Chapter 2 Literature Review

The literature research aims to fulfil objectives no. 1 and 2 (see chapter 1). As a result, this chapter comprises of four parts: 1) the NPD process of apparel industry in practice, 2) the NPD process of electronics industry in practice, 3) the NPD process of Smart Clothing development, and 4) comparison between Smart Clothing NPD processes and the established ones. In this way, a specific context of Smart Clothing development can be drawn. Finally, the conclusion is deduced and directions for the primary research are set out.

2.1 Apparel NPD Process in Practice

Three issues are presented in this part: 1) apparel product development in context, 2) NPD process in apparel industry, and 3) strategic approaches and NPD models.

2.1.1. Apparel Product Development in Context

Apparel is one of the main products of the textile and clothing area. Experts in this field comment that the apparel industry has the unique characteristics, which differentiate it from the others. These characteristics can be categorised into five groups:

1. Firstly, the competitive methods and product development are driven by seasonality and retailers' strategies (Easey, 2002). This situation results in:
   1.1 The retailers having a direct involvement in the NPD process in order to ensure a high level of uniformity and coordination of colour, style and other standards among the different types of garments in retail stores. Willans (2002) says *'several fashion retailers have adopted a concept known as 'edited retailing' whereby the*

customer is offered a limited though changing choice of merchandise that is highly co-ordinated, offering a high degree of product range compatibility.' Next is considered the initiator and a good example of retailers that successfully adopt this concept. Besides, some retailers, e.g. Marks and Spencer and Arcadia Group, have developed their own design capacities in order to establish and improve product specification to a standard that increase their reputation. A number of research indicate that there are many retailers involved in the NPD process from the very first stage (Rhodes, 1995). Moreover, the retail buyers are considered the key decision-makers. Their decisions cover the specification of fabric quality, style, colour, sizes and number to be manufactured. As a result, some of the NPD models demonstrate the influence of the retailers. In figure 2.1, the design process ends at the line presentation. This is because many producers do not own a store or brand. This design process focuses on fashion trend analysis and selecting fashion elements, such as colours and fabrics, rather than exploring new ideas.

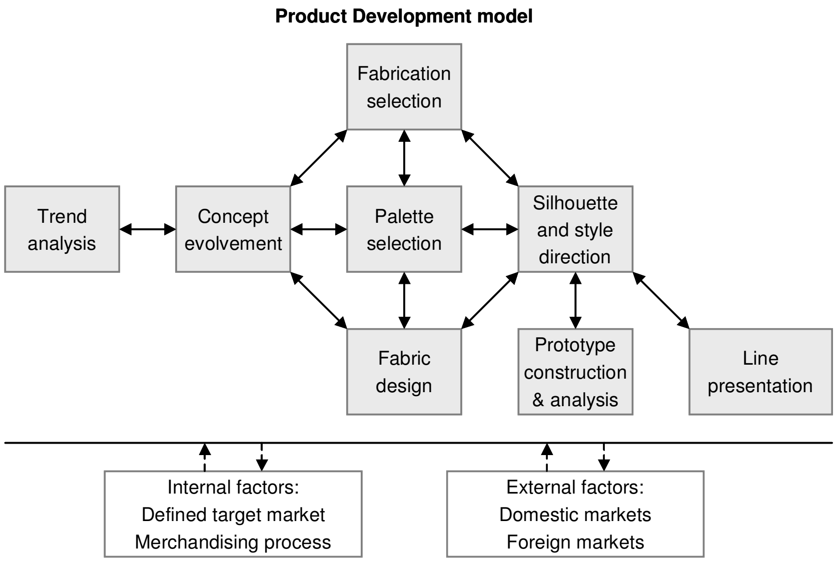

Figure 2.1: Retail product development model

Source: Gaskill (1992; cited in Le Pechoux, Little, and Istook, 2001)

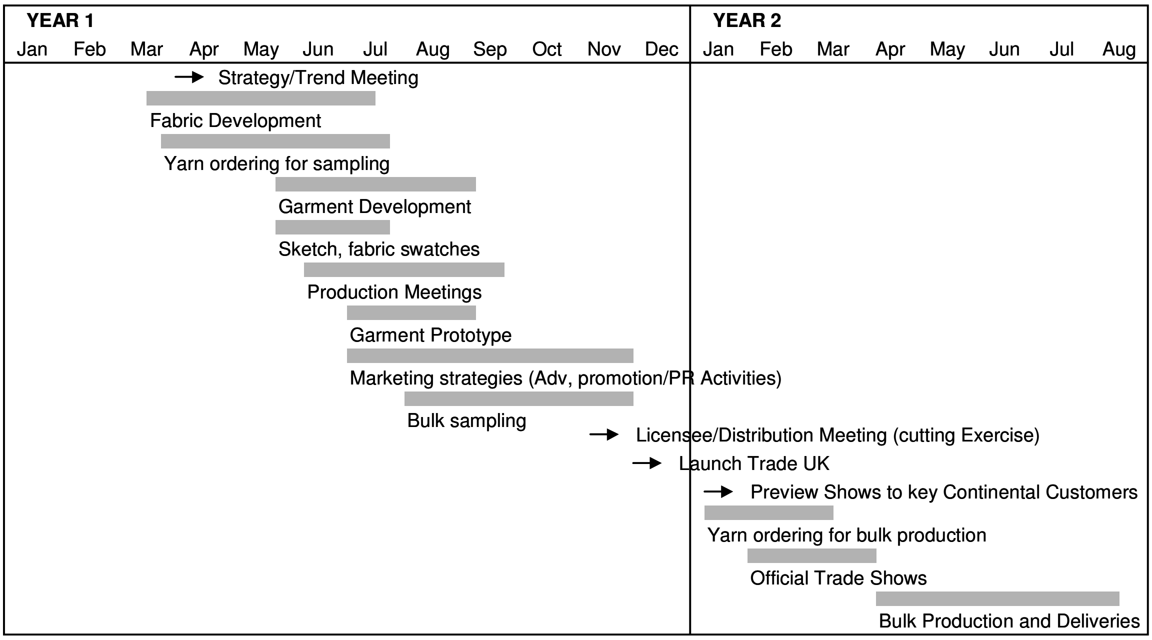

Figure 2.2: Fashion Calendar

Source: Herbert and Otto (1994; cited in Bhamra, Heeley and Tyler, 1998)

1.2 Due to its seasonal nature, the product development time is very tight and strict to the seasonal fashion calendar (see figure 2.2). Textile and apparel product development is normally planned one year in advance. As a result, product planning and development rely highly on the forecasting service, feedback from the retailers, and product performance analysis.

2. Secondly, the apparel product development seldom results in a single type of product. The emphasis is placed on the presentation of ‘ranges’ or ‘collections.’ Product mix within each collection is carefully planned and used as a means to reduce the risk of introducing new products and test the new styles (Atkinson, 2002). Johnson and Moore (2001) provide an example of the collection ratio as: 60% basic merchandise, 25% fashion merchandise, and 15% promotional merchandise.

3. The apparel NPD process is an iterative process, as the product planning is built

around 1) improvements or revisions of existing products, 2) addition to existing product lines and 3) incorporation of new products into the range (Sinha 2000). Through a regular analysis of the previous range's performance, the good-seller styles are identified, amended and/or repeated while the bad-seller styles are withdrawn.

4. Since the apparel products associate with frequent changes in customer lifestyle and requirements, and highly rely on the fashion marketing; the development process is considered as a *'planned obsolescence'* (Easey, 2002). A short lifecycle leads to a frequent product planning and product development. Most experts agree that the apparel products are associated with social attitude, psychological satisfaction and aesthetic presence (Au, Taylor and Newton, 2003).

Current trends indicate that the apparel products continually move from high-fashion garments towards casual garments and sportswear. This situation is a result of the change in consumer's lifestyle. Sorensen (2002) notes that people now require *'understated styles that combine realism, comfort and practicality.'* The circumstances lead to a blur of distinction between active wear and fashion. Moreover, the customer in late forties and fifties represent a good opportunity. It is likely that apparel products may become less transient, as casual garments can be used for longer periods and the customers in the older age group tend to value products for longer. This presents a good possibility for Smart Clothing applications, which focus on basic and functional garments.

2.1.2. NPD Process in Apparel Industry

The NPD process in apparel industry can be considered as a regenerative and sequential process (see figure 2.3 and 2.4). Bhamra, Heeley and Tyler (1998) describe *'conventional* *approaches to product development in textile and clothing industry have been characterised by functional independence. Each participant contributes to the process sequentially.'* Experts suggest that there are five steps in the NPD process: 1) consumer research, 2) design and concept development, 3) sampling, 4) specification development and 5) pre-production sampling (Sadd, 1996, cited in Le Pechoux, Little, and Istook, 2001). Noticeably, some of the NPD models (Carr and Pomeroy, 1992; Gaskill, 1992) stop at line presentation or pre-production sampling (see figure 2.1 and 2.3).

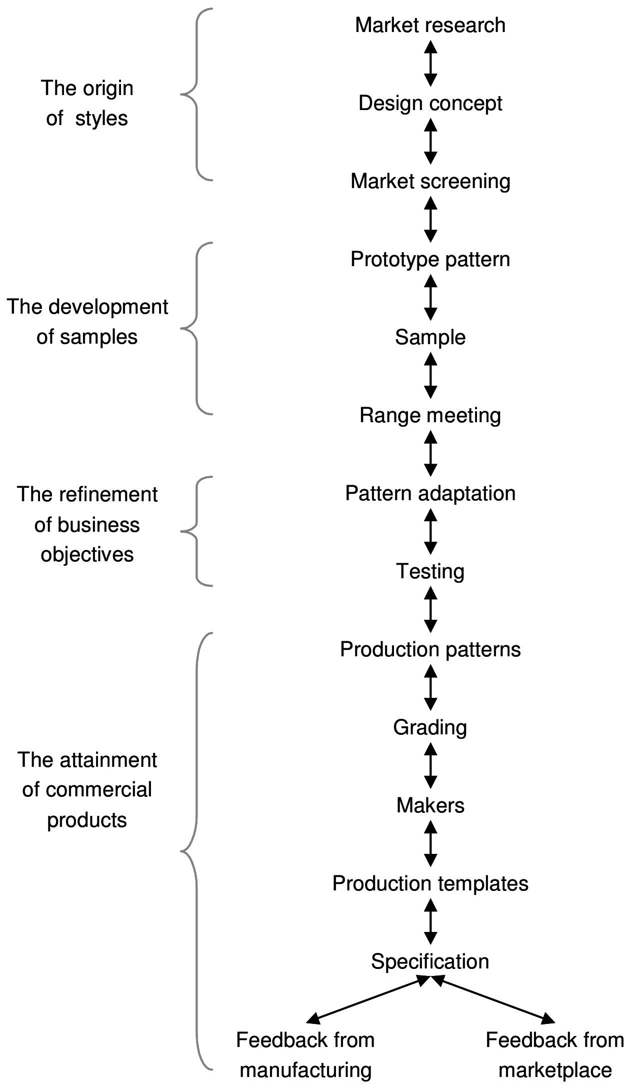

Figure 2.3: The process of apparel design and product development (Carr and Pomeroy, 1992, cited in Le Pechoux, Little, and Istook, 2001)

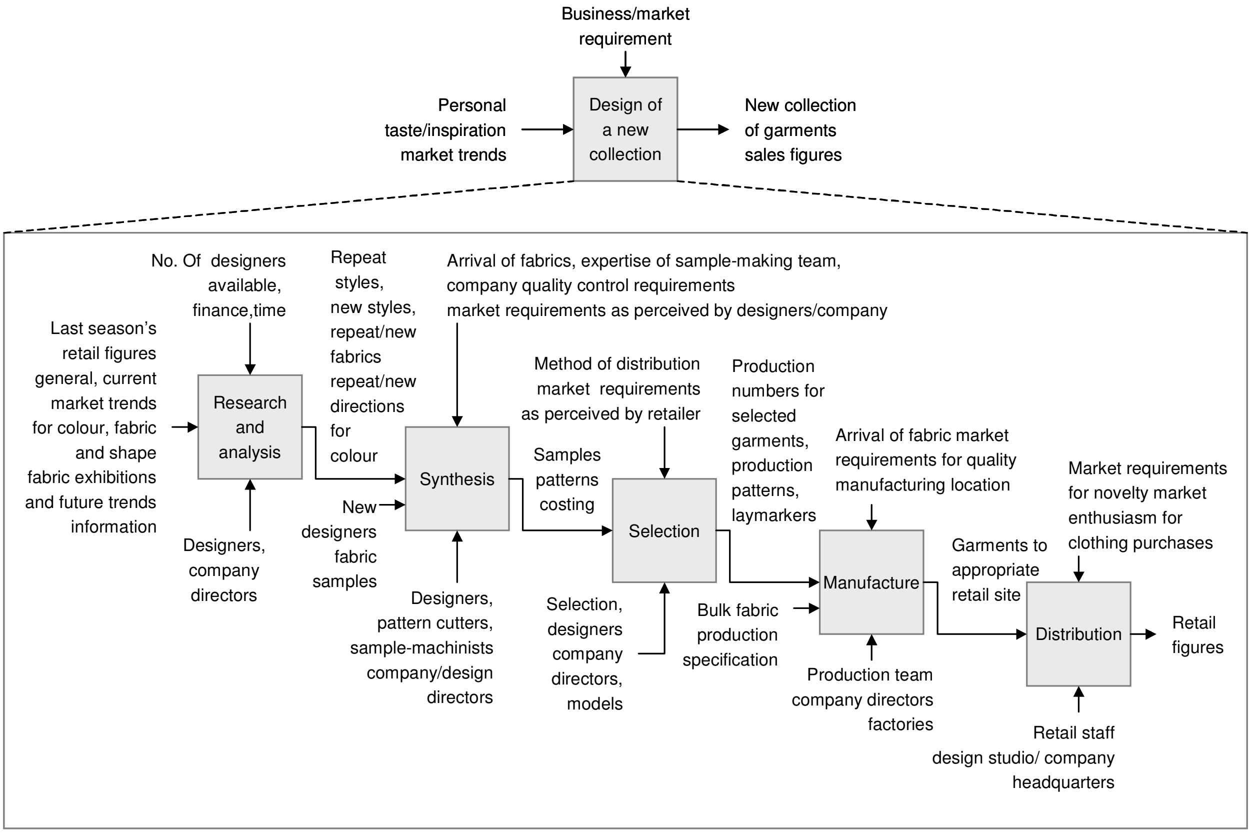

Figure 2.4: The generic fashion design process (Sinha, 2001)

Generally, the development team involves three key disciplines: 1) fashion designers, 2) technicians (e.g. pattern cutter, sample machinist, and garment technologist), and 3) business functions (e.g. merchandiser, sale personnel and retail buyer). The way development teams work depends on the size of the company. In the small companies, the designers, the pattern makers, and the sample machinists work very closely (Sinha, 2000). In some cases, the production machinists are involved in sample making to explain technical matters. This allows the designers to explore new materials, techniques and styles. In contrast, the fashion designers in the large organisations only produce sketches, swatch boards and specification sheets, which contain style numbers, colours, fabrics and so forth (Next, 2002). Therefore, the designers do not have to meet the sample making teams who work with the suppliers. Furthermore, communication between the large apparel companies and the suppliers is usually made by the buyers and/or merchandisers. This situation can cause problems, especially knitwear, as knitted structures are difficult to communicate (Eckert, 1999). It can be seen that the designers in large companies have less design freedom. As most designs are based on an improvement of good-selling styles, the designers have less chance to explore new materials and new styles (Sinha, 2000).

Most experts note that the role of the fashion designer in the apparel industry is crucial to the success (Le Pechoux, Little, and Istook, 2001). The task is interpreting society's current and anticipated moods into desirable and wearable garments for every market segment (Au, Taylor and Newton, 2003). As a result, designers must be in tune with the wider social, cultural, economic and political environment within which human beings conduct their daily lives (Sinha, 2001). Some research illustrate that all designers in the clothing companies were responsible for their designs until the stages of manufacture. In some cases, the fashion designers and apparel development teams also play an important role in textile design. For example, Atkinson (2002) notes that many development teams work closely with yarn and textile producers. In this way, fabrics can be dyed and woven according to specifications, and ordered for garment manufacturers.

Certain conceptual models are proposed to describe the NPD process in fashion industry. To demonstrate practical and theoretical models employed in this field, four examples of NPD process are chosen (see table 2.1). These samples are selected based on the richness of the information in terms of development team and product development process. To reduce bias, these samples are selected from both private sector and academic field.

Table 2.1 Five examples of the NPD processes employed in the fashion industry

Source	Next (2002)	Johnson and Moore (2001)	Sinha (2000)	Atkinson (2002)
Process	The Product Selection Process	Product Development Process	The Fashion Design Process	Retail Buying Sequence
Discipline	Fashion designer Merchandiser Buyer, Supplier Garment technologist Product director Manager	Fashion designer, Manager, Supplier, Buyer, Pattern maker, Quality controller, Manufacturer, Grader, Retailer/wholesaler	Fashion designer Pattern cutter Sample machinist Selector/buyer Supplier, Agent Retailer/wholesaler	Fashion designer Marketer Buyer, Supplier Controller Director Manufacturer
Phases	10 Stages	7 Steps	5 Phases	7 Stages
Procedure	1. Fashion designers identify key trends of all fashion capitals. 2. Fashion designers create mood boards and themes, and then present them to the buyers before they sample the latest fabrics from the fairs. 3. The design team creates a strategic plan for the next season based on the latest trends and the sale figures from the last season provided by the merchandisers. This 'range direction' is the key strategy that the designers and buyers must work to. 4. The team makes a decision about the suppliers, production	1. **Research**: In this case, the research includes previous successes and failures, changes in lifestyle and users' requirements. This research focuses on the fashion trend forecasting, which can be obtained from an external fashion and colours service. 2. **Analysis**: A design tool called 'triangle of balance' is proposed to balance three elements: 1) design and designer, 2) garment and store and 3) customer. 3. **Building the first design ideas**: The designers develop and alter the mood -	1. **Research and Analysis Phase**: Fashion designers conduct a design audit, while the business functions carry out a business audit. A product strategy is created based on the design trends and the sale figures of the last season provided by retailers/wholesalers. 2. **Synthesis Phase**: Samples are made by the pattern cutter and the sample machinist according to the design sketches and fabric swatch boards from the designers. In small companies, fashion designers work closely with a -	This NPD model is presented in a time frame. The autumn and winter season is used as an example. 1. **Early September**: Analysis and concept development take place at this stage. The analysis includes sale figures, fashion trends, and supplier performance. The basis of the range including colours, fabrics, styles and price is specified. The plan is built around the revisions or improvements of the existing lines. 2. **Late September**: The initial range is presented for the first screening. A design -

Source	Next (2002)	Johnson and Moore (2001)	Sinha (2000)	Atkinson (2002)
Procedure	- plan, and so on. 5. Fashion designers create and send a design pack, which contains the sketches of all relevant styles, etc, to the suppliers. 6. Suppliers produce the samples that must be approved by the buyers and garment technologists. If the samples are accepted, the buyers will negotiate a price point for production. 7. The team proposes the range at a pre-selection meeting. The merchandisers start to reserve the fabrics and agree a production schedule. 8. A final selection is held to show the complete range to the product director and the managers for the final approval. 9. Merchandisers and garment technologist manage and monitor the suppliers as well as control the quality to ensure that the new season will be -	boards and sketches until they satisfy. A merchandise ratio, which is divided into 1) basic, 2) fashion and 3) promotional ranges, is planned. 4. **Costing**: Product managers, designers, and merchandisers, negotiate the price point and the delivery date with the supplier. 5. **Line building**: Once the design and the cost of each style are specified, the line can be planned. The specification sheet containing designs, style numbers, etc, is created. The samples are made, evaluated and modified. These samples are made by wholesaler's sampling team, manufacturers, or external services. 6. **Production**: The pattern makers turn samples into patterns, while the graders grade these patterns into different sizes. The buyers source and order required -	sample-making team. Sampling is a crucial part of the process, as the styles will only be bought or manufactured after viewing as samples. 3. **Selection Phase**: Most companies must prepare their ranges to show to group of selectors. A decisions and a specification in terms of colours, style numbers, sizes, and number to be manufactured will be made. Some styles are modified due to the requirements of the retailers, since many of them have their own research, design and resources. 4. **Manufacturing Phases**: The samples are produced by the suppliers due to the order specifications. 5. **Distribution Phase:** The garments are delivered to the wholesale outlets or the retail shops. All companies collect -	alteration cycle and further research (e.g. visiting fabric fairs, etc) take place. 3. **Early to mid October**: The second screen is conducted. The development process continues. The suppliers are sourced and selected. After the concepts are approved by the controllers, a concept presentation is made at director level. 4. **November to the end of January**: The process is finalised. A market test is planned. The buyers negotiate about the sampling and price with the suppliers. A range meeting with the controller and the directors is held for the final approval. 5. **Mid February**: Marketers develop a promotional and a market plans for the launching. The price points are finalised. 6. **April to May**: The team focuses on -

Source	Next (2002)	Johnson and Moore (2001)	Sinha (2000)	Atkinson (2002)
Procedure	launched on time. 10. While the full production takes place, the buyers and the designers start working on the next season range.	materials. Finished garments will be checked by the quality control staffs. 7. **Selling**: The ranges are purchased by the wholesalers/retailers.	the wholesale figures over the season in order to make a plan for the next season. However, some of them can collect their retails' figures.	chasing a production, quality controlling and monitoring the suppliers' progress. 7. **July to August**: The whole range is launched in stores.

The diagrams that represent the conceptual models of the examples no. 1, 2 and 4 are developed, as the authors (NEXT, 2002; Johnson and Moore, 2001; and Atkinson, 2002) did not propose their ideas in the form of a diagram. Box diagram is chosen to demonstrate these ideas, as it is easy to compare with Sinha's models, which are constructed in the same structure. Since Sinha proposes five conceptual frameworks, a comparison between these five models is conducted before contrasting with the others. The conceptual model on the far right is a generic model drawn from five models proposed (see figure 2.5). This generic model contains all elements presented in the other models in order to show all elements the author addressed. In this way, the conceptual models no. 1- 4 are compared with each other and the conceptual models presented in chapter 1, such as Rhodes's Fashion Design cycle (figure 1.10). As a result, the similarities and differences can be identified (see figure 2.6). Subsequently, a 'generic NPD model' of the apparel industry is deduced, with a view to comparison with those of electronic industry and Smart Clothing.

According to the comparison, it can be seen that most models can be fitted in Sinha's conceptual framework comprising of five phases: 1) research and analysis, 2) synthesis, 3) selection, 4) manufacturing, and 5) distribution or retailing.

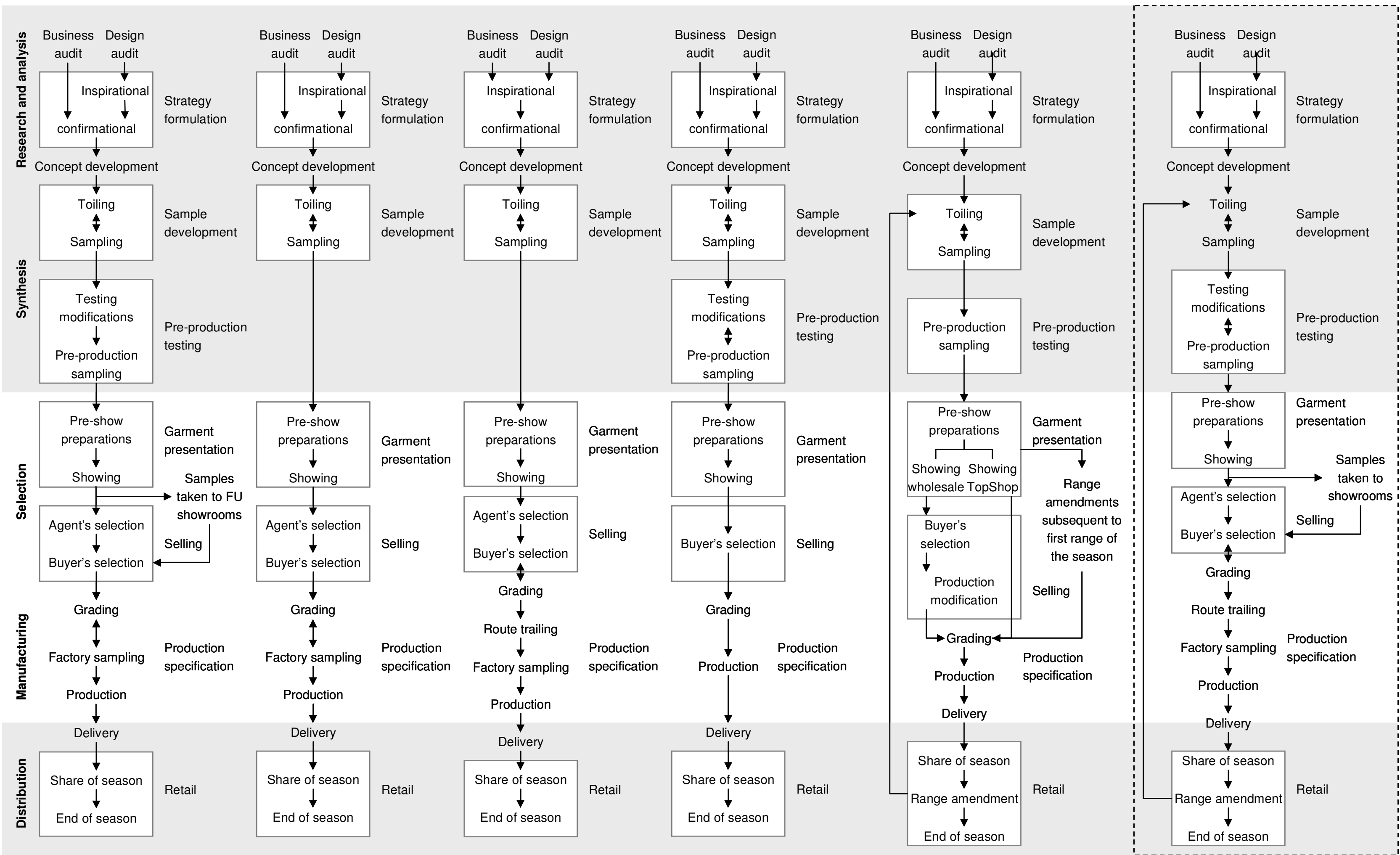

Figure 2.5: Comparison between five different design processes (Sinha, 2001)

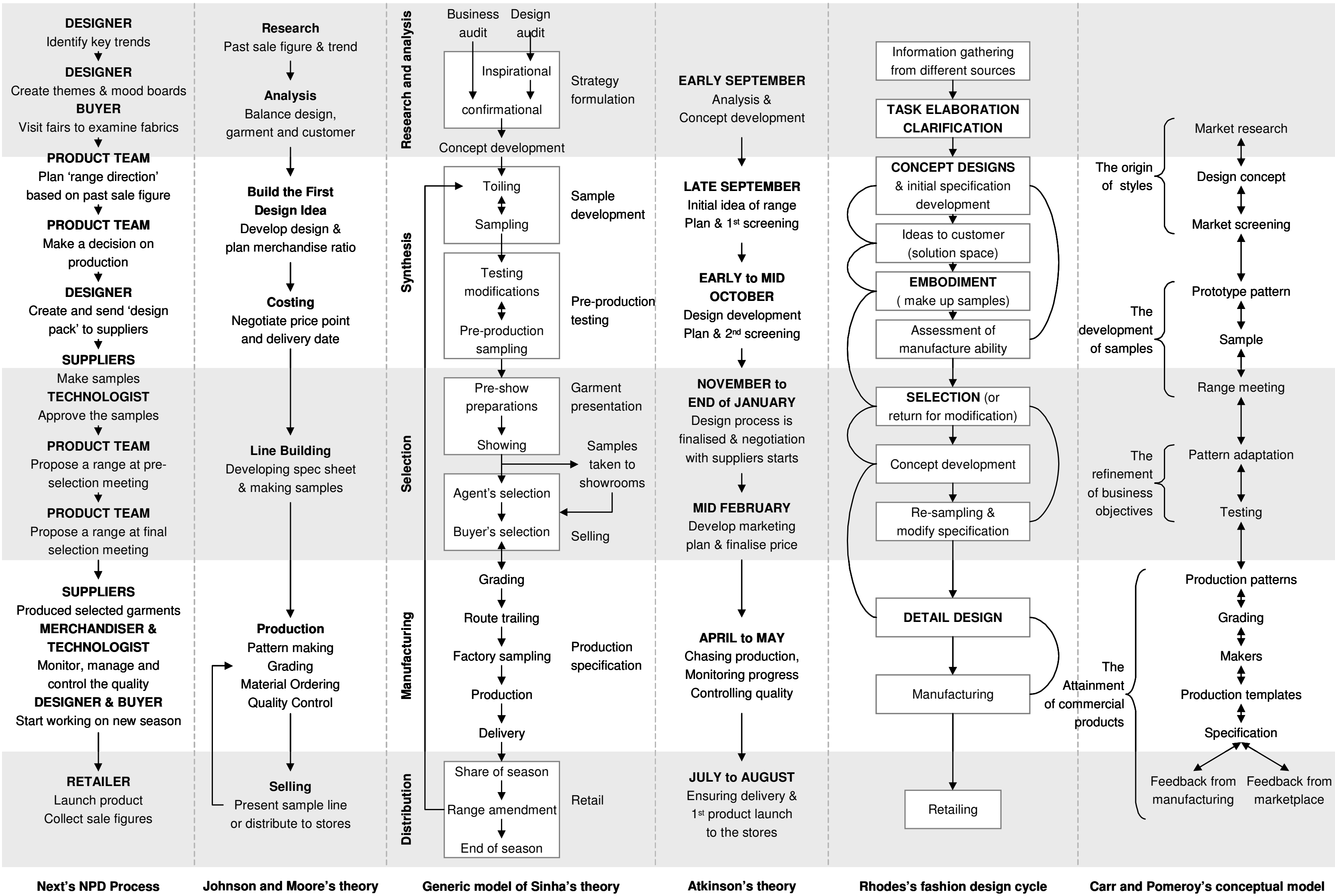

Figure 2.6: Comparison of the NPD models in apparel industry

Noticeably, most NPD models emphasise the synthesis (design development) and selection stages. The synthesis and selection stages are very complex, as they involve large number of tasks. Moreover, these tasks are iterative. For example, the mood boards and samples are developed and modified several times throughout the design process. Nevertheless, the time to complete all these complex tasks is very short. For instance, Atkinson (2002) states that these two stages start in late September and end in middle of February.

Evidently, most conceptual models do not pay much attention to the manufacturing and distribution. It is possibly because most companies do not own the factory. Therefore, after the selecting process is completed, the development teams will move on to the next season and leave manufacturing tasks to the suppliers. Clearly, its unique characteristics, such as direct involvement of the retailers, fixed timetable according to the seasonal calendar and regenerative character, have a great influence in the NPD process. For instance, direct involvement of retailers leads to emphasis being placed on the selection stage. This illustrates a strong relationship between product's context and NPD process. However, none of its specific characteristics is presented in the NPD model. Important activities, such as sampling and selecting, are not clearly stressed. It is difficult to identify the different priority among all activities addressed in conceptual model, as all activities are presented similarly in simple box diagram (see figure 1.10, 2.1 and 2.5).

2.1.3. Strategic Approaches and NPD Models

Experts note that recently most apparel companies have adopted a 'quick response strategy' in order to reduce the development time and stock (see Sawada, 2002) and make the delivery more flexible. The researchers, such as Bhamra, Heeley and Tyler (1998), start introducing the 'Concurrent Product Development', which uses a multidisciplinary approach to delivery better, cheaper and faster products to market, to the textile and clothing industry. For example, Zara, the Spanish clothing chain, has adopted just-in-time production in order to gain flexibility and quick response to fast changing fashion trends (Stengg, 2001). Zara's designers work closely with store managers and manufacturers. Since the designers get access to real-time sale data and the manufacturers are up-date with new designs, the company only needs three weeks to make the line from start to finish (cf: the industry average of nine months). In addition, New Look and George at ASDA also claim to have a product from design studio to store display within three or four weeks (Hines, 2001), and H&M aims to cut lead times to just fifteen days (Webb, 2001).

These examples indicate that a multidisciplinary approach has been widely adopted by the apparel companies. However, it is clear that the full benefits of multidisciplinary approaches have not utilised, since most companies employ this strategic approach only to reduce time to market and cost rather than explore new ideas and opportunities that multidisciplinary teams can bring. Although, the strategic approaches are closely linked to product development process, there is no evidence that strategic thinking is presented in NPD conceptual models or lead to any differences in terms of the model's structure. For instance, in figure 2.5, five different NPD models of five companies, which are very different in terms of design process, size and target group, look almost identical.

2.2 Electronic NPD Process in Practice

This part includes three key issues: 1) electronic product development in context, 2) the NPD process in electronic industry, and 3) strategic approaches and NPD models.

2.2.1. Electronic Product Development in Context

In this research, the term 'electronic product' refers to a consumer electronic product because it is often incorporated in Smart Clothing applications. Several researchers categorise consumer electronics as a platform product (Ulrich and Eppinger, 2000). A product platform is defined as a set of common components, modules, or parts from which a stream of derivative products can be efficiently created and launched (Meyer and Lehnerd, 1997). While key components of a product represent a major *'subsystem'* of the platform, a connection between the components is an *'interface between subsystems.'* A good example of a technology platform is the Apple Macintosh operation system.

Otto and Wood (2001) comment that an individual electronic product is only developed within the context of platform. Thus, the NPD process is repeated for every product in the same platform, but the key technological components are continually upgrading. As a result, strategy planning is usually developed for the whole product line rather than one individual product. According to the definition, a platform product is developed around a pre-existing technological subsystem or a technology platform (Ulrich and Eppinger, 2000). As a huge investment is made to develop the technology platform, most companies try to incorporate them into as many different products as possible. To some extents, platform product development processes are similar to those of technology-push product, since the development teams start by developing concepts that embody a particular technology. Nevertheless, developing platform products is lower risk compared to technology push products because the platform technology is not so new and radical. Moreover, it has already demonstrated its usefulness in the marketplace. As a result, the platform product development process is simpler than those of technology-push products.

Several experts suggest that electronic products can be described as a single element within larger interdependent systems (Bull, 1999). These devices rely upon the exchange of electronic information, such as sound, text, and image, and require the use of complex computing and technologies, which are frequently in the form of 'hidden' layers. This character makes it difficult for the user to develop a suitable understanding. In order to make the technologies match the user's lifestyle, social context and cultural background, the methods, such as collaboration, participatory design (Sonnenwald, 1996), user-centred design and transparency (Johnson and Evans, 1999), are recommended. Evans (1986) suggests that leading Japanese electronic product companies overcame the situation of interconnection and interdependence by dividing products into a limited number of groups according to the similarities. In this way, similar products shared technologies and other qualities. Nevertheless, this method is considered similar to the concept of platform.

Since the selling point of an electronic product is its features, ensuring its reliability is crucial. Although the amount of time spent on different stages of an electronic product development project varies enormously, the experts in this field note that typical figures of expenditure is 40% on specification, 20% on implementation, and 40% on proving that the design is correct (DTI's Electronic Design Programme, 2002a). These figures demonstrate that the specification, and verification and validation are the most important stages. The DTI's Electronic Design Programme (2002b) uses the term 'Design Flow' to describe the unique characteristics of the electronic product NPD process (see figure 2.7). Based on this idea, an overall flow comprises of several subsystems, and each subsystem contains a number of detailed flows. In this way, it is possible to modify an individual detailed flow without upsetting the 'higher level' of the flow. The design flow plays an important part in establishing the control over the design process and managing a project. The subsystems and detailed flows are specified through the partitioning process, which is one of the most important activities in the electronic product development process.

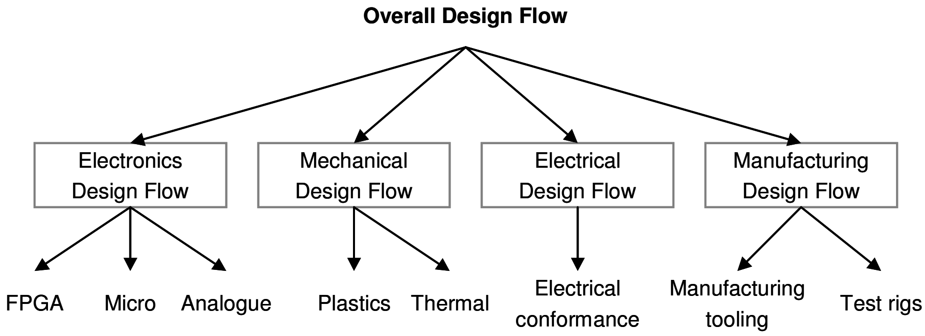

Figure 2.7: Design Flow (DTI's Electronic Design Programme, 2002b)

2.2.2. NPD Process in Electronic Industry

Ward and Angus (1996) suggest that the process of electronic product design requires a *'logical progression'* – that comprises of establishing the needs and specifications, designing system, designing for manufacturing, testing, and controlling quality. The DTI's Electronic Design Programme (2002a) notes that the traditional and widely practiced approach separates the NPD process into certain steps (see figure 2.8), and each step is carried out in sequence. Moreover, the NPD process can be described as an iteration process, as there is a facility to check back and modify the design at each step. For example, Monds (1984) observes *'in electronics, design means detail.'* The author also suggests that the NPD process involves an entrepreneur, a project manager, a design engineer, a production engineer, a marketer, a technological gatekeeper, and a controller of resources. Nevertheless, all these disciplines can be grouped into three functions: marketing, design and technical (Cooper, Prendiville and Jones, 1995). For instance, Heskett (1984) describes that Philips' NPD process involves three main disciplines:

industrial design, marketing and development production (see figure 2.9).

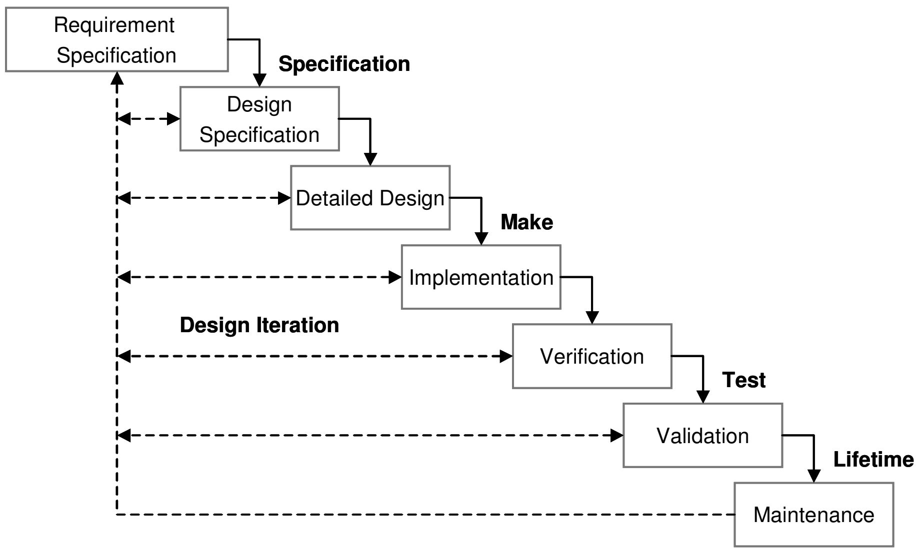

Figure 2.8: Traditional NPD Process (DTI's Electronic Design Programme, 2002a)

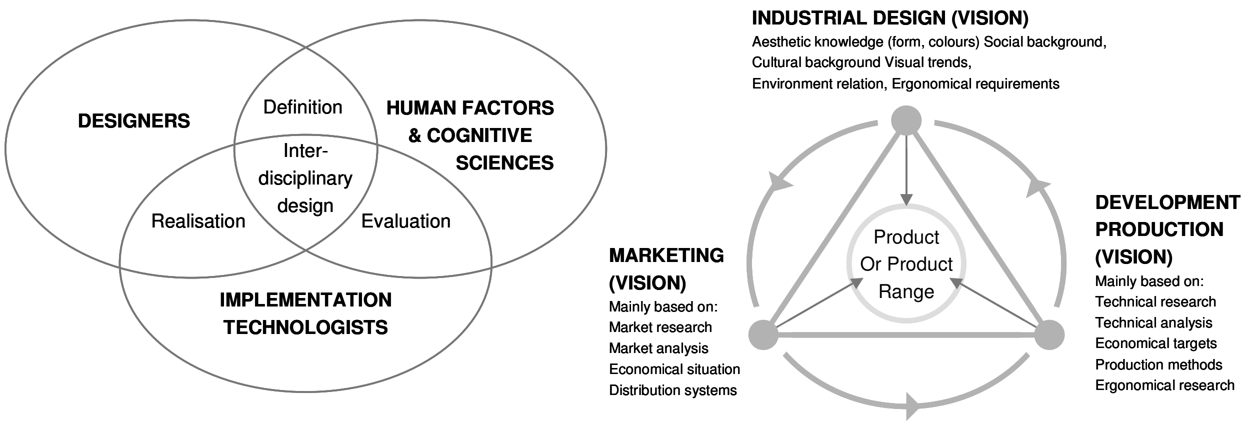

Figure 2.9: Model on left-hand side - Xerox's interdisciplinary team (Wynn, 2002)

Model on right-hand side - Philips' model of design function (Heskett, 1984)

Monds (1984) proposes a basic NPD process including four phases: 1) concept and definition, 2) feasibility study and the business proposal, 3) design and engineering, and 4) transition to production (see figure 2.10). In this NPD model, the author emphasises the importance of specification and feasibility study. It can be seen that Monds's idea supports the statement made earlier that specification and testing are the most important activities in the NPD process of the consumer electronic products.

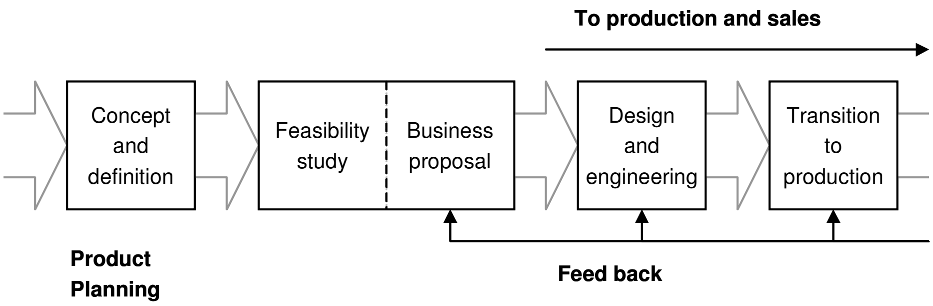

Figure 2.10: Project phase sequence (Monds, 1984)

To demonstrate practical and theoretical models employed in this field, four examples of NPD process are chosen (see table 2.2). The samples are selected based on the richness of the information in terms of conceptual model, development team and the NPD process. Two examples are selected from private companies and another two examples are chosen from academic research. Since each example also describes the model diagrammatically, the comparison between different approaches can be conducted (see figure 2.12). Three conceptual models are added in order to increase the richness of the comparison process. These models are 1) an adaptation of DTI's Design Flow employed by Tunstall Group PLC, 2) the schematic model of NPD process used by a manufacturer of electronic business equipment presented in the research done by Walsh *et al* (1992), and 3) Philips' NPD process called the Design Track (Heskett, 1989).

Table 2.2 Five examples of the NPD processes employed in the electronic industry

Source	Heskett (1989)	Engineering Product Design, Open University (1984)	Otto and Wood (2001) and Wynn (2002)	DIT Electronic Design Programme (2002)
Process	Philips NPD process – The Design Track	The Design Process Model	Xerox's NPD process	The Design Flow

Source	Heskett (1989)	Engineering Product Design, Open University (1984)	Otto and Wood (2001) and Wynn (2002)	DIT Electronic Design Programme (2002)
Phases	7 Stages (Stage 0-6)	8 Stages	7 Phases	5 Phases
Procedure	This model is rather similar to the design process than the NPD process. However, it provides an insight of how the electronic products are developed in practice. 0. **Project Request**: Ideas or requests for a new project were discussed at a design staff meeting. Next, the ideas or requests were translated into the design briefs. 1. **Briefing**: The design briefs were assigned to the group leaders of the design teams. Each leader was responsible to contact the technical and commercial staffs involved in the project. This phase was also called an 'investigation,' as it focused on preparing relevant information, e.g. product concept, available materials, specification, etc.	1. **Specification**: Firstly, a statement describing customer requirements and a broad outline of the functions is made. Next, this statement is translated into a specification, which explains all the functions in technical terms, such as power consumption, etc. 2. **Planning**: A plan of the entire project is made. It covers all the crucial decisions, such as which parts will be purchased from the suppliers, which parts will be manufactured, how to produce, and how to test the product. 3. **Hardware and Software Partitioning**: The decisions which functions should be performed by hardware or software are made. These are followed by the -	Otto and Wood (2001) note that Xerox's NPD process is closely related to the generic model. Nevertheless, the structure is slightly different due to the different emphases. According to these researchers, Xerox's NPD process focuses on reducing time to market. The term 'system' is used to describe Xerox's process, as its products are complex and regarded as platform product. 1. **Market and Product Strategy Vision**: A concept for a product family or platform including how many products will be embraced, the key technology, etc, is developed. The vision and strategy are created by the senior management as a part of the yearly -	1. **Concept Definition Phase**: This stage identifies the customer needs. Thus, the output is a *'user requirement specification,'* which will form a basis for all the subsequent engineering design. 2. **Analysis Phase**: The user requirement specification is converted into a *system specification* by evaluating the requirements and then partitioning the required functions into a set of smaller ones. This process is carried out in a 'top-down' manner. 3. **Design Implementation and Verification, Validation and Test (VVT):** This stage includes two main activities: 1) design implementation, and 2) VVT. The design implementation -

Source	Heskett (1989)	Engineering Product Design, Open University (1984)	Otto and Wood (2001) and Wynn (2002)	DIT Electronic Design Programme (2002)
Procedure	2-3. **Creating and Designing**: After the brief was completed, the creating and designing stage took place. Although, the communication and teamwork were needed, the author stressed that design was an individual contribution. 4. **Presenting**: This stage was the first screening. The pre-selection was held to assess the initial ideas presented in the form of sketches, models, etc. The modification took place after the decisions were made at the design staff meeting. The second selection was held to assess the final models. At the end of this stage, the design was approved by the Product Division and ready for production. 5. **Drawing**: The final drawings must be completed based -	refinement of the description of all tasks and interfaces between hardware and software. 4. **Circuit and Software Design**: This is an extension of the previous stage. The aim is to define all technical parts as clear as possible. 5. **Component Selection and Coding**: The details of the major hardware and software are completed. Decisions about the hardware choices are made, as well as the coding or a final translation of the required software is accomplished. 6. **Prototype and Test**: The prototype is made and tested. 7. **Manufacture and Test**: The product is produced using the final production tools and tested. Production is planned to gain the best performance. 8. **Service**: After-sale	corporate planning. 2. **Define Product Platform**: The senior management creates a strategic plan for a particular product in the family called 'market attack plan', and defines a market opportunity for it. 3. **Define Product and Deliver Technology**: The products are created within the context of the platform which includes print engine, user interface, paper delivery system, etc. 4. **Product Design**: Industrial Design Human Factor team is responsible for the design tasks. They employ many design tools and the inter-disciplinary approach to create the designs. 5. **Demonstrate Product**: Many forms of presentation are used to present the designs, for example, prototype. 6. **Deliver Product**:	comprises of two parts: hardware and software. Hardware implementation is centred on the Bill of Material (BoM) which is the process that converts system specification into a list of components. These components are created and assembled due to the required functions. (This process is carried out in the 'bottom-up' manner.) The verification is used to check the system specification, whilst the validation is used to check the user specification. In fact, the verification, validation and test are required at every stage of the process. 4. **Initial Manufacturing**: The BoM continues to ensure that all parts and components are available and are as cost-effective as possible. VVT also -

Source	Heskett (1989)	Engineering Product Design, Open University (1984)	Otto and Wood (2001) and Wynn (2002)	DIT Electronic Design Programme (2002)
Procedure	on the 'in-house style manual,' which was a basis for drafting to ensure consistency of Philips's designs. 6. **Follow-up**: This stage required very little input from the designers, since most works focused on the commercialisation.	- service is planned. (In conceptual model, the authors group and label stage 2-4 as concept design. Stage 5-6 are also grouped and labelled as detail design. Stage 7 is named manufacture and stage 8 is called sales and usage.)	Wynn (2002) states that stage 5-6 can be grouped and labelled as 'implementation', since they convert designs into products ready to be sold. 7. **Delight the Customer**: The main focus of this stage is selling the products.	continues to ensure that the designs, manufacturing tools and materials are ready for the volume manufacturing. 5. **Volume Manufacturing:** The products are produced and launched.

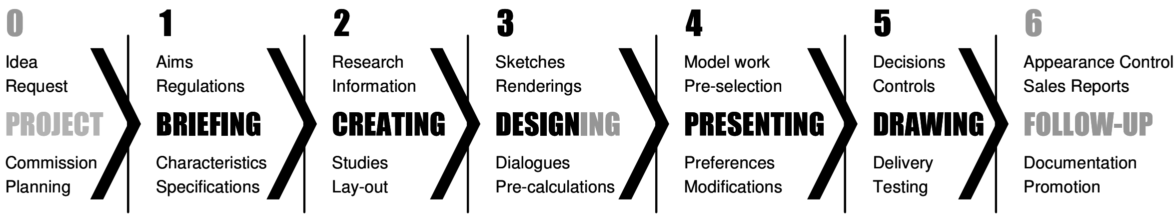

Figure 2.11: Philips' NPD process – the Design Track (Heskett, 1989)

According to the comparison, all conceptual models can be fitted in the DTI's model comprising of five stages: 1) definition of consumer requirements, 2) analysis and specification, 3) design and implementation, 4) test and preparation for manufacturing, and 5) volume manufacture and commercialisation. The structure of the electronic product NPD model is similar to those of apparel products. Nevertheless, while the apparel NPD process concentrates on sampling, selecting and modifying, the electronic product NPD process focuses on partitioning functions and verifying subsystems that make up whole products. Although all conceptual models are presented in a box diagram structure, one of the models, Tunstall's Design Flow, is able to illustrate the context of the NPD process, which involves partitioning required functions into smaller subsystems.

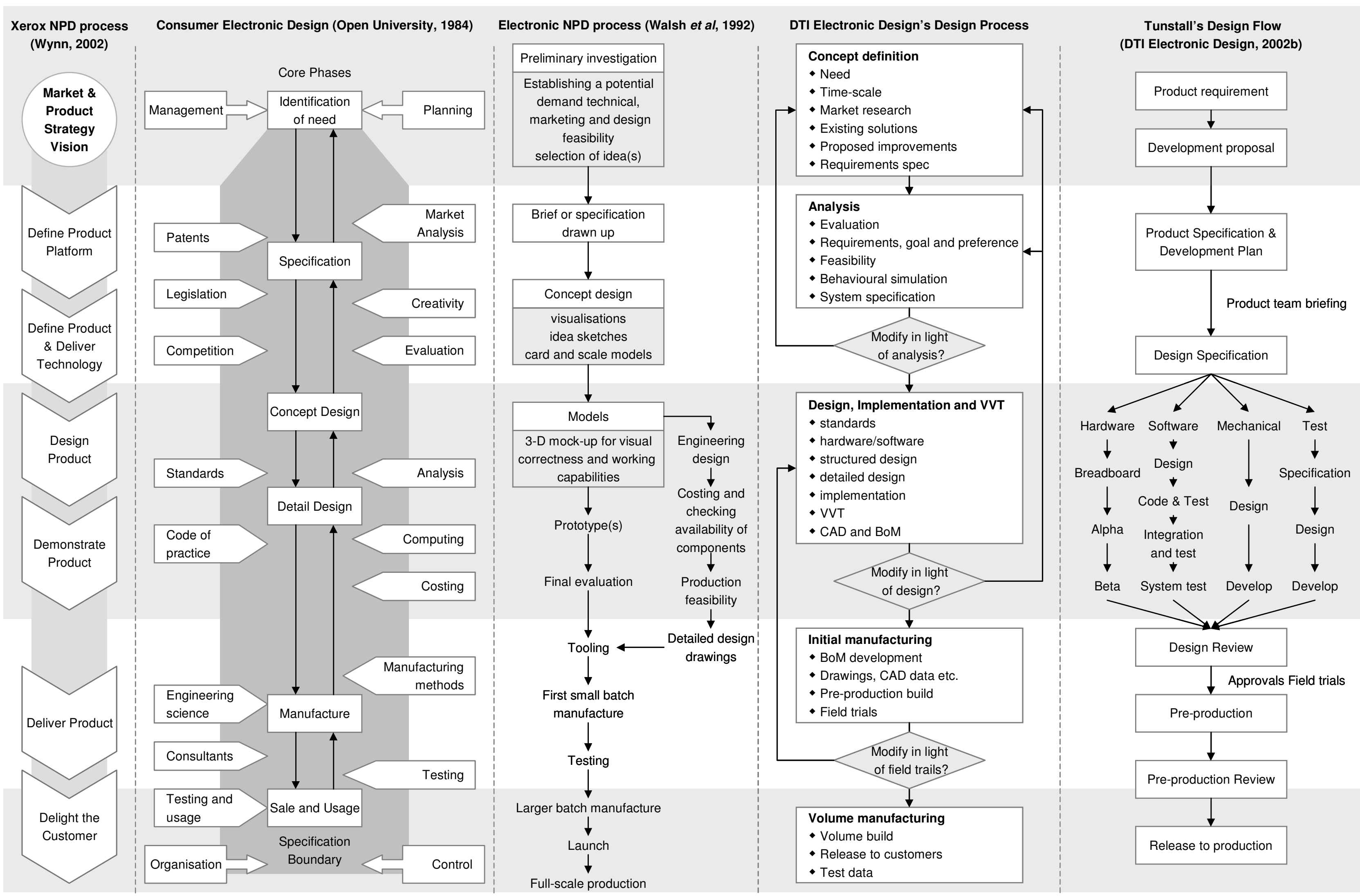

Figure 2.12: Comparison of the NPD models in consumer electronic industry

The ability to present this specific context lies in interpretation and translation skills that convert a verbal description into a visual form. However, another key activity, testing, is not visually presented in any conceptual model. Despite being described and stressed about its importance by many authors, none of the unique characteristics of the product platform are visually presented in the conceptual models. Based on the comparisons between both electronic and apparel NPD processes, it can be assumed that the product context, although having a strong influence on the NPD process, is not addressed clearly in any conceptual models. Furthermore, even though some NPD models start to incorporate the product context, the special characteristics are not totally addressed. Therefore, it is difficult to distinguish the NPD models employed in the different sectors from the structure. In addition, most NPD models rarely explain the responsibilities of each member, and the relationships of all participants as well as the key activities.

2.2.3. Strategic Approaches and NPD Models

The study of the NPD process in the high technology sector conducted by Cooper, Prendiville and Jones (1995) reveals that emphasis has been placed on optimising the effectiveness and reducing the time to market. As a result, concurrent engineering and interdisciplinary team are highly recommended as the most successful methods to achieve shorter and more effective product development. Recently, strategic approaches such as flexible NPD process, multidisciplinary team and customer involvement are considered the key trends (Herbruck and Umbach, 1997; Vogel, Cagan and Mather, 1997). For example, Philips Design developed a philosophy that has been embedded into every Philips's product called 'High Design', which concentrates on creating a 'harmonious relationship' between the user, products and the environment (Marzano, 2000a; Boult, 2002). Philips Design begins every project with a 'Strategic Future' methodology, which involves research on emerging lifestyle and technology, and then translates the final data into several future scenarios and opportunities for a new product and service. To ensure human-focus outcomes, Philips developed a multidisciplinary and multicultural team including experts from socio-cultural fields (e.g. sociologists, anthropologists and psychologists), designers, scientists, engineers, technologists and marketers.

Corporate strategy and culture play an important role in product development (Hertenstein and Platt, 1997). For instance, Sony's principles are *'doing what has never been done before'* and to *'always lead; never follow.'* Instead of doing consumer research, Sony's design teams start their projects by investigating new technologies and new opportunities. Moreover, Sony's designers are very proactive and often start the NPD process. Kunkel (1999) describes that several times a year, Sony designers present new concepts and product ideas to the senior management. If the ideas are accepted, the designers will work together with the product planners who analyse the designs, establish a price point, assess selling potential, and then report back to the designers to incorporate the new data into the concepts. If the designs are able to pass the second screening, the business model will be produced. Finally, the designs will be developed into production-ready concepts and tested to check whether they are feasible and can be manufactured in volume.

Similar to Sony, Samsung's corporate strategic approach influences its NPD process. Samsung Electronics' strategic objective was to transform itself from an OEM (Original Equipment Manufacturer) into an innovative, first-class product leader (Hardy, Chung, and So, 2000). Therefore, the company aims to develop products that present Samsung Electronics brand as innovative, approachable and of a high quality. To achieve this, interdisciplinary teams are created. In addition, the design and development concentrate on idea exploration. These exploratory ideas are routinely presented to the senior management to influence product development and envision new market opportunities. Samsung continues to search for new ideas and explore emerging areas, such as invisible communication and digital convergence (An, Delaney, Hardy and McFarland, 2003). In this case, invisible communication refers to an automatic data transfer between devices (e.g. PDA updates address book daily by connecting to the PC) and digital convergence is to an integration of several separate devices (e.g. laptop and home entertainment system).

It can be assumed that the multidisciplinary approach is widely adopted in the electronic industry. Moreover, the true benefits of the multidisciplinary approaches are starting to be utilised, as many companies use the multidisciplinary approach not only to reduce the time to market, but also to explore new ideas and opportunities that the teams can bring. In common with the apparel industry, despite a close relationship between strategic approaches and the NPD process, there is no evidence that strategic thinking is visually presented in the conceptual models or leads to the different structure of the diagrams represented the NPD processes (see figure 2.12). Most conceptual models are similar to generic models (see figure 1.8 and 1.9), and those of apparel product (see figure 2.6).

2.3 Smart Clothing NPD Process in Practice

Since the product context, development teams and key problems of Smart Clothing is already described in the first chapter, this part will address only two issues: 1) the NPD process in Smart Clothing projects, and 2) a comparison between the NPD models.

2.3.1. NPD Process in Smart Clothing Projects

Most Smart Clothing developments to date are experimental projects conducted by academic institutions or research centres within private companies or governmental organisations. As a result, they seldom include manufacturing and commercialisation. To demonstrate the practical processes employed in this field, four examples are chosen (see table 2.3). These examples are selected based on the richness of information in terms of conceptual models, development teams and descriptions of the NPD process. Besides, these examples are chosen from both academic research and collaboration projects.

Although most examples are experimental projects conducted by one researcher, the collaboration project (example no. 2) is able to illustrate the complexity of the NPD process in the Smart Clothing field, since it involves many different disciplines. Mattila (2001), the project manager, describes *'for a cross-scientific approach, a network of four university departments and four industrial companies were formed. The Institute of Electronics and the Institute of Textile from Tampere University of Technology, the Institute of Industrial Arts and the Institute of Textile Design from University of Lapland, the snowmobile suit manufacturer Reima Tutta Oy, compass and navigating systems producer Suunto Oyi, heart rate monitor producer Polar-Electro Oy, and Dupont Advance Fibre Systems were the participants. In addition, Siemens and Nokia Mobile Phones assisted with GSM (global system for mobile communication) communications.'* Figure 2.13 demonstrates the relationship of all the key elements in this collaboration.

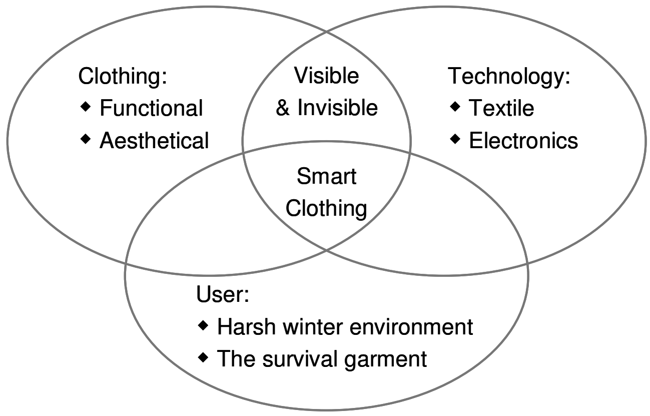

Figure 2.13: Relationship between clothing, technology and user (Rantanen, *et al*, 2000)

Example no. 4 is different from the others due to its approach. In this case, Smart garments were not regarded as an outcome, but as a part of the experiment. This was because the researcher aimed to develop a new tool for fashion designers to successfully incorporate computational technologies into clothes. These technologies were embedded to enrich user interaction, modes of expression and aesthetics, not to provide practical functions, such as wireless communication. Several garments were developed to explore new ideas, and identify potential problems that fashion designers might encounter.

Table 2.3: Four examples of the NPD processes employed in the Smart Clothing area

Source	Co (2000)	Rantanen *et al* (2000)	Dunne, Ashdown and McDonald (2002)	Galbraith (2003)
Project Title	Computation and Technology as Expressive Elements of Fashion	Cyberia Project	Smart Jacket (for a young sport practitioner living in a cold climate)	Embedded Systems for Computational Garment Design
Application	Wearable computer embedded in prototype garments	Survival prototype garment for the arctic environment	Monitoring and self-heating prototype garment	Computational garment that enriches user interactions

Source	Co (2000)	Rantanen *et al* (2000)	Dunne, Ashdown and McDonald (2002)	Galbraith (2003)
Developers	MSc Program of Media Arts and Sciences, MIT	University of Lapland, Tampere University of Technology, etc	Department of Textile and Apparel, Cornell University	MSc Program of Media Arts and Sciences, MIT
Phases	5 Stages	8 Stages	9 Stages	3 Stages
Procedure	This study aimed to introduce computing technologies as new expressive elements in clothing design. 1. **Research**: The background research including fashion history, psychology, garment construction, fashion elements, etc, was conducted. 2. **Analysis**: 'Design Space' parameters presented in polar scales with two opposing ends (e.g. static and dynamic) were developed as a basis for design and evaluation. 3. **Design and implementation**: This stage was carried out in the 'iterative' and 'trial and error' manners. Firstly, the researcher developed a design -	1. **Identification of user requirement**: The goal was to create a garment for an experienced snowmobile user to survive in harsh winter environment. They interviewed several potential users and identified the key problems. 2. **Identification of clothing design requirement**: The diagram showing the relationship between three key issues: clothing, technology and user (see figure 2.13) was created. 3. **Identification of system requirement**: Basic requirements of the electronic parts are identified. 4. **Specification**: Data from stage 1-3 was combined to -	1. **Identification of user**: This includes all information that the system needs to address, e.g. lifestyle, habitat, situation, etc. 2. **Identification of user needs**: User needs and problems are identified. 3. **Identification of architectural requirements**: The architectural requirements or the factors that limit a scope of design solutions is defined. 4. **Preliminary aesthetic design**: The data from stages 1-3 is combined to produce a reference. Preliminary aesthetic choices are created. 5. **Identification design decisions**: The functions are broken down into -	1. **Background research**: The researcher studied five areas: wearable computing, fuzzy logic, computational literacy, technology, and computational garment design. 2. **Preliminary work**: In this stage, several handbags and garments as well as many hardware and software were developed. Each design aimed to explore different functions and design dimension, e.g. form colours, shape, etc. For example, one bag was designed to inform its user about important events in a meaningful way. Its ornaments slowly move to form a new pattern. The closer -

Source	Co (2000)	Rantanen *et al* (2000)	Dunne, Ashdown and McDonald (2002)	Galbraith (2003)
Procedure	and prototype. Next, the first outcome was examined in order to identify problems and a new approach to improve the design. Then, a new design and prototype were created according to the analysis. This process was repeated several times until the researcher was satisfied with the design outcome. 4. **Evaluation**: At the end of the research, all designs were analysed, compared and evaluated using the design space parameters that were developed earlier. 5. **Conclusion**: Finally, a conclusion and recommendation about the future direction were drawn.	create a general description, such as functions, materials, electrical and non-electrical features. 5. **Design**: The garment comprised of four parts: jacket, encasing, supporting vast and underwear. Clothing design aimed to reduce the inconvenience caused by hard electrical parts and maintain an ordinary look. Textiles were selected due to the technical properties. 6. **Test**: Washing and performance tests (indoor and outdoor) were conducted. 7. **Conclusion**: A conclusion, recommendation, and future direction were deduced.	sub-systems until they become a list of individual design decision. Solutions are created for each design decision. 6. **Selection of alternatives**: Alternatives are evaluated against the constraints. The ones that pass the screen are listed for each design decision. 7. **Identification of evaluation criteria**: Criteria for each individual decision are created to assess the alternatives. 8. **Evaluation of Alternatives**: Usable alternatives are picked and combined. 9. **Selection of solution**: The final decisions are made to fulfil all the needs.	the events, the faster the speed. Thus, the user is reminded in an unobtrusive way. Moreover, one dress use flash lighting to tell the time. Hence, every design did not relate to the others. 3. **Analysis**: Through the series of designs, the researcher could identify the problems and familiarise with the design process. 4. **Development**: According to the analysis, a new web-based software called Zuf was developed and improved. 5. **Evaluation**: The tool was evaluated by the design students, and then the final conclusion about the application was drawn.

The comparison of the diagrams cannot be done, since only one example has a conceptual model in the form of a diagram (see figure 2.14). Examples no. 2 and 3 are very similar, as they took a functional approach and similar targets. Both NPD processes began with the *'user requirement identification'* that was then converted into the *'system requirement.'* As the system requirements were complicated, they were partitioned into sub-categories. The partitioning process continued until each sub-category was small enough to work on. In other words, each sub-category or subsystem contains only one hardware or software. As a result, each part was created and tested separately before merging at the end of the process.

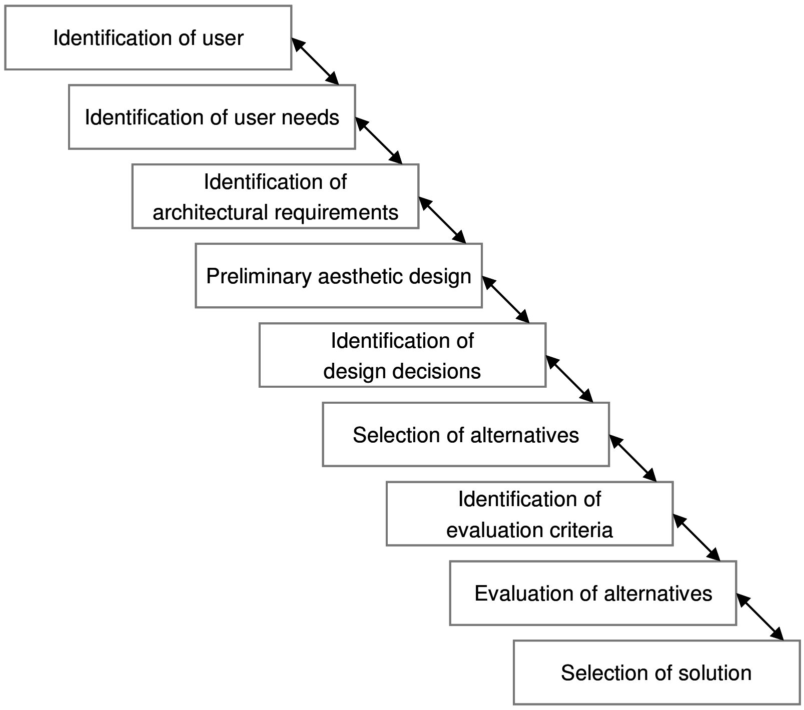

Figure 2.14: Design Process employed in example no. 3 is based on the principle of system engineering (Dunne, Ashdown and McDonald, 2002)

Although examples no. 2 and 3 took wearability and social acceptance into consideration (see figure 2.15), their NPD processes did not express much about fashion design. Examples no. 1 and 4 are relatively different because of their experimental approach. Despite the background research on fashion design and the aesthetic focus, the outcomes were far from a standard fashion design due to the limited fashion design skill (see figure 2.16). This illustrates the pressing need for fashion design input in the Smart Clothing development process. Nevertheless, these two examples demonstrate that technologies can be embedded and implemented differently from the mainstream projects.

Co's Wearable Computer (2000) | Cyberia Project (2000) | Dunne, Ashdown and McDonald's Smart Jacket (2002) | Galbraith's Computational Garment (2003)

Figure 2.15: The outputs of the four examples selected

Co's Puddlejumper (2000) | Galbraith's Twirl (2003) | Galbraith's Iris (2003) | Galbraith's Peppermint (2003)

Figure 2.16: Computational garments and accessories developed by the engineers

2.3.2. Comparison Between NPD Models

In this part, a comparison between NPD models employed in Smart Clothing development and the established ones in the apparel and the electronic industries is conducted. In this way, similarities and differences between three types of NPD models can be identified. Moreover, a specific context of Smart Clothing development can be recognised.

Comparison: Based on the descriptions of the NPD processes (see table 2.1 - 2.3), there are more similarities between Smart Clothing development process and electronic product development process than those of apparel industry. For instance, both Smart Clothing and electronic product development processes take a functional approach. Besides, their selling points are advanced technologies and features. In addition, the structures of NPD processes are almost identical. Both processes involve 1) conducting consumer research, 2) analysing and identifying required functions, 3) creating system specification, 4) partitioning the overall system into subsystems in the *'top-down'* manner, 5) designing and testing each subsystem according to the user and system specifications, 6) assembling all components in the *'bottom-up'* manner, and 7) testing the overall performance. This situation perhaps results from a strong influence of the electronic industry. Therefore, the unique characteristics of the apparel product development, such as fashion calendar, fashion trends, collection plan and retailer's direct involvement, are not taken into consideration. However, the Smart Clothing developers have taken the fashion design elements, such as wearability, comfort, appearance, and protection into consideration.

Product Context: Due to its functional approach, Smart Clothing can be categorised as 'functional clothing,' which is the same as industrial workwear, performance sportswear, etc. Functional clothing design is rather similar to product design (McCann, 2003). The only difference is that the required functions are fulfilled by the use of technical textiles and pattern cutting. In other words, a functional garment is a product that is made of textile materials. As a result, it can be assumed that Smart Clothing is a new type of **electronic product, which is designed with fashion design in mind and made with textile materials**. Consequently, functional clothing design, namely performance sportswear design, will be investigated further in primary research. However, there is another way to view Smart Clothing. For example, the Philips design team describes its goal as '*Philips technology in every shirt and skirt*' (Philips, 2000, p 5). Besides, the fashion designer within Philips's Wearable Electronic project envisions a future in which *'wearable electronic designers will apply the functionality of the phone just as in normal fashion they would choose buttons or zippers'* (Philips, 2000, p 9). The ideas that electronic components become parts of a garment, and electronic features are regarded as a new function of a garment, indicates that Smart Clothing can be viewed as an **apparel product designed with product design in mind and built around electronic technologies**. Whether it is fashion context that embeds into electronic products or electronic product context that embeds into apparel products, it is clear that Smart Clothing is about placing new context into an established field and extending the existing creative boundaries. As a result, product designers must incorporate fashion thinking in their design procedures, and fashion designers must integrate product thinking into their design process. The integrated outcome is possibly achieved through this way.

Apparently, all participants require a clear description of the product they have to work on. Despite the close relationship between product context and the NPD process, they are often presented separately. Furthermore, the strategic approaches are often excluded from the NPD conceptual models. It is important to incorporate all these key aspects into the NPD model in order to provide the developers a holistic view of the process. In addition, a new culture, embedding new thinking and extending the creative boundaries, must be addressed. In order to discover how to incorporate these issues successfully, the conceptual models of the NPD process that are able to present specific contexts are sourced out, compared, and analysed (see figure 2.17). For example, model no. 2 portrays the rapid development process, which is a unique characteristic of the software industry. In this case, each activity is given a strict schedule. Within the limited time, every programmer evolves features as much as possible and rapidly passes their work to the next stage. There is no time for debugging and stabilisation until the last stage.

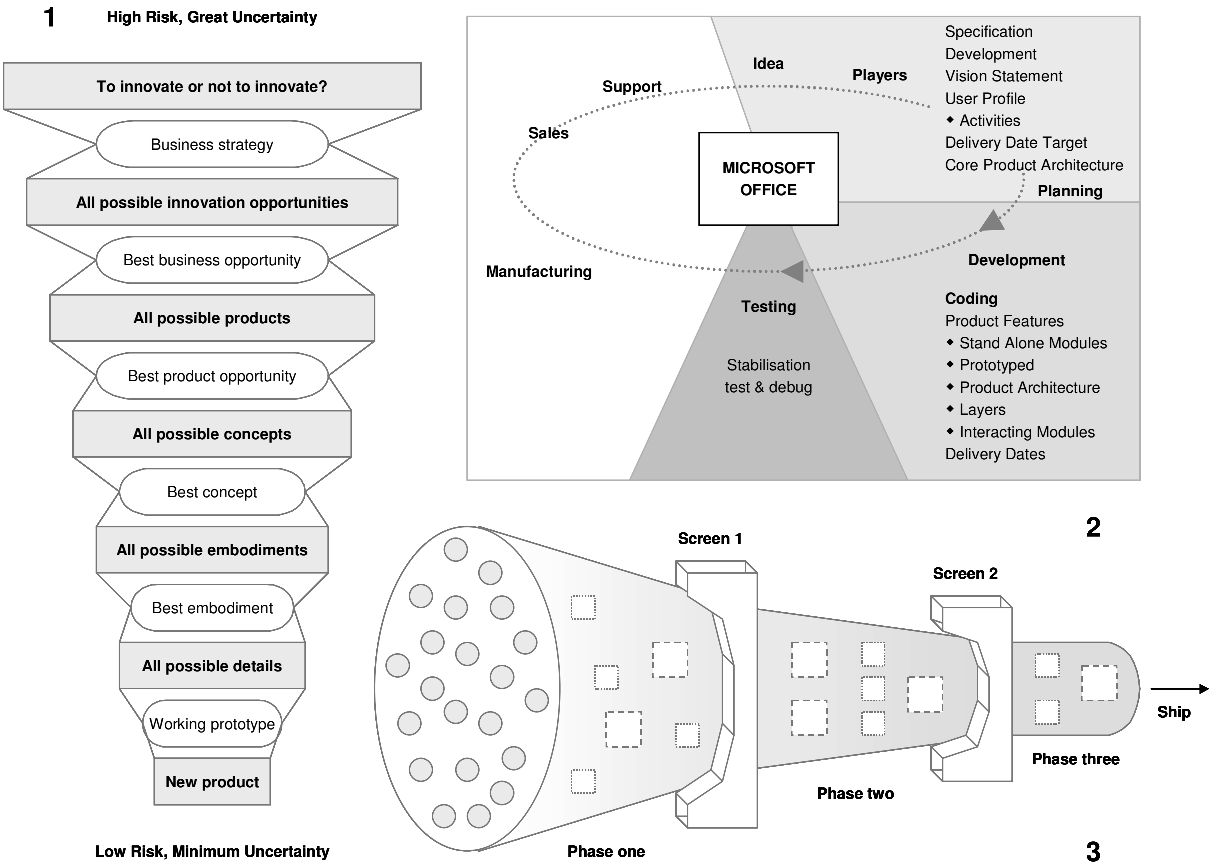

Figure 2.17: Model no.1 is Risk Management Funnel (Baxter, 1995)

Model no. 2 is Microsoft NPD process (Otto and Wood, 2001)

Model no. 3 is Risk Management Funnel (Wheelwright and Clark, 1992)

The analysis reveals that these conceptual frameworks share the same characteristics, and their visual diagrams echo their verbal descriptions. For instance, Baxter's Risk Management Funnel model concentrates on reducing risk and convergent thinking. Its specific focus is clearly explained verbally and visually. This supports the assumption made earlier that the ability to present product context, strategic approach and design culture lies in translation skill, which converts the verbal description into a visual one.

2.4 Conclusion

This literature review aims to fulfil two objectives. Firstly, it investigates and evaluates the established NPD models in three key areas. Secondly, it contrasts the similarities and differences between three types of NPD processes in order to identify the specific context of Smart Clothing. The literature review reveals that the NPD processes employed different sectors are very different. For example, the electronic product NPD process concentrates on: 1) developing system specification based on user requirements and available technologies, 2) partitioning required functions into subsystems, and 3) testing the outcomes to ensure the reliability. By contrast, the apparel NPD process focuses on the design and selection stages, since the retailers have a direct involvement and the co-ordination of the collection available in stores is very important. Moreover, the design and development are very strict because of the seasonal calendar and fashion trends.

The differences between the apparel product NPD process and the electronic product NPD process result from different strategic approaches and unique characteristics of the product contexts. However, the NPD conceptual models of different fields are very similar in terms of structure and number of phases. For example, most models are presented in blocked diagram format. Therefore, these models look almost identical (see figure 2.6 and 2.12). Moreover, both types of model comprise of five to six phases that are the same as a generic NPD model (see figure 1.8 and 1.9). These phases are 1) research and analysis, 2) product specification and concept design, 3) design and implementation or sampling, 4) testing or selecting, 5) manufacturing, and 6) selling or retailing. The comparison of NPD processes employed in three different areas reveals that

Smart Clothing development is more similar to electronic product development than those of apparel industry due to its functional approach. This leads to the assumption that Smart Clothing can be categorised as 'functional clothing' where practicality is the main concern. Practical functions in this case include not only electronic features, but also basic functions of clothing, such as wearablity, comfort, appearance and so on.

As a result, the product context and NPD process of Smart Clothing are similar to those of product design. It can be assumed that Smart Clothing is an electronic product developed with fashion design in mind and made with textile materials. Nevertheless, this assumption can be reversed, as many ideas propose that electronic features should add value to garments. Besides, miniaturisation trends make it possible for electronic components to become part of clothing. Hence, Smart Clothing can be viewed as a garment developed with product design in mind and built around electronic technologies.

There are opportunities and possibilities for both directions. Whichever direction is taken, it is clear that all participants need to incorporate a new culture – embedding a new way of thinking and extending their existing creative boundaries. For instance, fashion designers acknowledge a concern of product design (e.g. usability, and reliability) into their design process. A clear description of product context and strategic approach visually addressed in the NPD process is required. The analysis of the NPD conceptual models reveals that the ability to present these issues lies in translation skill that turns verbal explanation into visual description. Therefore, this translation skill will be explored further in the model formulation process. Moreover, how the Smart Clothing developers currently work, their cultures and their development teams will be investigated in the primary research.