis conducted with the design team used during the field study.

Figure 7.15: Recommended Improvements to the IBIS$^+$ Knowledge Structure

IBIS$^+$ KNOWLEDGE STRUCTURE

The IBIS+ notation was used as a starting point to structure the amassed design data in order to examine the requirements of a useful product design rationale representation.

IBIS^{PDR} KNOWLEDGE STRUCTURE

IBIS^{PDR}

The IBIS^{PDR} notation extends the IBIS$^+$ notation in order to address the identified limitations of using IBIS$^+$ to capture product design rationale.

- One generic link type.
- New node type: Resolution.
- Colour coded domain specific decision and resolution nodes.
- Temporal markings on nodes.

IBIS^{PDR} RETROSPECTIVE

The retrospective additions to the IBIS^{PDR} notation allow the representation to be reviewed, corrected, annotated and updated as part of a reflective stage.

- Annotate IBIS^{PDR} maps to provide a more complete design rationale representation.
- Link key Position, resolution and decision nodes to image files of the final products.
- Add an 'R' flag to retrospective decision nodes.
- New node type: Not Actioned.

IBIS^{PDR} TEMPLATE

Following the retrospective stage the complete representation of the design rationale can be used as a template to provide a starting point and support strategic planning and design decision making for the following design cycle.

IBIS^{PDR} LINKING CYCLES

Following the retrospective stage the IBIS^{PDR} maps can be linked to maps of previous and subsequent design cycles providing the opportunity to explore and comprehend the design progression through the cycles.

GUI'S SPECIFIC TO FASHION PRODUCT DEVELOPMENT

- Displays of product evolution from final product to initial concept.. (View 1)
- Viewing individual ranges and stages of range development in image galleries. (View 2)
- Viewing image galleries of ranges along side design rationale maps. (View 3)
- Viewing product images in a whiteboard area for annotation with thumbnail graphics of the product evolution along side the whiteboard screen. (View 4)

NAVIGATIONAL AND GENERAL INTERFACE TOOLS

- Scroll Bars.
- Zoom.
- Find and Replace.
- Spell Checker.
- List View.
- Forward and Backward Browse.

CHAPTER 8:

IBIS^{PDR} DESIGN KNOWLEDGE REPRESENTATION

The chapter describes how the IBIS^{+} knowledge structure was entirely reconstructed using the IBIS^{PDR} notation proposed in chapter 7, to account for the limitations in the IBIS^{+} representation discussed in chapter 6. The graphical user interfaces (GUI's) specific to fashion product design discussed in chapter 7 were implemented to assess their effectiveness. Some of the desired navigational facilities are provided by the interface to the mapping software used to construct the IBIS^{PDR} representation. In addition the IBIS^{PDR} maps were made available for viewing through a web browser in order to assess the extent of any benefits that might be reaped from using this alternative environment. A relatively informal task analysis, conducted in order to explore and confirm the success of the alterations to the representation, is described. A synopsis is provided of the task analysis results and a few minor refinements are proposed. The chapter concludes with a summary of the critical points.

8.1. Reconstructing the Multimedia Knowledge Representation

Chapter 6 outlined how a record of the design decision making process for an entire design cycle was constructed using an IBIS^{+} based tool. The design team in the field study reflected on the IBIS^{+} design rationale as it was being constructed during the design cycle. At the end of the design cycle when the IBIS^{+} maps were completed the product design team experimented with the complete representation for several weeks. A detailed analysis of the design team's reflections and opinions was conducted based on the feedback obtained at the beginning and end of each formal design meeting and in the structured interviews conducted and this is described in chapter 6. It was established that the knowledge structure based on the IBIS^{+} notation had certain inherent limitations within it to be addressed.

Chapter 7 then proposed extensions to the IBIS^{+} knowledge structure to address the identified limitations of the IBIS^{+} notation. Improvements to the notation were presented, forming the adapted notation referred to as IBIS^{PDR}. The importance was emphasised of incorporating a retrospective, reflective stage allowing the knowledge structure to be reviewed, corrected, annotated and updated in order for the design rationale to be a useful and reusable resource. Several further extensions to the IBIS^{+} notation were proposed to be incorporated into the IBIS^{PDR} notation as a critical part of this retrospective stage. An overview was given of the graphical user interfaces (GUI's) particular to the fashion product design process studied in the field research, which can be connected to the underlying design knowledge base.

This chapter provides a further evaluation of the knowledge structure once it had been reconstructed using the IBIS^{PDR} notation detailed in chapter 7. A different mapping software environment[1] was used to construct the IBIS^{PDR} representation. Many of the '*overview, zoom, and detail on demand*' (Shneiderman, 1998) navigational tools outlined in section 7.2.2 of chapter 7 as being required by the design team were implemented in the interface of the mapping software used to construct the IBIS^{PDR} maps.

Section 7.1.3 in chapter 7, outlined how following a retrospective stage a complete representation of the design rationale could be used as a template to provide a starting point and support strategic planning and design decision making for the following season's design cycle. Additionally the IBIS^{PDR} maps could be linked to maps of previous and subsequent design cycles providing the opportunity to explore and comprehend the design progression through the cycles. It was not within the scope of this thesis to test this empirically. In order to do so an entire further design rationale cycle would need to be followed using the IBIS^{PDR} maps from the current cycle to form a template and the maps from both cycles would need to be subsequently linked. This would however be a promising area for further research.

The graphical users interfaces (GUI's) specific to fashion product design discussed in section 7.2.1 of chapter 7 were implemented as prototypes using data from the design

[1] Visimap version 2.5b

cycle mapped and these were shown to the users for their comments. In addition the IBIS^{PDR} maps were made available for viewing through a web browser in order to explore benefits that might be reaped from using this alternative environment. Figure 8.1 outlines the stages of the knowledge base's development. A section of one of the IBIS^{PDR} maps is shown in Figure 8.2 and further examples taken from the IBIS^{PDR} maps can be seen in appendix G which illustrates the features of the maps. The IBIS^{PDR} representation was reviewed, once it had been implemented via a task analysis conducted with members of the design team used in the field study, in order to explore and confirm how successful the alterations to the notation had been.

Figure 8.1: Stages of Constructing the Multimedia Design Rationale Knowledge Base

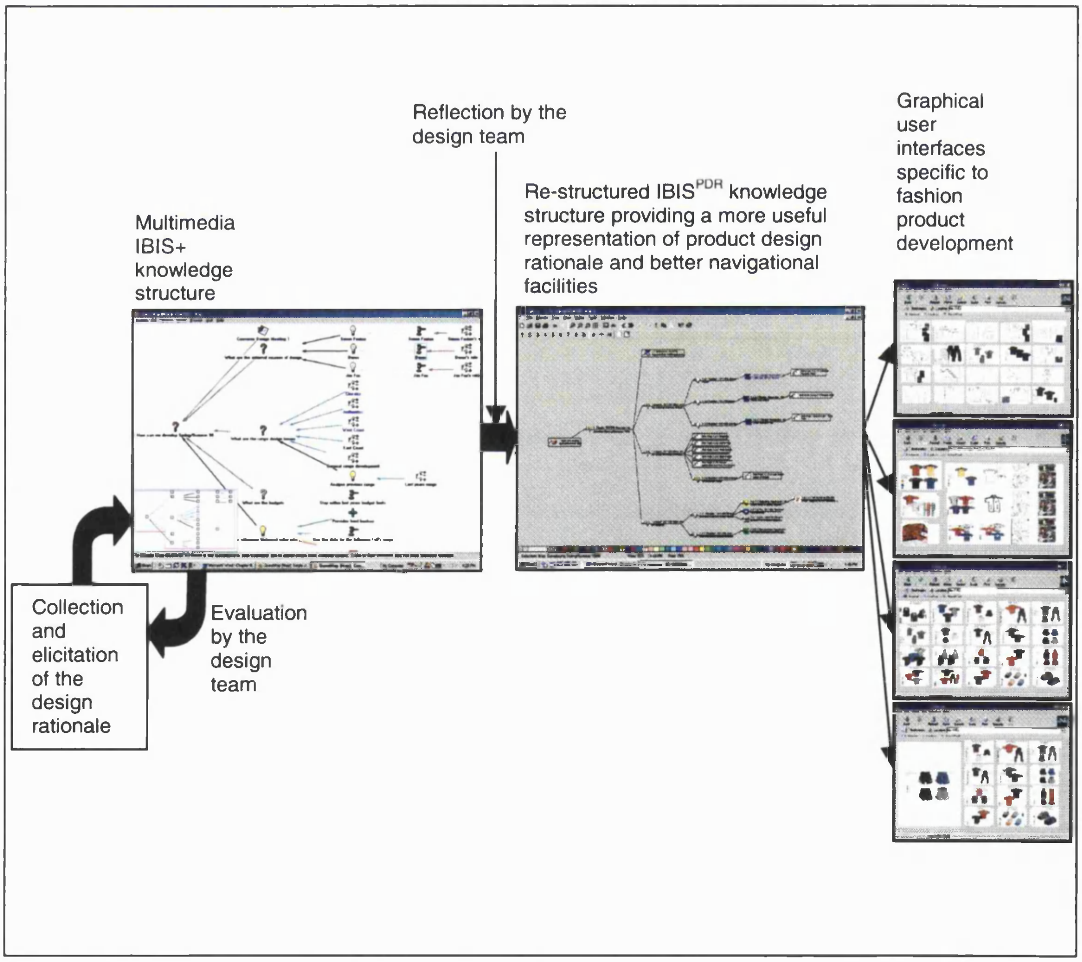
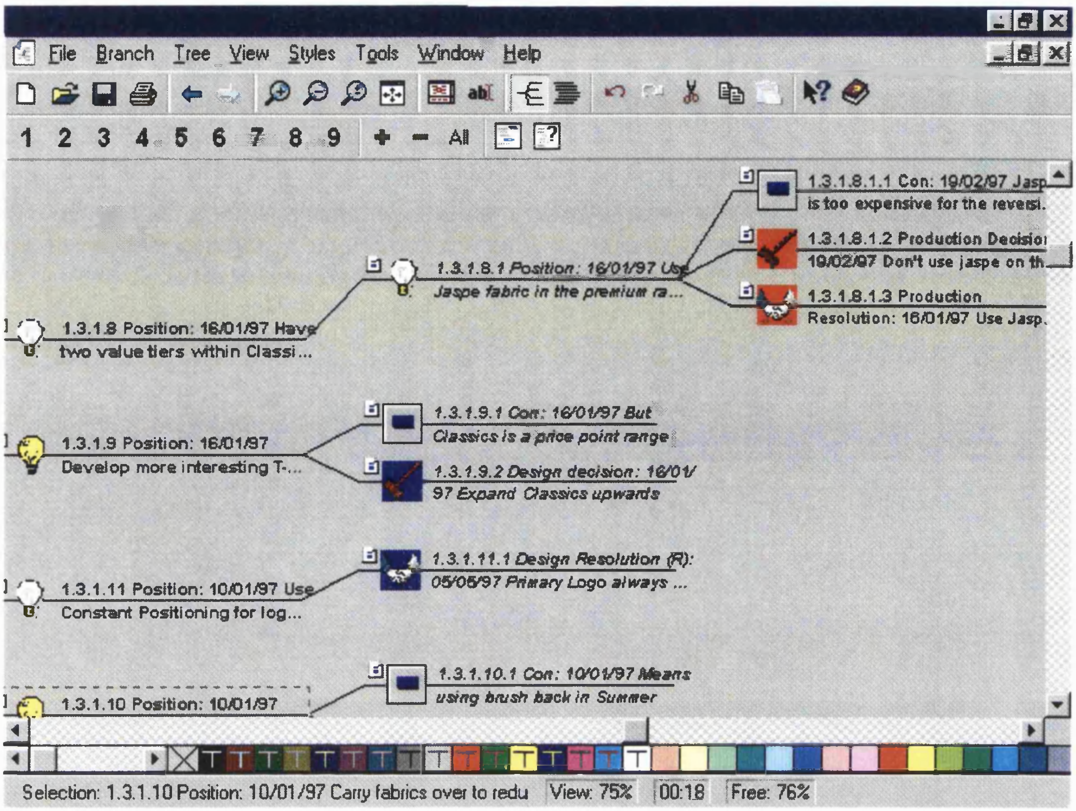


Figure 8.2: A Section of an IBIS^{PDR} Map



8.2. Task Analysis

It was deemed necessary to conduct a relatively informal task analysis on the reworked IBIS^{PDR} maps in order to assess how successful the alterations to the notation had been, and how easily the designers would learn to navigate and comprehend the reconstructed knowledge structure. Task analysis is based on the theory of exploratory learning and incorporates: Goal setting - users start with a rough description of what they want to accomplish - a task; Exploration - users explore the systems interface to discover actions useful in accomplishing their current task; Selection - Users select actions that they think will accomplish their current task, often based on a match between what they are trying to do and the interfaces description of actions; Assessment - users assess progress by trying to understand system responses, thus deciding whether the action they have just performed was the correct one and to obtain clues for the next correct action. (*Newman, 1995*)

Once the $IBIS^{PDR}$ knowledge representation had been constructed with the appropriate levels of functionality, performance and robustness, the task analysis experiment was designed. It was decided that the analysis should be weakly controlled, i.e. in a realistic task context as opposed to a rigid experimental investigation. Designing the experiment involved selecting the users required to participate in the experiment, defining the activities for them to perform and scheduling the tests. In order to evaluate the re-worked structure tests were run with four members of the design team who were involved in the design cycle originally captured in the field study by the $IBIS^{+}$ knowledge representation. They worked together as a group to conduct each task. They were presented with the following general problem statement: 'it is the requirement of the tool that it should support quick and easy retrieval of design rationale information.'

The emphasis of the task analysis was on examining the users understanding of the design rationale as it had been restructured using the $IBIS^{PDR}$ notation, not on how suitable they found the interface of the tool for constructing the rationale themselves. A brief manual for both the $IBIS^{+}$ structure and the $IBIS^{PDR}$ structure was given to the users to read before the tests were run and these manuals can be viewed in appendix H and I respectively. Where appropriate the tasks were timed. The users were asked to explore each knowledge structure (task 1 and task 2 respectively) and to make comments and comparisons on both. This provided an initial feel for whether they could instantly pick up on any of the improvements in the $IBIS^{PDR}$ representation and reminded them of the properties of the $IBIS^{+}$ knowledge representation. Tasks 1 and 2 were designed to evaluate the newly constructed $IBIS^{PDR}$ representation in comparison to the $IBIS^{+}$ representation. Task 3 was designed to explore any potential advantages and disadvantages of viewing the representation through a web browser. Task 4 was designed to evaluate the implemented domain specific graphical user interfaces. The remaining tasks 5-14 were included in the analysis in order to check that the users were able to efficiently navigate the $IBIS^{PDR}$ representation and understand the correct usage of the new additions to the notation. These tasks are designed to retrieve the type of information that a user might require from the $IBIS^{PDR}$ maps in a real product design setting. A summary of the tasks is as follows:

Task 1: Spend twenty minutes navigating through the IBIS^{+} representation and make some general comments about your understanding of it and problems you see with either the interface or the notation.

Task 2: Spend twenty minutes navigating through the IBIS^{PDR} representation and make some general comments about your understanding of it and problems you see with either the interface or the notation. Compare it to the IBIS^{+} representation used initially.

Task 3: Spend ten minutes navigating through the IBIS^{PDR} representation viewed through an internet browser and compare it to viewing it through the IBIS^{PDR} maps interface used previously.

Task 4: Examine the implemented domain specific graphical user interfaces and comment on their design.

Task 5: Using the IBIS^{PDR} maps demonstrate who the external design consultants were?

Task 6: Out of the external design consultants who had the most input to the design process?

Task 7: Out of the design consultants maps how many nodes were hyperlinked to visual files and which consultants' maps were they in, what did the files contain?

Task 8: Find a 'Not Actioned' node on the map and explain what it is indicating.

Task 9: Over what time period was the design rationale constructed?

Task 10: How many retrospective nodes are there in the maps?

Task 11: How many marketing (yellow) decision or resolution nodes are contained within the maps?

Task 12: How many production (red) decision or resolution nodes are contained within the maps?

Task 13: How many design (blue) decision or resolution nodes are contained within the maps?

Task 14: How many management (green) decision or resolution nodes are contained within the maps?

The data resulting from the tests was collected primarily by observation during the tests and via informal interviews at the end of the tests. However the sessions were also audio recorded and the users were asked to speak out loud as they conducted the task if they were experiencing difficulty. The data was then analysed to establish how the $IBIS^{PDR}$ structure compared with the $IBIS^{+}$ prototype. The $IBIS^{PDR}$ maps were evaluated on performance metrics including: time taken to complete tasks; assessments of acceptability or complexity and they were further evaluated on usability including: could the tasks be achieved with acceptable costs to the users; their effectiveness; learnability; and flexibility. Conclusions were drawn about further improvements needed in the knowledge structure and successful aspects were identified.

8.2.1 Results from the Task Analysis

The following summarises the results of the task analysis conducted with the marketing director, clothing product manager, marketing manager and the designer, from the company used during the field research. They were already familiar with the $IBIS^{+}$ representation and they were first asked to read through the two manuals for the $IBIS^{+}$ and the $IBIS^{PDR}$ representations. They were then asked to run through the following tasks speaking their thoughts out loud as they tried complete each task.

Task 1: Spend twenty minutes navigating through the $IBIS^{+}$ representation and make some general comments about your understanding of it and problems you see with either the interface or the notation.

The same problems in the $IBIS^{+}$ representation were reiterated as outlined as a result of the analysis in the chapter 6.[2] In particular the interface was still deemed very hard to navigate. The fact that there was no zoom facility on the interface was thought to be especially annoying because it was only possible to view a small section of the map at one time, making it difficult to make sense of without more context. In order to see the whole picture and make sense of the maps it was necessary to print each

[2] There were no unexpected findings as a result of task 1 and a reader who still has the issues raised in chapter 6 in mind, might wish to skip the text referring to task 1. Task 1 was included in the analysis merely to refresh the $IBIS^{+}$ notation in the minds of the user in order that their comparison with the $IBIS^{PDR}$ notation would be richer.

portion of them out and stick pages of A4 together, forming a large plan of a map. It was further emphasised that a visual overview of all the maps in the system would be essential. The designer stated '*the thing I would find difficult is there is no overview. That's the really hard thing because that is the most arduous thing to get your head round, in order to get the big picture. Maybe it would be helped if there was a zoom, or you could print a report that shows how it all links together – it doesn't necessarily even need to be visual it could just be a textual report showing the chain of maps, that would give you an idea of how from the first map to the end map, they are connected, because it is quite hard to follow the links because the interface makes it so hard to navigate.*'

It was thought that the representation would be ideal for identifying where bottle necks were occurring in the design process and also for identifying where decisions were required. The need for other '*overview, zoom and detail on demand facilities*' (Shneiderman, 1998) such as scroll bars, which the users were familiar with from other software packages, was repeated. In terms of the notation they were still familiar with it from the previous field study experiments. However problems were still encountered making sense of and remembering the meaning of the numerous coloured links and the section on the link types in the manual was referred to several times during the twenty minute exploration of the maps. The requirement to annotate the representation to bring it up to date was reiterated, in order that the design team would be able to set the record straight before they moved on with the design. For example, it was noted that there were too many positions left hanging with no decision nodes attached to them, where in many case decisions relating to the particular positions had been made. The need was stressed for the maps to be accurate in order for them to be used for quality analysis e.g. assessing the role of the external designers.

Task 2: Spend twenty minutes navigating through the $IBIS^{PDR}$ representation and make some general comments about your understanding of it and problems you see with either the interface or the notation. Compare it to the $IBIS^{+}$ representation used initially.

The initial comments related to the enhanced navigation elements provided within the $IBIS^{PDR}$ maps interface demonstrated in figures 8.3 and 8.4. It was possible to move through the maps much more smoothly using the vertical and horizontal scroll bars at the edges of the screen. The zoom facility which enable larger portions of map to be viewed in one go was also liked. It was however commented that it was a shame that when the whole map was viewed on the screen, the nodes and their annotations were too small to read. Linking the system to an extra large VDU in the design room to overcome this problem was suggested.

The split screen allowing the text associated with the nodes to be viewed at the same time as viewing the maps was referred to as being a great improvement. However it would have been preferred if the labels for the nodes were included in the text part of the split window, so that if the maps were zoomed out to the extent that you couldn't read the node labels, you would still be able to look at the labels by clicking on the node and reading it in the text window. It was further commented that the maps were clearer without the use of the colour coded links.

The addition of the new node types 'not actioned' and 'resolution' were noted. The marketing director referred to the manual and was able to succinctly describe the difference between when the decision or resolution node should be used, i.e. that a resolution would be attached to a position node if all the positions in the line of reasoning were addressed by the resolution and a decision nodes would be attached to a position node where only some of the ideas in the line of reasoning would be addressed by the decision. He was aware that any position (light bulb) nodes in the line of reasoning where a resolution was attached would be greyed out to indicate that each of the positions in this line of reasoning had been addressed by the resolution. It was commented that care would need to be taken to ensure that the correct usage was made of decision and resolution nodes, especially if the representation was being constructed rapidly in order to be concurrent with the design meetings. The marketing director used the section of the map shown in Figure 8.4, to explain the difference between the resolution and decision nodes types.

Figure 8.3. Zoomed Out View of an Entire IBIS^{PDR} Map

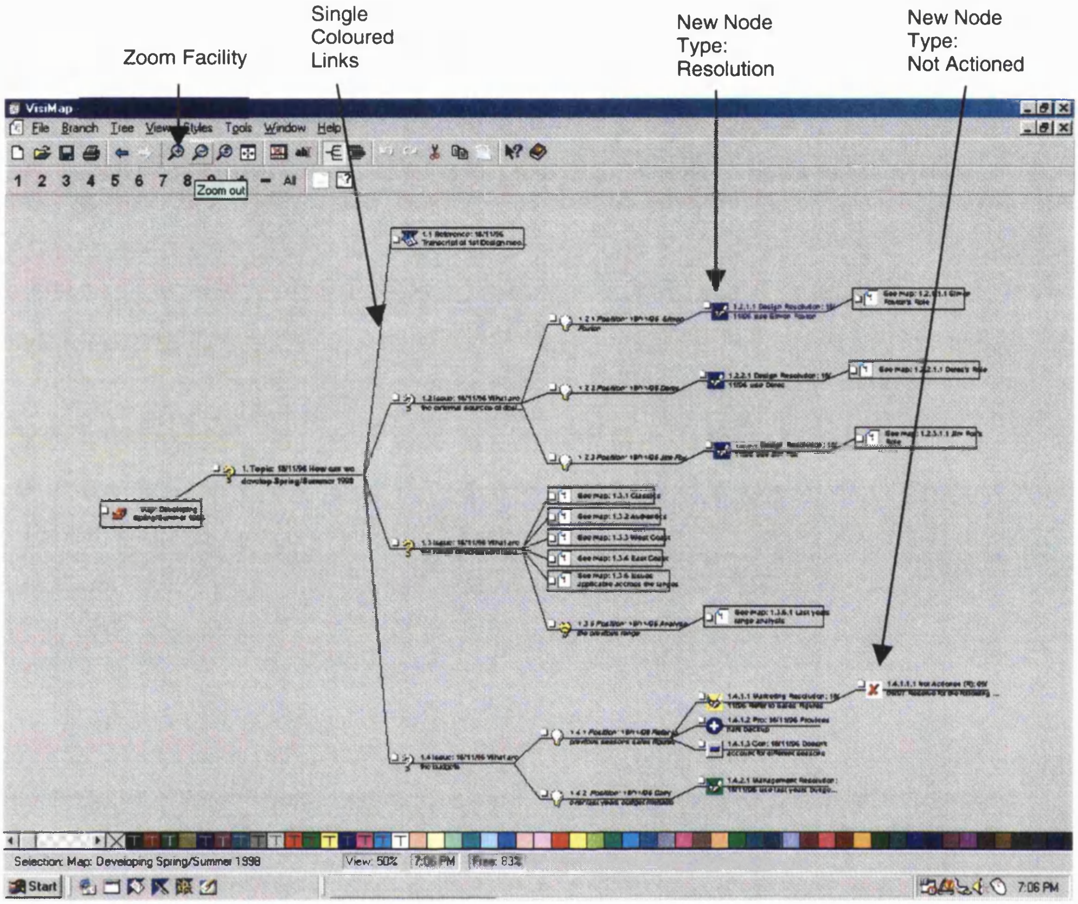
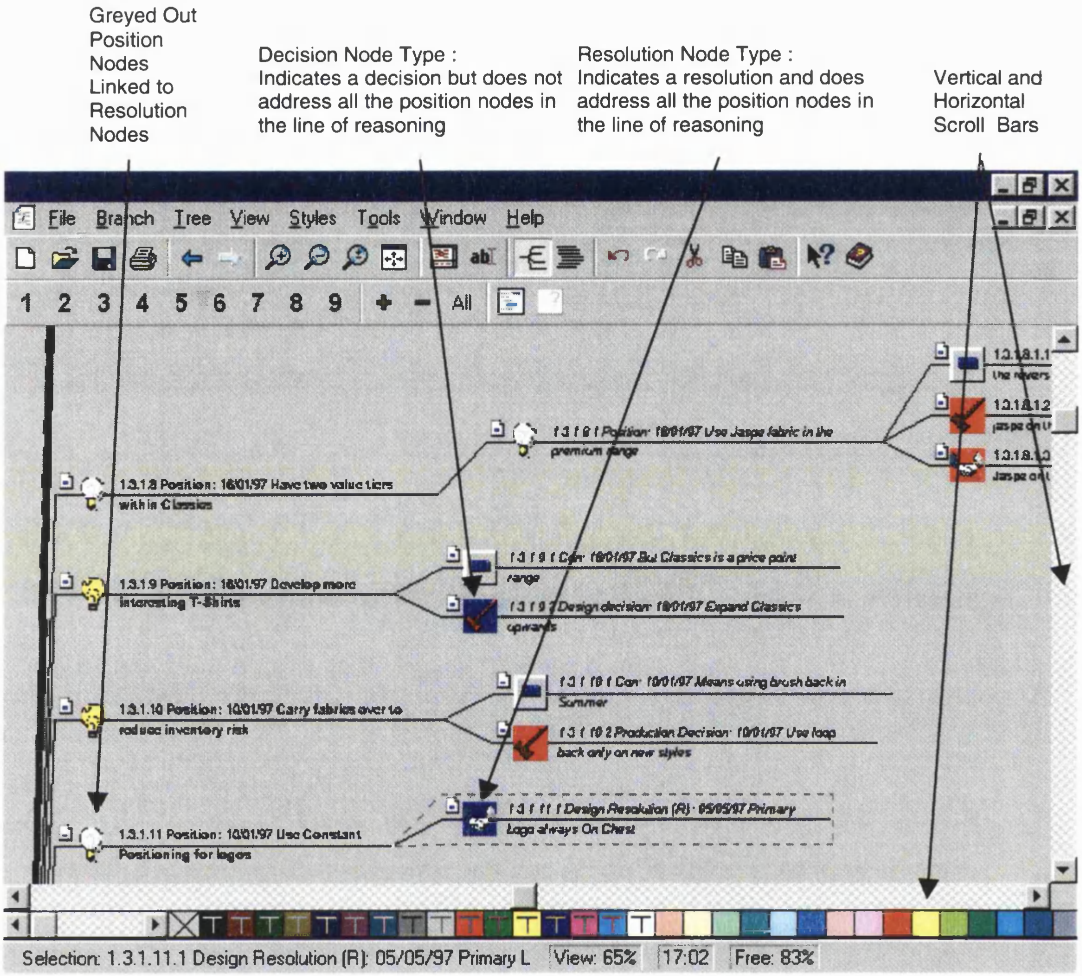
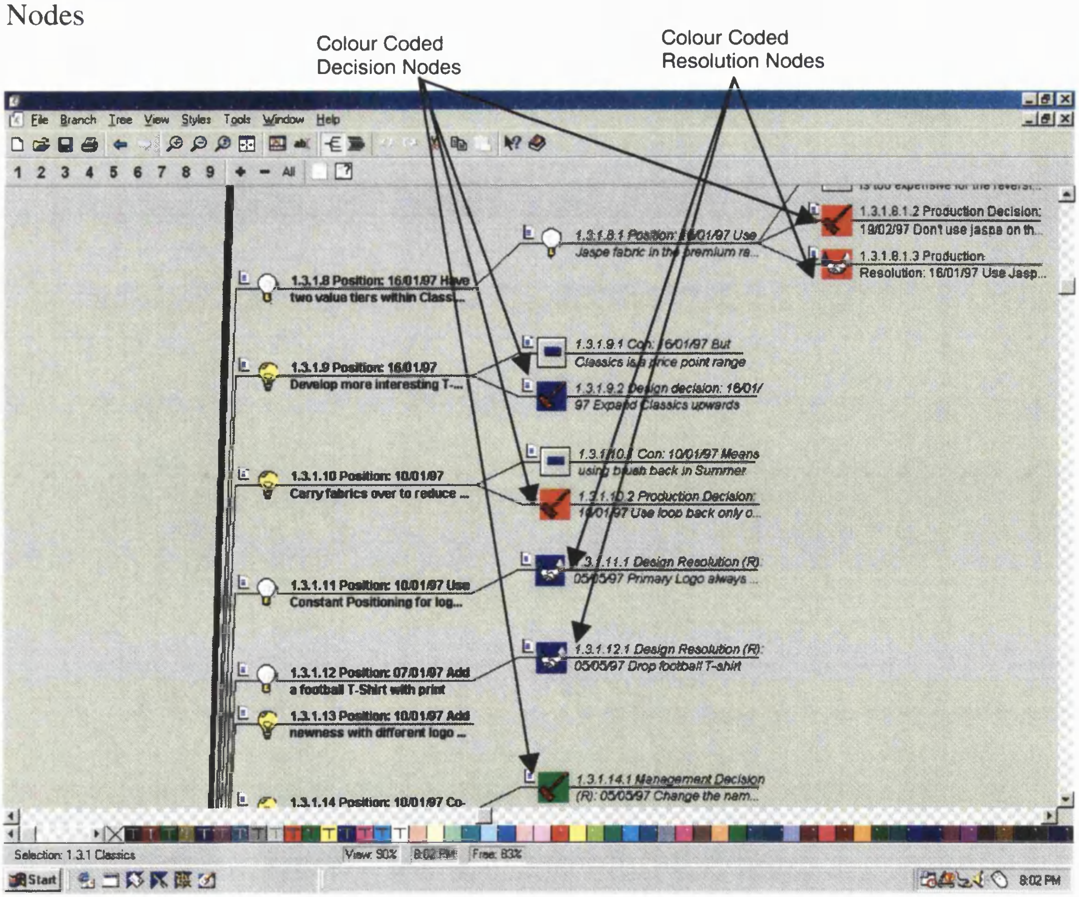


Figure 8.4. IBIS^{PDR} map demonstrating the use of Decision and Resolution Nodes



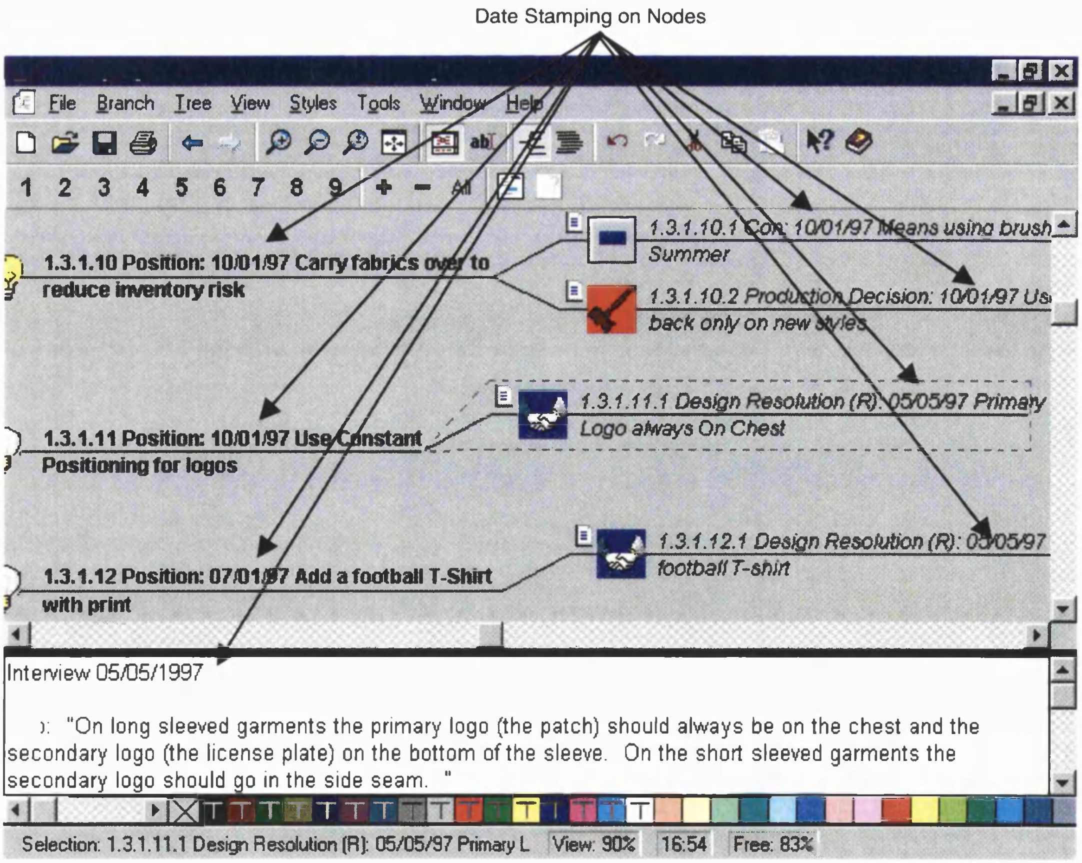
The manual was referred to several times in order to become familiar with the colour coding denoting the different departments for the decision and resolution node types as shown in the section of a IBIS^{PDR} map in figure 8.5. There was debate amongst the group as to whether this was a useful addition or not and whether colour coding was the best way of showing it or '*was this complicating the notation?*'. The designer noted that it would be obvious which department a node stemmed from by looking at the names of the person that had added the node but she then said that since people leave the company quite frequently this probably would not be possible a few years down the line. The consensus was that overall denoting the department that decisions and resolutions were coming from was quite useful and it was queried whether this could be extended across the whole notation. For example, could every node in the representation have a background colour that represented a particular department? This would then enable the production manager, for example, to quickly browse the map and look at the design dialogue just from the opinions of the production personnel involved in the design process. It would enable the themes being brought up from the different departments to be traced and facilitate tasks such as a search on all the comments added by the marketing team on the colour palette. The colour coded links used in the IBIS$^+$ maps had been very confusing, *'with the colour coded links it is just too much detail, you can't take it all in, with the colour coded nodes it is fine because when looking at the nodes there is a strong block of colour and the colour coded departmental nodes are easy to interpret at a glance and provide the notation with valuable additional functionality. With the links, adding different colours doesn't seem to provide the user with a lot more information. All you need to know is there a relationship between one node and another since the node type automatically infers what type of relationship exist. Also with the link lines, you don't see colour differentiation very well, whereas with the block of colour on the nodes it is very clear.'* For example it is not necessary to have a link type 'objects to' when there is already an 'objects to' argument node.

Figure 8.5. IBIS^{PDR} Map Demonstrating Colour Coded Decision and Resolution Nodes



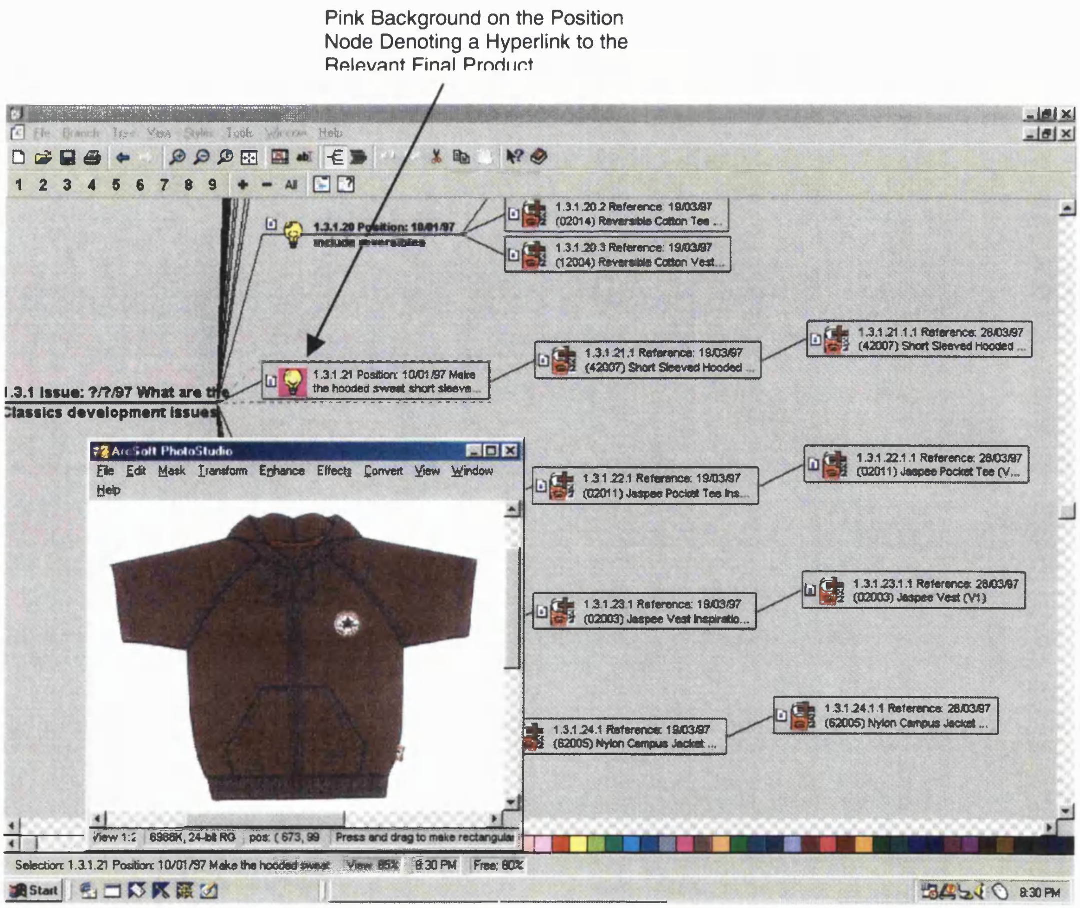
The addition of date stamping was particularly liked by the production manager who viewed it as a potential 'weapon' against deadlines not being heeded. It was also thought that this would be useful for allocating responsibility. The example shown in figure 8.6 was used, stating that on 05/05/97 it can be seen that the marketing director said to the designer: "*On long sleeved garments the primary logo (the patch) should always be on the chest and the secondary logo (the license plate) on the bottom of the sleeve. On the short sleeved garments the secondary logo should go in the side seam.*" If for any reason this instruction was not followed after the 05/05/97 it was identified that the representation could be referred to in order to establish exactly what and when it had been said. It was not however thought that stamping the nodes with the exact time of their addition would have any particular benefit and that date stamping would be sufficient.

Figure 8.6. IBIS[PDR] Map Demonstrating the Addition of Date Stamping to the Nodes



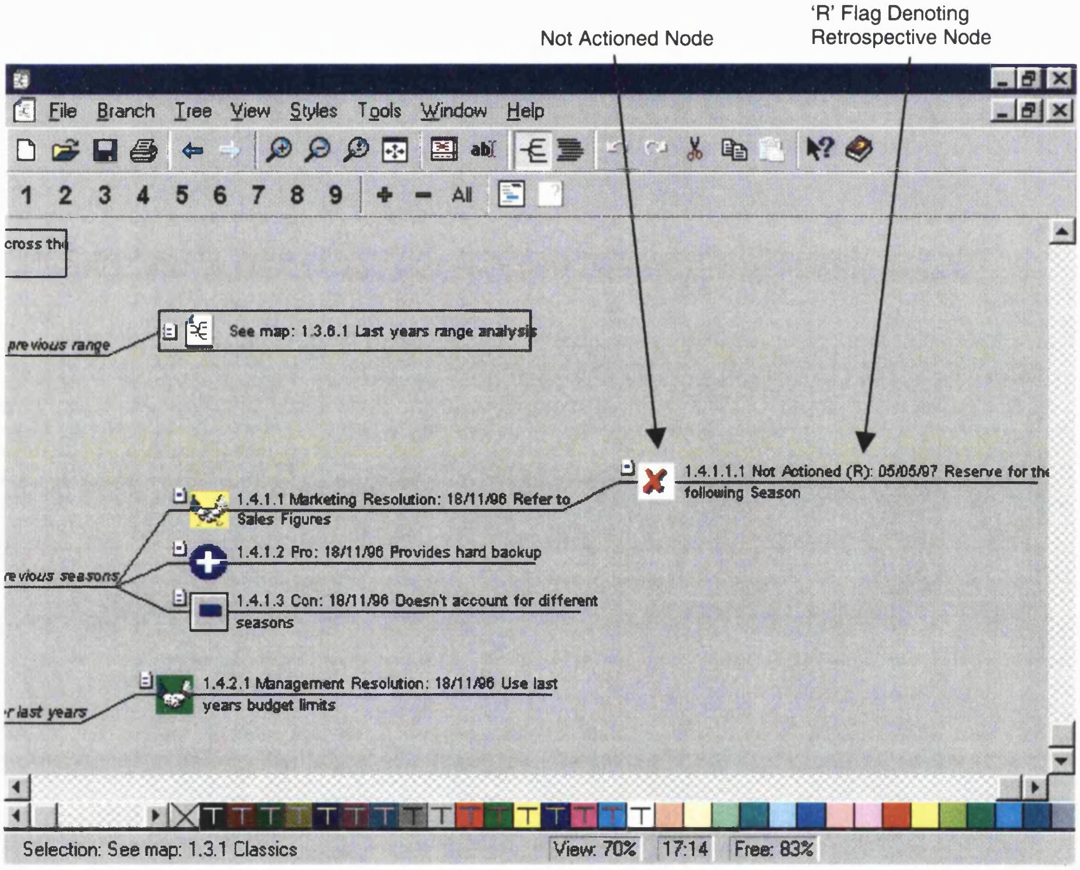
The hyperlinking of the key position nodes to visuals of the final product relating to the position, as shown in figure 8.7, was particularly liked by the designer. However the production manager mistook the pink colouring to mean that these were nodes added by the production department since she had confused it with the production resolution and decisions nodes that had a red background. There was discussion on the confusion that colour coding could cause if used too widely within the notation. The consensus was that it shouldn't be used in more than one capacity within the notation, they would prefer a different way of denoting a node was linked to a visual of the final product such as an 'V' flag next to the node.

Figure 8.7. Hyperlinking Position Nodes to a Visual of the Relevant Final Product



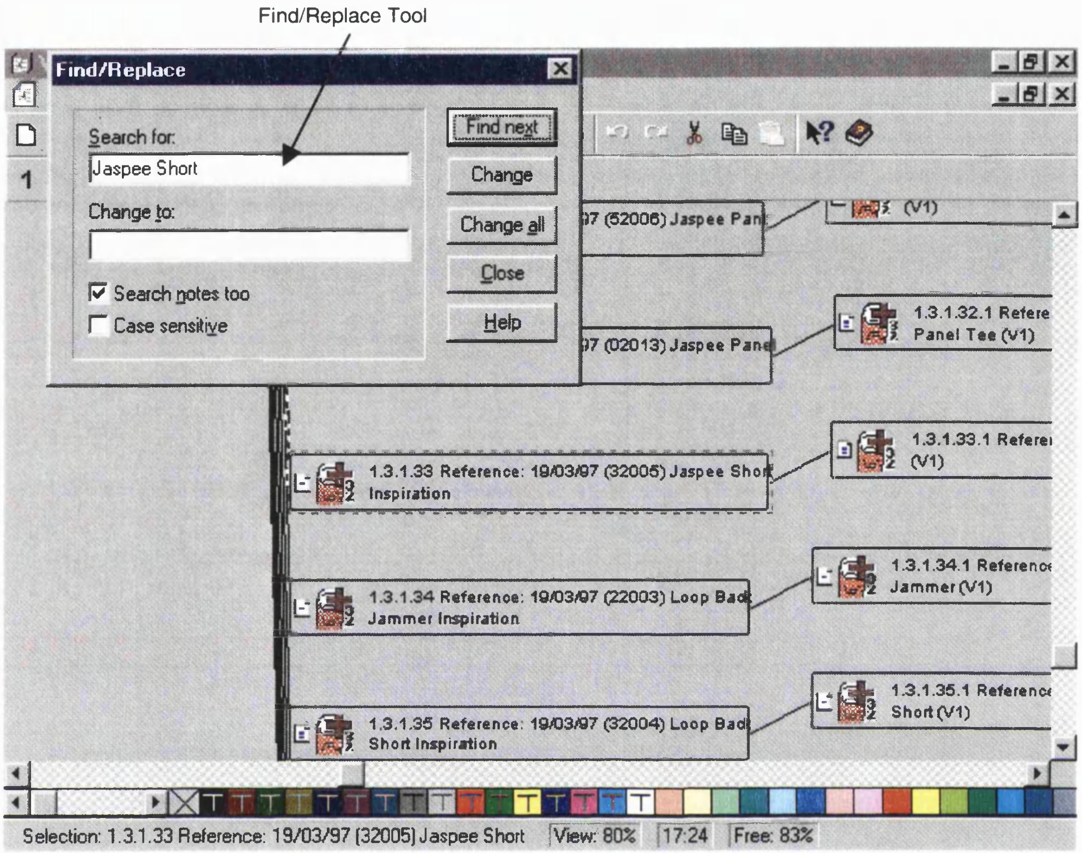
There was no problem understanding the use of the 'not actioned' node type seen in figure 8.8, but it was noted that the representation could now be annotated with some further 'not actioned' nodes that become the case since the design rationale was last updated. There was no comment on the 'R' flag that denoted retrospectively added nodes as shown in figure 8.8. When probed about this, the users felt it was interesting to see what had been added as part of the design discourse and what had been added later but the 'Not Actioned' node type was inherently a retrospective node and therefore the 'R' flag used with this node type was redundant.

Figure 8.8. IBIS[PDR] Map Demonstrating the 'Not Actioned' Node and the 'R' Flag



The 'Find/Replace' facility in the edit menu as shown in Figure 8.9, was found easy to use and identified as being an invaluable tool for tasks such as quickly locating any references to certain products within the knowledge base. This tool would become increasingly essential over time as the knowledge base grew with the addition of new data from each subsequent design cycle.

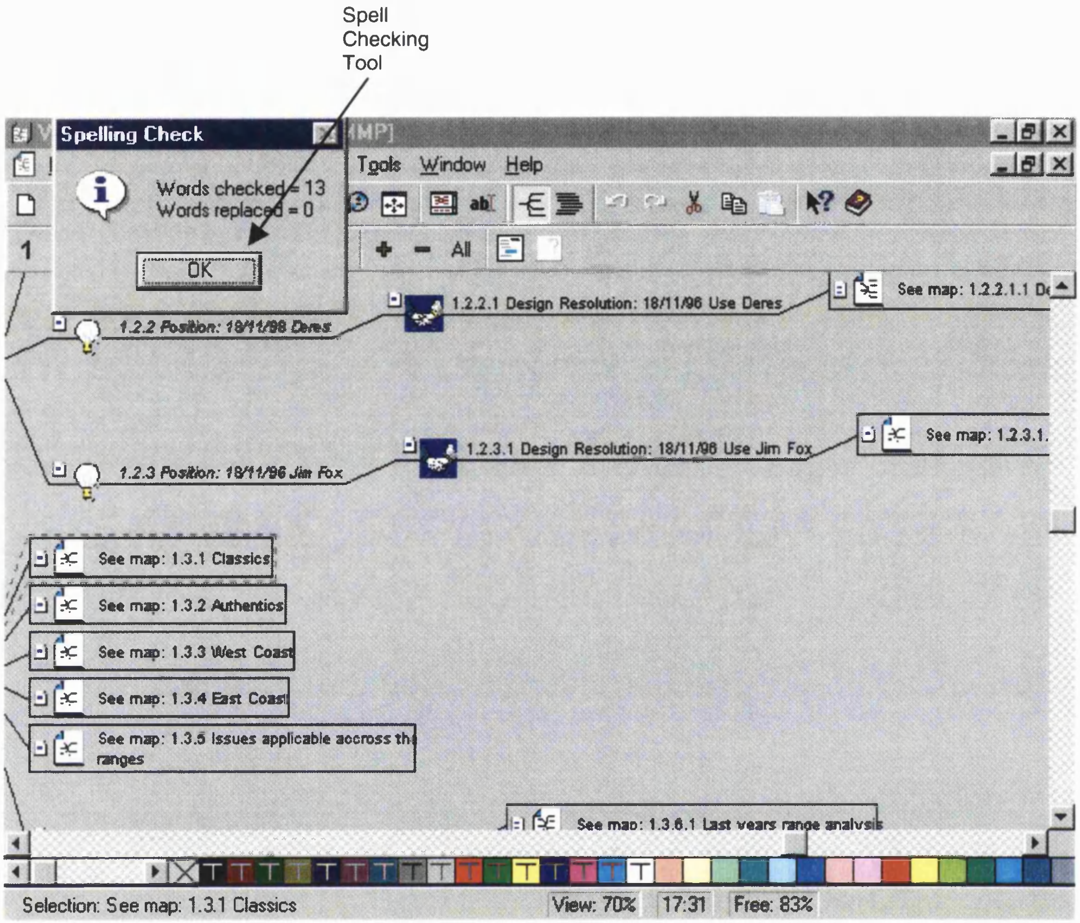
Figure 8.9. IBIS^{PDR} Map Demonstrating the Find/Replace Facility



Similarly the spell checker facility in the tools menu, shown in figure 8.10 was identified as being useful, particularly in view of the fact that data would be likely to be entered into the knowledge base by various people within the organisation and they would not necessarily be trained typists and might be prone to typing errors. [3]

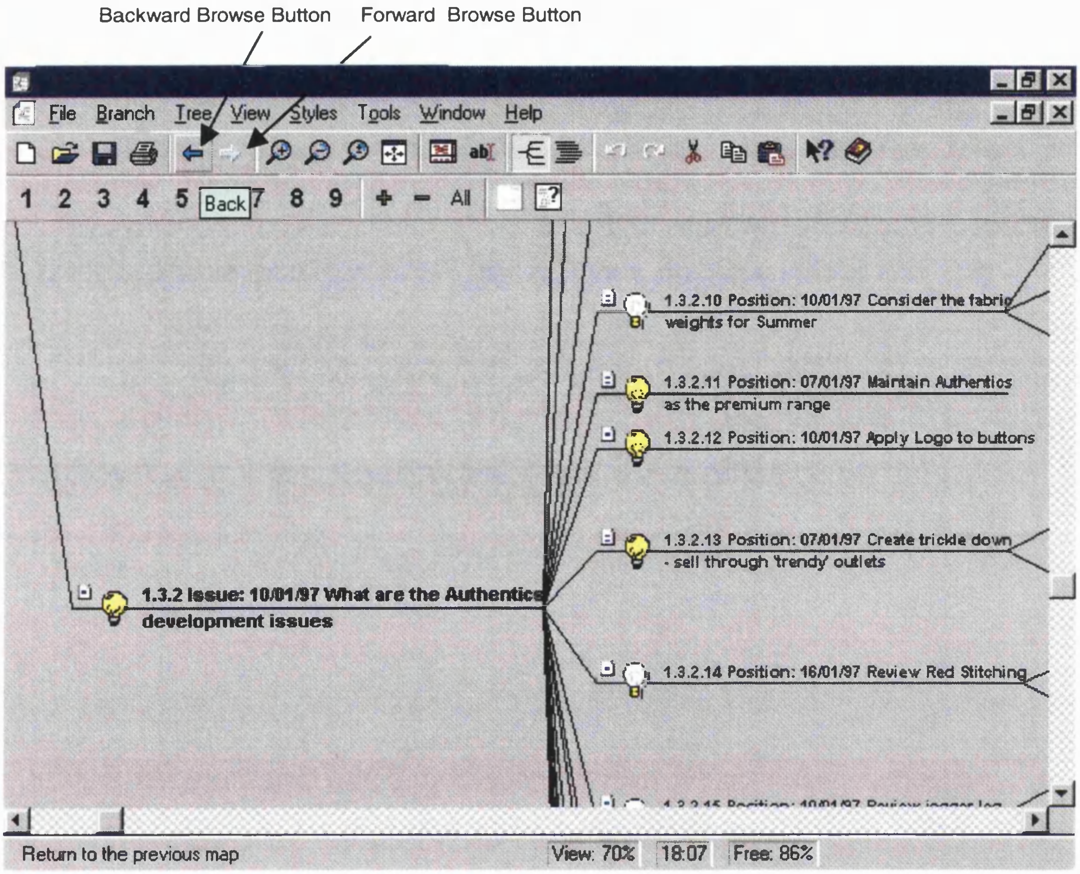
[3] The spell checking, find/replace, backward and forward browse and list view facilities described in this section are part of the development platform used to construct the maps and not part of the IBIS^{PDR} notation.

Figure 8.10. $IBIS^{PDR}$ Map Demonstrating the Spell Checker



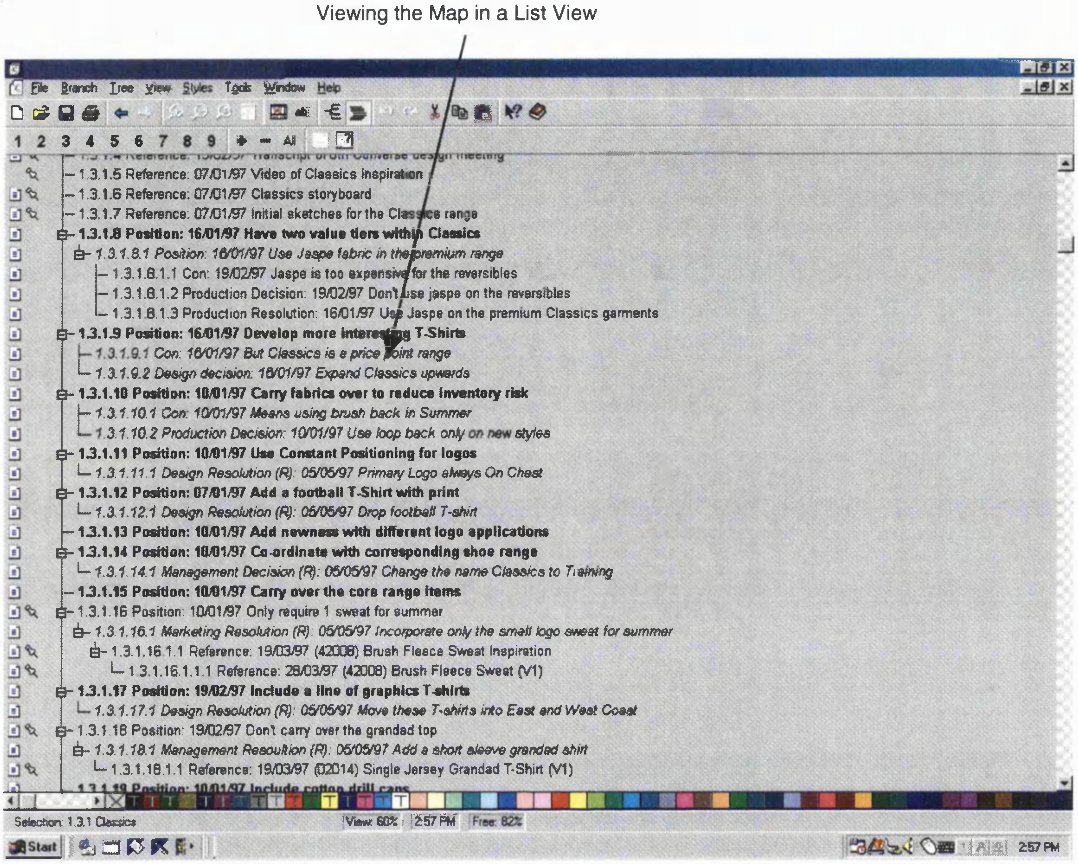
The facility to browse back and forward through the sections of the maps that had been previously viewed, shown in figure 8.11, was found to be another useful addition that helped with the enhanced navigation of the maps.

Figure 8.11. IBIS^{PDR} Map Demonstrating Back and Forward Browse Facility



The additional ability to view a textual list outline of each map as shown in figure 8.12, provides the users with a quick overview of the contents of a map, and was an identified requirement from chapter 7, demonstrated in figure 7.14. It was suggested that a visual overview of how many maps there are, what they are and how they link would be very useful in providing a user with a feel for the extent of the knowledge base. It was further pointed out that a report outlining the statistics for each map and for the whole representation would be valuable. It could contain summary information e.g. there are 50 marketing nodes and 20 marketing decisions, which could be used for tasks such as an analysis of the individual departmental dynamics and contribution within the design process.

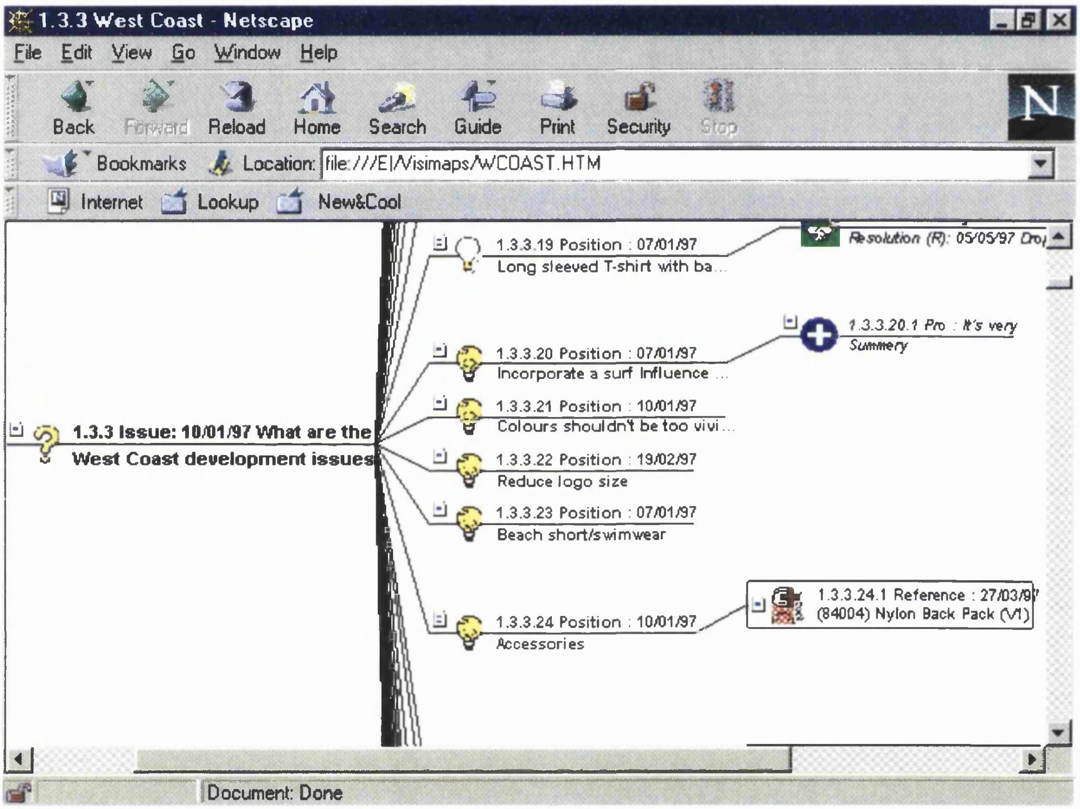
Figure 8.12. IBIS^{PDR} Map Demonstrating the Map List View



Task 3: Spend ten minutes navigating through the IBIS^{PDR} representation viewed through an internet browser and compare it to viewing it through the IBIS^{PDR} maps interface used previously.

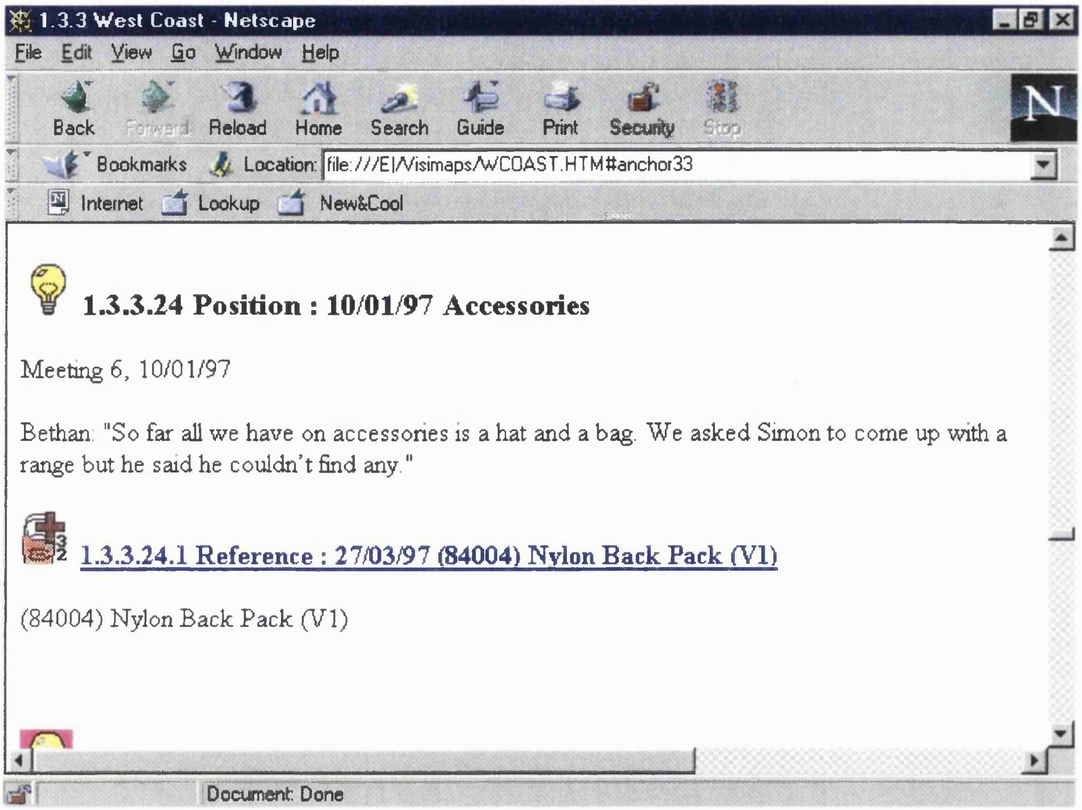
The idea of viewing and editing the representation through a web browser, as shown in figure 8.13, was very popular. The potential was highlighted of having the IBIS^{PDR} maps on the internet in order that designers at different sites could refer to them and use them as a shared workspace accessing them and altering them remotely. Some design companies use Apple Macs and others use PC's so by going down the web browser route the computability problems would be combated. However there would be grave security issues involved with placing the entire design rationale for a product design company on the internet. A security feature such as a password to access it would certainly be required but this really only gives a low level of security against industrial espionage. A preferred solution might be to create the maps in a different environment which the design team could remotely dial in to and incorporate the facility to export certain pages of the maps to the web in circumstances when it was required to be more widely viewable. A further consideration would be the political sensitivity that would be created if the design rationale were to be made so widely available. Employees may feel vulnerable if their work discourse and interactions was made available for general viewing.

Figure 8.13: Viewing a Section of an IBIS[PDR] Map Through a Web Browser



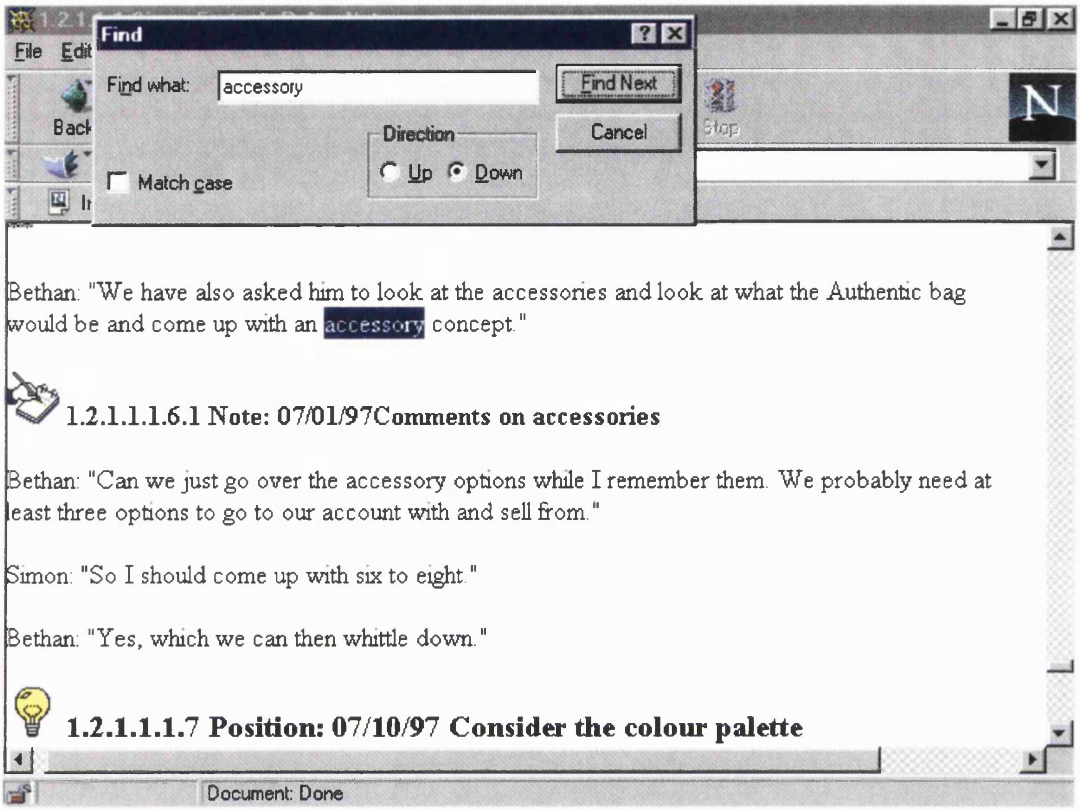
When viewing the representation through the web browser the ability to zoom in on the maps had not been incorporated and it was again reiterated that this was essential. Although scroll bars were provided, they were more clumsy, but clearly all these interface shortcomings would be surmountable if the interface were to be reprogrammed. The obvious advantage is the familiarity that many users now have with a web based environment. A further benefit of viewing the maps through a web browser was that when a map node was selected in the web browser interface the text contained within that node was displayed very clearly along with the icon and all the annotated details as shown in figure 8.14.

Figure 8.14. Viewing Text Contained within Map Nodes Through a Web Browser



There were advantages in using the web browser but these have to be balanced with the tradeoffs on the map navigation. It was again reiterated that the 'find' facility, as shown in figure 8.15, provided by the web browser could be very powerful for navigating large maps. Utilising the IBIS^{PDR} representation within a web environment might prove fruitful area for further research.

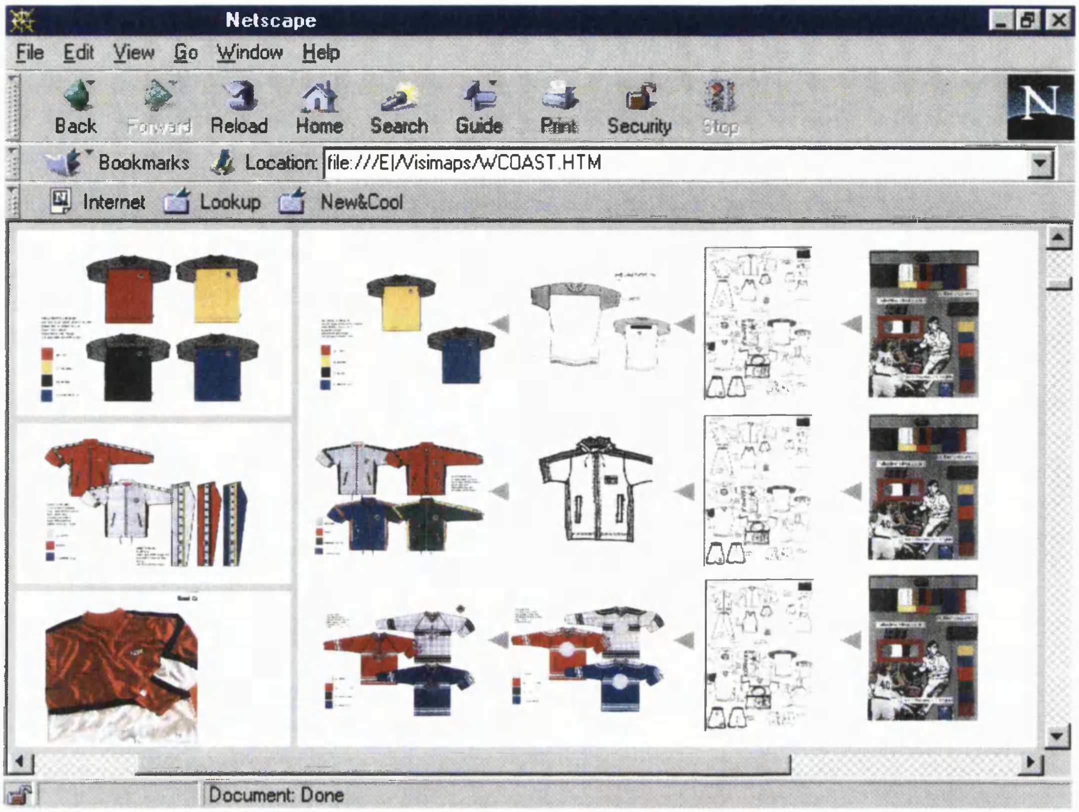
Figure 8.15 Utilising the Find Facility with $IBIS^{PDR}$ Maps Viewed Through a Web Browser

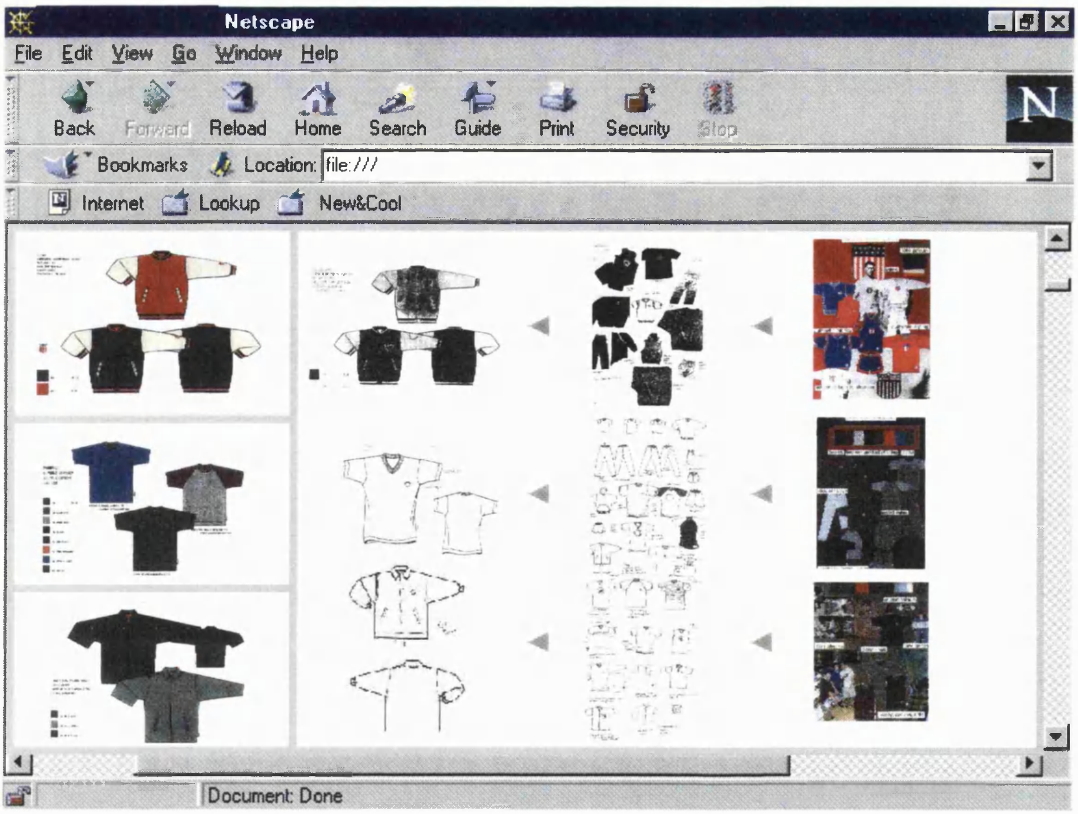


Task 4: Examine the implemented domain specific graphical user interfaces and comment on their design.

Useful ways of presenting information from the maps via domain specific graphical user interfaces are discussed here and referred to as views 1-4. They correspond with the views 1-4 discussed in section 7.2.1 of chapter 7. Each interface was implemented to provide the users with access to the underlying data in a manner that enhances certain tasks specific to their work. Nothing unexpected was found when this task was conducted but a few minor refinements were suggested. It was reinforced that the flexibility of instantly viewing the visual evolution of products as shown in figures 8.16 and 8.17 (view 1), from story board to final photo or coloured drawing, would provide a useful extension to the maps, particularly for gaining a quick insight into design stages for products from previous ranges.

Figures 8.16. and 8.17. Displaying the Visual Stages of Product Evolution (View 1)





Similarly the ability to view the visuals from each stage of range development, as demonstrated in figures 8.18 and 8.19 (view 2) provided a further invaluable graphical user interface with which to view the information in the knowledge structure. However it would not provide the user with the detailed knowledge on the design rationale that navigating the maps directly affords and therefore such interfaces would be an additional means of viewing the design resource, not a replacement.

Figure 8.18. Viewing Initial Sketches for a Range in a Gallery (View 2)

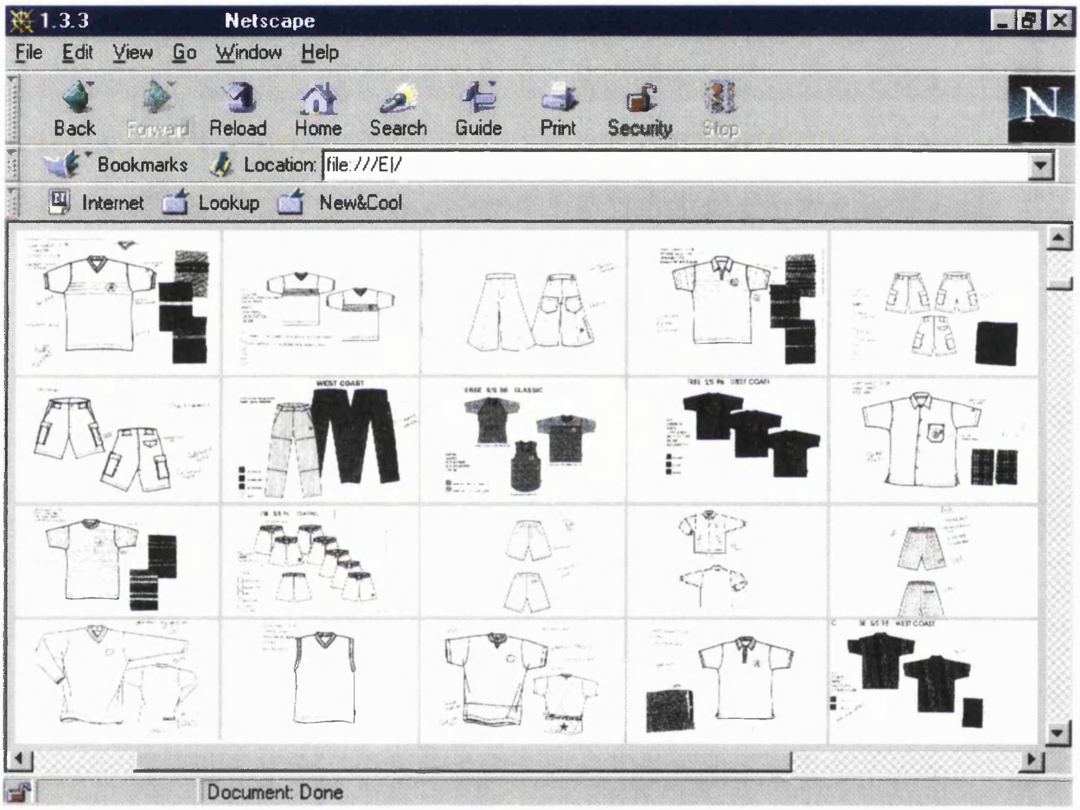
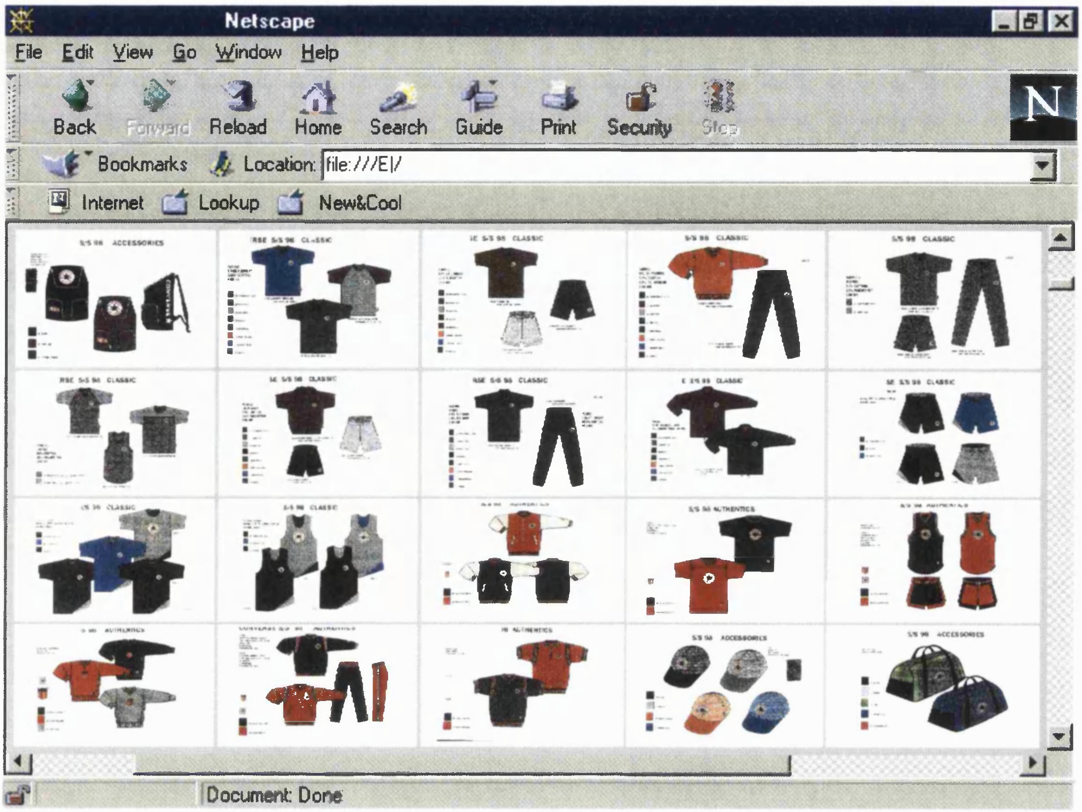
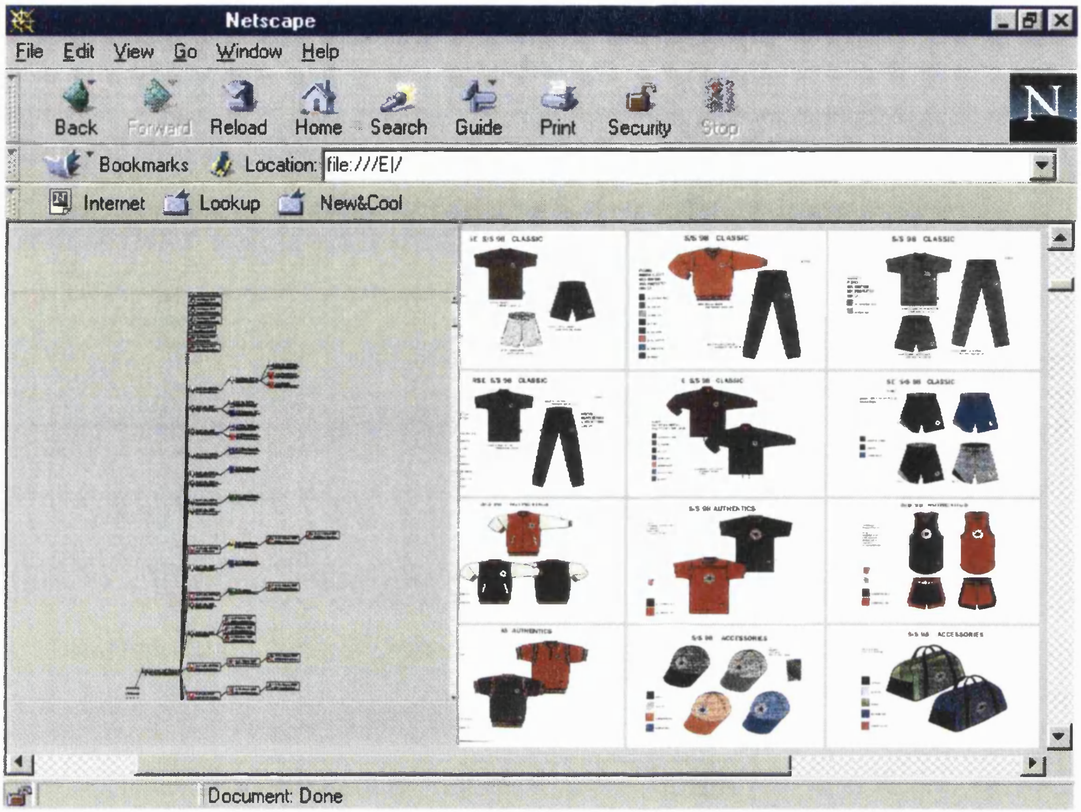


Figure 8.19. Viewing Coloured Drawings for a Range in a Gallery (View 2)



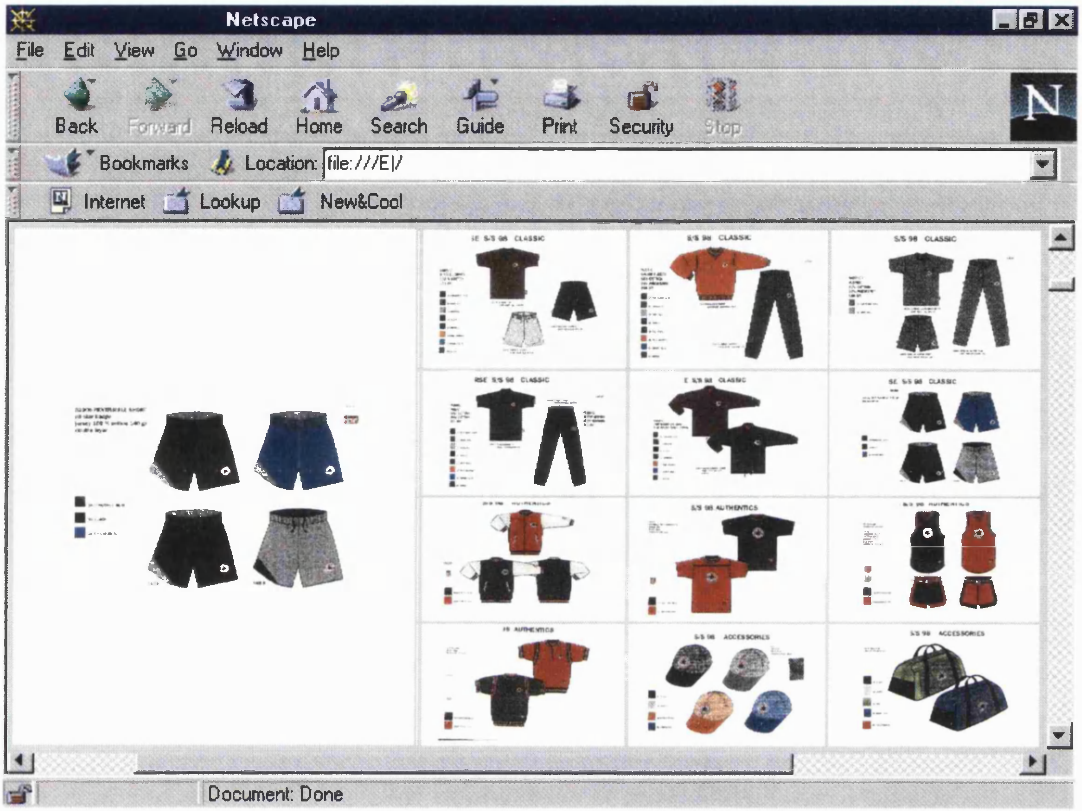
The interface demonstrating the ability to view an image gallery of a range alongside the IBIS^{PDR} map of the range, as shown in figure 8.20 (view 3), was also thought to be an essential method of viewing the data by the users. It enabled the users to relate to the products as they discussed their relevant nodes on the map.

Figure 8.20. Viewing an Image Gallery of a Range Alongside the IBIS^{PDR} Map for the Range (View 3)



In a similar vein there was no doubt though that having the facility to view products from a range in an image gallery and then select a particular product and work on it in a whiteboard screen area at the side of the gallery, as shown in figure 8.21 (view 4), would be another very useful tool for product designers. The designer in particular commented that they liked the idea of having an image gallery of the products on the screen, and a working screen at the side into which they could bring any of the products from the gallery, make alterations or annotate it and then communicate this to the other members within the design team. The possibility was discussed of being able to use it as a work in progress tool, whereby for example the design manager in the UK could use the working area to annotate designs which could simultaneously be viewed by the designer at the manufacturer in Denmark. This is moving into the domain of shared work spaces, but it is easy to see how it would be a useful addition to the tool. Woodcock and Scrivner (1998), in their research elaborate on the potential benefits of clothing designers using shared whiteboards over a network.

Figure 8.21. Viewing an Image Gallery of a Range Alongside a Whiteboard Screen Area (View 4)



To summarise then, tasks 1 and 2 were designed to explore and evaluate the newly constructed $IBIS^{PDR}$ representation in comparison to the $IBIS^{+}$ representation. Task 3 was designed to explore any potential advantages and disadvantages of viewing the representation through a web browser. Task 4 was designed to evaluate the implemented domain specific graphical user interfaces. The following tasks 5-14 are included in the analysis in order to check that the users were able to efficiently navigate the $IBIS^{PDR}$ representation and understand the correct usage of the new additions to the notation:

Task 5: Using the $IBIS^{PDR}$ maps demonstrate who the external design consultants were?

The external design consultants for the company had changed since this representation had been constructed but the designers had no problem going straight to the positions outlining each of the consultants.

Task 6: Out of the external design consultants who had the most input to the design process?

Each consultants map was opened in turn and it took 4 minutes to establish the answer. One member of the design team tried to access the map for the external consultant in question in this task by clicking on the position nodes that suggested him as an external consultant. However it was quickly realised that it was necessary to click on the map view node linked to it instead.

Task 7: Out of the design consultants maps how many nodes were hyperlinked to visual files and which consultants' maps were they in, what did the files contain?

The users were unsure about the answer to this question at first and referred to the manual to remind themselves that a node would be colour coded with a pink background if it was hyperlinked to an image file. It took 7 minutes to complete the task.

Task 8: Find a 'Not Actioned' node on the map and explain what it is indicating.

The users used the zoom out facility to view a wider part of the map and found a 'Not Actioned ' node very quickly on the main map. They correctly identified that the node indicated that the position it linked to had not been actioned.

Task 9: Over what time period was the design rationale constructed?

The users realised immediately that they could get the answer by looking at the date annotations, but it took 10 minutes to go through each map and check for the latest date. It would have been much quicker to browse the dates in the maps in list view instead of map view, or to include some information about the duration of processes in the previously proposed summary information.

Task 10: How many retrospective nodes are there in the maps?

In this instance the users used the list view to count the retrospective 'R' flags on each map. It took about 15 minutes to identify the 37 retrospective nodes within the maps. It would however have been quicker to use the find facility to do a search for 'R', upon opening each map.

Task 11: How many marketing (yellow) decision or resolution nodes are contained within the maps?

The users utilised the zoom facility to zoom out on the maps and count the relevant nodes which they identified by the colour, taking 12 minutes.

Task 12: How many production (red) decision or resolution nodes are contained within the maps?

The users utilised the zoom facility to zoom out on the maps and count the relevant nodes which they identified by the colour, taking 5 minutes.

Task 13: How many design (blue) decision or resolution nodes are contained within the maps?

The users utilised the zoom facility to zoom out on the maps and count the relevant nodes which they identified by the colour, taking 9 minutes.

Task 14: How many management (green) decision or resolution nodes are contained within the maps?

The users utilised the zoom facility to zoom out on the maps and count the relevant nodes which they identified by the colour, taking 7 minutes.

8.3. Evaluation of the Task Analysis

The following evaluation of the task analysis is split into five sections. The first contains issues raised during the task analysis that pertain to the general extensions to the $IBIS^{+}$ notation to form the $IBIS^{PDR}$ notation, as proposed in section 7.1.1 of chapter 7. The second contains issues raised during the task analysis that pertain to the retrospective additions to the $IBIS^{+}$ notation to form the $IBIS^{PDR}$ notation, as proposed in section 7.1.2 of chapter 7. The third contains issues raised during the task analysis that pertain to the Graphical User Interface (GUI) requirements for the $IBIS^{PDR}$ representation, particular to the fashion product design process, similar to those proposed in section 7.2.1 of chapter 7. The fourth contains issues raised during the task analysis that pertain to the navigational and general interface requirements for the $IBIS^{PDR}$ representation, similar to those proposed in section 7.2.2 of chapter 7. The fifth contains issues raised during the task analysis that pertain to navigating the $IBIS^{PDR}$ representation through a web browser.

8.3.1. Issues that Pertain to the General Extensions to the $IBIS^{+}$ Notation to form the $IBIS^{PDR}$ Notation[4]

The overriding feeling was that the $IBIS^{PDR}$ representation would be excellent for identifying where bottle necks were occurring in the design process and also for where decisions were required. The addition of the new node type resolution in the $IBIS^{PDR}$ representation was noted and after reference to the manual the users were able to quickly differentiate between the decision and resolution nodes. However the fact needs emphasising in the manual describing the notation that positions in the line of reasoning to which a resolution is attached are coloured grey (as opposed to the

[4] As proposed in section 7.1.1 of chapter 7: One generic link type; New node type: resolution; Colour coded domain specific decision and resolution nodes; Temporal markings on nodes.

usual yellow) to indicate that each of the positions in the line of reasoning has been addressed by the resolution. In a commercial tool this would obviously be an automatic consequence of adding a resolution node.

It was reiterated in the task analysis that the use of numerous coloured links in the $IBIS^+$ representation made the notation unnecessarily complex and the use of the single 'relates to' link in the $IBIS^{PDR}$ representation was far more acceptable. The consensus was that the usage of the one link type in the $IBIS^{PDR}$ representation was all that was required and served to provide an indication that a relationship exists between two nodes. However the use of colour coding the resolution and decision nodes to denote the department that was incorporating them into the structure, was found to be both clear and useful. It was suggested that the use of colour coded nodes to denote ownership could be extended across the whole notation and not limited to resolution and decision nodes. A user would then be enabled to quickly browse the map and look at the design discourse from the opinions of a particular department involved in the discourse. It would further facilitate the tracing of themes being brought up by the particular departments. Furthermore the hyperlinking of the key position nodes to the image file of the final product was considered to be a useful addition to the notation. However there was discussion on the confusion that could be caused by the use of the additional colour coding used to denote a hyperlink to an image file. The consensus was that colour coding shouldn't be used in more than one capacity within the notation, and a preferable solution would be to flag nodes that are linked to visuals of the final product with a 'V' flag.

Date stamping nodes, a further addition incorporated into the $IBIS^{PDR}$ notation was particularly liked by the design teams' production manager to be used as a prompter for deadlines not being heeded. It was also thought that this would be useful for allocating responsibility, but there needed to be awareness of the political issues that could arise. If the maps were to be used in this manner it could cause friction within the dynamics of the working group, leading to people being less willing to enter knowledge into the structure.

Tasks 5-14 that were conducted during the task analysis were incorporated to ensure that the users were fully comprehending the notation and to assess its ease of use. Each of these tasks was timed in order to raise the alarm when an unacceptable amount of time was taken to conduct a task due to difficulties being experienced by the users. Most of the these tasks were accurately and quickly conducted in each task analysis, proving that the users found the representation to be clear and easy to navigate. The minor problems that did occur would be rectified with continued use and practice with the representation. An example of this is when one member of the design team tried to access the map of an external consultant by clicking on the position nodes that suggested him as an external consultant. However it was quickly realised they needed to click on the map view node linked to the external consultants position node instead. Similarly the designer clicked on the resolution and position node for the external consultant before realising they needed to go to each of the design consultants map nodes in turn, but this particular task (6), still only took 2 minutes to complete, and the hitch was largely due to unfamiliarity with the environment and the notation. In other tasks the users did have to refer to the short manual before successfully completing the task but again this would be expected when first using a system and a notation.

8.3.2. Issues that Pertain to the Retrospective Additions to the IBIS^{+} Notation to form the IBIS^{PDR} Notation[5]

The necessity for the IBIS^{+} representation to be annotated to bring it up to date was reiterated since many decisions were missing and it was unclear whether positions without decisions attached to them had been actioned or not. It was correctly deduced from the manual to the IBIS^{PDR} representation that it should be assumed that all positions in the IBIS^{PDR} representation had been actioned if not annotated to the contrary or linked to a decision node, resolution or not actioned node. The IBIS^{PDR} representation was thought to be much clearer where positions had been retrospectively annotated with missing resolution or decision nodes. The users

[5] As proposed in section 7.1.2 of chapter 7: Annotate IBIS^{PDR} maps to provide a more complete design rationale representation; Link key position, resolution and decision nodes to image files of the final products; Add an 'R' flag to retrospective decision nodes; New node type: not actioned.

encountered no difficulty in understanding the use of the retrospective 'not actioned' node type. It was felt that the addition of the ‘R’ flag to denote retrospectively added nodes was worth incorporating because it would be useful if a study of the dynamics of the design process were to be conducted at any stage, using the representation as the reference point.

8.3.3. Issues that Pertain to the Graphical User Interface (GUI) Requirements for the IBIS^{PDR} Representation, Particular to the Fashion Product Design Process[6]

The implemented graphical user interfaces, corresponding to those outlined in section 7.2.1 of chapter 7 and aimed at providing domain specific access to the data in the IBIS^{PDR} representation, were shown to the users for their comments. It was confirmed that the flexibility they provided of viewing all the stages of development for a product through an image gallery would add a useful extension to the tool. They would be particularly useful for gaining a quick insight into the design stages for products from previous ranges. However, merely viewing the ranges in image galleries would not accommodate the in depth comprehension of the design rationale that navigating the maps manually provides.

In a similar manner there was no doubt that with design visual nature of design, having the facility to view products in an image gallery and then select a particular product, work on it in a whiteboard screen at the side of the gallery or directly in a IBIS^{PDR} map, make alterations or annotate it and then communicate this to other members of the production team at remote sites via the web or a dial in service would provide a further extremely useful tool for members of a product design team.

[6] Corresponding to those proposed in section 7.2.1 of chapter 7: Displays of product evolution from final product to initial concept; Viewing individual ranges and stages of range development in image galleries; Viewing image galleries of ranges along side design rationale maps; Viewing product images in a whiteboard area for annotation with thumbnail graphics of the product evolution along side the whiteboard screen.

8.3.4. Issues that Pertain to the Navigational and General Interface Requirements for the $IBIS^{PDR}$ Representation[7]

As reiterated in section 7.2 of chapter 7, navigational facilities provided by the mapping tool used to construct the $IBIS^+$ representation were very poor, making the $IBIS^+$ maps difficult to navigate. The additional navigational facilities in the $IBIS^{PDR}$ representation, such as the zoom facility, the forward and backward buttons, the horizontal and vertical scroll bars, and the split screen facility (allowing the text associated with the nodes to be viewed at the same time as viewing the maps), were found to greatly enhance the ability to browse and explore the knowledge structure. In particular the 'find' facility incorporated into the $IBIS^{PDR}$ representation enabled the rapid location of any references to specific data within the knowledge structure. In a similar vein, it was added that the spell checking facility would speed up the process of entering accurate data.

The problem was highlighted of the inability to read the node labels in the $IBIS^{PDR}$ representation when the maps were zoomed out to fit on one screen. The solution was suggested of linking the system to an extra large screen to overcome this. It was further proffered that in the $IBIS^{PDR}$ representation the labels for the nodes should be included in the text part of the split window. If the maps were then zoomed out to the extent it was difficult to read the node labels on the maps, it would be possible to look at the labels by selecting the node and reading the label it in the split text window.

The textual view of the map in the $IBIS^{PDR}$ was deemed provide a useful alternative to the map view but it was commented that a visual overview demonstrating the number of maps in the knowledge base and how they linked to each other would also help users to grasp the scope of the knowledge base. A statistics page was also suggested for each map and for the whole representation, containing information on how many nodes of different types and from different departments had been utilised.

[7] Corresponding to those proposed in section 7.2.2 of chapter 7: scroll bars, zoom, find and replace, forward and backward zoom, spell checker, list view.

8.3.5. Issues that Pertain to Using the $IBIS^{PDR}$ Representation through a Web Browser

The users were very keen on the idea of viewing and editing the representation through a web browser since they thought this would give them the added advantage of being able to add to and read the maps when they were on sourcing or production trips abroad. However the designer highlighted the fact that security could become an issue if the whole of the design rationale (which obviously would contain highly confidential and sensitive information) were to be posted on the web. It was therefore suggested that having a secure system that the designers could remotely dial into might be a preferable option. There might be the potential for posting the occasional map on the web in order to enable members of the design team at different sites to use them as a shared workspace accessing, discussing and altering them remotely. Additionally accessing the maps via the web would combat the compatibility problems caused where different platforms, such as Apple Macs and PC's, were being utilised by members of the groups. A further benefit of accessing the representation through a web browser is that with the ever increasing use of the internet, everybody involved in the task analysis had been exposed to navigating the world wide web. This meant that they were working within an environment which was familiar and they felt more confident about navigating the representation. However it was felt that many of the navigation facilities provided in the interface to the $IBIS^{PDR}$ representation were superior and that the facilities provided when viewing it through the web would need to be improved.

8.4. Summary

Section 8.1 describes how the $IBIS^{+}$ knowledge structure was entirely reconstructed using the $IBIS^{PDR}$ notation proposed in chapter 7, to account for the limitations in the $IBIS^{+}$ representation discussed in chapter 6. It emphasises that the $IBIS^{PDR}$ representation was constructed using a different mapping software environment, which incorporated many of the required '*overview, zoom and detail on demand*' (Shneiderman, 1998) navigational tools outlined in section 7.2.2 of chapter 7. Attention is drawn to the fact that it is beyond the scope of this research to further explore the possibilities of using the $IBIS^{PDR}$ maps to create a template for subsequent design cycles as alluded to in section 7.1.3 of chapter 7. However this is an area that would be promising for future research. The section goes on to detail that the graphical user interfaces (GUI's) specific to fashion product design, similar to those detailed in section 7.2.1 of chapter 7, were implemented. Additionally the $IBIS^{PDR}$ maps were made available for viewing through a web browser to assess the extent of any benefits to be reaped from an alternative environment.

Section 8.2 details how once the $IBIS^{+}$ knowledge base had been reconstructed using the $IBIS^{PDR}$ notation and the GUI's had been implemented, it was reviewed with the design team used in the initial field study. A task analysis was conducted to assess the $IBIS^{PDR}$ knowledge base. The users were asked to explore the $IBIS^{PDR}$ maps and then they were given a number of specific tasks to be conducted using the $IBIS^{PDR}$ structure. The tasks were designed to check if the users could retrieve the type of information that might be required in a product design setting. The aim was to evaluate the newly constructed $IBIS^{PDR}$ representation and the implemented GUI's.

Section 8.2.1 provides a summary of the tasks and their outcomes. The first four tasks are aimed at evaluating the newly constructed $IBIS^{PDR}$ representation and implemented GUI's in comparison to the $IBIS^{+}$ representation. The remaining ten tasks were included in the analysis to check the users were able to efficiently navigate the $IBIS^{PDR}$ representation and understand the usage of the new additions to the notation.

Finally section 8.3 evaluates the task analysis in terms of the issues raised that pertain i) to the general extensions to the $IBIS^{+}$ notation to form the $IBIS^{PDR}$ notation, as proposed in section 7.1.1 of chapter 7; ii) to the retrospective additions to the $IBIS^{+}$ notation to form the $IBIS^{PDR}$ notation, as proposed in section 7.1.2 of chapter 7; iii) to the GUI requirements for the $IBIS^{PDR}$ representation, particular to the fashion product design process, similar to those proposed in section 7.2.1 of chapter 7; iv) to the navigational and general interface requirements for the $IBIS^{PDR}$ representation, similar to those proposed in section 7.2.2 of chapter 7. The task analysis proved that the users found the $IBIS^{PDR}$ representation to be more succinct and easier to understand than the $IBIS^+$ representation. It may be concluded that many of the problems with the $IBIS^+$ representation had been successfully combated. The only alteration to the $IBIS^{PDR}$ notation proffered was that in order to denote the existence of a hyperlink from a position node to a visual file of the final product relating to it, a 'V' flag should be marked on the node as an alternative to a colour coded background. The enhanced navigational tools provide in the interface to the $IBIS^{PDR}$ representation were also preferred and some further minor improvements suggested. Much interest was shown in using the representation via a web browser, but issues of security would have to be carefully addressed.

The next chapter summarises the research outlined in this thesis and recapitulates the main conclusions to be drawn. The contributions of the work to the fields of information systems and product design are presented along with some suggestions for future work.

8.5. End Note - The Design Team's Perspective

The benefits summarised in figure 8.22, of using IBIS type hypertext maps to structure product design rationale, resulted from an analysis conducted with the design team during the field research. The figure explores the design team's opinions of the usefulness of this type of knowledge representation in a product design environment.

Figure 8.22. Viewpoint: The Design Team's Perspective

Benefit 1:Concise graphical overview of the product design process enabling reflection on the development cycle The design team expressed that the design rationale maps provided a very useful graphical reference of the design process which could be quickly glanced at to view the 'state of play' and the decisions made. The clothing product manager commented that *'a very useful aspect had been using the maps as a reflective tool on the ranges achievement and to highlight where not all the initial goals had been achieved. During the range development it was useful to use the maps to see what stages had been reached and identify what had been actioned and what hadn't - this tool also allows you to identify what was lost during the design process.'*
Benefit 2 : Preservation of design rationale in the event of the departure of key team members When the marketing director left the company the new marketing director was able to view the design process undertaken in the development season before he joined. The new marketing director was very impressed to be provided with an in depth record of the design direction, rationale and strategy. He commented that, *'when a key member of staff leaves and takes all their accumulated knowledge on the brand with them, it is difficult for their replacement to come in and provide consistency with the next season's rang this can then result in a lack of apparent direction which could obviously directly affect the consumer. The design rationale maps provide an effective deterrent against this.'*
Benefit 3 : Reflection on personal development The design team stressed that the design rationale maps allowed them to scrutinize and reflect on their personal development as the design process progressed. They were able to examine the effectiveness of their decision making and identify instances where they expressed decisions which were then later not carried out. The marketing director commented that, *'It was a good tool for allowing individuals to reflect on the process they went though as the cycle progressed, allowing them to make an analysis of where they may have been inconsistent, for example the maps highlighted to me a point in the design process where one minute I discussed the merits of a certain garment and then for no apparent reason discarded it from the range at a later stage.'*
Benefit 4 : Aiding analysis of the effectiveness of external design consultants The design team expressed that the design rationale maps provided the additional benefit of allowing the importance of the input from the external design consultants to be scrutinsed. The designer commented that, *'It was a good tool for reflecting on how well the external sources of design had fulfilled their roles and how critical they are to the process. The brand needs to be able to quantify the input and influence of the external sources of design on the range, and tie their initial brief to the end product. The IBIS+ maps facilitate this.'*
Benefit 5 : Aiding range planning The design team identified that the design rationale maps would be very useful in improving the efficiency of the range planning process for subsequent seasons. The marketing director commented that, *'They provide a useful starting point for the next seasons range planning. To review what the goals had been at the beginning of the previous season and draw up goals for the coming season.'*

Benefit 6 : Preservation of tacit design knowledge within the visual data
The design team emphasised that due to the visual nature of product design a lot of tacit knowledge would be contained in the visual data in the design rationale structure. In product development similar products are often created season after season and the amount of design reuse resulting from this makes it a very promising domain within which to capture design rationale. The designer commented that, '*with visual data such as story boards and inspiration videos it may not be obvious to a lay person what they are conveying but it is part of the skill of being a designer to understand the tacit knowledge within it.'*

Benefit 7 : Increasing potential benefits with the progression of time
The design team stated that the benefits of the design rationale maps would undoubtedly become more significant if the knowledge maps were maintained over a number of cycles of development. The product manager commented that, *'Obviously not all the rationale had been captured in the IBIS⁺ maps because many of the design narratives understood by the design team come from the previous season's development. However if this tool were to be used over a period of time this problem would be over come.'* Numerous other benefits would also then be provided including:

a) Savings on sourcing products from previous ranges for 'retro' lines, the product manager identified that, *'season on season savings would be reaped on paying for external specialist information, such as on retro design data that once captured should not need to brought in from outside.'* The designer expressed that, '*this was clearly demonstrated by the fact that during the product development this company purchased old examples of their own bags and shoes from the 50's, at much inflated prices, as they had no records of them*';
b) Facilitating higher quality decision making, the product manager identified that '*over progressive seasons of collating the design rationale, both aesthetic and technically orientated decision making would be improved on the basis of reflection on the previous design cycles*';
c) Providing a complete historical record of marketing and design development, the marketing director stated that '*on the basis that a complete record of design and marketing activity would be preserved in the design rationale maps, they would further provide an invaluable source for future design and marketing acitivity and for planning future marketing strategies, thereby aiding the maintenance of brand consistency and adherence to brand values and providing an archive of all previous design activity.* '

CHAPTER 9:

SUMMARY, CONCLUSIONS AND FUTURE WORK

This chapter summarises the research and outlines the main conclusions drawn. The contributions of the thesis are presented along with some potential directions for future work.

9.1. Thesis Summary

This thesis has explored how a design rationale representation can be used to capture the design process, and support decision making and reflection during product design. A multimedia design rationale representation was constructed using a notation based on that proposed by Kunz and Rittel (1970). A graphical implementation of this notation, referred to in this thesis as IBIS$^+$, provided an initial basis from which to investigate the real problems of design rationale in the field of product design. It was therefore critical that an extensive field study be conducted in order that the development of a useful multimedia design knowledge representation could be precipitated. Every formal design meeting was attended for a whole product development cycle and design knowledge elicited with regard to the four product ranges under development during that time. A schedule and transcripts of these meetings can be seen in appendices E and F. Conducting such extensive field research enabled a depth of understanding of the design process that otherwise would not have been possible. It facilitated the later structuring of a design rationale representation rich in design knowledge and that proved a realistic testing ground from which to assess the requirement of a more useful design rationale knowledge base. The knowledge base was intended to capture and retain aspects of the product development rationale for use in further range development and to provide a historical record of aspects of the design process for each product.

The IBIS$^+$ knowledge representation provided quality reflection from the product designers about how a multimedia design rationale might be used by them and what facilities would be required. The product design team from the field study used the representation as it was being constructed concurrently with the design process, to reflect on what they had stated they would achieve at earlier meetings and to identify what decisions had for various reasons, fallen by the way side. At the end of the design cycle when the design rationale was completed it was installed in their design studio in order that the design team could experiment with it for a few weeks. Then a detailed analysis of their use of and reflections on the structure was conducted. The predominant areas identified requiring improvement included:

- Weaknesses in the $IBIS^{+}$ notation when applied to product design, leading to certain aspects of the design rationale representation being inaccurate;
- Graphical user interfaces in order to present data from the knowledge structure in a suitable manner for specific design purposes;
- Navigational tools to facilitate ease of access to the data;
- Lack of accuracy in capturing a complete representation of the design rationale taking into account that not all decisions and issues would be explicitly stated during the formal design meetings;
- Reducing the time it takes to construct the design rationale;
- The dynamics of getting the whole design team involved in capturing and building the design rationale.

The evidence for these identified limitations was gained through conducting the study of the product design process, the field research, building the design rationale representation and via in depth discussions with the design team and their reflection on using the representation. The limitations of the $IBIS^{+}$ notation led to a complete restructuring of the material collected for the whole design cycle using the proposed adapted notation referred to as $IBIS^{PDR}$. The $IBIS^{PDR}$ notation, extends the $IBIS^{+}$ notation to cope with the realities of the product design process. A task analysis conducted with the newly constructed $IBIS^{PDR}$ representation confirmed its appropriateness for product design rationale.

Graphical user interfaces, specific to the domain of fashion product design were implemented for assessment by the design team. The task analysis confirmed the suitability of the prototyped graphical user interfaces for streamlining the access to the underlying data and aiding specific design tasks. In addition some of the required navigational tools were provided with the platform chosen to construct the $\mathrm{IBIS}^{\mathrm{PDR}}$ maps. It was identified that the problem of capturing design knowledge that is not explicitly expressed during a formal design meeting can be overcome to some extent by holding a session for reflection at the end of the design process. During such a retrospective stage the design rationale structure would be reviewed, corrected, annotated and rationalised in order to ensure the knowledge representation was accurate and of value for future reference. The $\mathrm{IBIS}^{\mathrm{PDR}}$ notation includes retrospective elements which would be added to the representation during such a stage.

It was not within the scope of this thesis to address the last two identified limitations centering on the time, man power and organisational dynamics required to construct the design rationale and they are discussed further in section 9.4 as potential directions for future research. The focus of this thesis is on the usefulness of a design rationale in product design to support design decision making and the most beneficial way to structure and present multimedia product design knowledge. It does however address many of the identified limitations by extending the IBIS approach through developing the adapted $\mathrm{IBIS}^{\mathrm{PDR}}$ notation. It further examines potential suitable interface facilities for presenting and accessing the data in order to enhance certain design tasks.

9.2. Thesis Assertions and Conclusions

It is shown how hard it is to keep track of the design process and designers' reasoning due to the implicit nature of design decision making. It is a valid concern that any notation used to represent design rationale will always be found to be lacking the depth of expressiveness required to accurately capture the design process. However, in product design much of the tacit/implicit knowledge and information is contained within visual data of a multimedia nature. This thesis demonstrates how this can be captured and usefully retained for later use/reference. The nature of product design means that much of this tacit knowledge understood by the designers would be contained in the predominantly visual multimedia data linked to the design rationale structure. Although this data may not mean anything to the untrained eye, to an experienced designer it would contain valuable information and would indeed add an expressive element to the formal and semi-formal design rationale notations. In addition the multimedia material is set in context and the design rationale preserved, by structuring it using the $IBIS^{PDR}$ notation.

In clothing product design a range of similar products are created over a series of design cycles, there being 2 or 3 seasons each year. The amount of design re-use prevalent suggests that it would indeed be justifiable to capture the design rationale in this domain as opposed to design domains such as engineering where the data is not primarily visual in nature, the focus is on technical excellence, design cycles are long and aesthetics are of minimal importance. On the basis of the work conducted it can be concluded that maintaining a multimedia design rationale representation would:

- Provide new team members with a history of previous product development and design decisions and enable new personnel to quickly appraise themselves of the company's design direction;
- Provide an archive of previous design that will become increasingly useful with the passing of time as a resource for visual research/inspiration. Information is retained that would previously have been lost or discarded due to storage and access problems;

It can be strongly asserted that maintaining a multimedia design rationale representation would:

- Aid and speed up the planning for the following seasons ranges;
- Provide the opportunity for the re-use of design efforts and knowledge put into developing prototypes, not all of which will have gone into production;
- Allow team members to analyse their own personal development;
- Ensure higher quality decisions are made on the new ranges on the basis of reflection on the previous design season;

- Help branded products to retain consistency in their brand identity. A company may retain a historical perspective on their products and design progress, thereby promoting the maintenance of design and image consistency;
- Provide a resource of inspiration and reference for marketing activities.

This thesis demonstrates that creating a design rationale structure requires an investment in terms of resources but the rewards of rationally structured multimedia material to design based companies where data is primarily visual in nature, where design cycles are rapid, and where brand consistency is important are proved to be substantial.

9.3. Thesis Contributions

A principal contribution to come from this thesis is the proposed $IBIS^{PDR}$ notation, a suitably revised and extended notation underpinned by IBIS, which provides an adequate base from which to structure a useful multimedia knowledge representation of the design rationale and the data collated during product development.

The notation includes some elements which should be used retrospectively to consolidate the design rationale as a useful resource for future reference. It is established how some of the limitations of capturing the entire design rationale can be overcome by a formal review meeting as part of a retrospective stage at the end of the design cycle.

A practical way is suggested in which $IBIS^{PDR}$ maps from one design cycle might be used as a starting point for the following cycle, through the creation of an $IBIS^{PDR}$ template at the end of each design cycle.

Through careful structuring of product development information using the $IBIS^{PDR}$ notation, the rationale behind product design can be captured in a manner which supports future product development and product range planning. It achieves this by enabling designers to see what goals have and have not been achieved throughout the design process, enabling reviews to be quickly conducted of the goals identified at the beginning of the previous product cycle and a new set of goals to be drawn up for the coming product cycle, sparking debate as to why certain design issues remain unresolved, allowing exploration of the design rationale through a number of seasons thereby providing an immediate understanding of previous design scenarios and decisions, and further supporting range development, strategic planning and design decision making for subsequent design cycles.

It is further demonstrated how a range of domain specific graphical user interfaces connected to an $IBIS^{PDR}$ knowledge structure, would empower the design team to access, reflect on and utilise the underlying data for specific design tasks that enhance the product design process and aid future range planning.

As a result of this thesis, two papers were published on preliminary work referred to in chapter 3 [(Phillips, 1996), (Phillips, 1997)] and three further papers were published on the core work of the thesis [(Phillips and McDonnell, 1998a), (Phillips and McDonnell, 1998b), (Phillips and McDonnell, 1998c)].

9.4. Future Work

There are a number of areas which look promising for potential further research in this field. Research could be undertaken to explore the potential of using an $IBIS^{PDR}$ structure alongside a shared workspace environment. Correspondingly, another direction that may prove fruitful for further research in this field is a more detailed exploration of the possibilities of utilising the $IBIS^{PDR}$ representation within a web environment. The $IBIS^{PDR}$ notation could also be used in other product design disciplines to investigate the graphical user interface requirements particular to these disciplines. The interfaces outlined in this research were developed specifically for use with clothing product development but it would be interesting to explore how they might be adapted for other product design disciplines.

An additional direction for future research is the potential which was touched upon in the thesis of using the design rationale representation from one product development cycle as a template to commence developing the next cycle's range. Section 7.1.3 in chapter 7, outlined how following a retrospective stage a complete representation of the design rationale could be used as a template to provide a starting point and support strategic planning and design decision making for the following design cycle. However it was not within the scope of this thesis to fully test this but it would be a promising area for further research.

The time it takes to capture the rationale also warrants further investigation and this is a well known problem among those working with design rationale. In the field study the design team were not required to construct the rationale themselves and therefore their time was not impinged upon. Research should be conducted into how members of the design team could be more closely involved in the construction of the rationale themselves to ensure it contains the necessary depth of knowledge without it becoming an unfeasibly time consuming activity.

Finally the dynamics of how to best involve the members of a design team in the construction of a design rationale representation should be explored. This thesis has demonstrated that through the use of a domain specific knowledge representation, the creativity of a design team can be effectively enhanced and valuable data on the product design process can be stored for future reference. Moran and Carroll state that "*It is possible to see the capture of rationale either as a by product of the design process or as something that must be constructed.*"(Moran and Carroll, 1991) However during this research it has become clear that in order to effectively capture design rationale it is necessary for the organisation concerned to make a commitment to it and that it cannot be an entirely automated by-product of the design process. Conklin affirms that '*while the technology must be very good and the user interface transparent, the organisation must also shift to making capture and use of organisational memory an important and natural practice.*'(Conklin, 1992)

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Appendix A:

Review of Computer Supported

Ciothing Design and Manufacture

The History of Computer Supported Clothing Design and Manufacture

Some of the first computer systems for supporting design and manufacture in the clothing industry were developed in the late sixties in America for the purpose of marker making and grading by companies such as CAMSCO and Gerber. A marker or lay plan, is a plan of how pattern pieces should be placed on the fabric before cutting, in order to get minimum wastage of material. Marker making is a is very time consuming process if done manually. The reason that software was initially developed for this area is that it is relatively easy to input patterns into a computer via a digitiser or scanner and manually move the miniature images of the pattern pieces into an efficient lay on the screen. Furthermore the process of lay planning can be accurately defined and it is therefore suitable for adaptation to computerised tools.

Most of the systems initially developed used Hewlett Packard minicomputers. In the 1980's Pattern Design Systems (PDS) were developed which actually allowed patterns to be designed using the computer as opposed to just digitising a manually drawn up pattern into the computer in order to grade it and create a lay. As the eighties progressed the number of companies using CAD systems increased as the price of the systems dropped. With the introduction of the PC, systems were adapted to run on a PC platform making them far more affordable for the smaller company. Today, clothing CAD/CAM systems are IBM compatible which further enables designers to import from standard PC graphics and desk top publishing packages.

Tools such as Pattern Design Systems (PDS), costing systems and computer controlled fabric cutters are increasingly being integrated into systems used in clothing design rooms. PDS allow the user to scan or digitise patterns into the system and then manipulate or alter them on screen. Alternatively, the user can create pattern blocks from scratch on the screen. Costing systems are often incorporated and important to be able to provide quick and accurate costs for production. Computer controlled cutters are used to automatically cut patterns created or manipulated on a PDS. These are vital at the high fashion end of the market where quick response is essential and samples must be made in a matter of days not weeks.

Computerised work surfaces were also developed that can be used just in the same manner a pattern cutter would use his regular cutting table and with all the traditional pattern cutting tools. As the pattern cutter works the information is drafted into the computer system where it can be stored, graded and lay planned. Sketching can also be done in a similar fashion where the sketch is simultaneously entered into the computer as the user draws on an electronic sketch pad.

Another area that was developed alongside the pattern manipulation systems was software used for textile manufacture, where the design of a knitted jacquard, for example, could be displayed on a VDU and the electronic information transferred to control the machines producing the fabric. The introduction of colour graphics had a large impact on computer systems for the clothing industry, making them a more appealing prospect for designers. Systems now allow designers to design and visualise garments, fabrics, colour palettes etc. on a VDU. Fabric simulations can be mapped onto 2D silhouettes of garments and a 3D look can be given to a 2D image. Designs can be either displayed on a high resolution monitor, colour printed onto paper or printed onto fabric. Fabric can therefore be designed on screen and sample lengths of it printed in a very short period.

There are several companies that produce software and systems aimed at the clothing industry including Gerber Garment Technology, Lectra, Investronica, Assyst and

Microdynamics. Competition among the companies is fierce which has been another force driving the price of the systems down. Automatic marker lay planning systems, where the computer determines where the pattern pieces should be placed on a lay plan, are not yet efficient enough to be used in manufacturing. Pattern pieces still have to be manually moved about on the computer system to achieve the desired efficiency. Automatic lay planning systems usually can usually achieve a lay plan with 10% wastage, yet no more than 5% is acceptable. '*Lay planning is essentially a creative process requiring good spatial awareness, and not everyone has the ability to do it. It is not a jigsaw puzzle with a perfect solution in which each piece has only one possible position; it is a compromise between material and cutting efficiencies in which each piece has an infinite number of possible positions and orientations. Computers are particularly inept at dealing with processes in which there is a creative element, and the trial and error approach is limited by the possible variations.*'(Aldrich, 1994).

Increasingly design software is being viewed as an integral part of the design process, particularly with newly trained designers entering the industry. Although resources are sometimes limited, CAD is becoming a bigger part of design courses at colleges and universities. Designers and companies are beginning to wake up to the advantages technology can provide them with including: faster and better communication between the buying, design, sales, marketing and manufacturing departments; encouraging creativity; allowing the rapid creation of complex prints, designs and multiple colourways; ultimately enabling a designer to select the best from a wide range of options. The time and costs between initial concept and sample garment can be greatly reduced, by developing the first range conceptions using a computer system and then by a process of refinement and selection, choosing a few designs to be printed out and made into story boards. The best of these designs can then be chosen to be constructed into sample garments.

A company at the forefront of using technology to support clothing design and manufacture is Benetton, the Italian casual wear producer and retailer. It '*owes much of its explosive growth and success to across the board cycle time reduction. Time* *compression starts in new product development, where a CAD system automatically explodes the new design into a full range of sizes, then transmits these patterns to computer numerically controlled fabric cutting machines to await orders for the new product. Fabric is inventoried in neutral greige and then cut and dyed to order. This allows the company to minimise rolled goods inventory and still respond quickly to the full range of customer demand. Orders are sent to a chain of pull-scheduled, just-in-time factories that allow Benetton to replenish its U.S. retail shelves in 15 days, a response time previously unimaginable in fashion retailing. This not only satisfies customers but lets the company avoid under and over production as well.'* (Clark, K. et al, 1994, p.53) Benetton has also implemented sophisticated information systems, which link their retail outlets, warehouses, factories and suppliers. Information on the fastest selling styles, colours and sizes is available instantly enabling production to be adjusted accordingly and market trends to be accommodated quickly. This enables Benetton to keep their prices low and replenish their shops very efficiently.

To date, software for the industry is most often divided into two types, those designed for pattern design and manipulation and those aimed at textile or garment design. These types are rarely integrated. The aim for the future should be to offer more fully integrated software for the clothing and textile industry. The design illustration and styling software available tends to be split into 2-dimensional, simulated 3-dimensional or actual 3-dimensional categories, (Aldrich, 1994). The 3D systems are still very much in the early development stages and the cost of them is prohibitive to most companies. The problems of accurately representing fabric drape and hang still don't appear to have been overcome in these packages. The 2D systems allow 2D images to be created and manipulated on screen and are good for creating images and simulating effects. They promote sequential designing to take place, where a basic design shape is used and different elements such as the sleeve length, pocket shape etc. are altered. This is valuable for illustrating and selecting design concepts and ideas. 2D systems can also be used to draw up production specifications or working drawings of the garments.

There are numerous benefits for a company in supporting the clothing design and production process with technology. The speed with which samples and designs can be produced can be increased, productivity can also be improved and if the software has been well designed and tested, accuracy in certain tasks which are subject to human error, should be improved. Computers are far less likely that humans to make silly errors when conducting repetitive tasks. The capacity for greater communication and sharing of information between the various divisions of a company can also be enhanced. Improvements in technology should lead to an overall increase in quality of the service and product offer.

On the other hand there are of course pitfalls that come with the introduction of new technology to support design. Among these are the breakdown in person to person contact in the product development process. This is a very important aspect of any business and it is wrong to think that everything can be conducted by the transfer of computer data. Other pitfalls are that further advances in technology need to be made before certain areas of CAD become acceptable. For example looking at an on screen image or print out of a fabric cannot portray its texture or feel. It is also a worrying prospect that less people will be trained with traditional skills, such as pattern cutting, because of the incorrect belief that due to the advance of Pattern Generation Systems (PGS), highly trained pattern cutters are no longer required. Other problems could occur due to lack of training to correctly use the software and problems of breakdown with the newly developed technology.

New technology aimed at supporting design should be used to enhance current working practices and skills, not to try and replace them. Traditional knowledge skills and expertise should not be allowed to disappear but training with CAD tools should be incorporated into college curriculum's. Computers can be used creatively, but many computer aided design packages have a tendency to produce work that looks very similar or repetitive, therefore it should not be seen as a design tool to replace a designer's creativity, but as an accessory to enhance it. *'This new technology must be seen as an instrument of assistance rather than a replacement* *technique. Imagination, initiative, and intuitive response can be found and nurtured in any student but cannot as yet be found in any computer.'* (Aldrich, 1994).

A Future Vision for Computer Supported Clothing Design and Manufacture

Despite the fact that as outlined previously designers are prone to resist the introduction of computer technology to the design process, increasingly CAD/CAM is forming a compulsory part of many product development degree courses and even the smaller product manufacturers are moving towards computer-aided design and manufacture. Clearly many uses for technology have already been found in design companies. However there are still many applications of technology to the design process to be improved or developed, some of which are touched upon below:

Pattern Design Systems

Pattern Design Systems (PDS) are one area that could be much enhanced. These systems are used in clothing product development when 2D cutting is required from a flat malleable material, be it plastic, fabric or some other substance that makes up part of the product in question. The systems enable the pieces that are needed to be cut to be laid out and planned in an efficient manner in order to reduce wastage of the material being cut. Current PDS are restricted by the fact that the pattern pieces to be cut are entered and viewed on a small scale and a technician is unable to view the whole pattern at a time. Large monitors would make it possible to view the pattern pieces in a larger scale which would not strain the pattern cutters' eyes.

A further drawback of current PDS is that they only allow flat 2D pattern cutting, whereas most designers want to model the pieces in a 3D environment. This problem will be overcome in the future through the use of 3D modeling and virtual reality allowing products to be modeled on a 3D image using computer generated materials. The ability to use a software package to imitate the way designers work when making initial prototypes out of various material, i.e. making 3D to 2D transformations and vice versa, will be a big advance for pattern design systems.

Colour

A lot of additional work is also required in the area of colour communication and matching in design support packages. On current systems it is common for the colours that have been selected from a pantone colour chart to be quite different from the colours of a material displayed on a VDU. It is essential that research and development continues in this area, thereby allowing designers to get a realistic view of colours that they might be considering.

3D Scanning

The use of 3D scanning technology is likewise predicted to be a big growth area for CAD/CAM in the future. A 3D body scanner allows a human to be scanned and a 3D image representing the dimensions of their body to be viewed on a VDU. Such technology will have a big impact in the area of custom-made clothing for example where accurate size and fit is essential. This could also be very useful for conducting an up to date size survey of the population. Average body scans for certain sectors of the population could then be viewed and the body dimensions obtained.

3D Design

Three dimensional design will be one of the most important development areas for computer aided product design software in the future. There is already a lot of research being conducted into this area at academic institutions. As virtual reality is refined, it is clear that it will enter the world of design support tools. Designers will be able to use computers to design products in 3D and then see them transformed to 2D and 3D components that go to make up the product. Currently the biggest problem to overcome in this area is that of accurately and realistically representing texture, malleability, handle etc.. Further into the future it is likely that the problem of touching and feeling the texture of the components on the computer will be overcome, probably by the use of data gloves which pass sensations to the users finger tips.

Visualisation

Further work is also being done with concept visualisation, where attempts are being where 3D computer images of products can be viewed and manipulated. The main problems so far encountered in this area have again been realistically visually representing different substances and providing a visual texture of the materials when placed on a 3D image. This problem is compounded when the images are animated and the products are required to move and flow realistically on the animated forms. There will however be great potential for animated 3D images of products, which could be experimented with cheaply in various designs and looked at from different angles. There would be a knock on effect here for buying and retailing. Buyers would be enabled to look at the animated forms of products from a range at the flick of a switch.

Virtual Merchandising

The above technology could also be used for virtual store merchandising in shops where customers could enter cubicles containing computers and view various products such as shoes, on an animated 3D body scan of themselves. It is also envisaged that a similar virtual retailing system could be used for remote shopping in the home. Multimedia catalogues could be produced where consumer goods would be viewed being used by animated images and then orders placed via the Internet. Store layouts and merchandising could also be planned using visualisation packages that allow the shop floor to be viewed in 3D. A merchandiser or store manager could then plan in advance the most suitable places to display the different types of merchandise that will be sold in the shop. This will allow companies not only to sell a product but the whole concept surrounding that product including the design of the point of sale display and marketing. Animation of 3D images will also be incorporated into marketing software.

Telecommunications

On-line design services, which can be accessed via the telephone network will also increase. An example of such an on-line service already up and running, is FINS, (Fashion Information Service), run by Nottingham Trent University. FINS is a multimedia database containing information on sourcing, forecasting, archive information, market intelligence, a designer register, hardware and software and business support. This information is updated on a regular basis. These sorts of services will be particularly useful for smaller design and manufacturing companies that cannot invest in their own dedicated systems. On-line services have the further advantage that information can be accessed very quickly and easily and companies only need to pay for the information they use.

The increasing availability of good telecommunications links means data can be transferred more easily and cheaply world-wide, between the various design, manufacturing and retailing sites of large companies. Advances in telecommunications also mean that the different modules of a CAD/CAM package installed at different sites in a company, can be fully integrated allowing access to any part of the software from each site. In the future much of the buying process will be able to be performed interactively via the Internet. A designer would for example be able to send their designs over the Internet for the buyer to view on their VDU and have an interactive discussion with the buyer, immediately making any alterations the buyer requested. This would facilitate quick response enabling designs to be chosen and sampled very quickly without the need for time consuming selection meetings between the designer and buyer. Faster transmission and networking links will be required in the future so that graphics images and data can be shared between the different sites and departments of an clothing manufacturing company and it client/s. The images created by the designer using computer software must be capable of being reproduced in production. The most important factor here is obtaining true colour representation between the colours on the VDU and those printed onto fabric or paper.

Information Management

Computer Aided Design and Manufacture systems are already prevalent in the mass market clothing sector and through their use, the speed with which samples and designs can be produced has undoubtedly been increased. The industry is now beginning to move towards the introduction of Computer Integrated Manufacture

(CIM), where CAD/CAM systems are used throughout the process of apparel design and production, right from garment conception through to distribution of the products. Historically, software packages for the clothing industry have been developed for distinct purposes such as pattern design and manipulation or garment design, and the different types have rarely been integrated. Increasingly though this lack of integration is being addressed, enabling the various computer systems within clothing companies to communicate with each other. These new integrated systems will enable the incorporation of sophisticated information management capabilities. This ability of the different computer systems to intercommunicate will provide managers with valuable real time information on the design and production process. *'The concept of a CAD system utilised only for grading and marker making is replaced with the CAD/CAM concept of a common database with a totally integrated manufacturing philosophy linking manufacturers' mainframe computers to control production units, resulting in real time data capture of work in progress.'* (Aldrich, 1994).

Multimedia Design Knowledge Bases

Product designers need access to a lot of reference information during the design process. Much of this data they refer to could be retained for future reference in multimedia knowledge bases. The types of information they may wish to view includes images and attributes of previously manufactured designs, patterns for previous designs, historical data for inspiration, and libraries of available materials, trimmings and logos. The drawback with many existing multimedia design knowledge bases is that they do not retain the context of the design information stored within them and have complicated, ineffective interfaces that are hard to navigate.

This brief review has outlined some of the areas in which advances can be expected in the application of technology to product design in the foreseeable future. There are many other sectors, currently being researched, such as the application of artificial intelligence to design support systems. Lorenz emphasises that *'the ramifications of computer-aided design and manufacture for the management of product development are so far reaching ... they offer the opportunity to: design and develop products more rapidly than in the past; tailor designs to target market segments much more* *precisely and economically; radically improve the process of design for manufacture, so that expensive and time consuming rework can be avoided; and lower the unit cost of short production runs.'* (Lorenz, C., p26, 1990) However it would certainly be wrong to assume that in the future most of the tasks currently conducted manually by a product design team could be replaced by computer systems, thereby eliminating the functions of some personnel. CAD provides another tool to be used by the design team personnel, but the skill acquired by designers, over years working as part of the design team, will not be able to be replaced by a computer in the foreseeable future.

Appendix B:

Computerised Textile Library Development Criteria

1. Initial interviews with the textile lecturers and textile designers took place at the London College of Fashion (LCF) to establish how the database could be structured and what field names would be required. The initial criteria that was raised was as follows:

- LCF had identified 4000 textiles in their manual textile library that they wished to be catalogued and the data for each fabric along with a bitmap image, stored in a computerised database.

- They wanted the database to be easy for non-computer literate people to use and they needed it to incorporate search facilities enabling them to retrieve textile data by searching on multiple fields.

- They also wanted to be able to print records from the database in the form of a report or form. They wanted each record to fit onto a sheet of A4, include all the fields and include an image of the fabric.

- The hardware and software for the Textile Library had already been purchased by London College of Fashion (LCF). The library was to be run on a PC with 2 Gigabytes Hard disk, 32 Megabytes RAM, running Windows NT. Images of the textiles were to be scanned using a flat bed scanner and where necessary they could be re-touched using Adobe Photoshop. Microsoft Access is the software that had been purchased with which the database was to be developed.

- Different levels of permissions would be required within the database. For example students would only be allowed to view and search the database and not edit it. Textile lecturers on the other hand would need to be able to add or delete records to and from the database aswell as view and search it.

- A code number for each fabric would need to be allocated to act as the primary key field, the field that could uniqely identify that fabric. - i.e. separately to any design number it has already been given.

- Fields such as Fibre content would contain 3 options i.e. Natural, Man-made and Mixed, A separate field would need to be provided where fibre percentages could be put, the predominant fibre or fibre mix must also be provided in another field with a menu offering a choice of fibre names.

- Fabric structures i.e. Woven, Non-woven and Knitted probably need a formula attached to the field i.e. if the value is this then give this list from which to select, if the value is this then go to this list.
- Under Woven, Non Woven and Knitted have a field describing the categories under each.

- There needs to be another field for yarns, followed by a field for the application of colour, then a field for colouring methods, followed by a field for colour category (i.e. predominant and second category) and a field for finishes (divided into two fields).

- Another field is needed for special categories.

Some samples may need to have dates attached, along with cost, weight, company, catalogue number, width.

2. A freelance textile designer was consulted and detailed attributes for the 'Patterned Textiles' category were identified.:

Cluster 1: Floral Derivatives

1. Floral
2. Fruit

3. Foliage

Cluster 2: Paisley

4. Paisley

Cluster 3: Ethnic

5. Ethnic
6. Dye Effects (i.e. printed dye effects - this can be subdivided into tie dye and ikat which has a water effect as it is woven but has a printed warp)

Cluster 4: Mixed Pattern

7. Borders (e.g. one band that can go across or down)
8. Bands (bands always go across)
9. Random Mix (patchwork comes within this)

Cluster 5: Figuratives

10. Photo Real (i.e. implies photos or realistic images)
11. Figuratives (fruit and leaves could come under figuratives but due to their frequent use they really warrant a separate category on their own. A figurative could be anything such as a person or a feather.)

Cluster 6: Classics

12. Spots
13. Stripes (this can be further subdivided into regular and variegated.)
14. Checks
15. Geometrics (a sub-category of geometrics would be Foulard, i.e. small separate motifs such as spots or diamonds, as printed on cravats.)
16. Weave Effects (e.g. printed herringbone or tweed)

Cluster 7: Abstracts

19. Abstract
20. Textures

Cluster 8: Co-ordinates

21. Co-ordinates (i.e. groups of printed textile designs which co-ordinates with each other.)

Cluster 9: Placements

17. Placement (e.g. individual image or printed motif on garment)
18. Character (e.g. character printed on garment)

Cluster 10: Engineered Prints

22. Scarf Prints
23. Swimwear/Lingerie Prints

3. Within each field a number of options were identified which needed to be incorporated in the database in the form of a pull down list. It was established that selecting certain options in one field may effects the options presented in the pull down list of another field. For example if 'Natural' was the selected option in the 'Fibre Type' field, then only natural fibre names would need to be listed in the 'Fibre Name' field. The field names, and criteria identified were as follows:

- FABRIC ID - a counter automatically added to each new record in the database giving a unique number for each fabric.
- FABRIC DESIGN NAME - optional text to be specified by the person adding the record to the database.
- FABRIC TYPE - optional text that can either be manually typed by the user or selected from the pull down list of common fabric types: DENIM, COTTON, VELVET, VOILE, LINEN, TWEED.
- FIBRE TYPE - non-optional text to be selected from the pull down list: MAN-MADE, NATURAL, MIXED OR UN-KNOWN.
- FIBRE NAME - non-optional text to be selected from the list in the relevant table:
- NATURAL FIBRE NAMES: LAMBSWOOL, MERINO, SHETLAND, CASHMERE, CAMEL, MOHAIR, ANGORA, VICUNA, CASHGORA, ALPACA, CULTIVATED SILK, WILD SILK, SHANTUNG SILK, COTTON, LINEN/FLAX, RAMIE, HEMP, JUTE, SISAL, UNKNOWN, OTHER.
- MAN-MADE FIBRE NAMES: VISCOSE, MODIFIED VISCOSE, ACETATE, TRIACETATE, SECONDARY ACETATE, POLYAMIDE/NYLON,

POLYESTER, ACRYLIC, POLYURETHANE, ELASTANE, POLYVINYLCHLORIDE, METALLIC, MICROFIBRE, UNKNOWN, OTHER.

- MIXED FIBRE NAMES: COTTON/POLYESTER, COTTON/VISCOSE, ACRYLIC/WOOL, UNKNOWN, OTHER.
- FIBRE PERCENTAGES - optional text to be entered by the user.
- FABRIC STRUCTURE TYPE: non optional text to be selected from the pull down list: WOVEN, NON-WOVEN, KNITTED, UNKNOWN.
- STRUCTURE NAME - non-optional text to be selected from the list in the relevant table:
- WOVEN STRUCTURE NAMES: PLAIN (SIMPLE), TWILL (SIMPLE), HERRINGBONE (SIMPLE), SATIN (SIMPLE), SATEEN (SIMPLE), CREPE (SIMPLE), JACQUARD (COMPLEX), LENO (COMPLEX), CLIPSPOT (COMPLEX), DOUBLE CLOTH (COMPLEX), LACE (COMPLEX), BRAID (COMPLEX), NET (COMPLEX), UNKNOWN.
- NON-WOVEN STRUCTURE NAMES: FELT, BONDED FIBRE FABRIC, UNKNOWN.
- KNITTED STRUCTURE NAMES: WEFT KNITTED, SINGLE JERSEY, DOUBLE JERSEY, WARP KNITTED, TRICOT, RASCHEL, UNKNOWN.
- YARN TYPE - non-optional text to be selected from the pull down list: CONTINUOUS FILAMENT, STAPLE, FANCY, UNKNOWN.
- YARN NAME - non-optional text to be selected from the list in the relevant table:
- CONTINUOUS-FILAMENT YARN NAMES: TEXTURED, UNKNOWN.
- STAPLE YARN NAMES: COMBED, CARDED, UNKNOWN.
- FANCY YARN NAMES: CHENILLE, BOUCLE, UNKNOWN.
- TEXTILE DESIGN - non-optional text to be selected from the pull down list: PLAIN/NONE, FLORAL, FRUIT, FOLIAGE, PAISLEY, ETHNIC, DYE EFFECTS, BORDER, BAND, RANDOM MIX, PHOTO REAL, FIGURATIVE, SPOT, STRIPE, CHECK, GEOMETRIC, WEAVE EFFECT, ABSTRACT, TEXTURE, CO-ORDINATE, PLACEMENT, CHARACTER, SCARF PRINT, OTHER.
- PATTERN SCALE - non-optional text to be selected from the pull down list: NONE, SMALL, MEDIUM, LARGE.
- PATTERN SPACING - non-optional text to be selected from the pull down list: NONE, SPACED, ALL-OVER, RANDOM.
- COLOURING METHODS TYPE - non-optional text to be selected from the pull down list: DYED, PRINTED, NONE, UNKNOWN.

- COLOURING METHOD NAME - non-optional text to be selected from the relevant table:
- DYED METHOD NAMES: FIBRE DYED, YARN DYED, PIECE DYED, COLOUR WOVEN, MARL, MELANGE, BATIK, IKAT, TIE DYE, UNKNOWN.
- PRINTED METHOD NAMES: FLOCK, DEVORE, BLOCK, DISCHARGE, RESIST, BATIK, UNKNOWN.
- COLOURWAY - non-optional text to be selected from the pull down list: SINGLE COLOUR, BI-COLOUR, TRI-COLOUR, MULTI-COLOUR.
- COLOUR TONE - non-optional text to be selected from the pull down list: PALE, MEDIUM, BRIGHT, DARK, NEUTRAL.
- GROUND COLOUR - non-optional text to be selected from the pull down list: RED, BLUE, YELLOW, GREEN, PURPLE, BLACK, NAVY, WHITE, GOLD, SILVER, BRONZE, PLATINUM, BROWN, GREY, PINK, MAROON, OTHER.
- PREVAILING FOREGROUND COLOUR - - non-optional text to be selected from the pull down list: NONE, RED, BLUE, YELLOW, GREEN, PURPLE, BLACK, NAVY, WHITE, GOLD, SILVER, BRONZE, PLATINUM, BROWN, GREY, PINK, MAROON, OTHER.
- FINISHES - non-optional text to be selected from the pull down list: CHEMICAL, MECHANICAL, NONE, UNKNOWN.
- FINISH NAME - optional text to be selected from the relevant tables:
- CHEMICAL FINISH NAMES: CREASE RESISTANT, WATER REPELLENT, MERCERIZED, CHLORINATED, OTHER, UNKNOWN.
- MECHANICAL FINISH NAMES: RAISED/BRUSHED, EMERIZED, SANFORIZED, EMBOSSED, SANFORDIZED, PLEATED, OTHER, UNKNOWN.
- FABRIC WIDTH IN CENTIMETRES - optional text to be manually typed in by the user.
- FABRIC WEIGHT - non-optional text to be selected from the pull down list: FINE, MEDIUM, HEAVY, UNKNOWN.
- FABRIC PRICE PER METRE - optional text to be entered by the user.
- PREVALENT FABRIC END USE - optional text to be entered by the user or selected from the pull down list: GENERAL CLOTHING, SHIRTING, WOMENSWEAR, CHILDRENSWEAR, MENSWEAR, SUITING, LINGERIE, SWIMWEAR, JEANSWEAR, SPORTSWEAR, UPHOLSTERY, CURTAINING, EVENINGWEAR, OTHER, UNKNOWN.
- MANUFACTURER - optional text to be entered by the user.

- MANUFACTURER'S REFERENCE NUMBER - optional text to be entered by the user.
- MISCELLANEOUS INFORMATION - optional text to be entered by the user.
- DATE/ADDED AMENDED - the current date is automatically added when the record is input into the database.
- TEXTILE IMAGE - non-optional image of the textile is to be added to the record by the user.

Once the knowledge had been elicited from the textile experts about what data they wanted the library to contain and some idea was gained about how they wanted the database to be structured, an initial prototype and mock up of the textile library interface was constructed. This prototype was shown to the end users and certain changes were required to the field names and their layout.

Appendix C:

Textile Library User Manual

- **Requirements:** A PC with a 486 processor or higher and running Windows v3.1 or Windows 95 is required to run this textile library. Due to the fact that the software is designed to store and retrieve graphical images the database must be run on a PC with enough RAM. 32 MB of RAM is recommended. Microsoft Access must also be installed on the PC.

- **Function:** The purpose of this software is to allow the storage and retrieval of textile images and attributes in a computerised database. Every textile stored in the database will have its own record. Each record contains an image of the textile and other attributes associated with that particular fabric. The database may be searched on any of its fields and multiple fields may also be used as the criteria for a search. When querying the database, the more specific the user is with the parameters, the fewer images will be retrieved. For example if the user enters the specific 'Fabric ID' number as the search criteria for a textile record then only that specific record will be retrieved. On the other hand, if the user enters 'Woven' for the 'Textile Structure' field and 'Dark' for the 'Colour Tone' field then all the Woven fabrics that have a Dark colour tone will be retrieved.

- **Navigating The Screens:** The interface has been designed to be self explanatory. Each screen consists of buttons which allow the user to select the option written on the button when that particular button is clicked using the left mouse button. Each textile record is displayed on a form that consists of text boxes for each field and an image box in which the textile image is displayed. At the side of many of the text boxes on the forms, there are pull down lists of options to select from. To view the pull down lists, click on the small down arrow at the side of the text entry field. To select an entry in the list click on it once. Alternatively the user may enter their own text by clicking the mouse in the data entry field so that the cursor appears and then typing in the text manually. Buttons are also provided on the form, allowing the user to print the record, delete the record, exit the database or return to the main menu. Arrows along the bottom of the form allow the user to scroll through the records currently contained in the database.

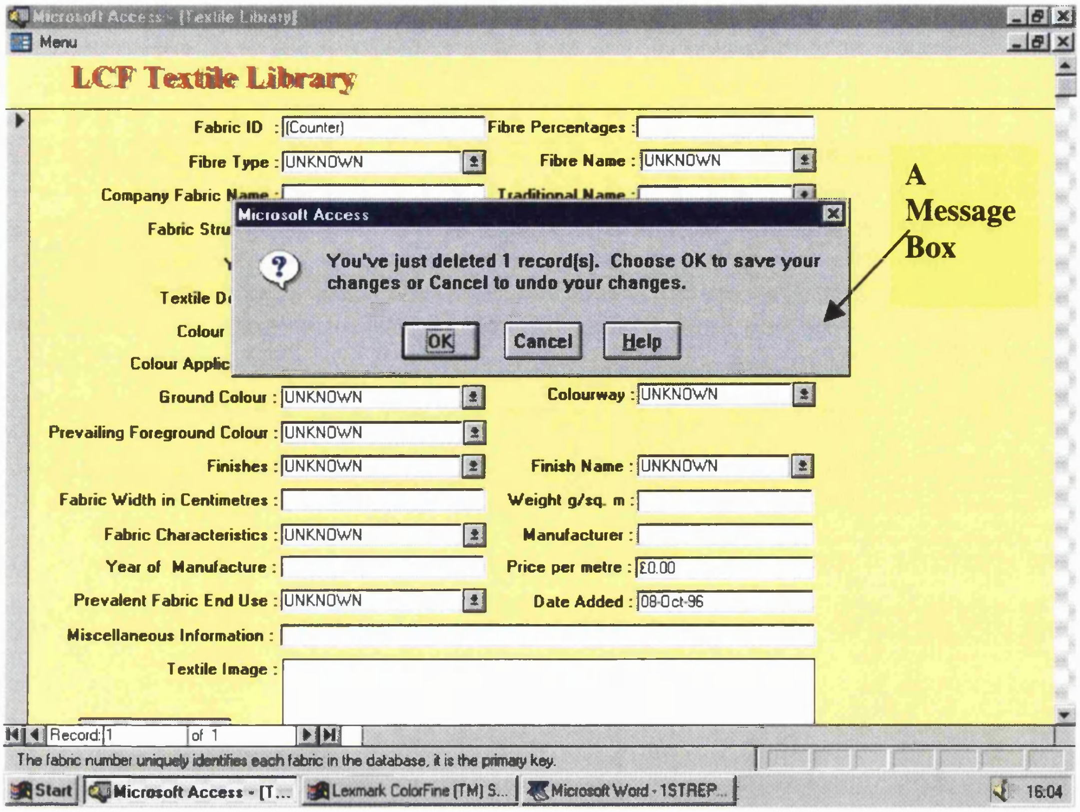
- **Logging On To The Textile Library:** When first entering the textile library the user will be asked for their 'Name' and 'Password'. The name and password entered at this stage will dictate what permissions the user will have whilst using the library. The correct case must be used when entering the name and password. They must always be typed in lower case. Certain options displayed by the buttons will not always be available to users. For example if a user logs on as 'user' they will not be able to activate the delete button.

Name: designer
Password: designer
Permissions: View the library, Search the library, Edit the library, Alter the design of the library.

Name: admin
Password: admin
Permissions: View the library, Search the library, Edit the library.

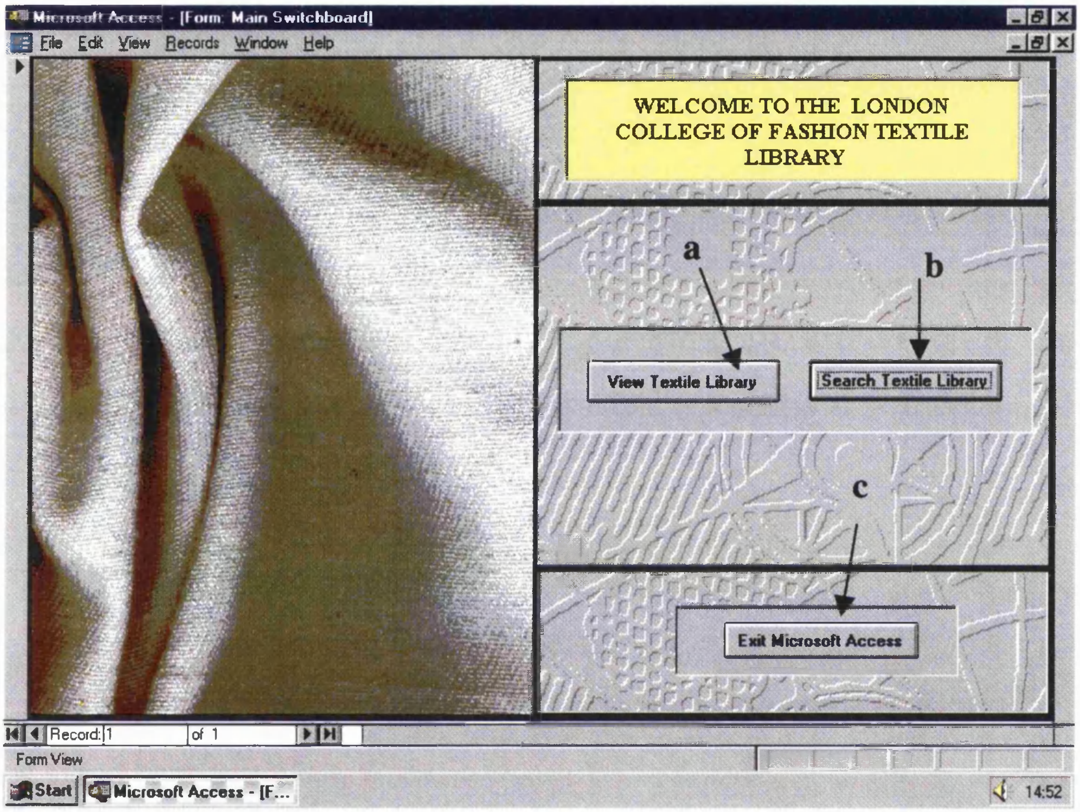
Name: user
Password: user
Permissions: View the library, Search the library.

- **Message Boxes:** Message boxes will sometimes appear to inform or prompt the user. The instructions in the message box must be followed before attempting to do anything else and then the 'OK' button in the message box clicked once with the left mouse button:



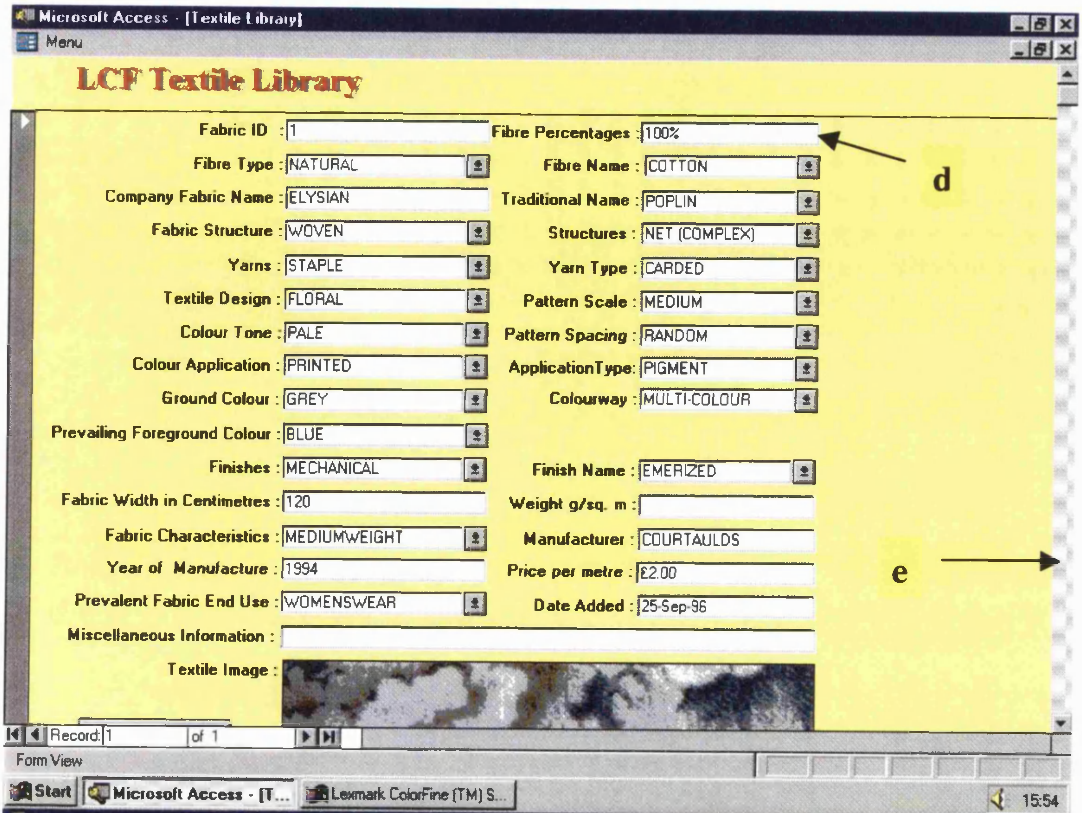
- **Quitting:** The user may exit the program at any time by clicking on the 'Exit Microsoft Access' button. Any changes to the textile library will automatically be saved where permissions allow it.

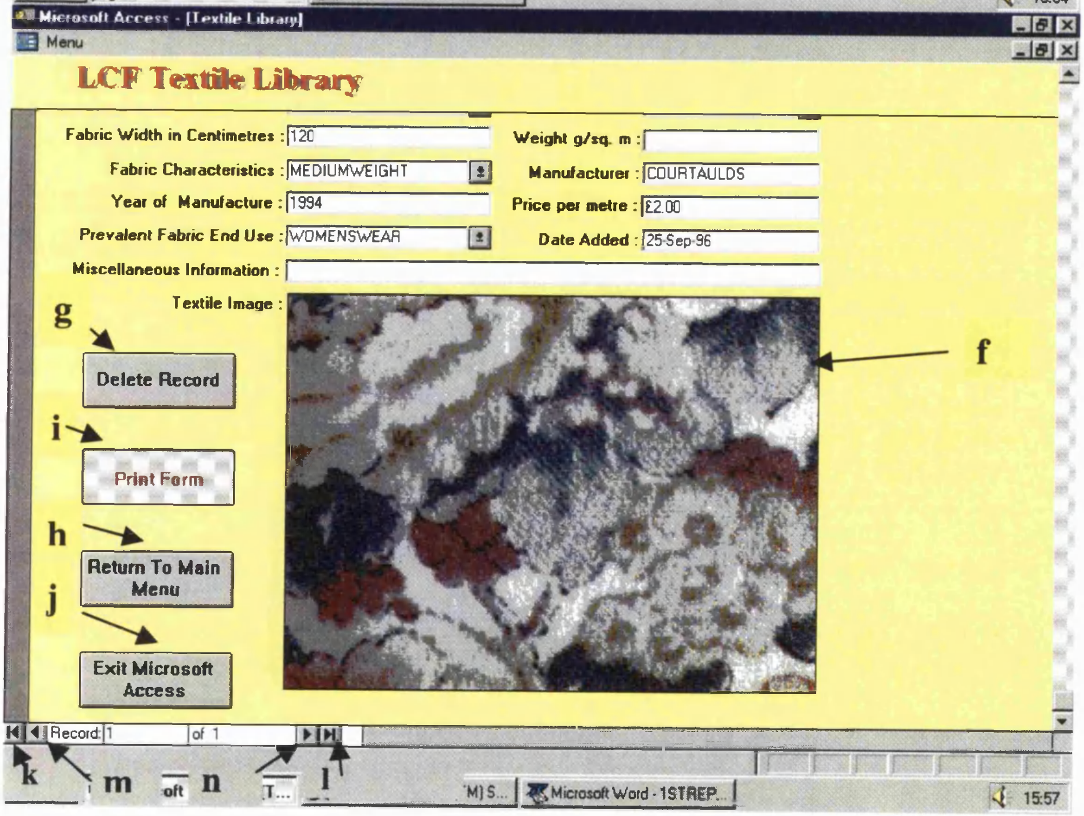
* **Using The Database:** On entering the database the user will be presented with the following screen:



The user may use the left mouse button to click once on the buttons to activate their functions. If the user clicks at '**a**' they may enter the textile library and view all of its records. If the user clicks at '**b**' the user may do a simple search on the textile library using only one search criteria. If the users clicks at '**c**' they will be exited from the textile library and Microsoft Access will be closed.

* **Viewing Records:** If the user decides to click button '**a**' they will be presented with a form displaying the first textile record:

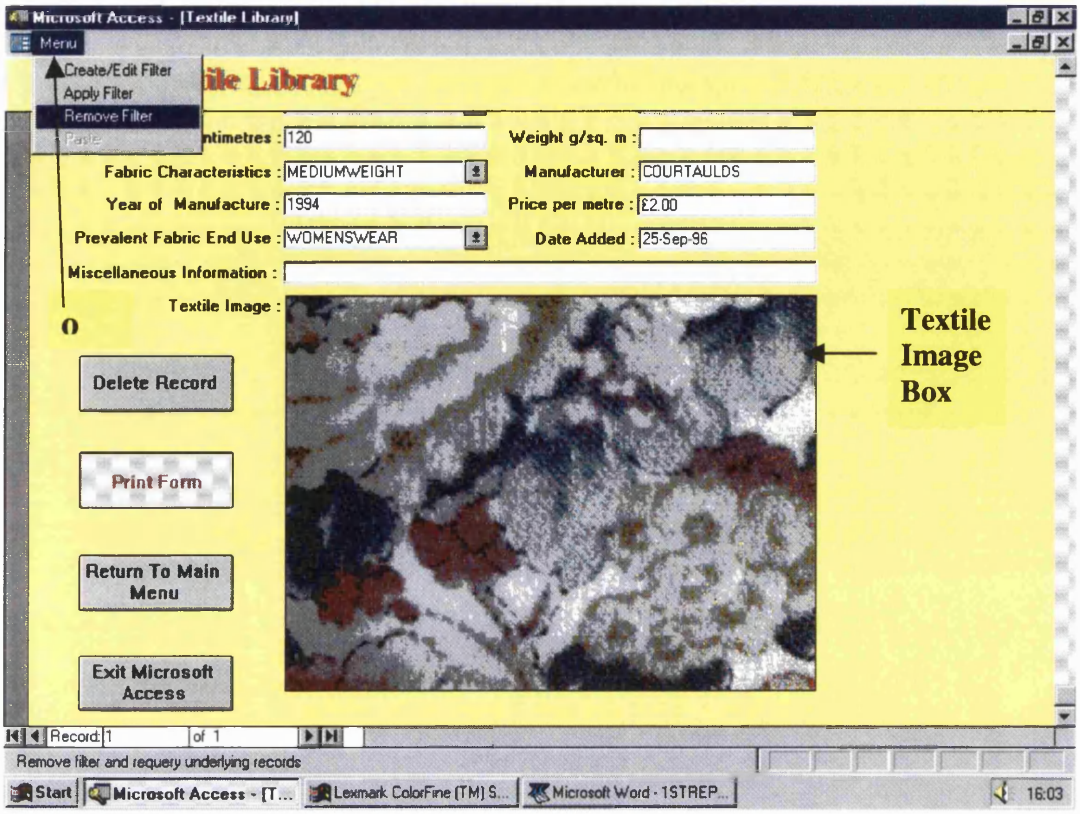

Microsoft Access - [Textile Library]
Menu
LCF Textile Library
Fabric ID : 1
Fibre Percentages : 100%
Fibre Type : NATURAL
Fibre Name : COTTON
Company Fabric Name : ELYSIAN
Traditional Name : POPLIN
Fabric Structure : WOVEN
Structures : NET (COMPLEX)
Yarns : STAPLE
Yarn Type : CARDED
Textile Design : FLORAL
Pattern Scale : MEDIUM
Colour Tone : PALE
Pattern Spacing : RANDOM
Colour Application : PRINTED
ApplicationType: PIGMENT
Ground Colour : GREY
Colourway : MULTI-COLOUR
Prevailing Foreground Colour : BLUE
Finishes : MECHANICAL
Finish Name : EMERIZED
Fabric Width in Centimetres : 120
Weight g/sq. m :
Fabric Characteristics : MEDIUMWEIGHT
Manufacturer : COURTAULDS
Year of Manufacture : 1994
Price per metre : £2.00
Prevalent Fabric End Use : WOMENSWEAR
Date Added : 25-Sep-96
Miscellaneous Information :
Textile Image :
Record: 1 of 1
Form View
Start
Microsoft Access - [T...
Lexmark ColorFine (TM) S...
15:54
d
e


Microsoft Access - [Textile Library]
Menu
LCF Textile Library
Fabric Width in Centimetres : 120
Weight g/sq. m :
Fabric Characteristics : MEDIUMWEIGHT
Manufacturer : COURTAULDS
Year of Manufacture : 1994
Price per metre : £2.00
Prevalent Fabric End Use : WOMENSWEAR
Date Added : 25-Sep-96
Miscellaneous Information :
Textile Image :
g
Delete Record
i
Print Form
h
Return To Main Menu
j
Exit Microsoft Access
f
Record: 1 of 1
k
m
n
l
Microsoft Word - 1STREP...
15:57

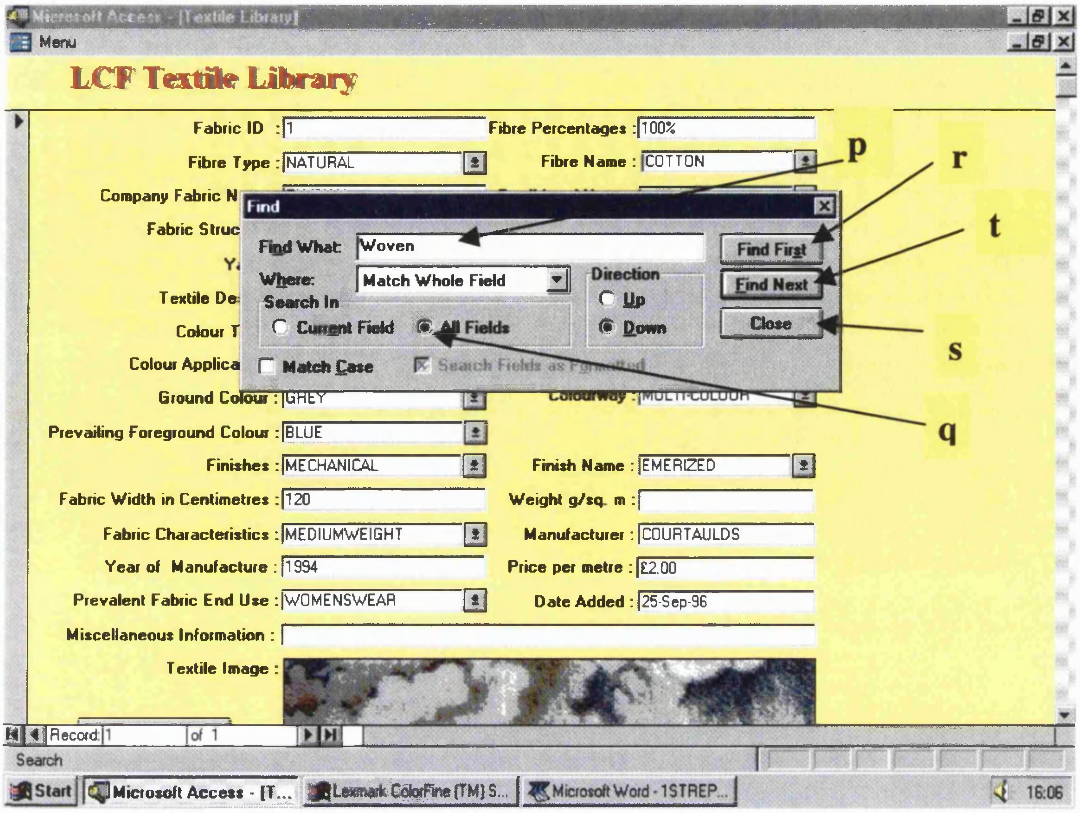
The user may:

- Click at **d** to pull down the pull down list of options relevant to the field. To select one of the options to be entered into that field, click on the required option.
- Click at **e** to scroll down the form and view the textile image box.
- Click at **f** to select the textile image box.
- Click at **g** to delete the current record (if your log on id allows it).
- Click at **h** to print the current record.
- Click at **i** to return to the first screen.
- Click at **j** to close down the database.
- Click at **k** to go to the first textile record.
- Click at **l** to go back one record.
- Click at **m** to go forward one record.
- Click at **n** to go to the last record.

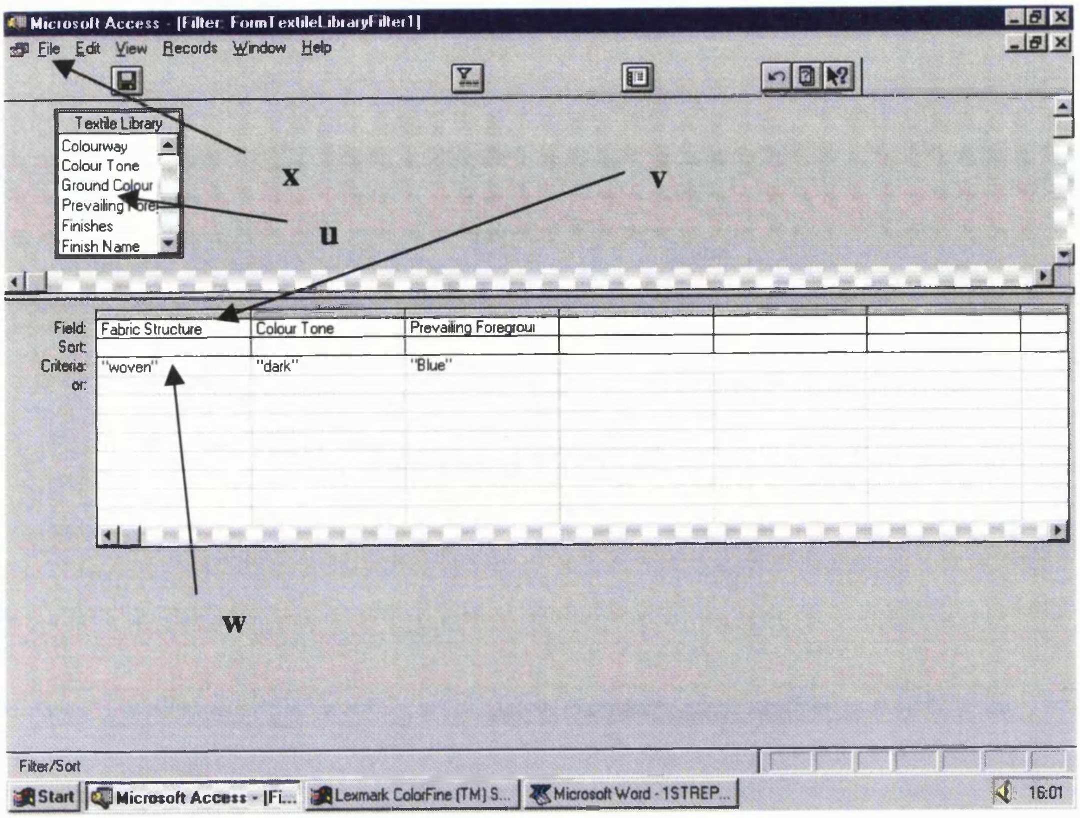
- **Entering A Textile Image:** To enter a textile image into the database the user must first scan in the image at the correct size and save it in the textile image directory. The image can then be selected in 'File Manager' and copied by going to the 'Edit' menu and choosing 'Copy'. The user must then return to the record where they wish to enter then textile image and click on the textile image box so it is selected. The menu at '**o**' in the top left hand corner of the screen should then be opened and the 'Paste' option within it selected. The textile image that has previously been copied will then be pasted into the textile image box.



- **Searching The Database Specifying Only One Search Criteria:** From the first screen the user should click the 'Search Textile Library' button at '**b**'. The records will then be opened up and the user will be prompted to enter a search criteria at '**p**'. The user must also click on the 'Search All Fields' option at '**q**', before clicking on the 'Find First' button at '**r**'. The first record fulfilling the search criteria will then be found. If the user wishes to view the record they must click on the 'Close' button at '**s**' to finish the search. If they wish to view the next record fulfilling that criteria they must click on the 'Find Next' button at '**t**'.



• **Searching The Textile Library Using Multiple Search Criteria:** To search the database using multiple search criteria the user must click on the button 'View Textile Library' at '**a**' on the first screen. Once the textile library is opened the user must go to the menu at '**o**' in the top left hand corner of the screen. This menu can be pulled down by clicking on it and then the 'Create/Edit Filter' option can be selected. The following screen will then be opened up:



The user must click on the required fields at '**u**' and hold the left mouse button down and drag them one by one to the Fields part of the table at '**v**'. Then at '**w**' the user must type in the search criteria for each field that has been dragged to the table. Once this has been completed the user must open the 'File' menu at '**x**' and select the close option. The filter screen will then be closed. To apply the filter the user must open the menu at '**o**' and select the 'Apply Filter' option. The filter will then be applied and the only records showing will be those that match the search criteria. To remove the filter the user must go back to the menu at '**o**' and select the 'Remove Filter' option. To change the search criteria the user must select the 'Create/Edit Filter' option and start the process from the beginning. When the database is closed the filter will automatically be removed.

Appendix D:

Range Plan

The range plan for each of the four ranges, Authentics, Classics, East Coast, and West Coast is as follows:

Authentics Range

This range must pay absolute homage to original, authentic, American products in terms of styling, fabric, construction, colours and logo application. The objective is for it to be the Levi's of the Sportswear industry. This is to be the premium collection, acting as the signature for the brands clothing line and carrying the advertising for all the ranges.

Authentic American Vest and Short

The authentic American polyamide vest and short set evolved from the need for performance wear, fit for the purpose of basketball. The fabric influence is from the late 1930's early 1940's. 1940's performance fabrics moved away from woollen interlocks. A printed logo is included on the garments. Logo's have been used on sportswear since the turn of the century. They were instigated with the start of sports athletics in order to distinguish the teams. The use of ribs on the shorts originated from the early boxing shorts designed for boxers. They are an evolution from the cotton woven shorts used in the 1920's. The woven patch was used to inform the kit washer who owned the garment that he had just washed and what size it was.

Authentic American Socks

The authentic American Sports socks were traditionally worn at knee length for warmth. The socks are knee length and are made from a wool with a heavy rib. In the 1950's branding began to be used on the socks in order that the sock print identified the sports team to which the student belonged.

Authentic American Tee

The authentic American T-shirt evolved from underwear to a garment worn by athletes when training. As college sports became a more serious pursuit and the military demanded though sports apparel for troops, the tee became a staple sports product. This T-shirt takes it's influence from a 1950's sports tee. The top shoulder panel however was used particularly for American football over the pads. The fabric has been redeveloped from a 1940's military high performance sportswear textile made from a mix of rayon, cotton and acetate. The woven patch was used to inform the kit washer who owned the garment that he had just washed and what size it was. A printed logo is included on the garment. Logo's have been used on sportswear since the turn of the century. They were instigated with the start of sports athletics in order to distinguish the teams.

Authentic American Hooded Sweatshirt

The authentic American hooded sweat evolved from underwear to a garment worn by athletes when training. As college sport became a more serious pursuit and the military demanded tough sports apparel for troops, the hooded sweat became a staple sports product. The fabric used is a reverse weave developed in the 1960's to reduce shrinkage and be tougher for outdoor performance. The double V detail was first used in the 40's as an added value styling detail. The long ribs and big waistbands were incorporated to match the larger waistbands on the joggers.

Authentic American Sweatshirt

The authentic American sweatshirt evolved from underwear to a garment worn by athletes when training. The fabric used is a reverse weave developed in the 1960's to reduce shrinkage and be tougher for outdoor performance. The double V detail was first used in the 40's as an added value styling detail. The long ribs and big waistband have been incorporated to match the larger waistbands on the joggers. The side inserts are used to prevent shrinkage in the length of the garment. The woven patch was used to inform the kit washer who owned the garment that he had just washed and what size it was.

Authentic American Jogger

The authentic American jogger evolved from underwear to a garment worn by athletes when training. As college sport became a more serious pursuit and the military demanded tough sports apparel for troops, the jogger became a staple sports product. The jogger has no side pockets in order to retain the authenticity of the styling. In the 1940's athletes would have left all their personal belongings in the locker-room, and did not require pockets. One patch pocket has been incorporated on the back of the jogger. This is a legacy from the single pocketed denims worn in the late 18th century. The ribbed gusset originates from the 1940's to allow for stretching, prevent shrinkage, and allow for extra wear. The woven patch was used to inform the kit washer who owned the garment that he had just washed and what size it was.

Authentic American Warm-Up Jacket

The authentic American basketball warm up jacket evolved from the need for performance training kits with the growth of basketball as an active team sport. The styling for this garment originated from those worn in the 1950's for basketball warm ups. The fabric used is similar to the performance fabrics created in the 1940's, that marked a moved away from the traditional woollen interlocks used in previous decades. The woven patch was used to inform the kit washer who owned the garment that he had just washed and what size it was.

Authentic American Warm-Up Pant

The authentic American basketball warm up pant evolved from the need for performance training kits with the growth of basketball as an active team sport. The styling for this garment originated from warm-up pants worn in the 1950's for basketball warm-ups. The fabric used is similar to the performance fabrics created in the 1940's, that marked a moved away from the traditional woollen interlocks used in previous decades. The woven patch was used to inform the kit washer who owned the garment that he had just washed and what size it was.

Authentic American Letterman Jacket

The authentic American Letterman jacket evolved in the collegiate 1950's. As college sport became a more serious pursuit this jacket was given to students who were selected for their college sports teams. The side pockets and other general styling features on this garment, originate from the 1950's letterman jacket. The badge would originally have been used to provide information on whose jacket it was. The lightweight nature of the garment makes it more of a summer jacket.

Authentic American Fraternity Jacket

The authentic American Fraternity Jacket evolved in the collegiate 1950's. As college sport became a more serious pursuit this jacket was given to students who became members on particular sporting societies. The side pockets and other general styling features on this garment, originate from the 1950's fraternity jacket. The badge would originally have been used to provide information on whose jacket it was. The heavier weight nature of the garment makes it more of a winter jacket used for driving.

Authentic American Coach Jacket

The authentic American Coach Jacket evolved in the collegiate 1950's. As college sport became a more serious pursuit this lightweight jacket was used during training by the college coach. The Jacket styling derives from the 1950's original style and hence it is made in lightweight nylon for durability and warmth with traditional side pockets. The chest badge would originally have been used to identify the sports team to which the student belonged.

Classics Range

This range must be the "take - down" version of the Authentics range, coming in at a lower price point. It should form a basic collection of sportswear garments, with fewer products than in the Authentics range. It must embody wholly the brand values, however, the governing factor throughout is the price and competitiveness. The Classics range is a diffused version of the Authentics range outlined above.

West Coast Range

This range must have its roots in west coast American culture and at it's core must be the west coast lifestyle. The range must endeavor not to be a cliché of the west coast culture, but rather to take only that which is authentic and original from within it. The range is required to strike a balance between commercial volume and brand image.

West Coast Logo Tee

This garment is a V neck plain T-shirt, derived from the early 1970's college tees, worn casually.

West Coast Polo Tee

This garment originates from the 1960's golf/polo tee worn by the ivy league students.

West Coast Striped Tee

This garment takes it's influences from the 1970's engineered stripe surfing tees.

USAF Jacket

This garment originates from the jackets used by the radio controllers in the US Airforce.

Original Skate Jammer

The long shorts emanated from skaters cutting down their jeans.

Folded Neck Top

This garment takes it's styling details from 1950's casual wear, with a shorn collar for extra warmth.

Skate Hood Top

The single V detail was first used in the 1940's as an added value styling detail. The side panelling is incorporated to prevent shrinkage in the length of the garment.

Skate Shirt

This garment is derived from the 1950's work shirt.

Skate Pant

This garment is derived from the 1950's work pant.

Skate Top

The single V detail was first used in the 1940's as an added value styling detail.

Skate Canvas Jacket

This garment is based on the railway coach jacket developed in the 1940's.

Canvas Nylon Skate Jacket

This garment is a contemporary skate jacket

East Coast Range

This range must have it's roots in east coast American culture and encompass the east coast lifestyle. It must endeavor not to become a cliché of the east coast American culture, but rather to take only that which is authentic and original from within it. The range must strike a balance between commercial volume and brand image.

Appendix E:

Schedule of the Design Meetings

Schedule of Meetings & Interviews

Meeting 1

Date & Place: 18/11/1996 - Design Office, Epsom.

Attended by: European Marketing Director, European Clothing Product Manager.

Meeting Context: Formal design meeting to hold an initial discussion about the points that need to be taken into account when developing the spring/summer 1998 clothing range.

Meeting 2

Date & Place: 22/11/1996 – Stylist's Office, London.

Attended by: European Marketing Director, European Clothing Product Manager, Stylist.

Meeting context: Formal design meeting to review the main points that need to be taken into account when developing the spring/summer 1998 clothing range, with the stylist.

Meeting 3

Date & Place: 10/12/1996 – Design Office, Epsom.

Attended by: European Clothing Product Manager, Stylist.

Meeting Context: Formal design meeting to enable the stylist to make comments on the previous clothing range and to decide what stage would need to be reached by the beginning of January when a meeting with the clothing manufacturer would be held.

Meeting 4

Date & Place: 17/12/1996 - Palm Beach, America.

Attended by: European Marketing Director, European Clothing Product Manager, Designer from the manufacturer, Business Manager from the manufacturer.

Meeting Context: Formal design meeting to go over the main points that need to be taken into account when developing the spring/summer 1998 clothing range with the manufacturer and decide when the prototype samples and master collection would be delivered.

Meeting 5

Date & Place: 07/01/1997 - European Head Office, Epsom.

Attended by: European Marketing Director, European Clothing Product Manager, Stylist, Designer from the manufacturer, Business Manager from the manufacturer, Vintage American Clothing Expert.

Meeting Context: Formal design meeting to have a brainstorming session with the external sources of design input.

Meeting 6

Date & Place: 10/01/1997 - European Head Office, Epsom.

Attended by: European Marketing Director, European Clothing Product Manager.

Meeting Context: Formal design meeting to go through everything that was presented by the external sources of design at the previous meeting and start to pull the range into shape. Decisions need to be made around the colour palette and also on which styles should be immediately discarded. The sketches of the range assembled so far need to be scrutinised and unwanted styles thrown out.

Meeting 7

Date & Place: 16/01/1997 – Manufacturer's Head Office, Copenhagen.

Attended by: European Marketing Director, European Clothing Product Manager, Designer from the manufacturer, Business Manager from the manufacturer.

Meeting Context: Formal design meeting to finalise the designs with the designer at the manufacturer so that she can transfer them to sketch form on the CAD system.

Meeting 8

Date & Place: 19/02/1997 - Head Office, Epsom.

Attended by: European Marketing Director, European Clothing Product Manager.

Meeting context: Formal design meeting to finalise the range before samples are made.

Meeting 9

Date & Place: 18/03/1997 - Head Office, Epsom.

Attended by: European Marketing Director

Meeting Context: Formal design meeting to view the samples for the whole range.

Meeting 10

Date & Place: 14/04/1997 - Head Office – Epsom.

Attended by: European Clothing Product Manager.

Meeting Context: Interview to obtain detailed feedback on the $IBIS^+$ knowledge structure that the design team had been given access to throughout the design process and to acquire further design data that needed to be input into the structure.

Meeting 11

Date & Place: 10/05/1997 -

Attended by: European Marketing Director, European Marketing Manager, European Clothing Product Manager.

*Meeting Context: M*eeting to install the finished version of the $IBIS^+$ knowledge structure.

Meeting 12

Date & Place: 02/06/1997 - Head Office, Epsom.

Attended by: European Marketing Director, European Marketing Manager.

Meeting Context: Interview to establish feedback and reflections on the $IBIS^+$ knowledge structure now that it had been installed at the company for 1 month and to ascertain what changes would be required to make it a useful tool for the representation of design rationale.

Meeting 13

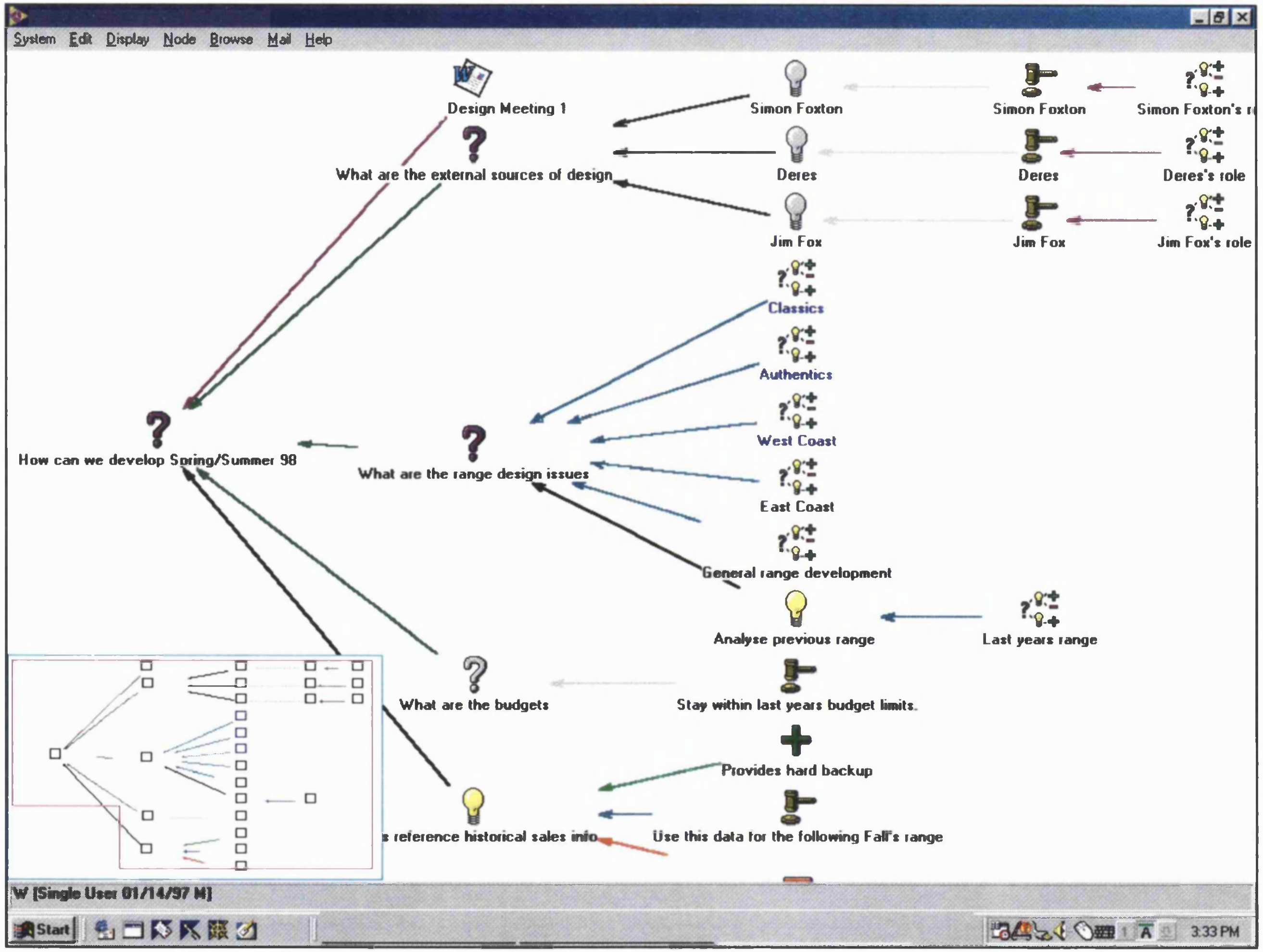
Date & Place: 10/07/1997 - Head Office, Epsom.

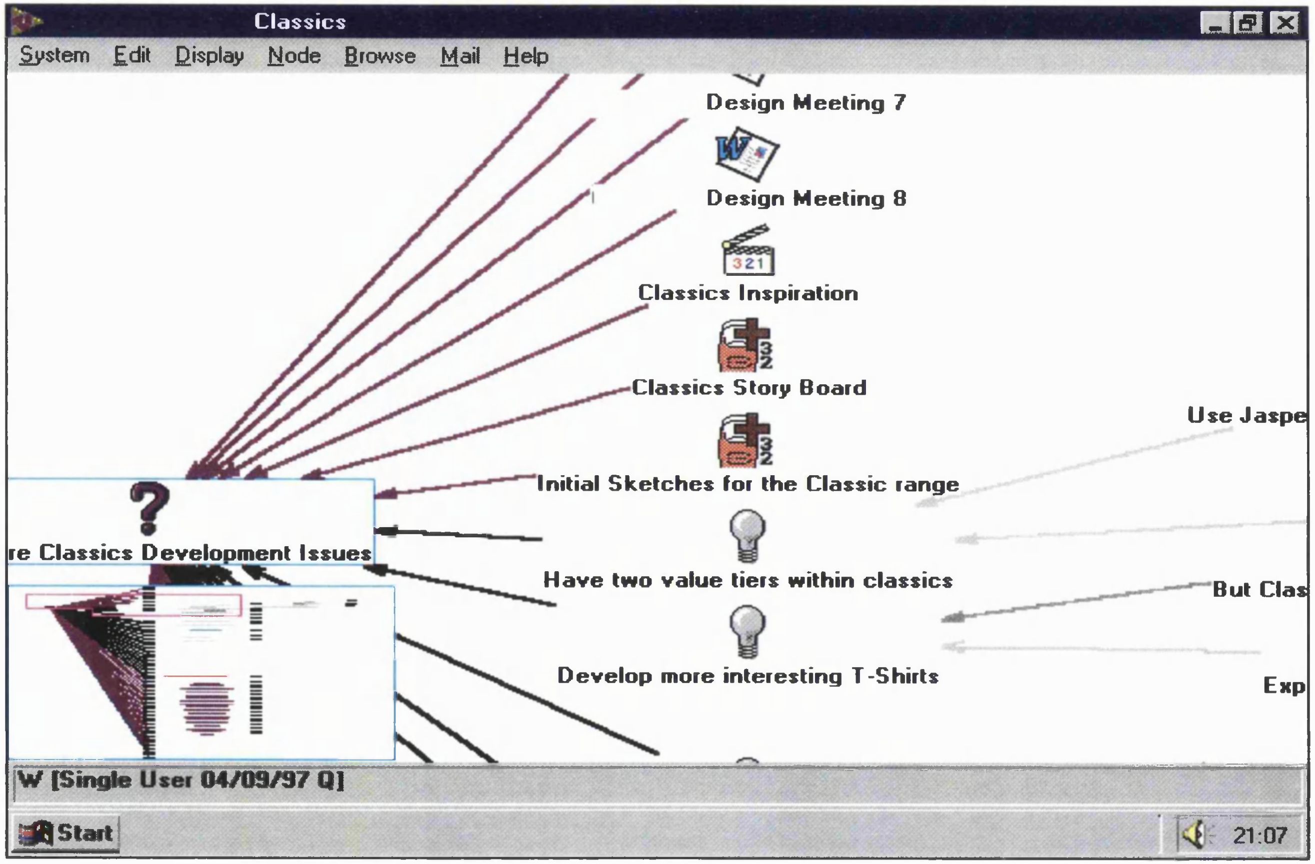
Attended by: European Clothing Product Manager.

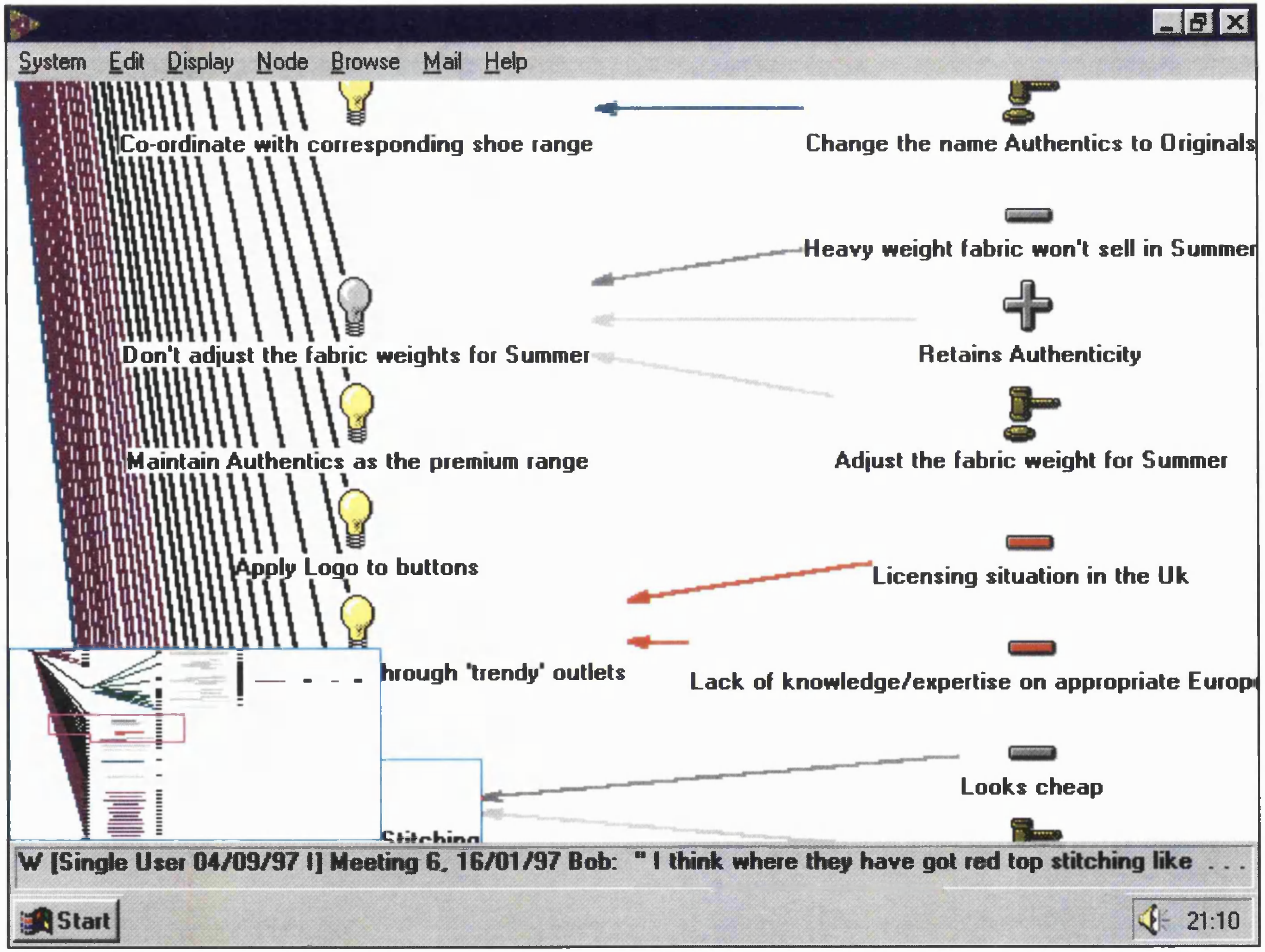
Meeting Context: Interview to establish further feedback and reflections on the IBIS$^+$ knowledge structure and to ascertain what changes would be required to make it a useful tool for the representation of design rationale from a product managers point of view.

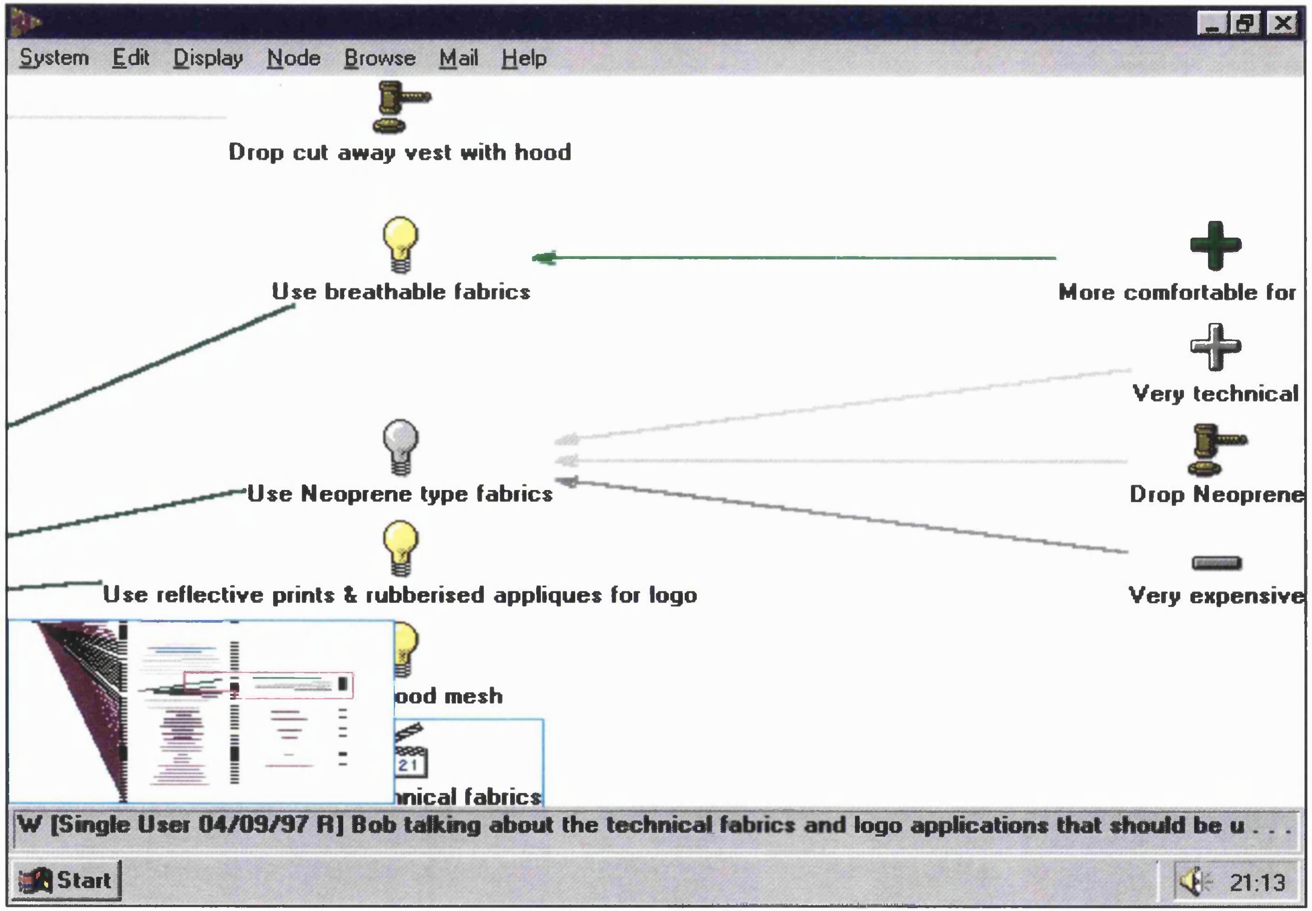
APPENDIX F:

Fragments of the $IBIS^+$ Knowledge Maps

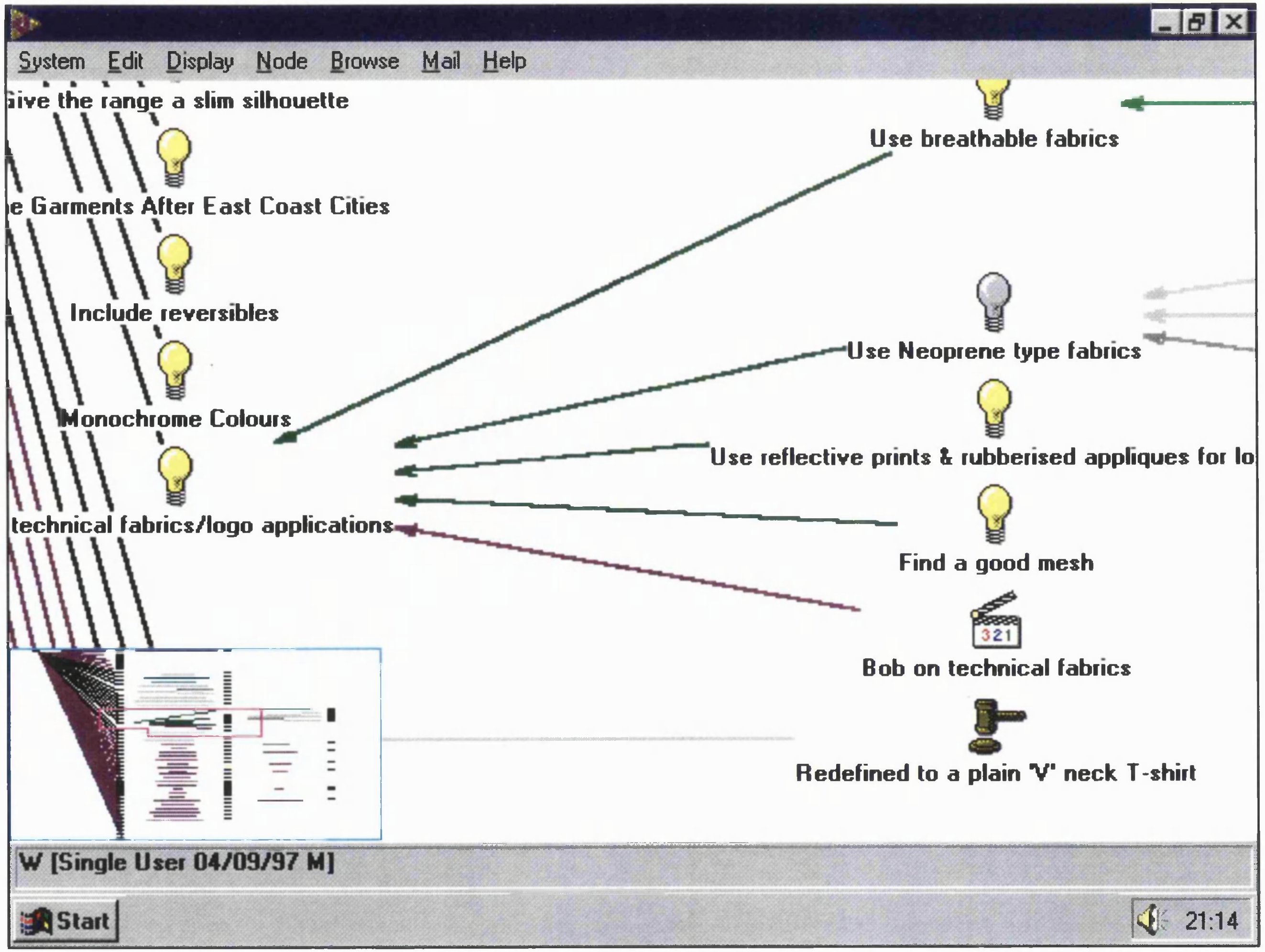

System Edit Display Node Browse Mail Help
Design Meeting 1
What are the external sources of design
Simon Foxton
Deres
Jim Fox
Simon Foxton
Deres
Jim Fox
Deres's role
Jim Fox's role
Classics
Authentics
West Coast
East Coast
General range development
How can we develop Spring/Summer 98
What are the range design issues
Analyse previous range
Last years range
What are the budgets
Stay within last years budget limits.
Provides hard backup
Use this data for the following Fall's range
s reference historical sales info
3:33 PM

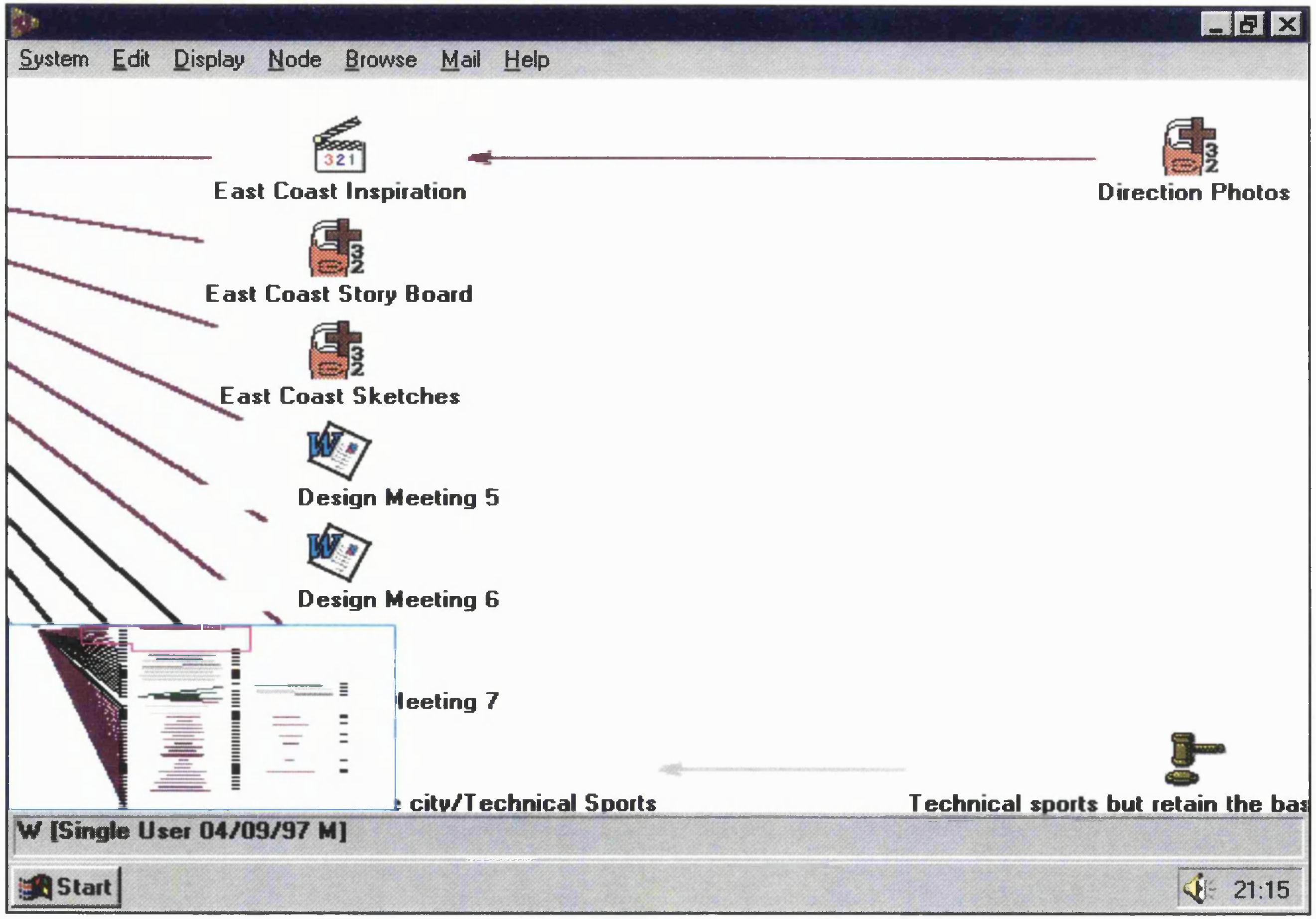

Classics
System Edit Display Node Browse Mail Help
Design Meeting 7
Design Meeting 8
Classics Inspiration
Classics Story Board
Initial Sketches for the Classic range
re Classics Development Issues
Have two value tiers within classics
Develop more interesting T-Shirts
Use Jaspe
But Clas
Exp
W [Single User 04/09/97 Q]
Start
21:07

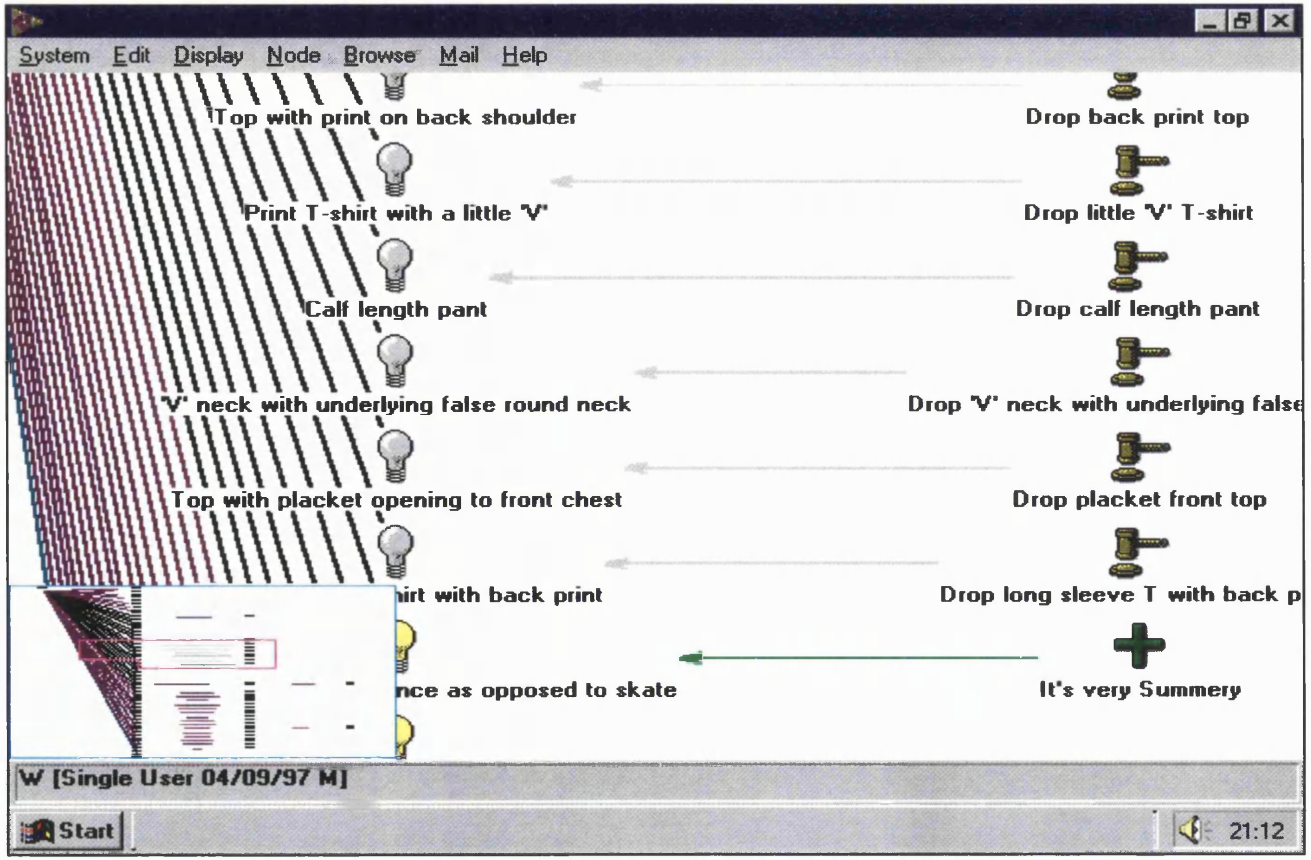

System Edit Display Node Browse Mail Help
Co-ordinate with corresponding shoe range
Change the name Authentics to Originals
Heavy weight fabric won't sell in Summer
Don't adjust the fabric weights for Summer
Retains Authenticity
Maintain Authentics as the premium range
Adjust the fabric weight for Summer
Apply Logo to buttons
Licensing situation in the Uk
hrough 'trendy' outlets
Lack of knowledge/expertise on appropriate Europ
Looks cheap
W [Single User 04/09/97 I] Meeting 6, 16/01/97 Bob: " I think where they have got red top stitching like . . .
Start
21:10

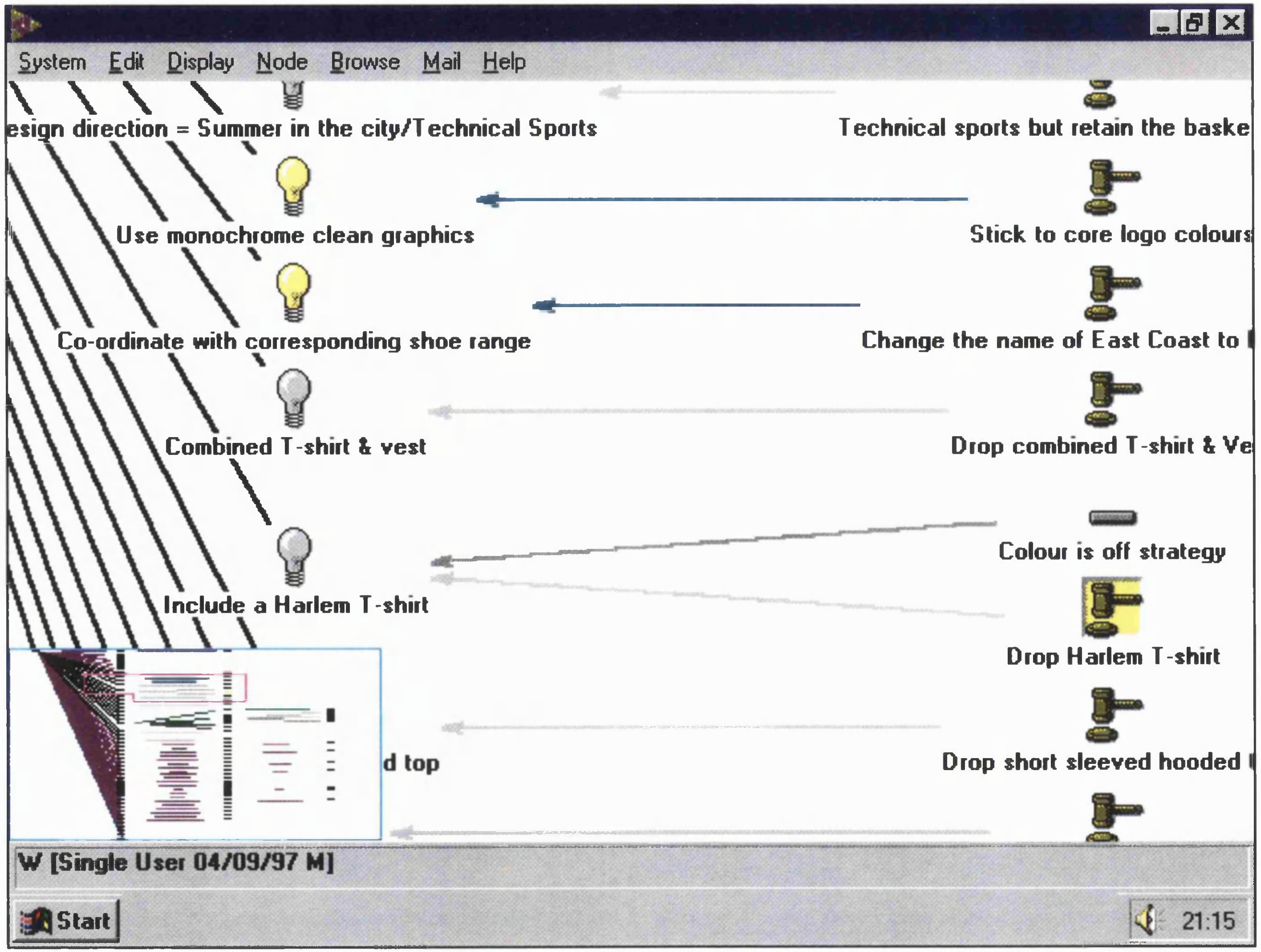


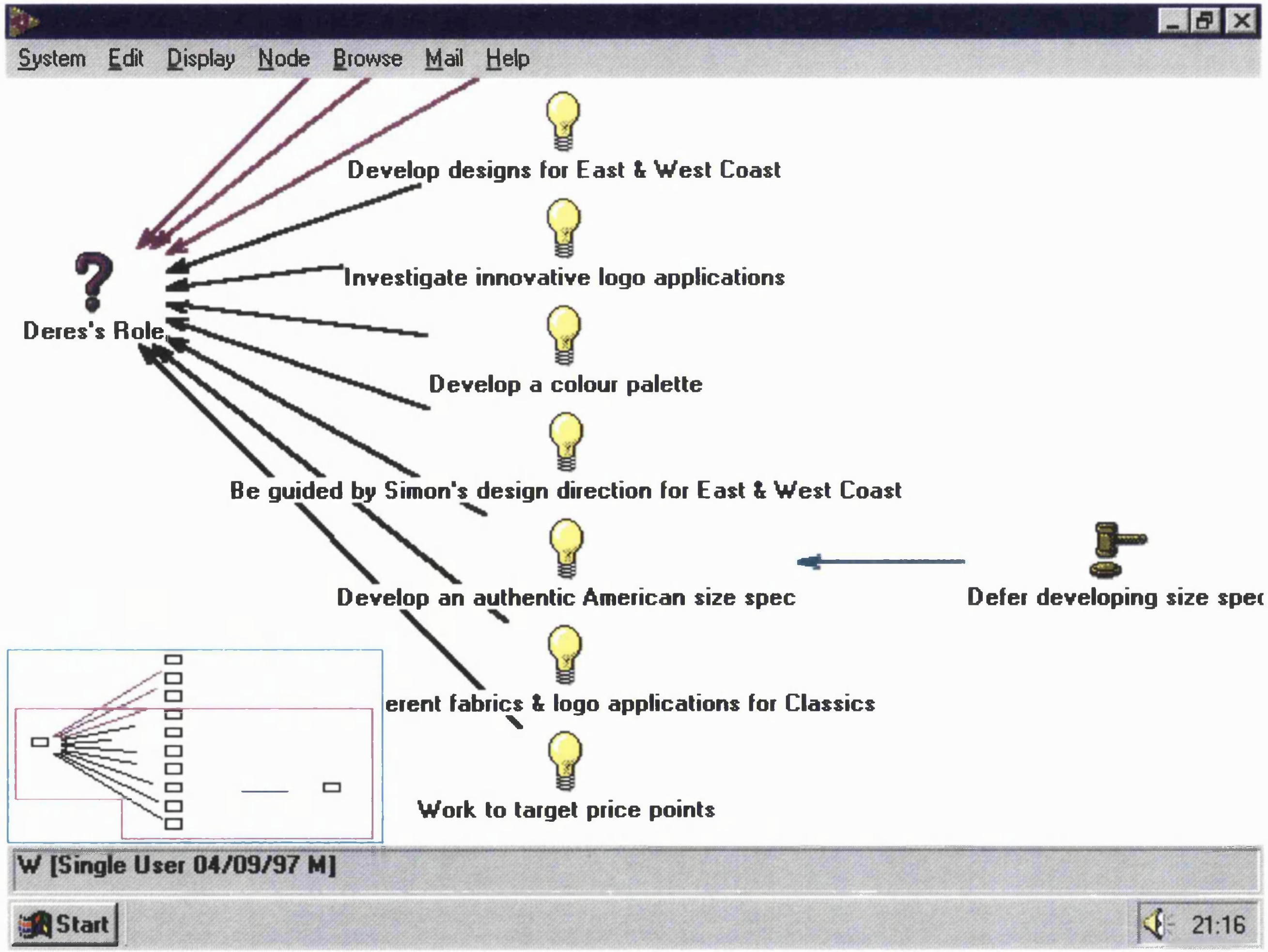
System Edit Display Node Browse Mail Help
Drop cut away vest with hood
Use breathable fabrics
More comfortable for
Very technical
Use Neoprene type fabrics
Drop Neoprene
Use reflective prints & rubberised appliques for logo
Very expensive
ood mesh
nical fabrics
W [Single User 04/09/97 R] Bob talking about the technical fabrics and logo applications that should be u . . .
Start
21:13

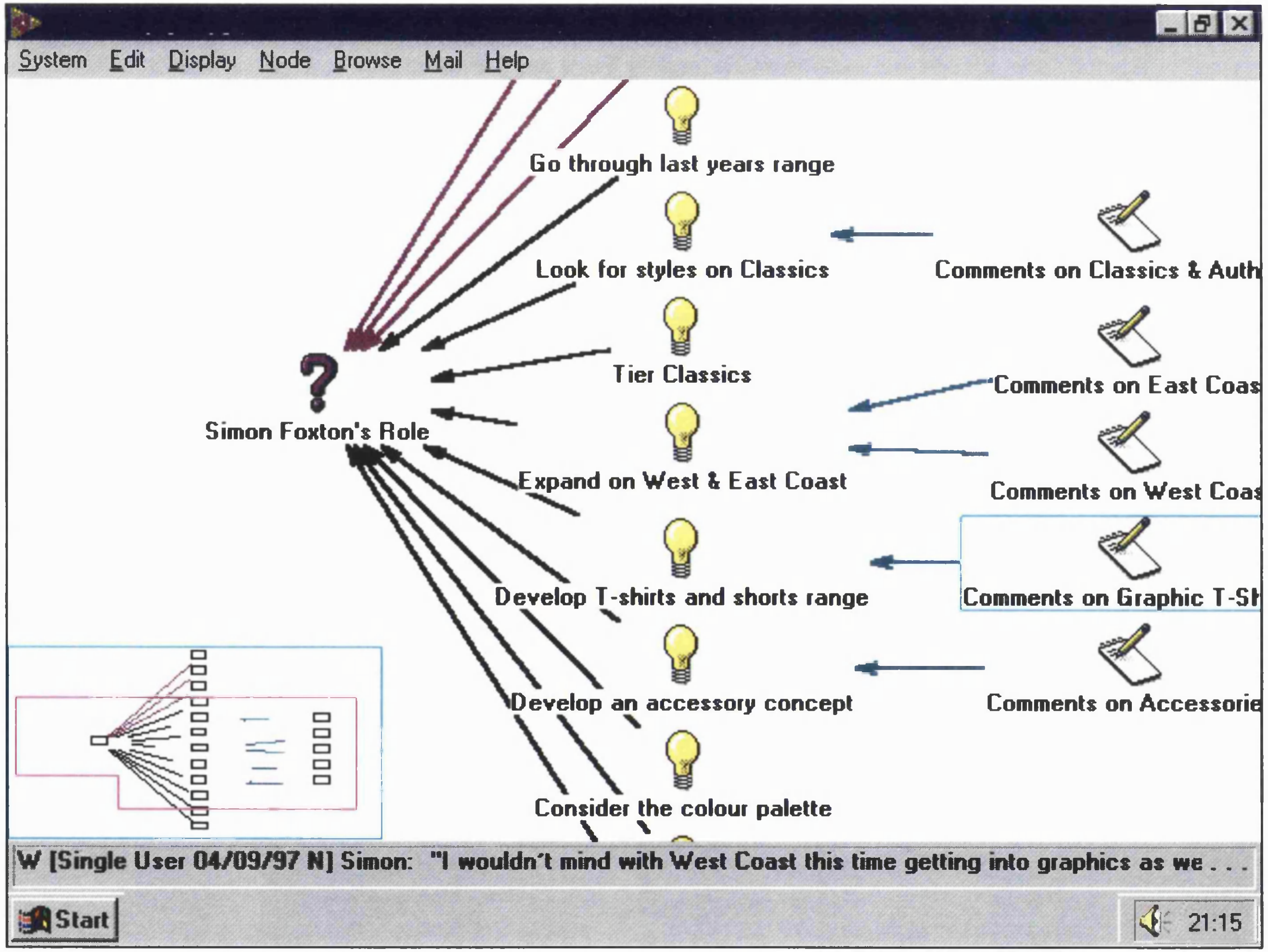

System Edit Display Node Browse Mail Help
ive the range a slim silhouette
e Garments After East Coast Cities
Include reversibles
Monochrome Colours
technical fabrics/logo applications
Use breathable fabrics
Use Neoprene type fabrics
Use reflective prints & rubberised appliques for lo
Find a good mesh
Bob on technical fabrics
Redefined to a plain 'V' neck T-shirt
W [Single User 04/09/97 M]
Start
21:14

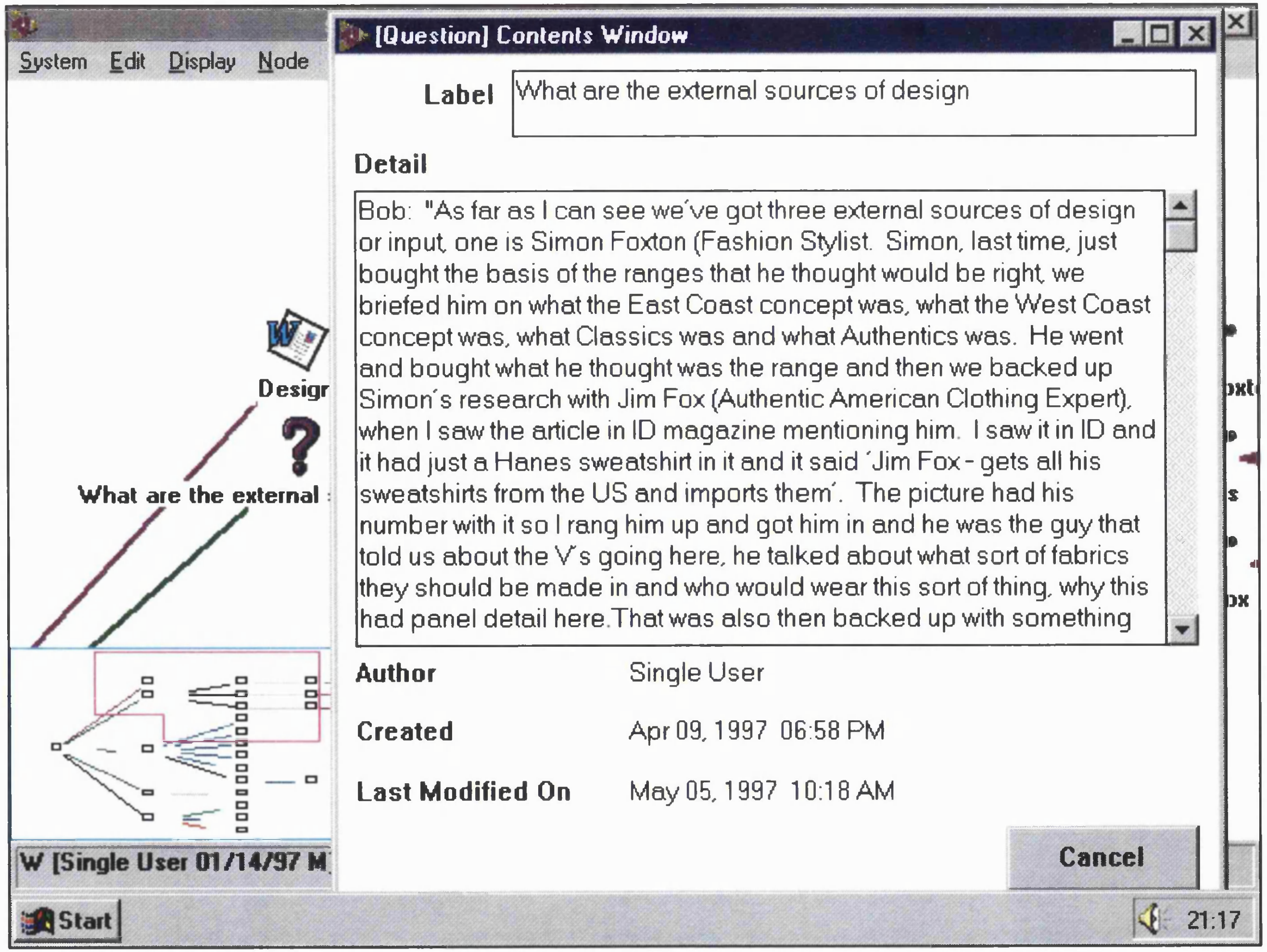

System Edit Display Node Browse Mail Help
East Coast Inspiration
Direction Photos
East Coast Story Board
East Coast Sketches
Design Meeting 5
Design Meeting 6
leeting 7
city/Technical Sports
Technical sports but retain the bas
W [Single User 04/09/97 M]
Start
21:15

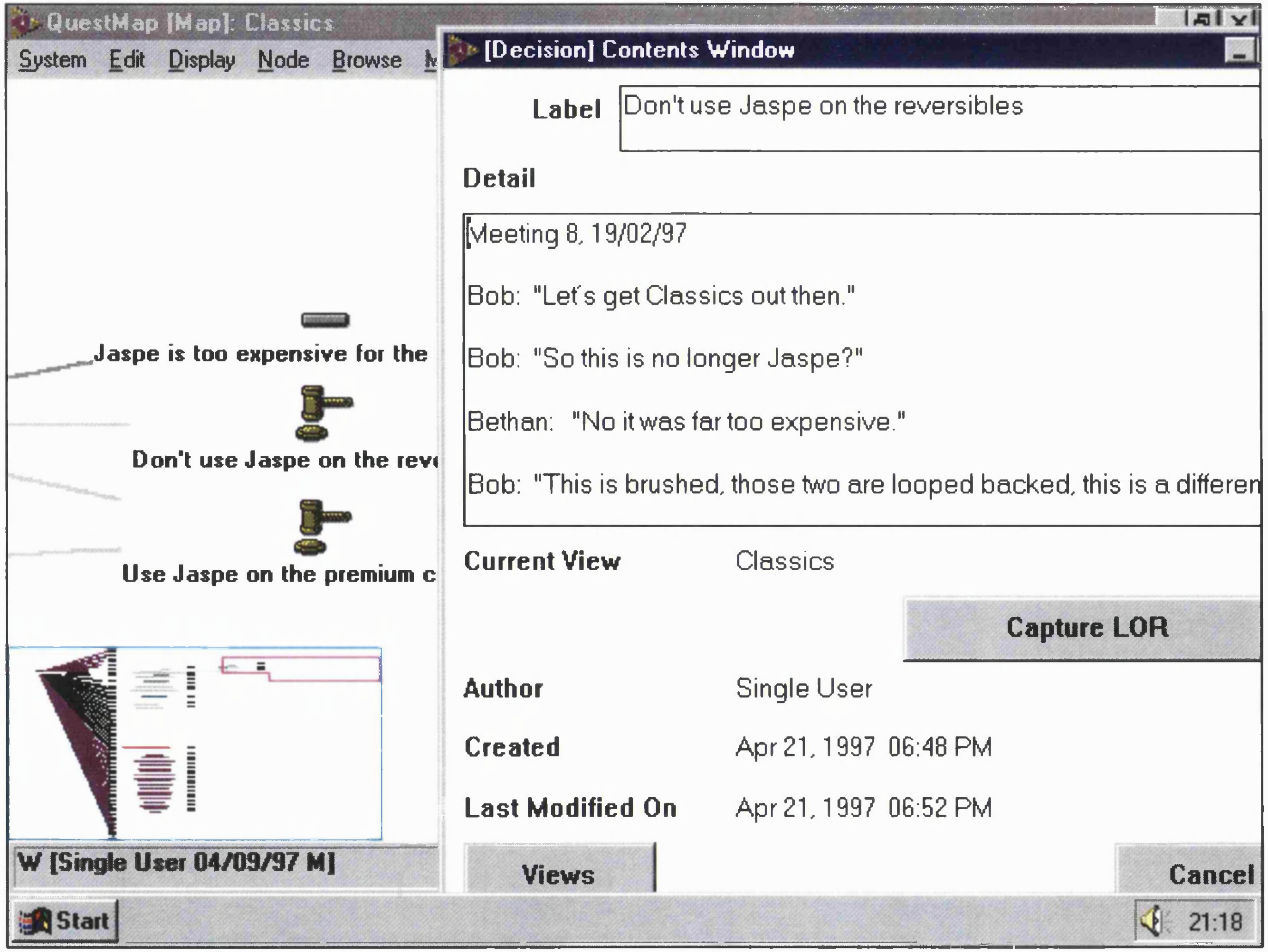

System Edit Display Node Browse Mail Help
Top with print on back shoulder
Drop back print top
Print T-shirt with a little 'V'
Drop little 'V' T-shirt
Calf length pant
Drop calf length pant
'V' neck with underlying false round neck
Drop 'V' neck with underlying false
Top with placket opening to front chest
Drop placket front top
hirt with back print
Drop long sleeve T with back p
nce as opposed to skate
It's very Summery
W [Single User 04/09/97 M]
Start
21:12

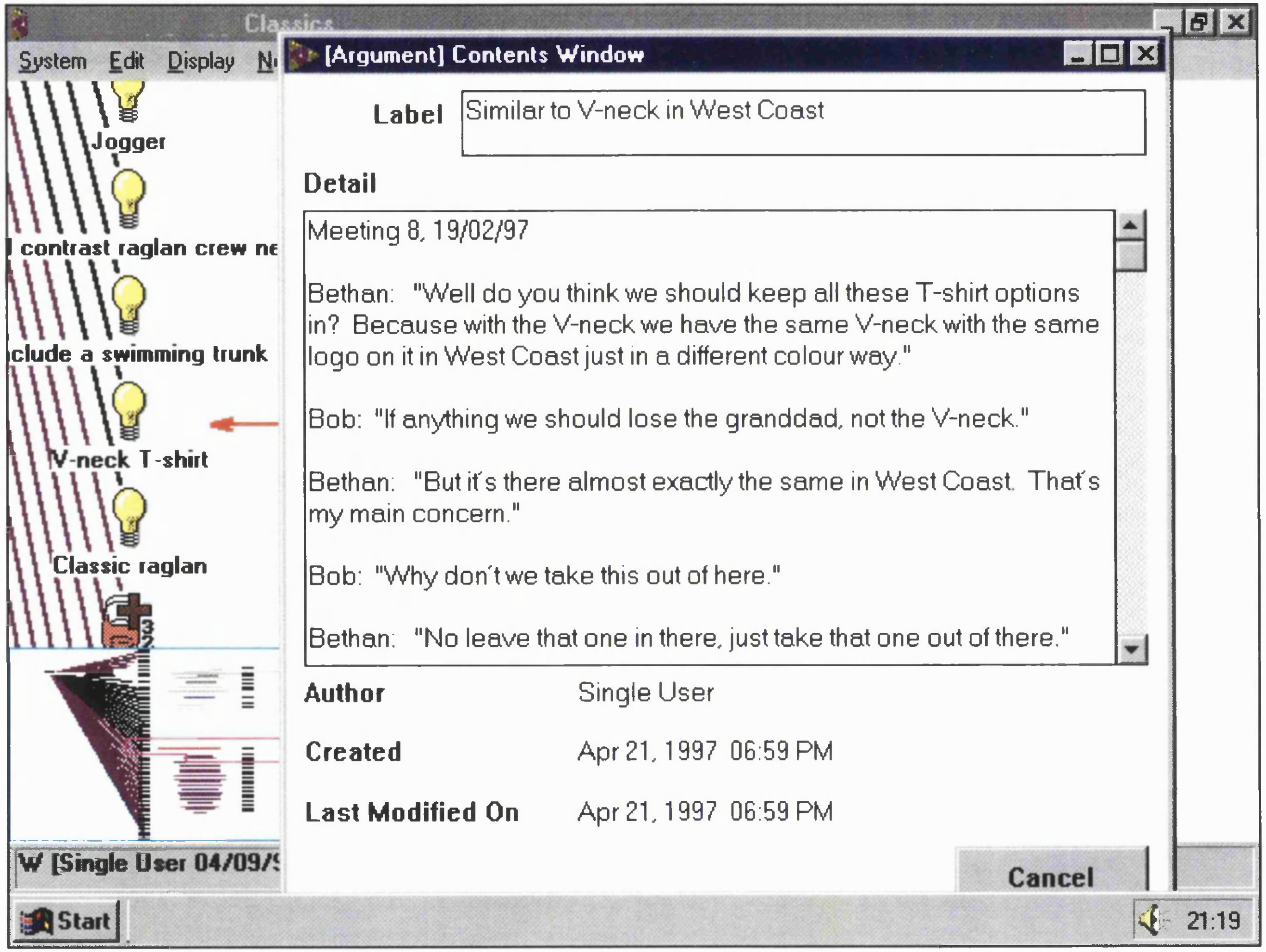

System Edit Display Node Browse Mail Help
esign direction = Summer in the city/Technical Sports
Technical sports but retain the baske
Use monochrome clean graphics
Stick to core logo colours
Co-ordinate with corresponding shoe range
Change the name of East Coast to
Combined T-shirt & vest
Drop combined T-shirt & Ve
Colour is off strategy
Include a Harlem T-shirt
Drop Harlem T-shirt
d top
Drop short sleeved hooded
W [Single User 04/09/97 M]
Start
21:15

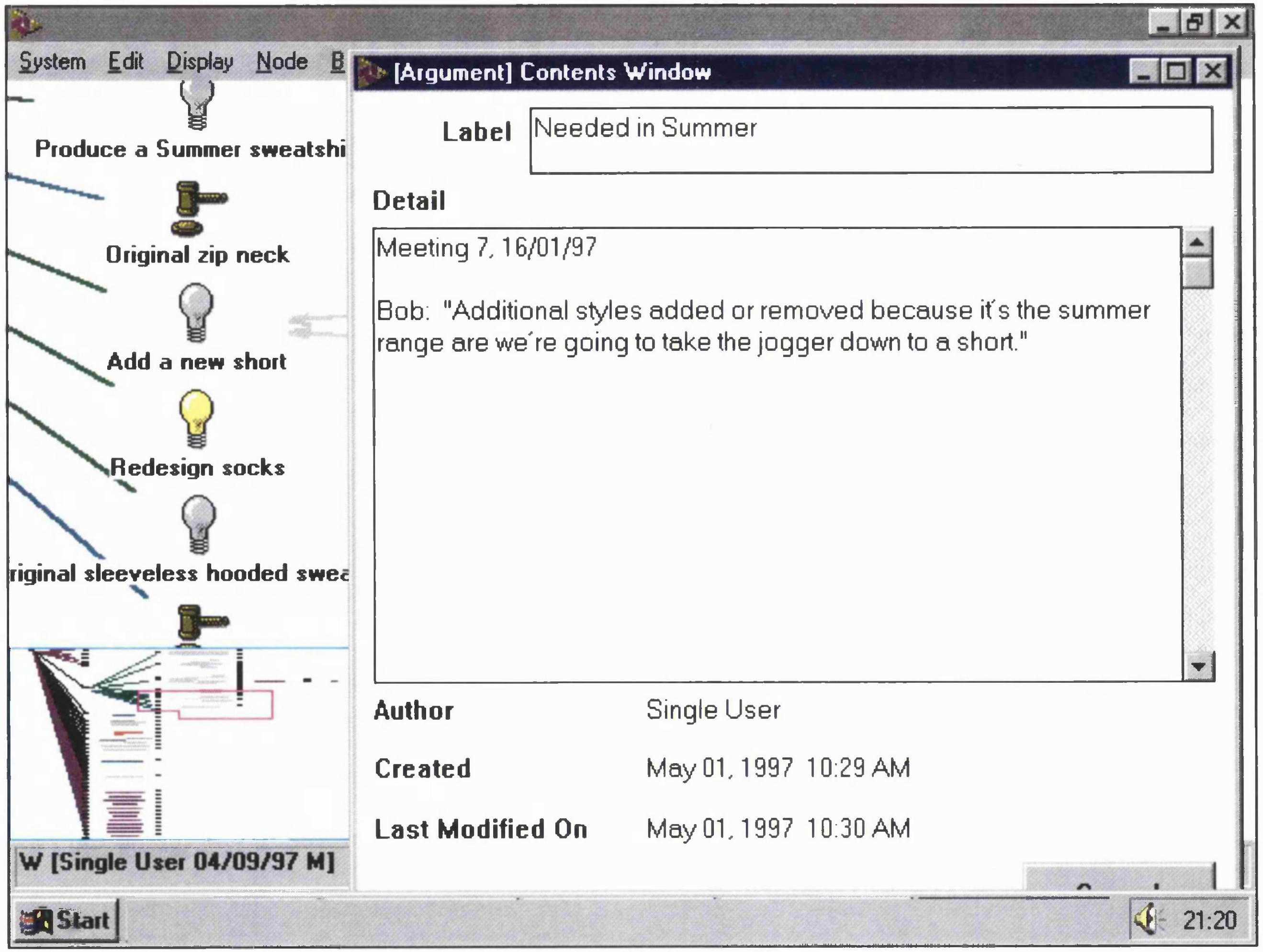

System Edit Display Node Browse Mail Help
Develop designs for East & West Coast
Investigate innovative logo applications
Deres's Role
Develop a colour palette
Be guided by Simon's design direction for East & West Coast
Develop an authentic American size spec
Defer developing size spec
erent fabrics & logo applications for Classics
Work to target price points
W [Single User 04/09/97 M]
Start
21:16

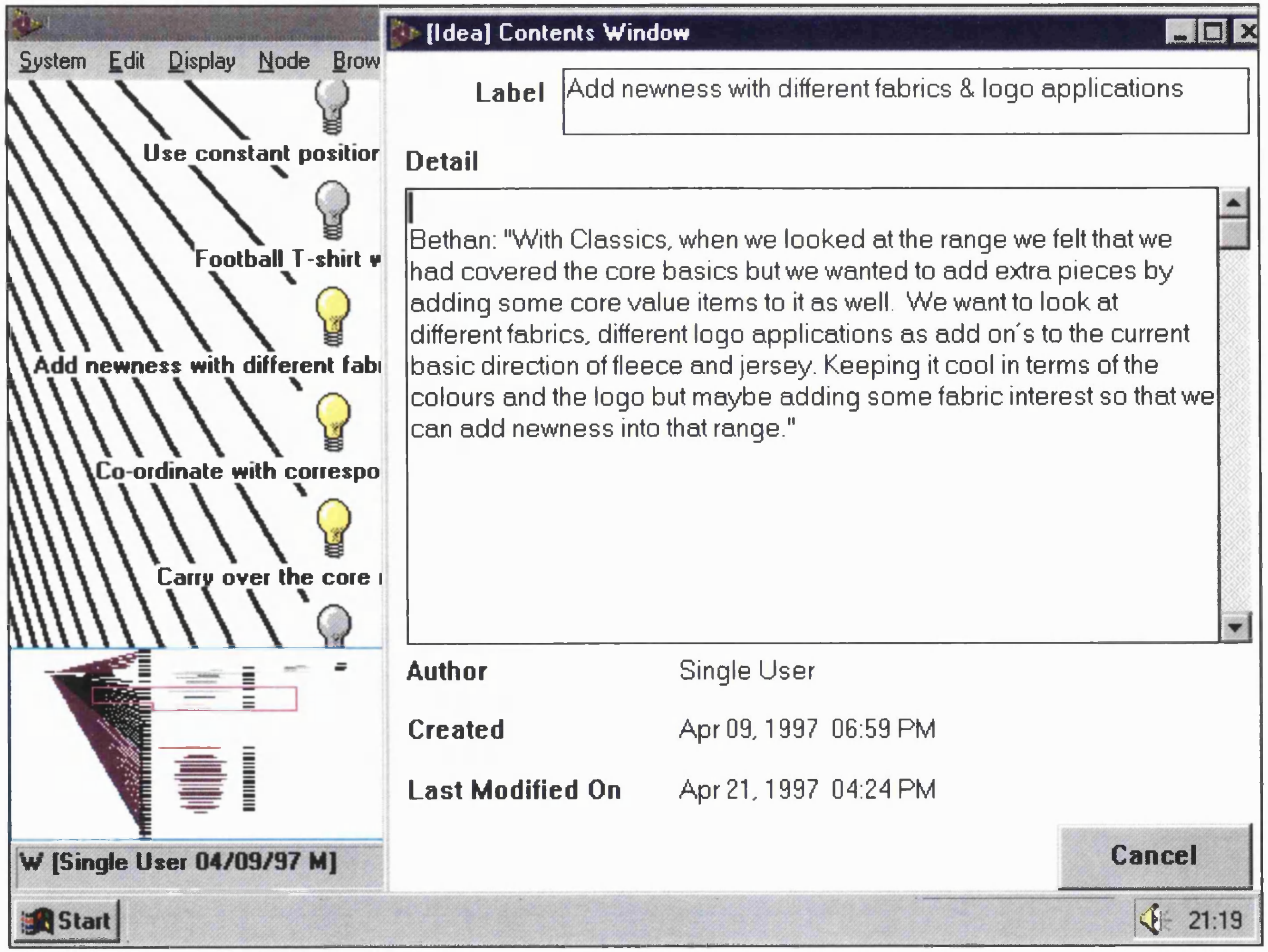

System
Edit
Display
Node
Browse
Mail
Help
Go through last years range
Look for styles on Classics
Comments on Classics & Auth
Tier Classics
Comments on East Coas
Simon Foxton's Role
Expand on West & East Coast
Comments on West Coas
Develop T-shirts and shorts range
Comments on Graphic T-Sh
Develop an accessory concept
Comments on Accessorie
Consider the colour palette
W [Single User 04/09/97 N] Simon: "I wouldn't mind with West Coast this time getting into graphics as we . . .
Start
21:15

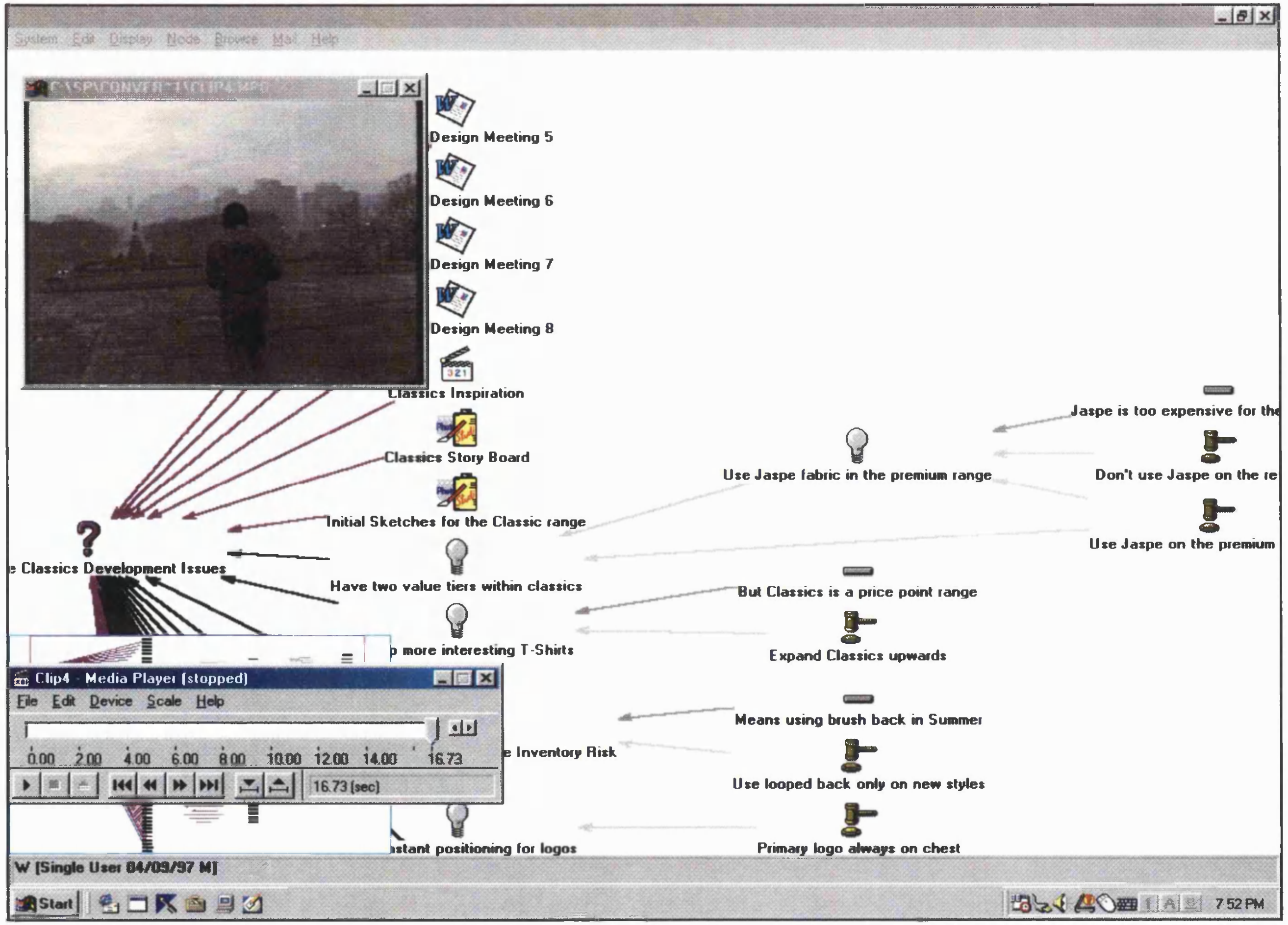

System Edit Display Node
[Question] Contents Window
Label
What are the external sources of design
Detail
Bob: "As far as I can see we've got three external sources of design or input, one is Simon Foxton (Fashion Stylist. Simon, last time, just bought the basis of the ranges that he thought would be right, we briefed him on what the East Coast concept was, what the West Coast concept was, what Classics was and what Authentics was. He went and bought what he thought was the range and then we backed up Simon's research with Jim Fox (Authentic American Clothing Expert), when I saw the article in ID magazine mentioning him. I saw it in ID and it had just a Hanes sweatshirt in it and it said 'Jim Fox - gets all his sweatshirts from the US and imports them'. The picture had his number with it so I rang him up and got him in and he was the guy that told us about the V's going here, he talked about what sort of fabrics they should be made in and who would wear this sort of thing, why this had panel detail here.That was also then backed up with something
Author
Single User
Created
Apr 09, 1997 06:58 PM
Last Modified On
May 05, 1997 10:18 AM
Cancel
Design
What are the external
W [Single User 01/14/97 M
Start
21:17


QuestMap [Map]: Classics
System Edit Display Node Browse
[Decision] Contents Window
Label
Don't use Jaspe on the reversibles
Detail
Meeting 8, 19/02/97
Bob: "Let's get Classics out then."
Bob: "So this is no longer Jaspe?"
Bethan: "No it was far too expensive."
Bob: "This is brushed, those two are looped backed, this is a differen
Current View
Classics
Capture LOR
Author
Single User
Created
Apr 21, 1997 06:48 PM
Last Modified On
Apr 21, 1997 06:52 PM
Views
Cancel
Jaspe is too expensive for the
Don't use Jaspe on the reve
Use Jaspe on the premium c
W [Single User 04/09/97 M]
Start
21:18

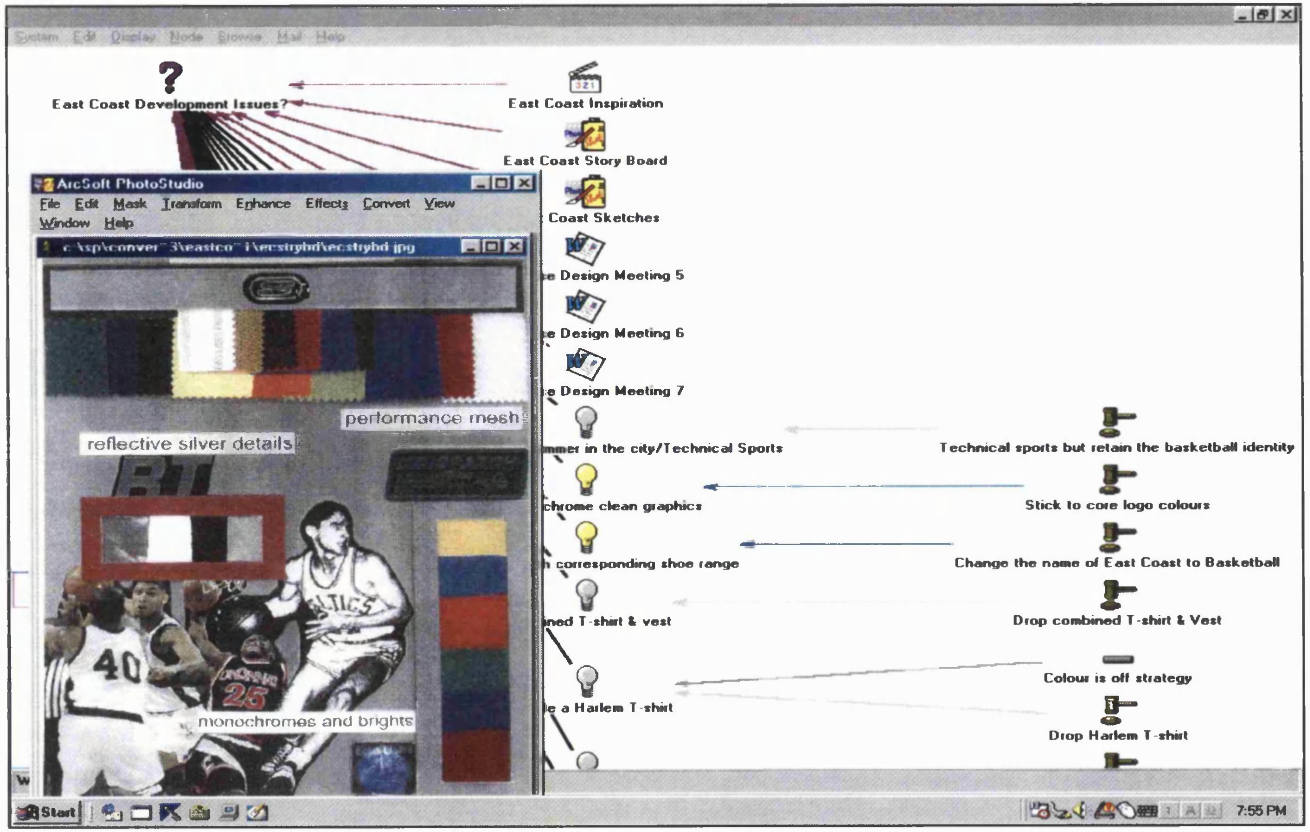

Classics
System Edit Display N
[Argument] Contents Window
Jogger
contrast raglan crew ne
clude a swimming trunk
V-neck T-shirt
Classic raglan
Label
Similar to V-neck in West Coast
Detail
Meeting 8, 19/02/97
Bethan: "Well do you think we should keep all these T-shirt options in? Because with the V-neck we have the same V-neck with the same logo on it in West Coast just in a different colour way."
Bob: "If anything we should lose the granddad, not the V-neck."
Bethan: "But it's there almost exactly the same in West Coast. That's my main concern."
Bob: "Why don't we take this out of here."
Bethan: "No leave that one in there, just take that one out of there."
Author
Single User
Created
Apr 21, 1997 06:59 PM
Last Modified On
Apr 21, 1997 06:59 PM
Cancel
W [Single User 04/09/
Start
21:19


System Edit Display Node B
[Argument] Contents Window
Produce a Summer sweatshi
Original zip neck
Add a new short
Redesign socks
riginal sleeveless hooded swea
Label
Needed in Summer
Detail
Meeting 7, 16/01/97
Bob: "Additional styles added or removed because it's the summer range are we're going to take the jogger down to a short."
Author
Single User
Created
May 01, 1997 10:29 AM
Last Modified On
May 01, 1997 10:30 AM
W [Single User 04/09/97 M]
Start
21:20


System Edit Display Node Brow
Use constant positior
Football T-shirt w
Add newness with different fabi
Co-ordinate with correspo
Carry over the core
W [Single User 04/09/97 M]
[Idea] Contents Window
Label
Add newness with different fabrics & logo applications
Detail
Bethan: "With Classics, when we looked at the range we felt that we had covered the core basics but we wanted to add extra pieces by adding some core value items to it as well. We want to look at different fabrics, different logo applications as add on's to the current basic direction of fleece and jersey. Keeping it cool in terms of the colours and the logo but maybe adding some fabric interest so that we can add newness into that range."
Author
Single User
Created
Apr 09, 1997 06:59 PM
Last Modified On
Apr 21, 1997 04:24 PM
Cancel
Start
21:19



Design Meeting 5
Design Meeting 6
Design Meeting 7
Design Meeting 8
Classics Inspiration
Classics Story Board
Initial Sketches for the Classic range
Classics Development Issues
Have two value tiers within classics
more interesting T-Shirts
Inventory Risk
stant positioning for logos
Use Jaspe fabric in the premium range
But Classics is a price point range
Expand Classics upwards
Means using brush back in Summer
Use looped back only on new styles
Primary logo always on chest
Jaspe is too expensive for the
Don't use Jaspe on the re
Use Jaspe on the premium
Clip4 - Media Player (stopped)
File Edit Device Scale Help
0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.73
16.73 (sec)
W [Single User 04/09/97 M]
Start
7:52 PM


East Coast Development Issues?
East Coast Inspiration
East Coast Story Board
Coast Sketches
Design Meeting 5
Design Meeting 6
Design Meeting 7
ArcSoft PhotoStudio
performance mesh
reflective silver details
monochromes and brights
Technical sports but retain the basketball identity
Stick to core logo colours
Change the name of East Coast to Basketball
Drop combined T-shirt & Vest
Colour is off strategy
Drop Harlem T-shirt
7:55 PM

Appendix G:

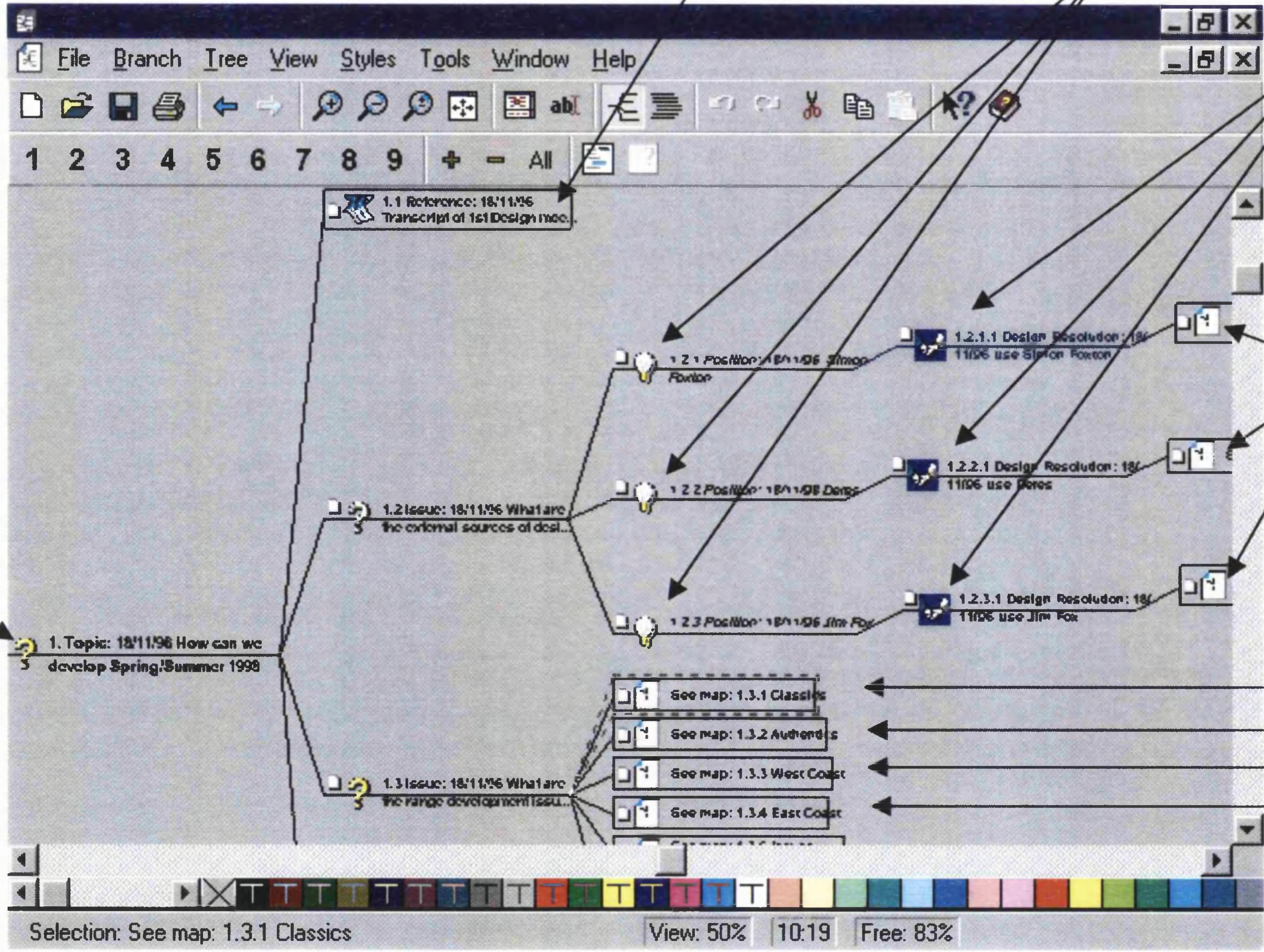
Illustration of Features of the IBIS^{PDR} Knowledge Maps

This is a section from the first map in the knowledge structure.

This is a hyperlink to a reference file – a Word document containing a transcript of the first design meeting which contains information pertinent to this map.

These positions demonstrate the ideas put forward as sources of external design.

These design decisions demonstrate the chosen sources of external design input.

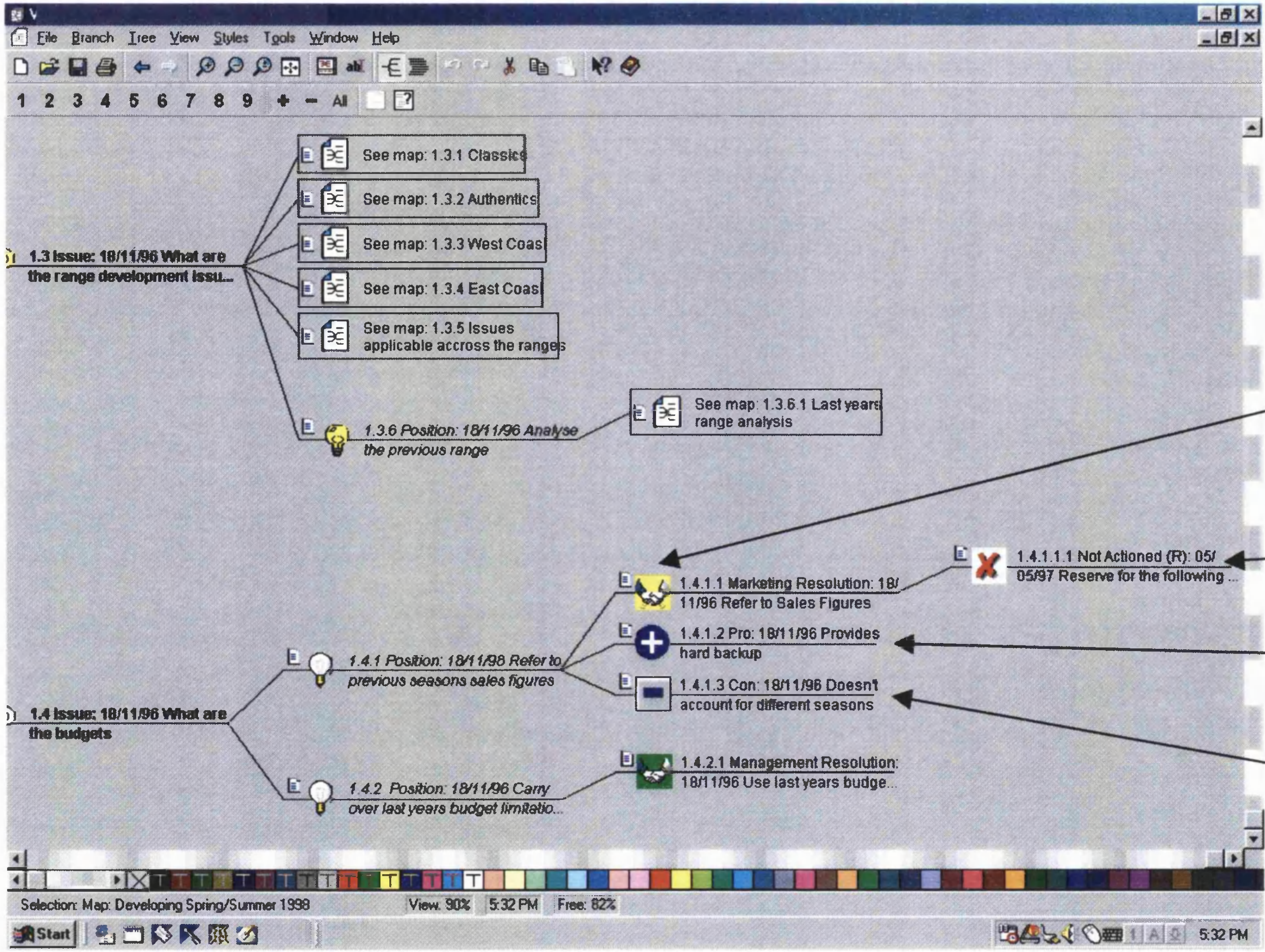


These are hyperlinks to the maps which focus on the input of the individual external sources of design input.

This is the root topic demonstrating the focus of the entire knowledge structure.

These are hyper links to the maps which focus on the development of the individual ranges.

This is a section from the first map in the knowledge structure.



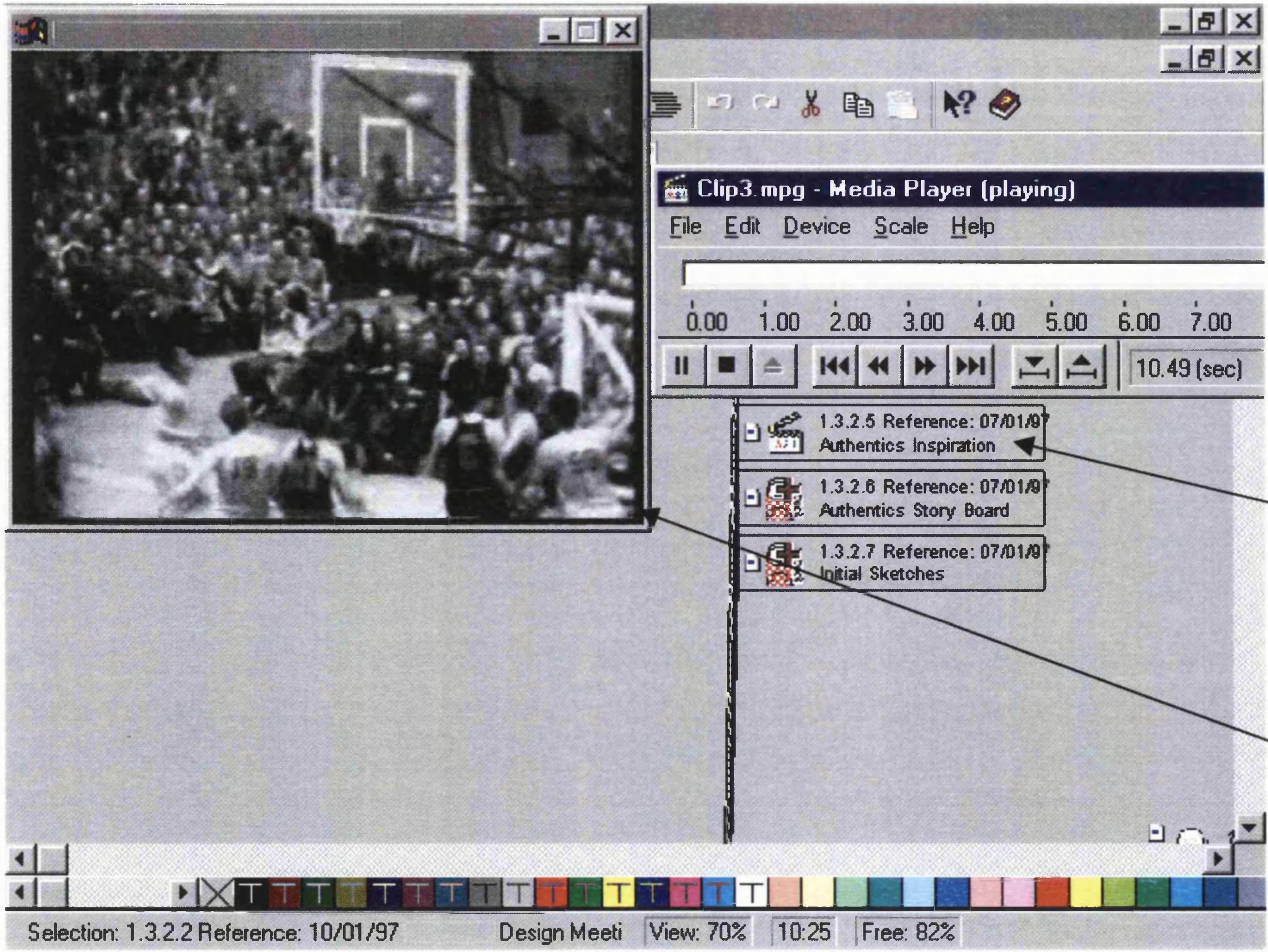
This is a marketing resolution to refer to previous sales figures.

This is a 'Not Actioned' node added retrospectively to demonstrate the resolution was not actioned.

This is an argument supporting the position.

This is an argument against the position.

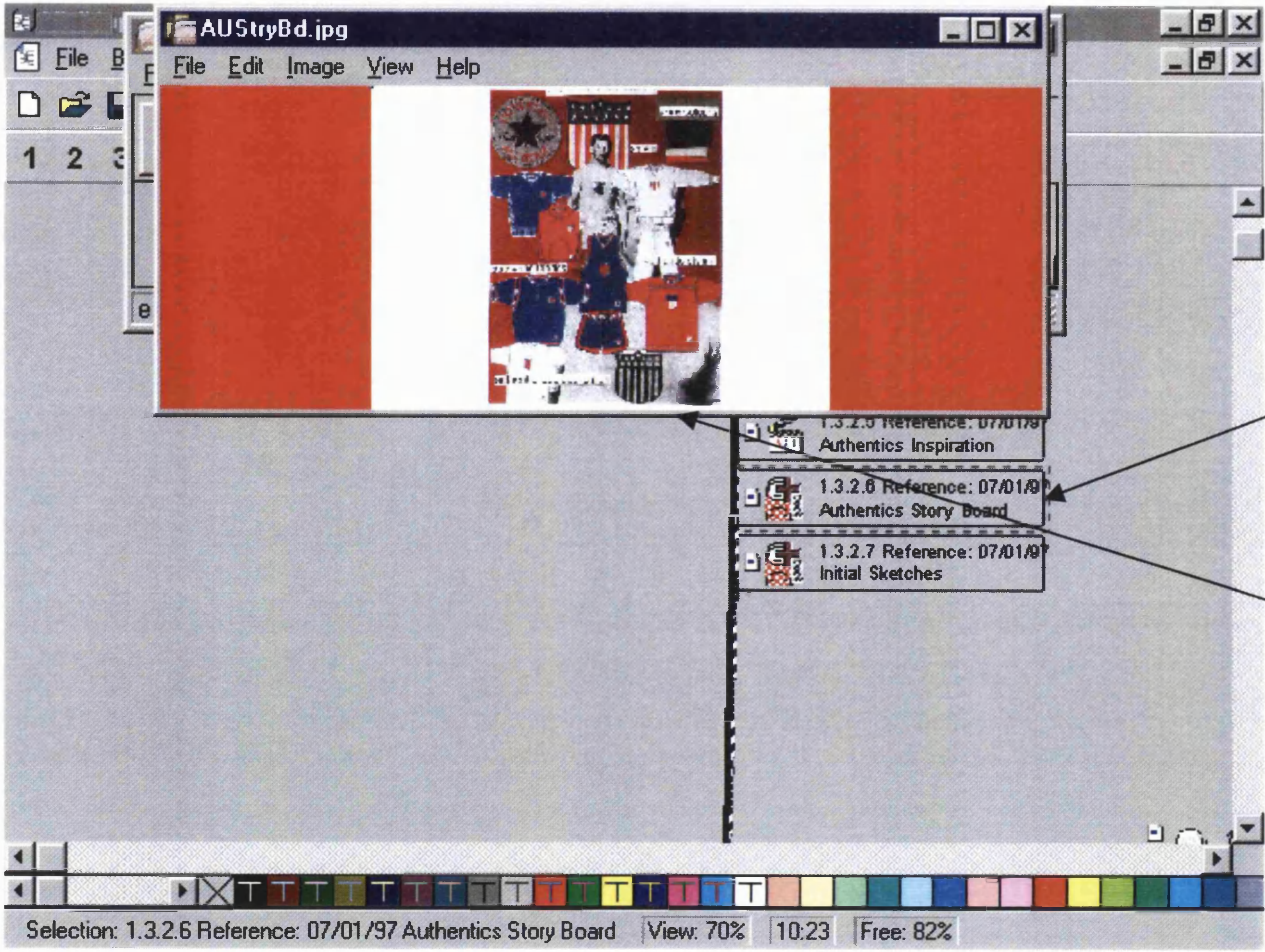
This is a section from
the map focusing on
the Authentics range



This node is a hyperlink to the Authentics inspiration video.

This demonstrates a still from the launched Authentics inspiration video.

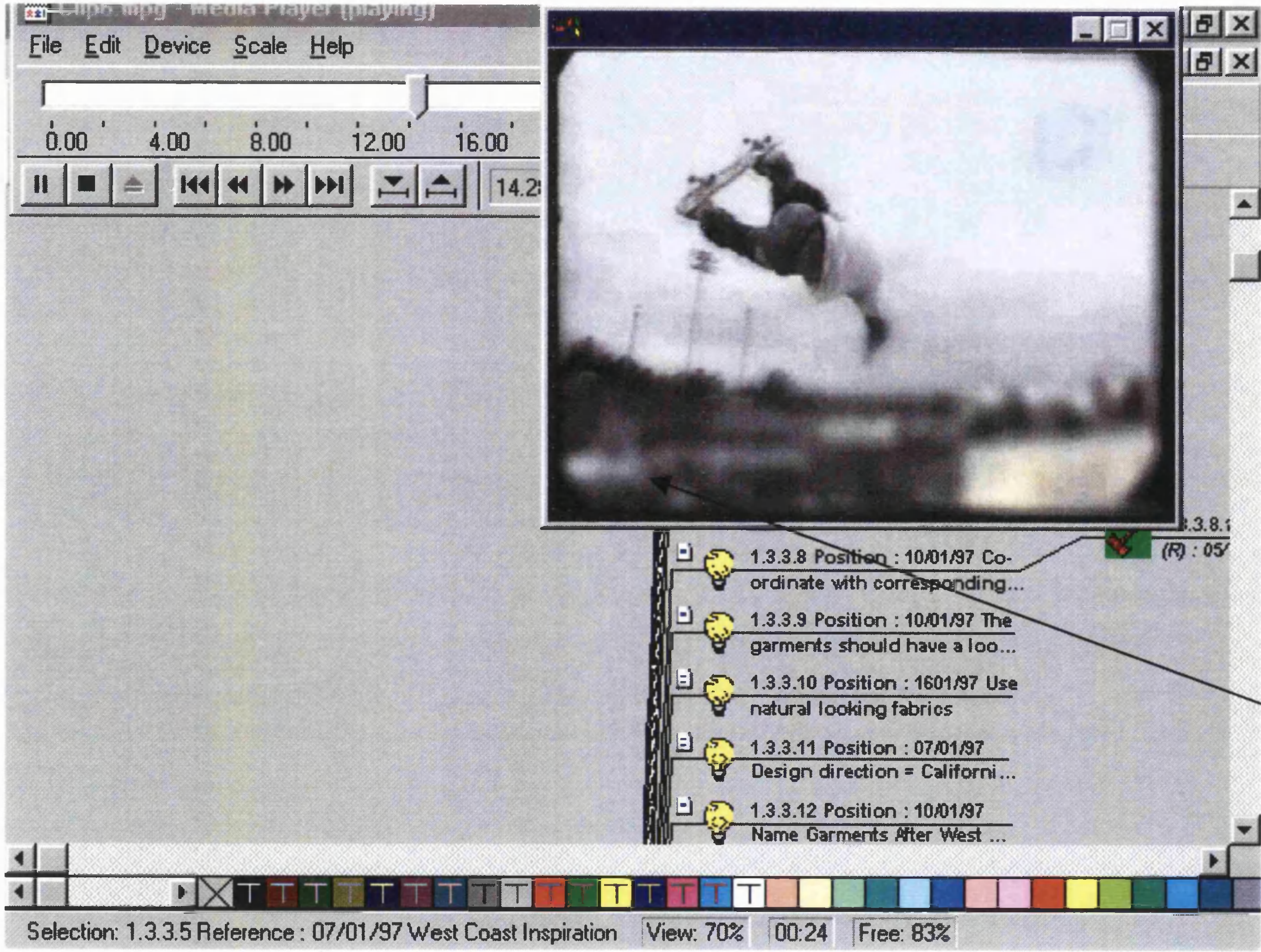
This is a section from the map focusing on the Authentics range.



This node is a hyperlink to the Authentics storyboard.

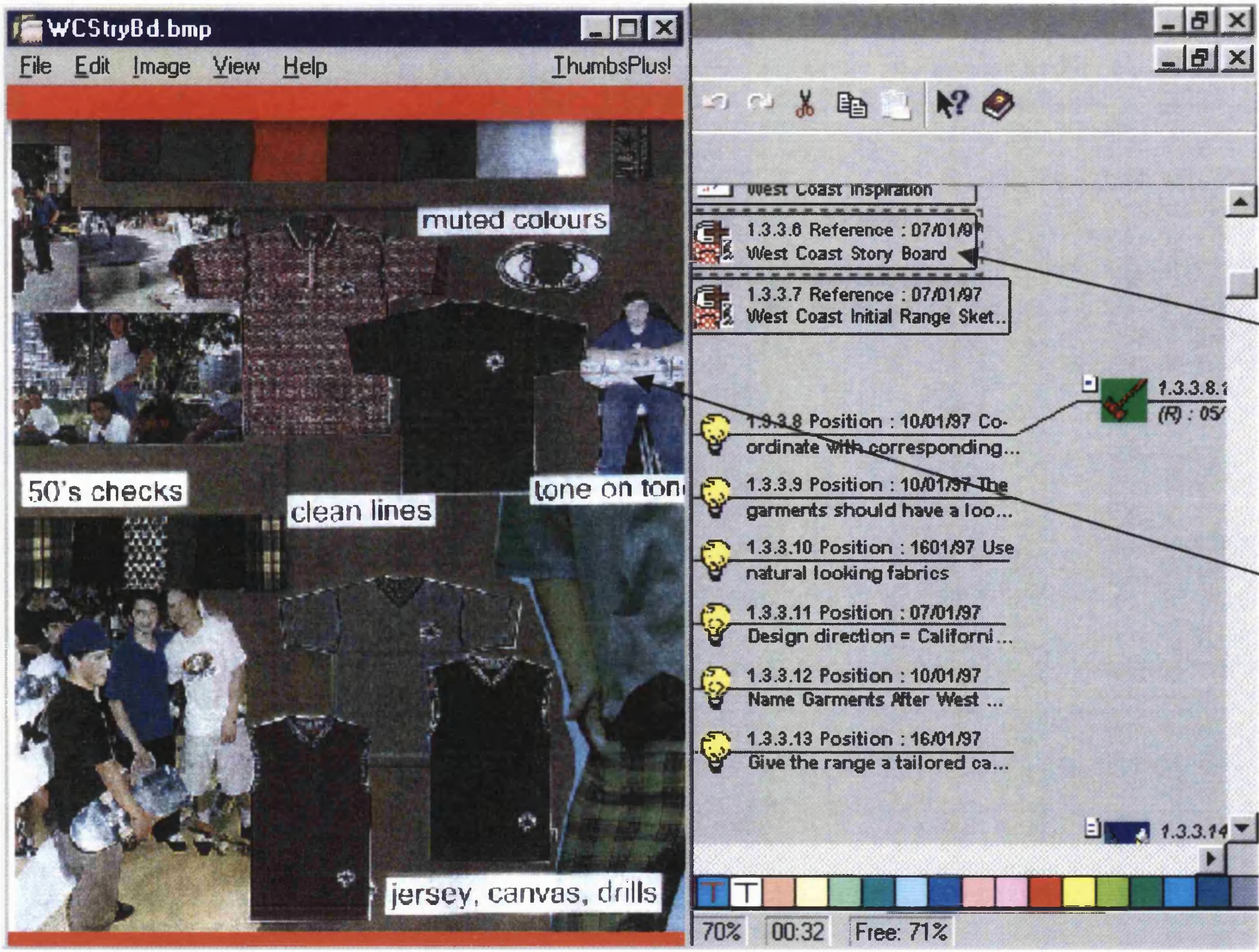
This demonstrates the launched graphic of the Authentics storyboard.

This is a section from
the map focusing on
the West Coast range



This demonstrates a still from the launched West Coast inspiration video.

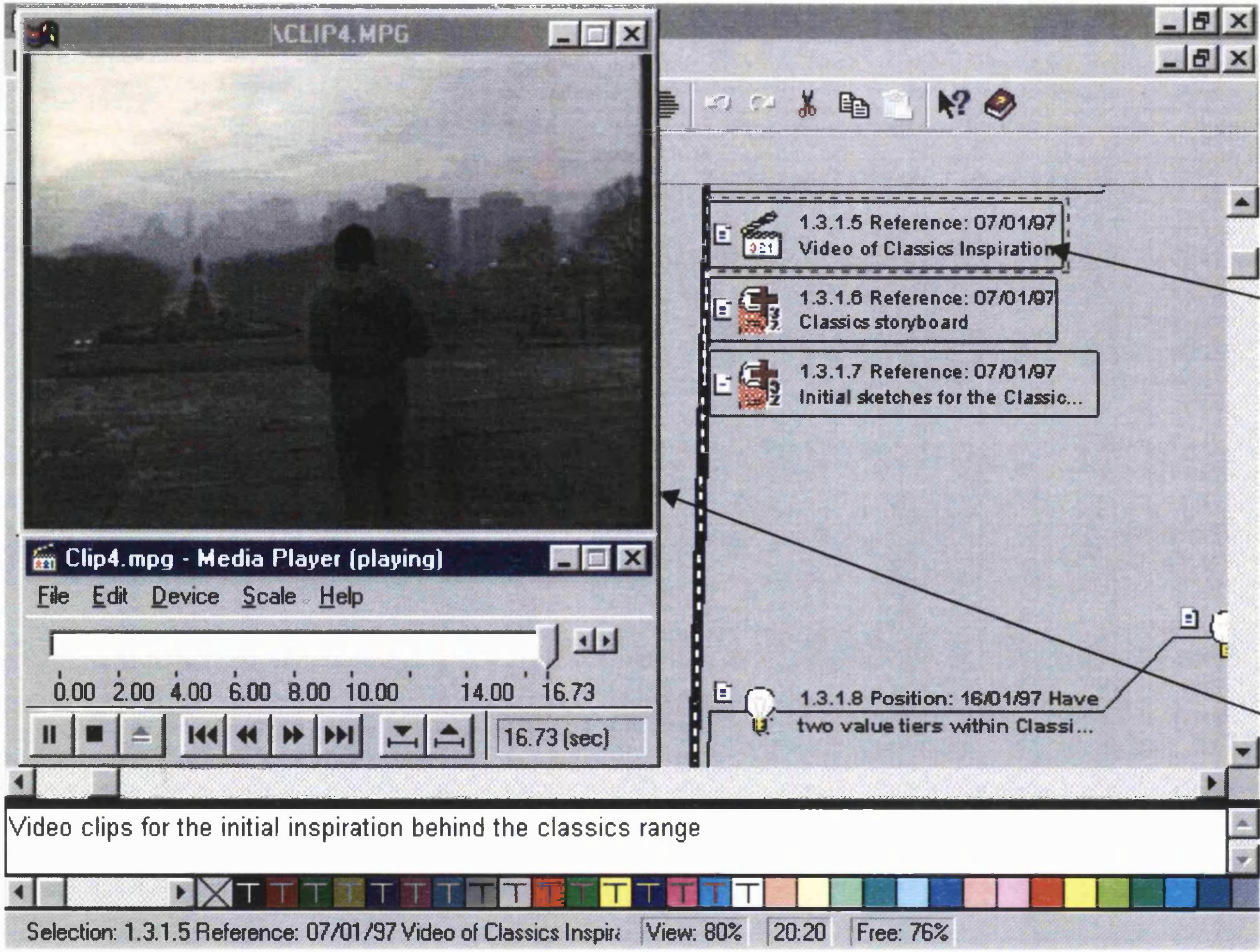
the West Coast range



This node is a hyperlink to the West Coast storyboard.

This demonstrates the launched graphic of the West Coast storyboard.

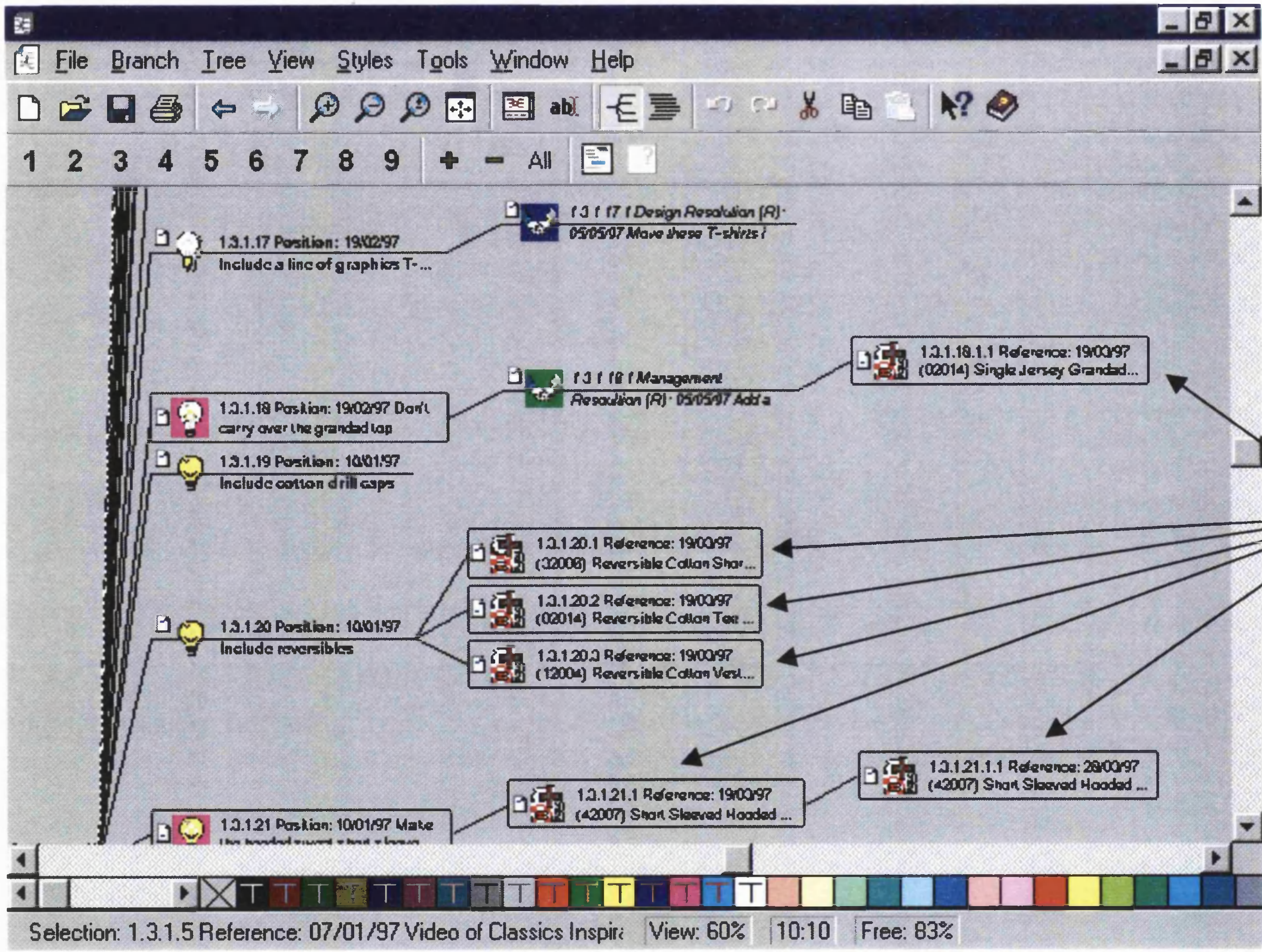
This is a section from the map focusing on the Classics range



This node is a hyperlink to the Classics inspiration video.

This demonstrates a still from the launched Classics inspiration video.

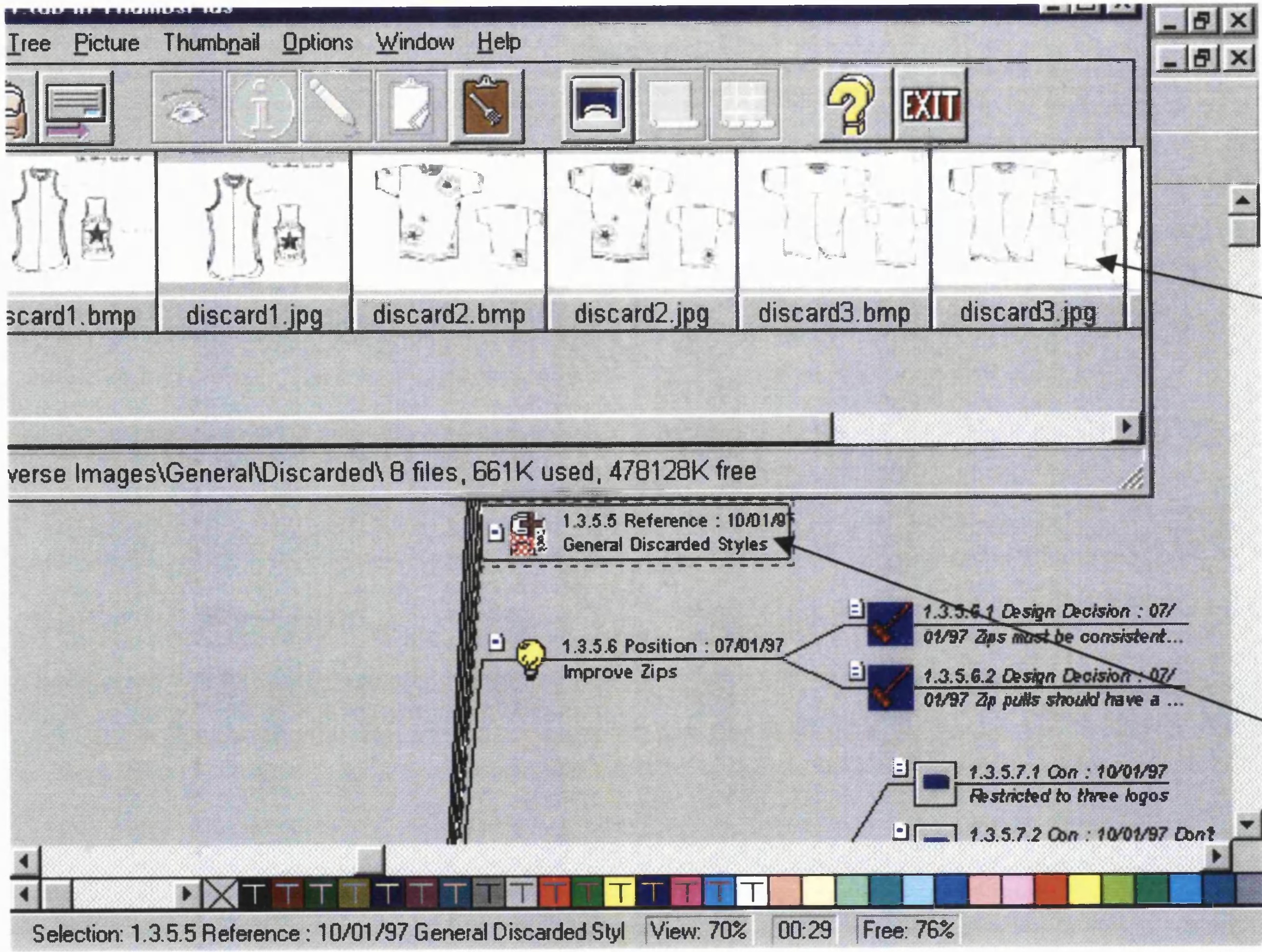
This is a section from
the map focusing on
the Classics range



These thumbnail reference nodes denote hyperlinks to image files of products in the Classics range

This demonstrates a still from the launched Classics inspiration video.

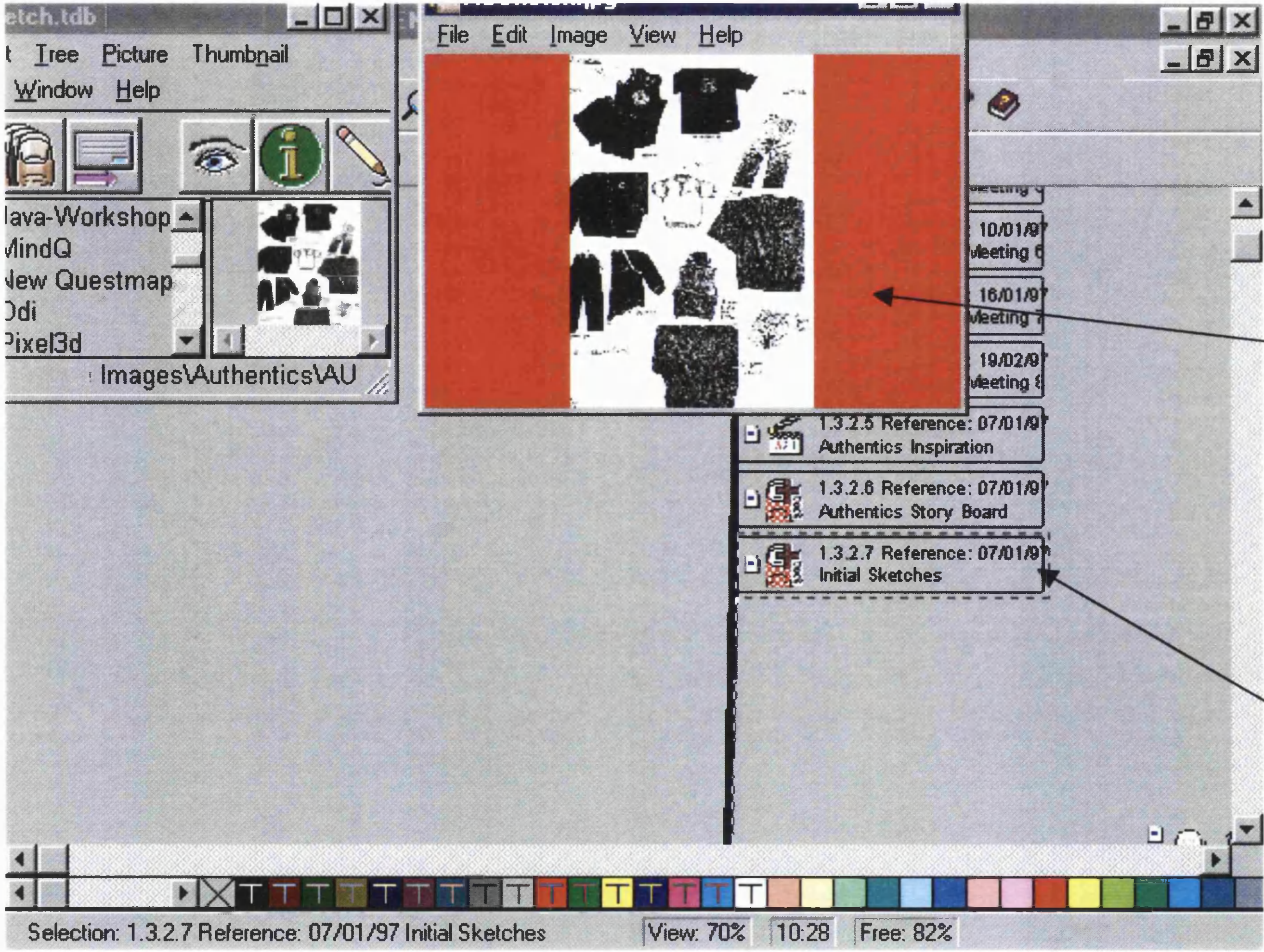
This is a section from the map focusing on general range issues



This demonstrates a launched thumbnail images of general discarded styles.

This node is a hyperlink to thumbnail images of general discarded styles.

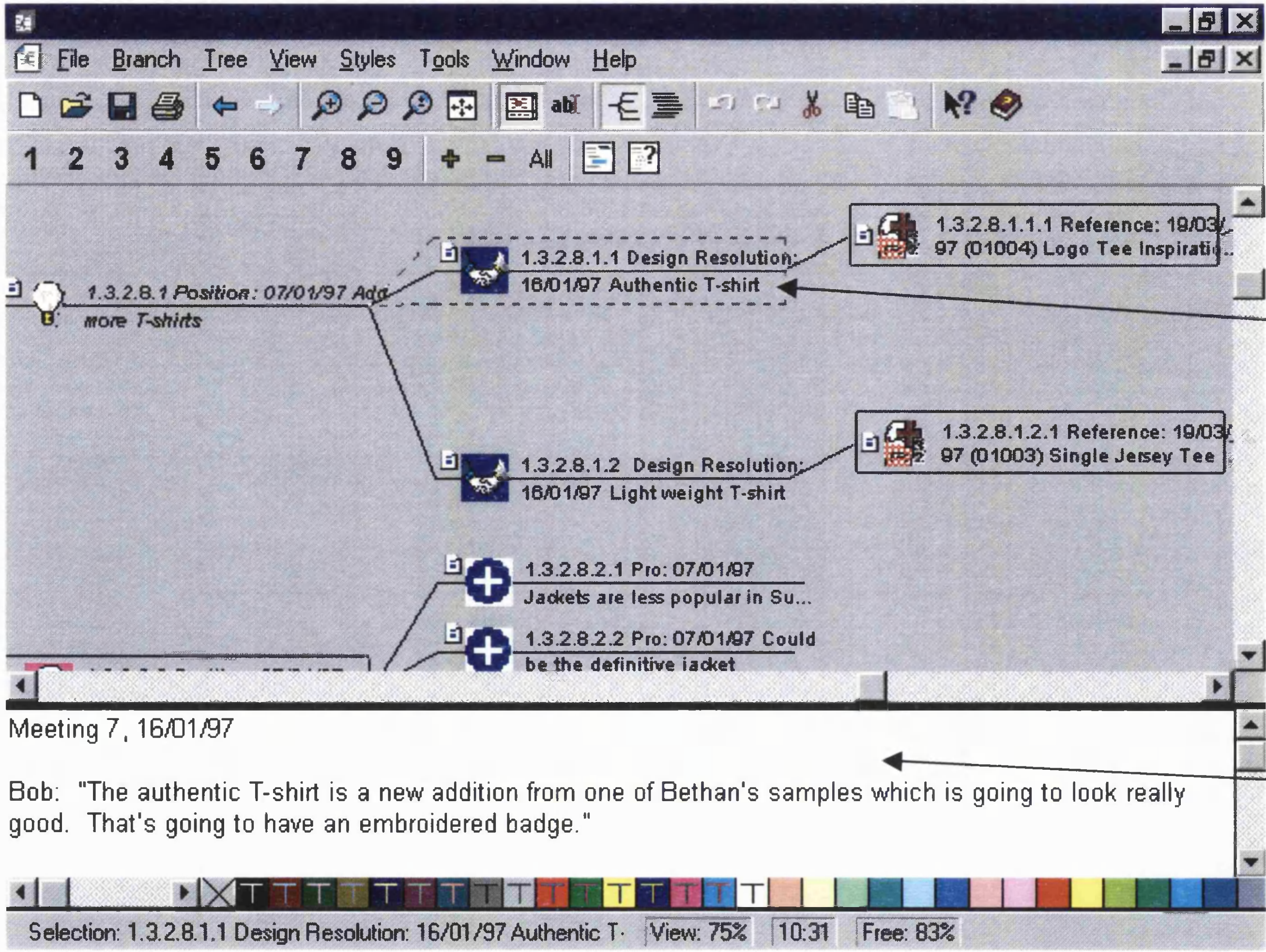
This is a section from the map focusing on the Authentics range issues



This demonstrates a launched image of the initial sketches for the Authentics range.

This node is a hyperlink to an image of the of the initial sketches for the Authentics range.

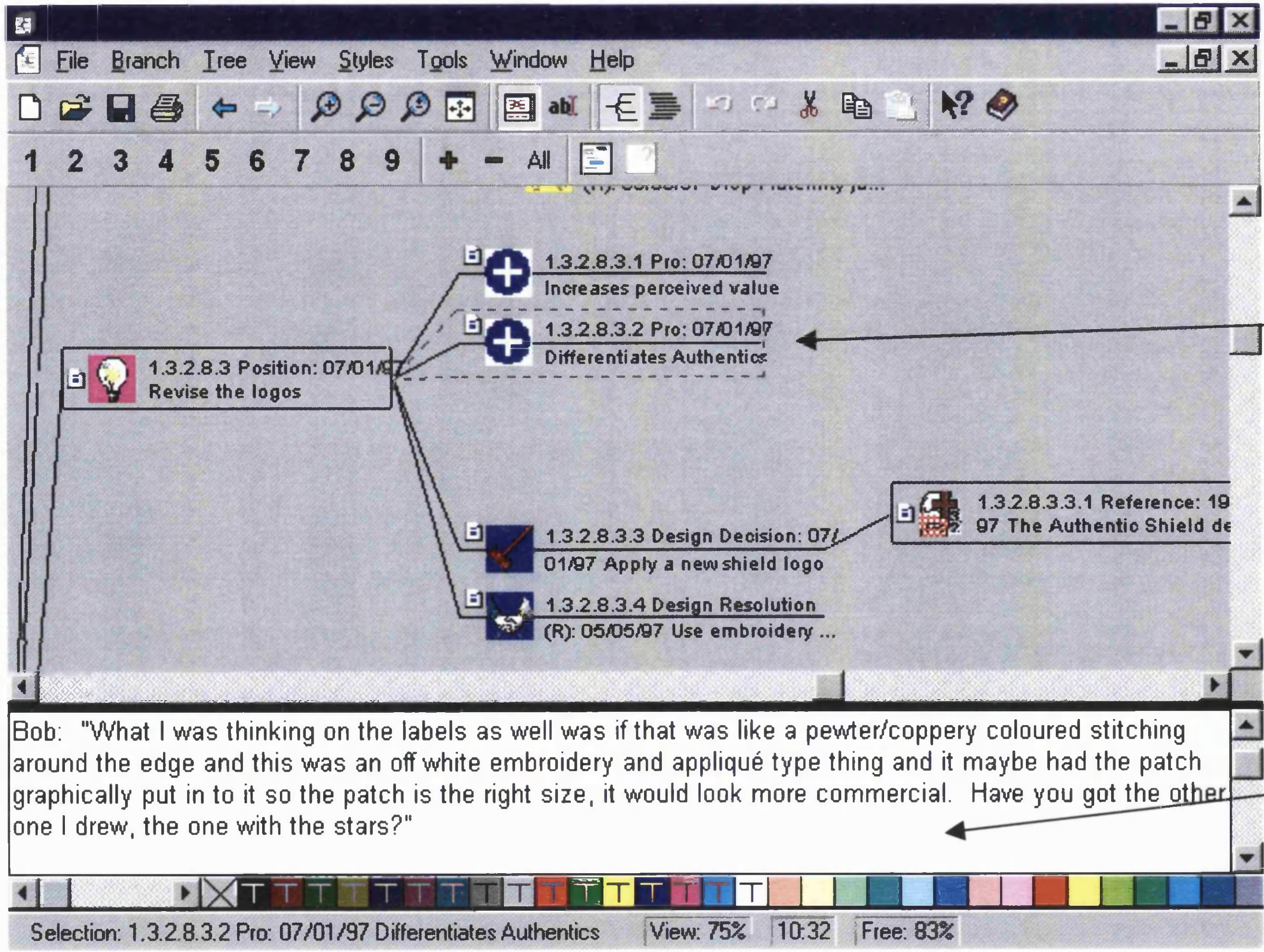
This is a section from the map focusing on the Authentics range issues



This node is a design resolution to add an Authentic T-Shirt

This split screen window elaborates on the textual description in the node referred to above.

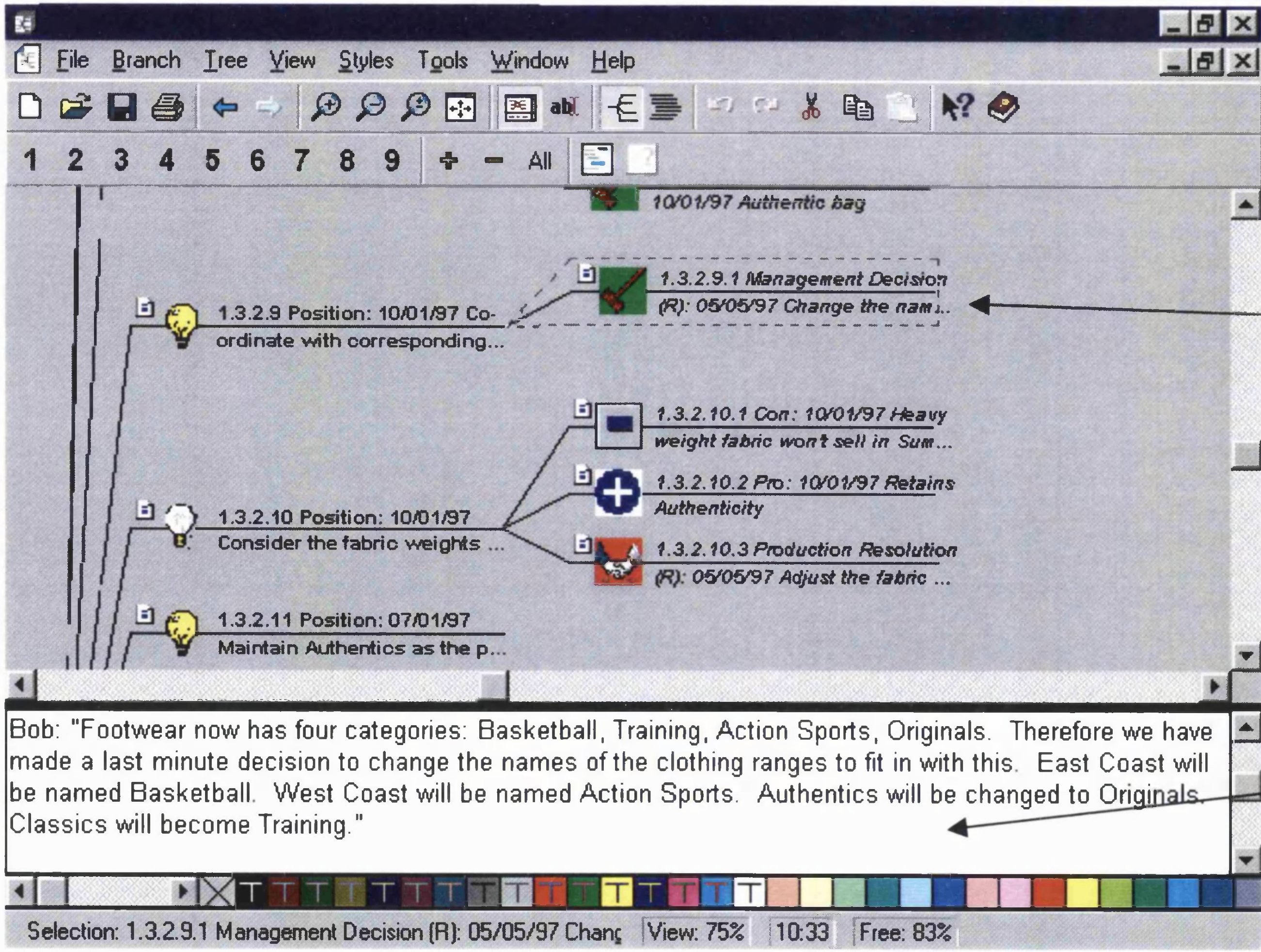
This is a section from the map focusing on the Authentics range issues



This node is an argument for the position it links to – i.e. to revise the logos.

This split screen window elaborates on the textual description in the node referred to above.

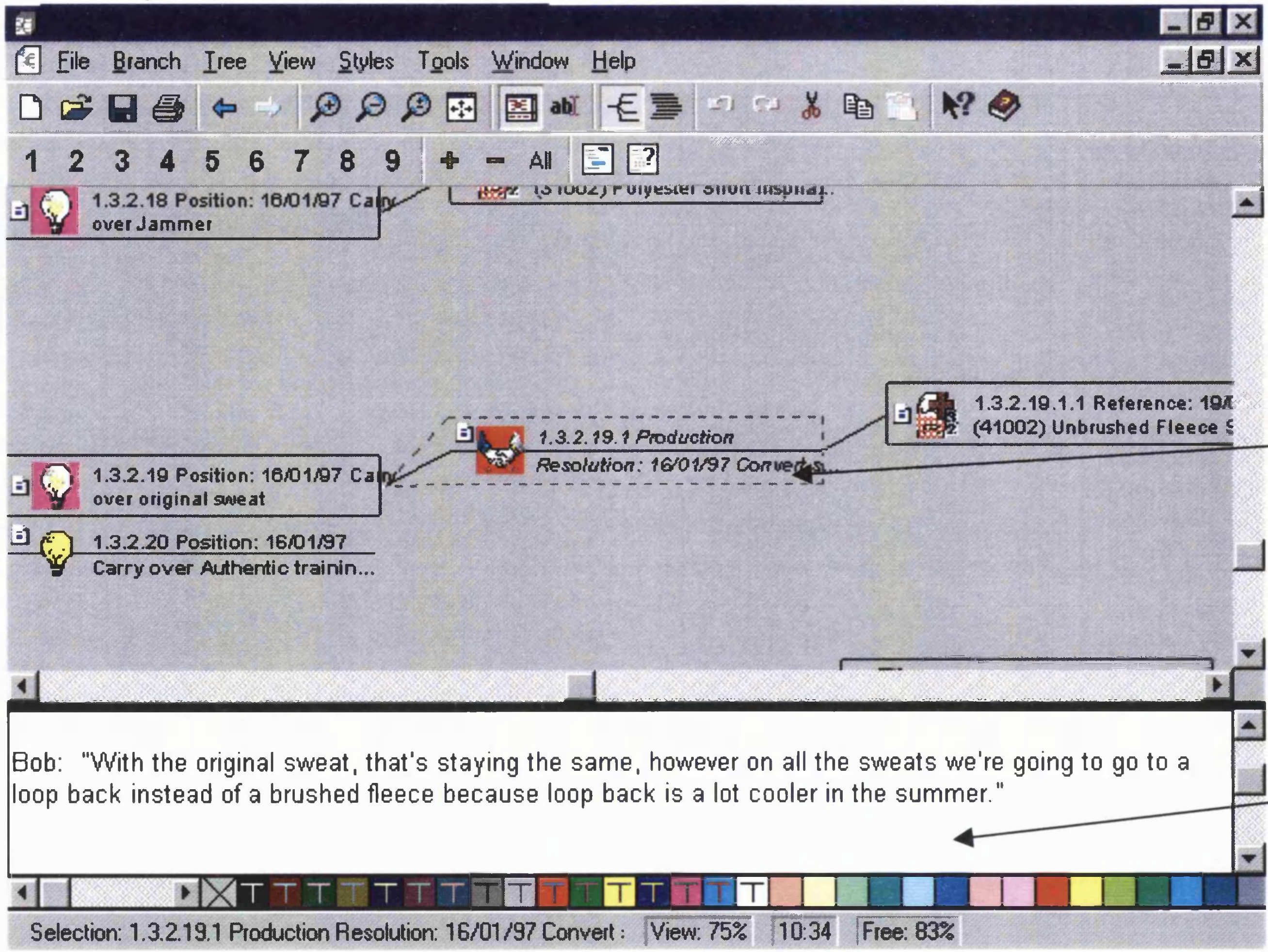
map focusing on the
Authentics range issues



This node is a management decision to alter the names of the clothing ranges.

This split screen window elaborates on the textual description in the node referred to above.

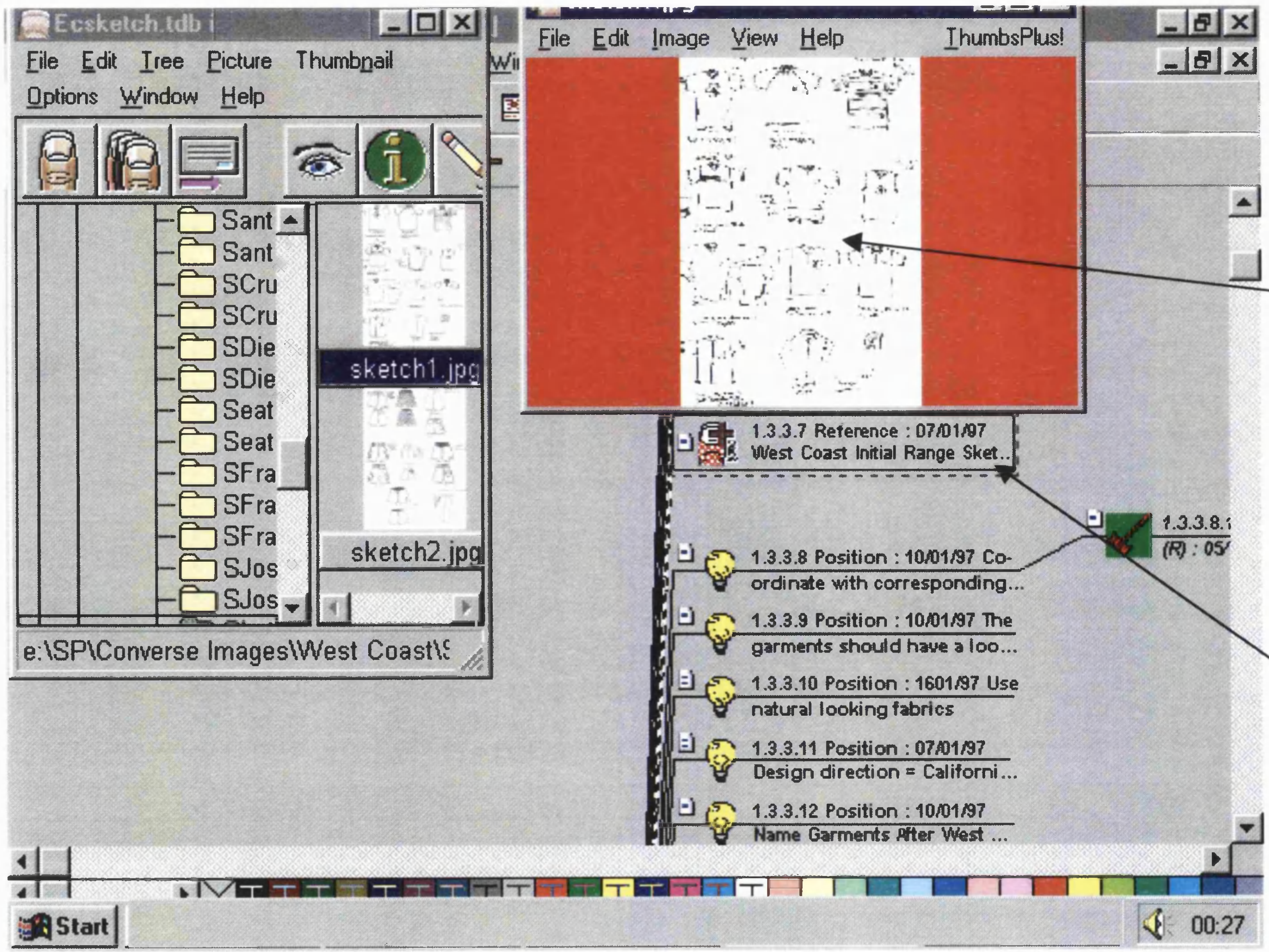
This is a section from the map focusing on the Authentics range issues



This node is a production resolution carry over the sweat shirt style to the next season.

This split screen window elaborates on the textual description in the node referred to above.

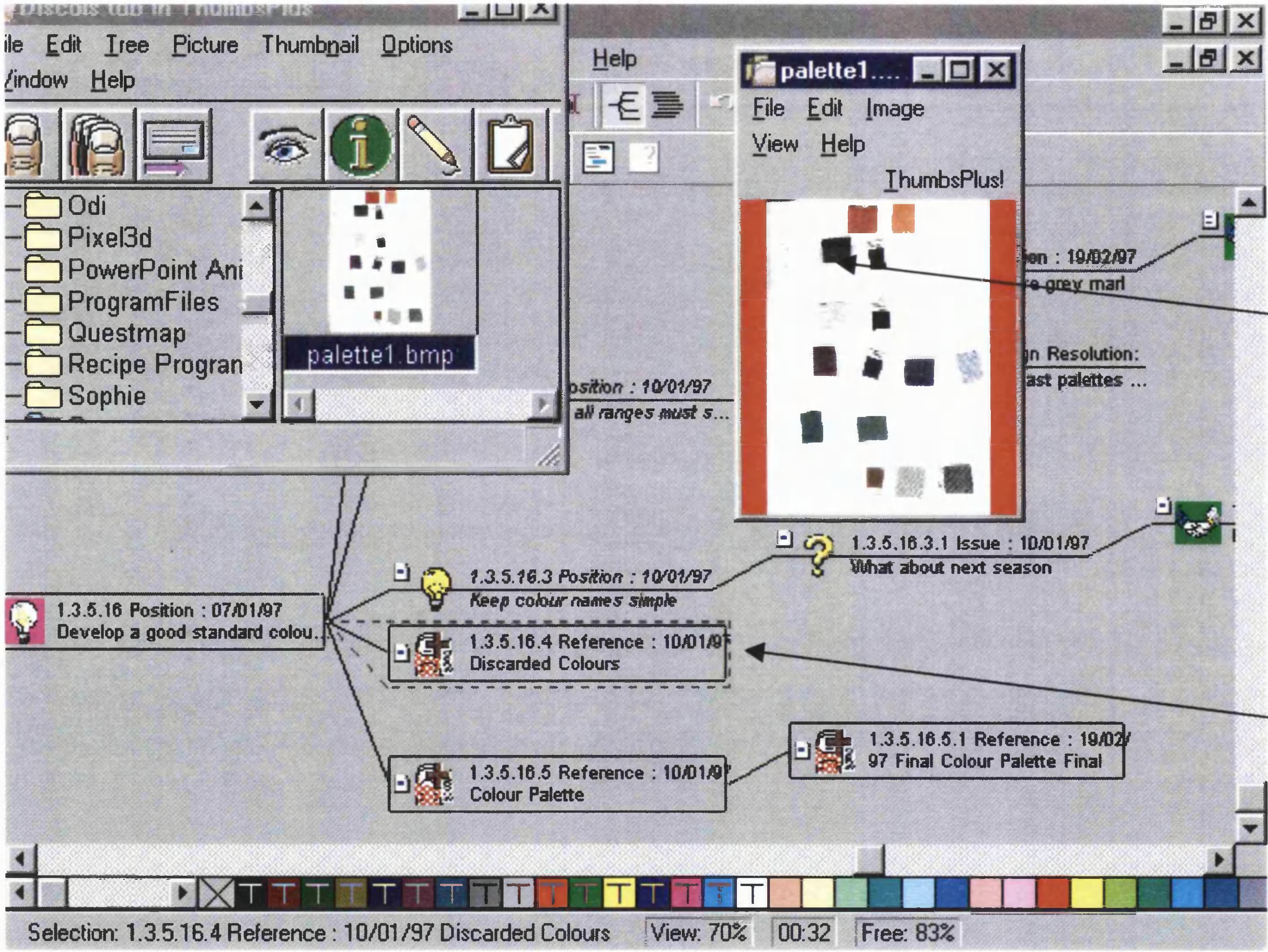
This is a section from the map focusing on the East Coast range issues



This demonstrates a launched image of the initial sketches for the East Coast range.

This node is a hyperlink to an image of the of the initial sketches for the East Coast range.

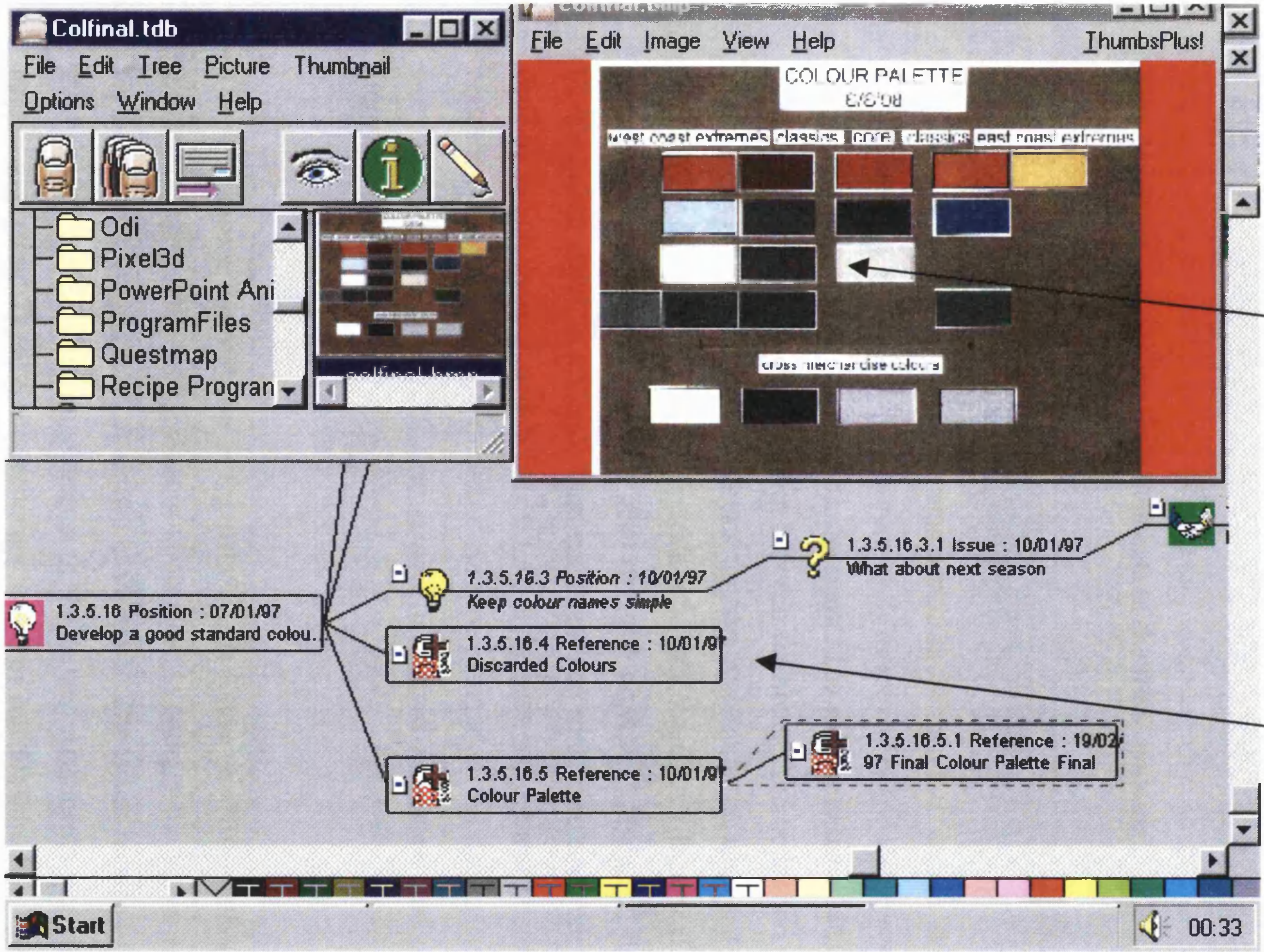
This is a section from the map focusing on the colour palette issues



This demonstrates a launched image of the discarded colours from the initial colour palette.

This node is a hyperlink to an image of the discarded colours from the initial colour palette.

This is a section from the map focusing on the colour palette issues



This demonstrates a launched image of the final colour palette.

This node is a hyperlink to an image of the final colour palette.

APPENDIX H:

IBIS$^+$ Manual

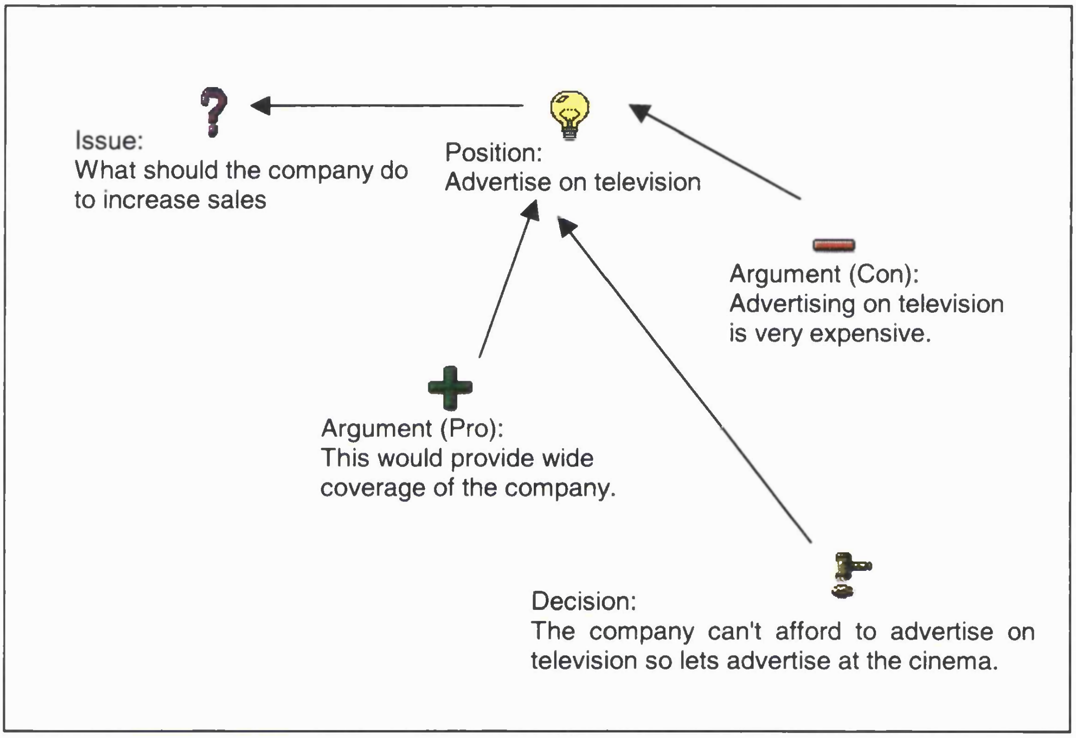
This document outlines the main elements of the IBIS$^+$ notation:

IBIS$^+$ Maps

IBIS$^+$ maps enable a graphical representation of product design dialogue to be constructed. A hypertext type structure of different nodes and link types is utilised to denote the main IBIS$^+$ elements on the maps. The maps consist of IBIS$^+$ nodes and links to demonstrate the relationship between the nodes. The nodes can also be linked to other map views or files of various formats which can be launched directly from the maps by clicking the nodes. A node is a data object in a hypertext database and operates as the junction between links or other objects. A hypertext node may also have content, either in a simple form such as a text or a more complex form, such as code to launch another application. A link is the connecting mechanism between two nodes and can also be used to define the type of relationship that exists between the two nodes. Each individual map created is classed as a view and predominantly addresses a certain topic.

The fundamental components of the IBIS$^+$ maps follow the IBIS methodology in that the nodes represent issues, positions about how to address the issues and arguments for and against the positions as shown in Figure 1. The issues require a resolution and the position proffer possible solutions to the issues. Arguments can either be for or against a position. These components are linked by relationships between one another. Positions always responds to an issue, while an argument (pro/con) either supports or objects to a position. In addition, the notation allows issues to be directly linked to other issues and positions to be linked to other positions. A decision node type is also incorporated into the notation which can be linked to issues or positions, this too is an extension of the original IBIS notation. Each node can contain some explanatory text and can be connected to other reference files launched directly from the nodes, such as other IBIS$^+$ maps, graphic, video or audio files.

Figure 1: Fragment of an IBIS$^+$ Map Dialogue



The following is a description of the node types that may be incorporated into the IBIS$^+$ maps:

Topics 

A topic may be defined as the problem area being explored and it should describe the broad issue that is under scrutiny. Topics are denoted by a question mark node as shown above.

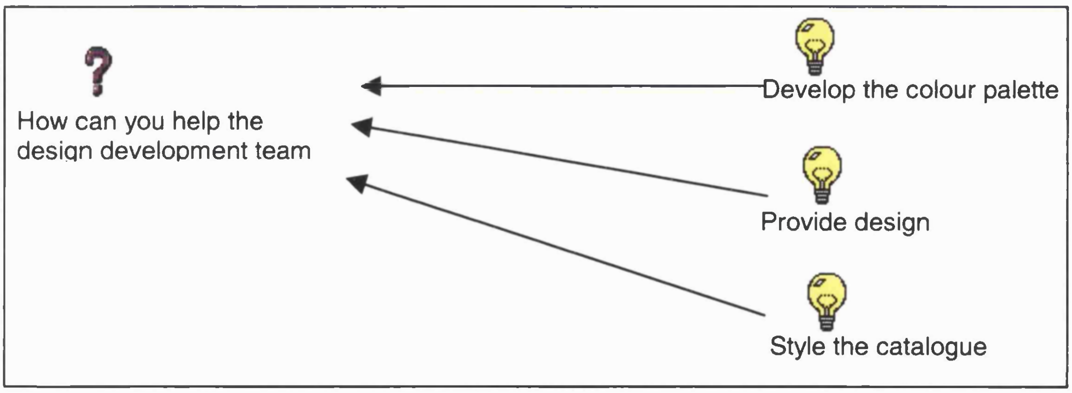
Issues 

Issues are the questions raised specific to the topic and sub-topics that arise, questioning how the topics might be approached. The Issues require exploration in order to address the overall problem. Each IBIS$^+$ map begins with an issue. Throughout the conversation, new issues may be created as needed. Issues when raised may or may not be settled through the deliberation process.

Positions 

Positions may be described as the ideas put forward by members of the team in order to resolve the issues. A position responds to an issue and outlines one possibility for a resolution. Positions are represented in the maps by light bulb nodes. An example is shown on the segment of a map illustrated in Figure 2, which explores the role of a clothing stylist. It starts off with the issue, 'How can you help the design team', from which stem several factual positions raised by the stylist concerned, demonstrating where he saw his role within the product development team.

Figure 2: Using an IBIS$^+$ Map to Explore Issues and Positions



Arguments 

Arguments are posed by members of the group, and may either support (pro) or oppose (con) a position that has arisen during the discourse. Argument nodes respond to positions and assert a belief about the position, held by a member of the group.

The process whereby members put forward their positions on certain issues may continue until a solution is reached through convincing the rest of the team by using the strongest arguments. In the IBIS$^+$ notation arguments for a particular issue are denoted by a plus node and arguments against a particular issue are denoted by a minus node.

Views 

View nodes denote that the currently open map view is connected to another map view. The view may be launched by clicking on the map view node. View nodes are denoted on the maps as miniature IBIS$^+$ maps icons.

Decisions 

A decision node is used to indicate when a decision pertaining to a position has been reached. When a decision relating to an issue is reached it is denoted on the maps by linking a decision node to the position being upheld or disregarded. Decision nodes are represented on the maps by a mallet icon.

Notes 

Notes can be connected to any other node types on the maps, and can contain textual information pertinent to the node they are connected to. Notes nodes are denoted by a notebook icon.

References 

Reference nodes can be connected to any nodes on the maps and represent an object, whether it be a document, graphic, video etc. In other words reference nodes launch files containing pertinent reference information related to the node they link to. They allow external files to be included in the discourse. Reference nodes can be linked to any other node type and are denoted by a book or will display the icon of the file type to which they point.

Relationships

The relationship types in table 1 are incorporated into the IBIS⁺ notation and are denoted on the maps by different coloured links:

Table .1: IBIS⁺ Relationship Types

The Responds to link, a black arrow, connects a position node to an issue node and is used to indicate that the idea offers an answer to the issue posed by the issue icon.
The Supports link, a green arrow, connects a pro argument node to a position node and indicates that the pro node favours the stance taken by the position node.
The Objects to link, a bright red arrow, connects a con argument node to a position node and indicates that the argument node opposes the stance taken by the position node.
The Challenges link, a dark red arrow, connects an issue node to another issue node, position, argument, or view node and indicates that the issue node questions the validity, assumptions or pertinence of the node to which it is attached.
The Specialises link, a dark green arrow, connects an issue to another issue, a position to another position, or an argument to an argument and indicates that the node refines, or further focuses, the node to which it is attached.
The Expands on link, a blue arrow, connects an issue to another issue, position, argument or view node and indicates that the issue node asks a question about a specific detail implied by the node to which it is linked.
The Related to link, a magenta arrow, connects a reference node to an issue, position, argument, or other reference node, and a view node to reference, note or another view and indicates that the node from which it originates contains information pertinent to the node to which it is attached.
The About link, a dark cyan arrow, connects a note node to any other node, a view node to an issue, position, or argument node, and an issue node to a reference, or note node and indicates that the node from which it originates contains information relevant to the node to which it is attached. The About link is a general purpose link that shows only the broadest relationship between nodes.
The Resolves link, a grey arrow, connects a decision node to an issue node and indicates that a decision has been made concerning the issue according to the line of reasoning and other notations listed in the decision node contents.

To recap, the fundamental components of an $IBIS^+$ map are issues, positions, and arguments (pro or con), as shown in figures 1 & 2. The issues require a resolution and the position proffer possible solutions to the issues. Arguments can either be for or against a position. These components are linked by relationships between one another. Positions always responds to an issue, while an argument (pro/con) either supports or objects to a position.

APPENDIX I:

IBIS^{PDR} Manual

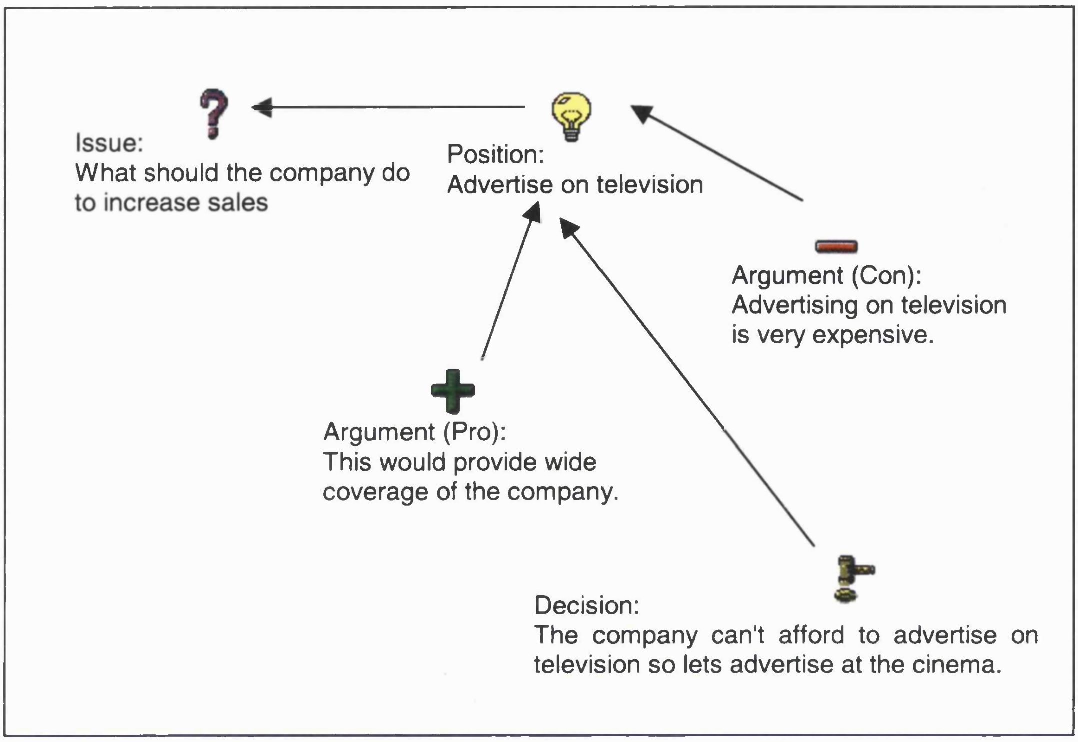
This document outlines the main elements of the IBIS^{PDR} notation:

IBIS^{PDR} Maps

IBIS^{PDR} maps enable a graphical representation of product design dialogue to be constructed. A hypertext type structure of different nodes and link types is utilised to denote the main IBIS^{PDR} elements on the maps. The maps consist of IBISPDR nodes and links to demonstrate the relationship between the nodes. The nodes can also be linked to other map views or files of various formats which can be launched directly from the maps by clicking the nodes. A node is a data object in a hypertext database and operates as the junction between links or other objects. A hypertext node may also have content, either in a simple form such as a text or a more complex form, such as code to launch another application. A link is the connecting mechanism between two nodes and can also be used to define the type of relationship that exists between the two nodes. Each individual map created is classed as a view and predominantly addresses a certain topic.

The fundamental components of the IBIS^{PDR} maps follow the IBIS methodology in that the nodes represent issues, positions about how to address the issues and arguments for and against the positions as shown in Figure 1.

Figure 1: Fragment of an IBIS^{PDR} Map Dialogue



The following is a description of the node types that may be incorporated into the IBIS^{PDR} maps:

Topics 

A topic may be defined as the problem area being explored and it should describe the broad issue that is under scrutiny. Topics are denoted by a question mark node as shown above.

Issues 

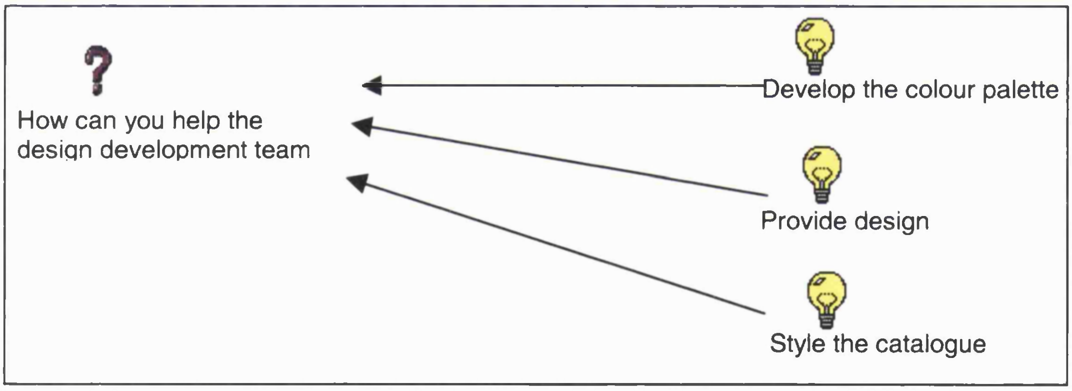
Issues are the questions raised specific to the topic and sub-topics that arise, questioning how the topics might be approached. The Issues require exploration in order to address the overall problem. Each IBIS^{PDR} map begins with an issue.

Throughout the conversation, new issues may be created as needed. Issues when raised may or may not be settled through the deliberation process.

Positions 

Positions may be described as the ideas put forward by members of the team in order to resolve the issues. A position responds to an issue and outlines one possibility for a resolution. Positions are represented in the maps by light bulb nodes. An example is shown on the segment of a map illustrated in Figure 2, which explores the role of a clothing stylist. It starts off with the issue, 'How can you help the design team', from which stem several factual positions raised by the stylist concerned, demonstrating where he saw his role within the product development team.

Figure 2: Using an IBIS^{PDR} Map to Explore Issues and Positions



Arguments 

Arguments are posed by members of the group, and may either support (pro) or oppose (con) a position that has arisen during the discourse. Argument nodes respond to positions and assert a belief about the position, held by a member of the group. The process whereby members put forward their positions on certain issues may continue until a solution is reached through convincing the rest of the team by using the strongest arguments. In the IBIS^{PDR} notation arguments for a particular issue are denoted by a plus node and arguments against a particular issue are denoted by a minus node.

Views 

View nodes denote that the currently open map view is connected to another map view. The view may be launched by clicking on the map view node. View nodes are denoted on the maps as miniature IBIS^{PDR} maps icons.

Decisions 

A decision node is used to indicate when a decision pertaining to a position has been reached. When a decision relating to an issue is reached it is denoted on the maps by linking a decision node to the position being upheld or disregarded. Decision nodes are represented on the maps by a mallet icon.

Notes 

Notes can be connected to any other node types on the maps, and can contain textual information pertinent to the node they are connected to. Notes nodes are denoted by a notebook icon.

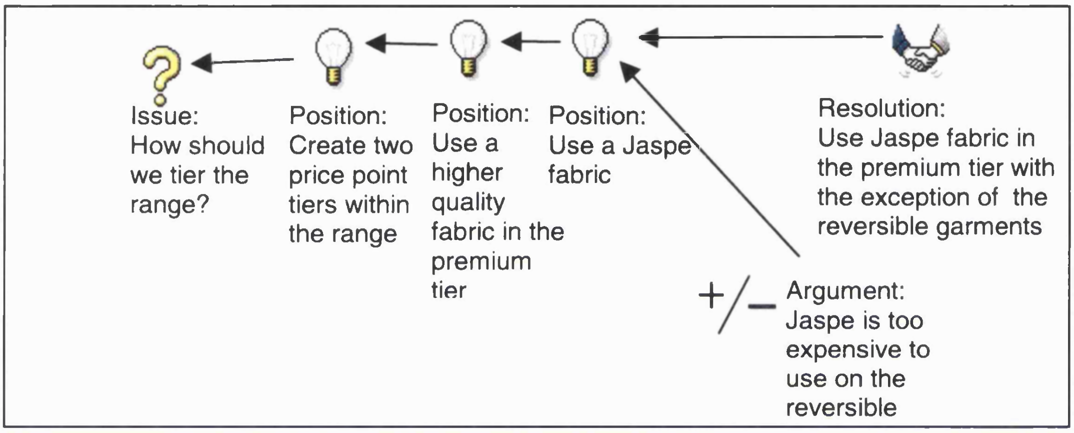
References 

Reference nodes can be connected to any nodes on the maps and represent an object, whether it be a document, graphic, video etc. In other words reference nodes launch files containing pertinent reference information related to the node they link to. They allow external files to be included in the discourse. Reference nodes can be linked to any other node type and are denoted by a book or will display the icon of the file type to which they point.

Resolutions 

'Resolution' nodes are used when the whole of the line of reasoning is being addressed and all the issues and ideas in the line have been solved by that particular decision, as demonstrated in figure 3 (all the light bulbs are grey, denoting that they are resolved). Obviously, when constructing the map a user must decide whether a decision reached solves the whole line of reasoning, or just part of it, before selecting either the decision or resolution node type.

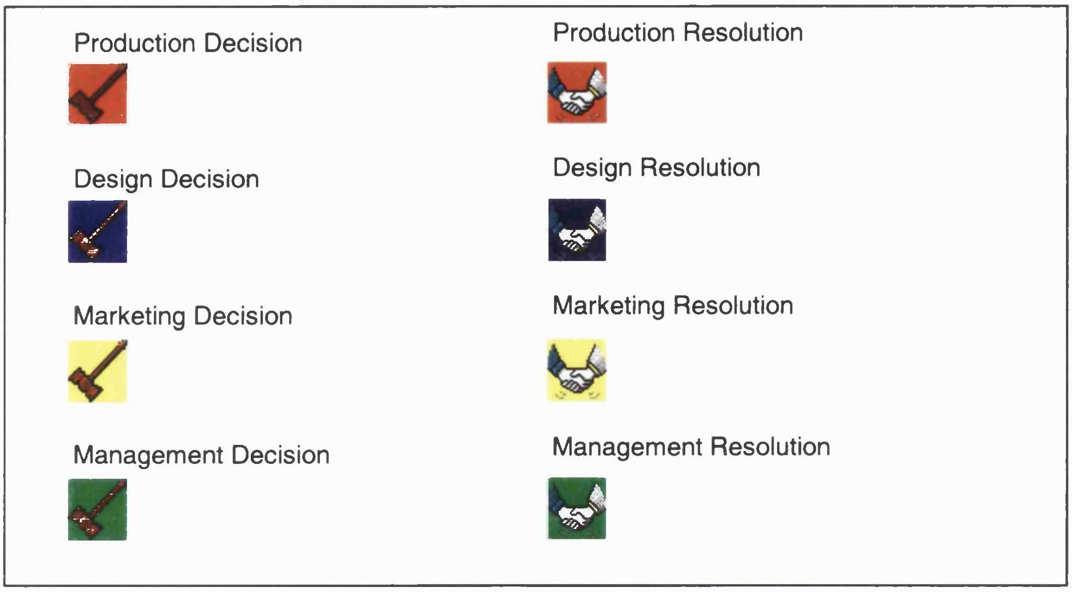
Figure 3: Using the Resolution Node Type

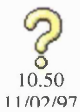


Colour Coded Domain Specific Decision & Resolution Nodes

It is possible to differentiate decisions according to which department or perspective they were coming from (e.g. Marketing, Sales, Management, Production, Design). For this we use colour-coding on decision and resolution nodes as shown in figure 4, each department being identified by a different colour.

Figure 4: Colour Coded Decision and Resolution Nodes

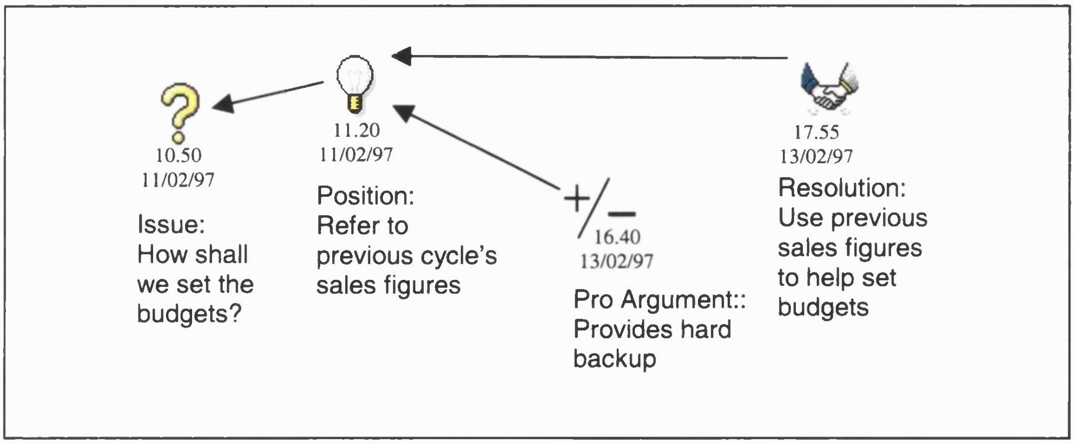




Time And Date Stamped Nodes

A temporal aspect to the representation is included by time and date stamping all the nodes when they are added to the maps as shown in figure 5.

Figure 5: Time and Date Stamped Nodes



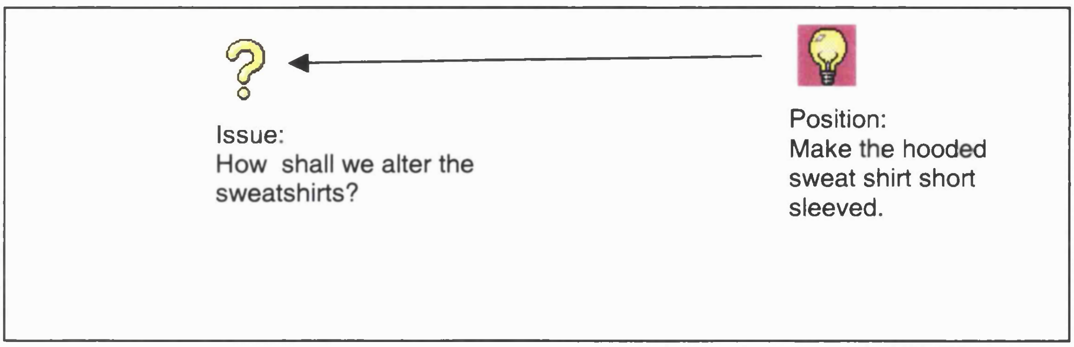
REFLECTIVE RETROSPECTIVE ADDITIONS

A reflective stage at the end of the map creation allows the maps to be reviewed, corrected, annotated and updated in order for the status of the knowledge representation to be accurately maintained. The following additions to the IBIS^{PDR} maps are incorporated into the notation as part of this retrospective stage:

Link The Key Position And Decision Nodes To Image Files Of The Final Products - Denoted by Colour Coding Nodes in Pink

Once the final products are determined they are clearly and directly linked back to the initial ideas to which they relate. The key position nodes can be linked to graphics files of the end product they affected. Such a link from an idea node is shown by a pink colour-coding which alerts the user to a retrospectively added association, as shown in figure 6. For example where a position node is shaded pink, it alerts the user to the fact that if they double click on that node an image of the finished product relating to it would be launched.

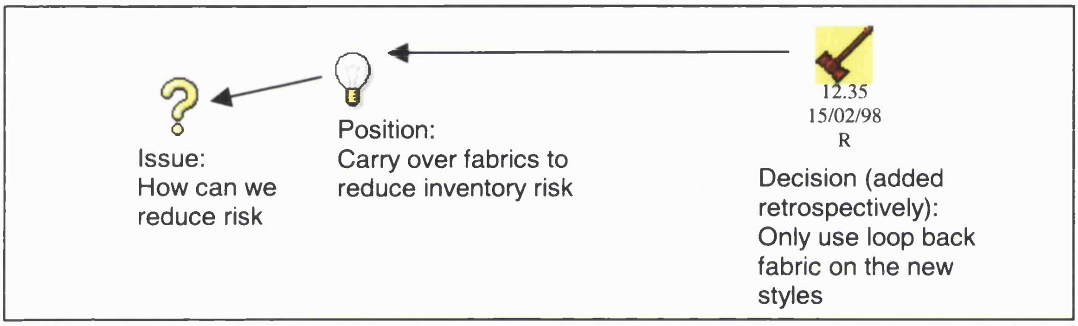
Figure 6: Colour Shaded Position Node Denoting a Hyperlink to the Finished Product



'R' Flags Annotating Retrospective Nodes

During retrospective editing nodes that are omitted from the maps need to be added and connected to the nodes to which they relate. Otherwise it could appear when looking back in the future that some ideas had not been resolved and decisions had not been made, when actually they have been addressed. All these “tidying” up operations that take place retrospectively are flagged as such, by adding an “R” flag to any node added at the retrospective stage, as in figure 7.

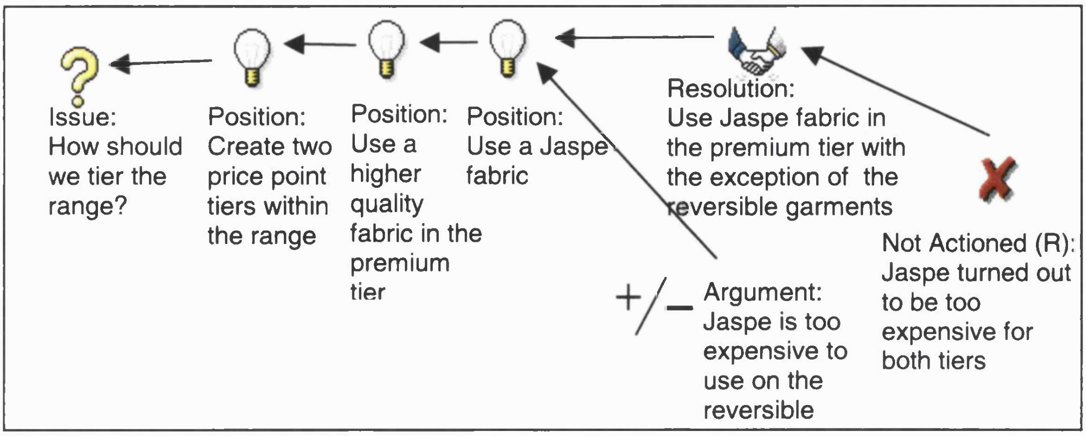
Figure 7: Adding an 'R' Flag to Retrospective Nodes



Not Actioned

In order to denote that certain decision hadn't been implemented even though they had been discussed during the design deliberations a node type called not actioned, linked to decision nodes, is used to annotate the maps, at the end of the design cycle, ensuring the information on the maps is up to date, as shown in figure 8. Text should be added to the node explaining why it was not actioned. Where this node is not connected to a decision node it can be assumed by the user that the decision was actioned. Where positions don't have decisions linked to them either during the design conversation or in the retrospective stage, the user may assume that the ideas raised in those positions were not followed up.

Figure 8: Adding the New Retrospective Node Type – Not Actioned



Relationships

Relates To

Only one link is used, denoting that one node is relevant to another, the nature of the links being implied by the types of nodes it connects.