Chapter 1 Introduction

This research aims to investigate and develop a conceptual model of the New Product Development (NPD) process for the Smart Clothing field. Furthermore, a strategic approach for the Smart Clothing applications is explored and recommended to the Smart Clothing developers. In this chapter, two key subject areas of the research, namely overview of Smart Clothing development, and existing theories and conceptual models of the NPD process, are introduced. Moreover, the purpose of the research, including a problem statement and hypotheses, research scope, aim and objectives, research contributions, and structure of the thesis are explained hereafter.

1.1 Overview of Smart Clothing Development

This section comprises of six parts: 1) definition and origin of Smart Clothing, 2) participants in Smart Clothing development, 3) drivers of Smart Clothing development, 4) evolution and future trends of Smart Clothing, 5) current situation, and 6) problems of Smart Clothing development process. Finally, the section is concluded by a summary.

1.1.1 Definition and Origin of Smart Clothing

'Smart Clothing' is defined as all clothes made with intelligent textiles and/or provide intelligent functions (Mattila, Mäkinen, and Talvenmaa, 2001). Experts agree that 'intelligent' or 'smart' means an ability to sense stimuli from the environment, and then react or adapt behaviour to the circumstances (Baurley, 2003). According to the manner of reaction, smart textiles can be categorised into three groups: passive smart, active smart and very smart (Zhang and Tao, 2001; Van Langenhove and Hertleer, 2003). Passive smart textiles can only sense stimuli from the environment; active smart textiles can sense and react accordingly; very smart textiles can sense, react and adapt themselves to the environmental conditions. In most cases, Smart Clothes are designed to sense user requirements and environmental contexts, and provide appropriate service at the right time and place accordingly with minimum effort required from the user (Marzano, 2000). Nonetheless, in this research, Smart Clothing only refers to garments and fashion accessories that contain intelligent functions based on electronic technologies.

The application was first developed in the Wearable Computing field. The idea of attaching small computer systems to garments was first created in the late 1970s by a group of physicists and PhD graduates to assist them in playing roulette (Mann, 1996). Because of the product scenario (casino environment), the systems had to be operated in an unobtrusive manner. The idea of having a process that can be operated without much conscious thought or effort or while doing something else triggered the need for a new conceptual framework for computing. As a result, Smart Clothing was perceived as an alternative way to develop wearable electronics or computing devices. Therefore, user requirements, wearablity, and design were neglected until recently. Experts from the fashion field stress that the truly ‘smart’ applications should encompass a full integration of technology and consumer requirements into clothing (Lee and Stead, 2001).

1.1.2 Participants in Smart Clothing Development

The concept of Smart Clothing became widespread in a short period of time and drew great attention from many organisations in different fields. Currently, the participants and applications are no longer restricted to the electronics and computing field. A number of research studies have been carried out by many academic institutes, e.g. MIT Media Lab, Royal College of Art, Central Saint Martins College of Art & Design, Brunel University, University of Bristol, University of Ghent, Cornell University and University of Lapland. Governmental organisation initiatives, particularly in the military field, such as NASA in the USA and Ministry of Defence in the UK, are considered as the main reasons for the fast development of intelligent textiles and Smart Clothing (Design Council, 2001).

Moreover, many consumer electronic companies conduct their own research or carry out collaborative projects with academic institutes or sponsor external laboratories and/or design consultancies, such as Starlab, Frog Design and IDEO. Significantly, most of these organisations are multinational companies, e.g. Nokia, Philips, Motorola, Samsung and Pioneer Corporation; thus, it can be deduced that the leading companies perceive Smart Clothing as part of the next generation of electronic devices. Experts in the electronics field suggest that Smart Clothing will have a great impact in the near future (Mehrgardt, 2002). In addition, a number of apparel companies, especially in winter-sportswear field, namely The North Face, Burton Snowboarding, Rosner and Reima-Tutta, have started conducting research in collaboration with academic institutes or electronic companies. The increase in number of collaborations and multi-disciplinary teams highlights the need for a strategic approach and a NPD process that optimises the inputs from all the parties.

1.1.3 Drivers behind Smart Clothing Development

According to the analysis of the current projects in the Smart Clothing field, it can be summarised that there are four driving forces behind the intensive development:

1. The first driver is an attempt to empower people with electronic devices so that they have access to the required functions wherever and whenever (Marzano, 2000b).
2. To achieve a highest level of mobility, electronic devices are rapidly reducing in size. As a result, they can be attached to clothes or become fashion accessories. But by contrast, their functions and features continually increase. The conflict between size and function leads to difficulties in terms of use, as the functionality embedded in the devices is often complicated and inaccessible (Van Heerden, Mama and Eves, 2000).
3. The third driver is the need to solve usability problems. Integrating electronics into garments might be an appropriate solution, since it provides many benefits such as mobility and less complexity, due to a potentially bigger and/or better interface, which probably makes it easier to use (see Mikkonen *et al*, 2001; France Telecom, 2003).
4. The last driver is the advanced technological development in smart textiles and microelectronics. These new technologies bring a large number of possibilities and opportunities for new applications. Many applications are the results of experiments with the conductive properties of fabrics (Orth, Post and Cooper, 1998; Gould, 2003).

It is clear that none of the drivers comes from the textile or clothing area. Besides, the drivers mainly focus on solving technical problems and exploring potential opportunities of new technologies. As a result, it is difficult to incorporate fashion thinking and clothing techniques into the projects. Furthermore, the user requirements are not clearly addressed and expressed. Thus, the functions and added values of the Smart Clothes remain unclear.

1.1.4 Evolution and Future Trends of Smart Clothing

The literature review was conducted to identify the design evolution and trends in Smart

Clothing development. Information and images of the current research and development projects from different teams were collected and put on a timeline chronologically.

Figure 1.1: Diagram explaining evolution of the Smart Clothing development

Product scenarios of these projects were compared and analysed in order to discover the ideas and inspirations behind the developments. Moreover, they reveal each team's vision of the future and how they respond to new possibilities that Smart Clothing brings. The analytical results indicate that the design evolution can be divided into three periods:

1. In the first period, 1980s to 1997, the design approach was regarded as technology-driven, since most research and developments focused on Wearable Computing and applications of advanced technologies (see De Vaul, Schwartz and Pentland, 2001 for example). For instance, Randell (2001) predicted that integrating sensing and displaying technologies could bring a lot of opportunities to textile manufacturers. Thus, the researcher and his team developed 'CyberJacket', which integrated location sensors (GPS), displays, etc, to demonstrate the possibilities. Nevertheless, this prediction was based on the trends of miniaturisation of electronic devices not consumer requirements. Whether people carry electronic devices around means they want these devices to be part of their clothes and operate unobtrusively without the user being conscious of it is debatable. Furthermore, the inputs from fashion design and business were neglected. Hence, the products were more 'portable' rather than 'wearable' (see Forman, 2001; MIT Media Lab, 2002 for example), as Salmimaa (2001) at Nokia Research Centre commented *'you don't wear a device, you carry it.'*

Steve Mann's work 1980 | University of Bristol 1997 | MIT Media Lab 1997 | MIT's Fashion Show 15/10/1997

Figure 1.2: Examples of Smart Clothing applications from the first period

2. In the second period, 1998 to 2000, the awareness and involvement of the fashion and textile sector significantly rose. Consequently, the number of the collaborative projects between electronic and fashion fields rapidly increased, for example, the Cyberia project (Rantanen *et al*, 2000), Philips and Levi's ICD+ project (Philips Press Information, 2000), and the i-wear project (Starlab, 2001a). Moreover, experts in textile and clothing started to conduct their own research and development (Braddock and O'Mahony, 1998). For instance, the Haute Couture designer, Alexandra Fede, worked with Du Pont and Mitsubishi Materials Corporations to develop the collections incorporating advanced technologies. Most applications were garments with several hard electronic components, such as circuit board, hidden inside the linings. Each electronic part was connected via conductive textiles, which although they look and feel like normal fabric, they should not be directly exposed to harsh environments, e.g. heavy rain or strong sunlight. By attaching electronic modules into clothing separately, the size of interface or display was no longer restricted. Hence, the developers claimed that the applications provided electronic features in a more 'natural' manner. Although the applications became more wearable, most outcomes were still prototype garments, as the technologies were underdeveloped (Meoli and May-Plumlee, 2002; Schwirtz, 2002). Besides, product concepts did not match requirements of the mass market.

France Telecom 2000 | Charmed Technology Fashion Show 2000 | Starlab's i-wear 2001 | Clothing+ and Reima Tutta's Wearaphone 2001

Figure 1.3: Examples of Smart Clothing applications from the second period

3. In the third period, 2001 to 2004, the number of research studies and Smart Clothing applications available in the market increased dramatically e.g. The North Face's MET5™ jacket (Ward, 2001), Adidas's smart shoes (Momphard, 2004) and GapKid's sweatshirts with embedded FM radio (CNN, 2004). As multidisciplinary approach and user-centred design are widely adopted by most development teams, the development process became more complex. The boundary of Smart Clothing applications expanded into new areas, such as sportswear, protective clothes and workwear (see Bowie, 2000; Marculescu *et al*, 2003; Cummings, 2004; ETH Zurich Wearable Computer Lab, 2004). Dodson (2003) reports that Northwest Airlines in the US give their staff a wearable computer to reduce the time for the check-in. The latest applications utilise the properties of the conductive textiles further. For example, the North Face MET5™ jacket uses conductive fibre to heat up the garment. Moreover, sensory fabrics that can detect pressure and movement are widely adopted in healthcare or sportswear products.

Cornell University's Smart jacket 2002 | Pioneer Corporation's Media fashion 2002 | Nokia's Medallion 2004 | Klaus Steilmann Institut's Smartwear 2004

Figure 1.4: Examples of Smart Clothing applications from the third period

The evolution shows that the future of Smart Clothing development is going towards a multi-disciplinary approach and becoming more commercialised, and indicates the significant change in the development teams and process. For example, the current applications are developed for specific tasks such as health monitoring (see VivoMetrics's

Lifeshirt cited in Momphard, 2004), rather than to adhere to every day-to-day activity like the early applications did. As a result, the target users have become clearer.

Nevertheless, these products are unable to attract the mass market, since Smart Clothes are still about portability rather than electronics being fully integrated (Edwards, 2003). For instance, a researcher at Vodafone Group R&D comments *'we know people don't want to look odd. People don't want to carry a lot of kit around'*. Considering the few extra functions that Smart Clothes offers, the products are regarded as very expensive. For example, Ward (2001) describes The North Face's MET5: *'the jacket will retail in the UK at £380. Combined with relatively small scale production of the new material, uptake of the new garment is unlikely to be widespread.'* This situation has not only been caused by the unsolved technical problems, but also by a lack of a strategic approach and design direction, as the developers failed to recognise what function is desirable for the users.

1.1.5 Current Situation of Smart Clothing Development

Experts in the electronics, and textile/clothing fields note that Smart Clothing represents the convergence of both industries in the future. From the electronic industry's standpoint, the garment is an ideal interface medium between humans and electronic products due to its mobility, natural interaction, and advanced technologies in microelectronics and the smart textile field (Richard, 2003). The fashion industry views it as a good opportunity to incorporate new technologies, which helps it evolve (Stengg, 2001; Cummings, 2004). Based on the literature review, the current situation can be summarised:

1. Currently, the research and product developments mainly focus on four areas: healthcare, entertainment, sportswear and communication. Initially, the areas that drew

most attention were communication and entertainment (see Kaario, 2000 for example). Nevertheless, the interest in healthcare and sportswear is gradually rising.

2. According to the user centred approach and increasing input from the design and business, most development teams create product scenarios before developing the applications to ensure that the functions meet user requirements and the future lifestyle.
3. Due to its origin, technology-driven character and key drivers, the technical approach still has a strong influence. Thus, the developments emphasise heavily on unconscious-operating manner and context-aware applications (Accenture, 2002; O'Mahony, 2002). However, whether the unobtrusive operation will be valued by the users is debatable.
4. As the functionality is designed to be 'invisible' and embedded into everyday garments, the character of Smart Clothing applications becomes anonymous. As a result, it is difficult to differentiate the applications from the conventional clothes.
5. Influence from fashion design is continually increasing. There is evidence that the electronic industry must adapt itself to fashion (Ainamo and Pantzar, 2000; Philips, 2000; Starlab, 2001b; Taipei Times, 2001). At present, fashion designers only use their garment making skill to attach electronic components to the clothes. However, it is likely that fashion designers will have more design freedom in the future, as many hard components reduce in size and some are already replaced by smart fabrics (Infineon Technologies, 2002; SOFTswitch™, 2002; Design Council, 2004).
6. Although some applications have proved to be feasible and already available in the market, they are offered in limited numbers and focus on the niche market. Due to the large amount of investment, it can be seen that the target market must be extended in order to cover the development cost. The difference between investments and benefits suggests that the applications need to be more commercial and have added values.

Philips and Levi's ICD+ jacket 2000 | The North Face's Met5 jacket 2001 | Burton Snowboarding MD jacket 2002 | Infineon Technologies and Rosner's jacket 2004

Figure 1.5: Examples of Smart Clothing applications available in the market

1.1.6 Problems of Smart Clothing Development

Venture Development Corporation estimates that Smart Clothes and Wearable Computers will grow more than 50% each year through to 2006 and their shipment will reach 563 million dollars in 2006 (Broersma, 2002). Nevertheless, the true potential of Smart Clothing can only be reached if improvements are made in consumer-based products. At present, Smart Clothes are struggling to gain social acceptance because they fail to follow the norms of social interaction (Edward, 2003). The Rich Picture technique in the Soft System Methodology (Checkland and Scholes, 2001) was employed to identify the problem situation that prevents Smart Clothes from enter the mass market (see figure 1.6).

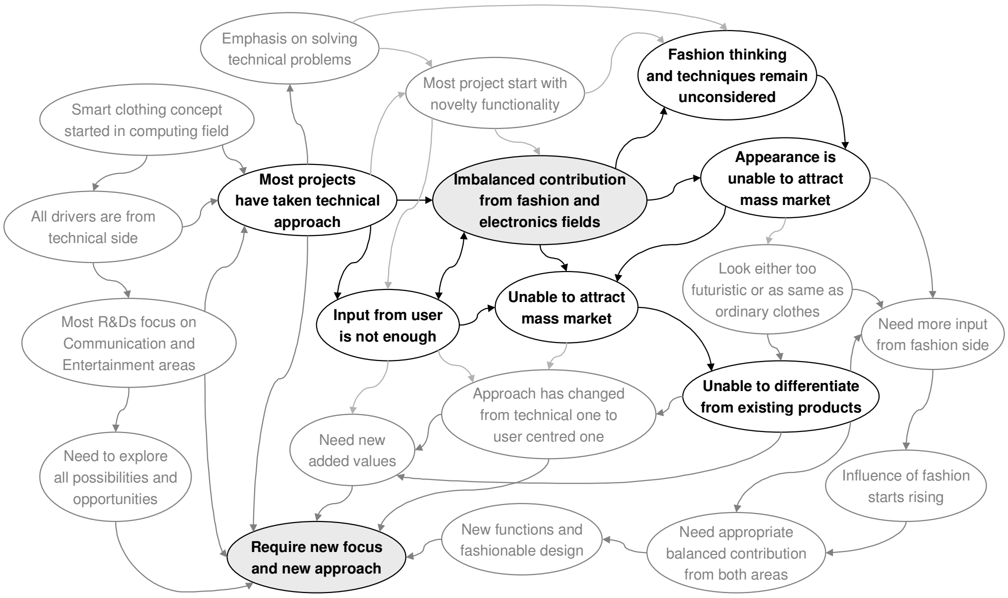

Figure 1.6: Diagram representing the key problems and relationships

Each problem was examined and linked to one another. In this way, the key problems in Smart Clothing development can be defined, and the key ones are discussed below:

1. The imbalanced contributions from electronic and clothing industries result in incompletely integrated applications. As the electronics field still dominates this area, the developments to date centred on the clothing industry are still uncommon. Besides, some projects do not take into consideration or integrate the special product development and processing techniques of the apparel sector (Mattila, Mäkinen and Talvenmaa, 2001). Moreover, the fashion industry has been slow to incorporate high technologies due to a lack of knowledge about new technologies and/or an absence of motivation to use such technologies (Co, 2000). Currently, only few clothing companies develop Smart Clothes. However, most apparel companies have adopted the technical approach rather than create an integrated approach themselves.
2. The unclear direction of the applications illustrates the lack of a strategic approach and added value. Without a strategic approach and added value, it is difficult for the applications to differentiate themselves from conventional clothing and existing electronic devices. As a result, they are unable to attract the mass market.
3. At present, the outcomes reflect the different approaches between fashion-lead and electronic-lead projects. The former pays attention to aesthetic exploration (see Brown, 2003), while the latter focuses on developing functions and attaching them to the garments. This situation results from the lack of an *'integrated approach'* to optimise the input from the different areas. Smart Clothing developers view applications as either electronics or fashion design but rarely as 'Smart Clothing,' they therefore try to make the applications fit into the conventional NPD process. Clothing and electronics are created separately and assembled together at the end of the process. Integration implies

that the developers require a new way of thinking and working.

Figure 1.7: Functional/technical approach VS fashion approach

To conclude, Smart Clothing development requires a new strategic approach and a new NPD process. Since fashion design, product design, and electronics design are established fields, it is difficult for the developers to adopt or switch to the others' methods. The cultural-barrier breakthrough is possibly the key challenge. At present, no NPD process is developed for such collaborative work. This new NPD model should encourage the development team to think differently and go beyond their current creative boundaries, as Smart Clothing is an entirely new type of product not only a combination of the two.

1.1.7 Summary of Smart Clothing Development

Smart Clothing, the convergence between electronics and apparel industry, and one of the most intensive research areas, has struggled to chase up its true potential, due to the imbalanced contributions from the electronics and fashion industries. Subsequently, the full integration has not been achieved. This is caused by the lack of a strategic approach and added values. Furthermore, the opposing design approaches of fashion and electronic industries need to be harmonised or reconciled. This situation indicates that a strategic approach as well as a NPD process that optimises all the contributions and addresses new values is required. The strategic approach should challenge the development teams to: 1) think and work differently in order to prevent the conflict between different approaches, and 2) go beyond their current creative boundaries to ensure the integrated outcomes.

1.2 Theories and Models of NPD Process

According to the aim of the research, the existing theories of the NPD process in relation to the strategic approach are examined. This research focuses on the big picture of the NPD process, such as conceptual models and structures of the NPD process, how a strategic approach can be addressed in the NPD process, how collaborative effort is described to all the participants involved, and the impact of the NPD process on the participants in practice. As a result, the details of each element comprised in the process are excluded. Moreover, this research concentrates only on the front-end of the NPD process. This is because most research and development projects in the Smart Clothing field end at the prototyping stage. Therefore, information about production and commercialisation is insufficient. In addition, the main problems of Smart Clothing development are at the strategic level. This part includes two issues: 1) strategic approach and conceptual models of NPD process and 2) NPD process and collaborative approach.

1.2.1 Strategic Approach and NPD Conceptual Models

This section describes five issues: 1) definition of strategic approach in the NPD process, 2) key elements of strategic approach, 3) definition of the NPD process, 4) generic models of the NPD process, and 5) relationship between the strategic approach and the conceptual model of the NPD process. In the end, the summary of this part will be provided.

Definition of the Strategic Approach in NPD Process

Experts in the Design Management field define ‘strategic approach in the NPD process’ or ‘product strategy’ as a link between corporate strategic direction and the NPD process. The strategic approach is based on a clear mission or vision of an organisation, and related to market and technological change (Nyström, 1985). As a result, it ensures that new product developments will fulfil corporate goals and objectives (Gill, Nelson and Spring, 1996). Strategic approach is used to explore new product opportunities and set a goal for the NPD process; therefore, it must be creative, visionary and goal-oriented (Baxter, 1995). However, there must be a strong element of control present in order to ensure that the activities remain realistic with respect to time and resource constraints, etc (Cross, 1994). Hence, a strategic approach is essential for every corporation because it secures the long-term competitiveness of that organisation (Cooper and Press, 1995). McGrath (2000) states that product development strategy flow from vision to platform strategy, to product line strategy, and to new product development or vice versa. It is noted that the key aspects that determines the direction of the approach is the *‘area of excellence’*, which is defined as special expertise, skill, competence, or capability, that a company cultivates to a level of proficiency greater than anything else it does and particularly better than any competitor does. Nevertheless, no company can pursue two strategies simultaneously, as no organisation has enough resources to develop excellence in several areas concurrently.

The strategic approach serves as a basis for product management and a harness for the integration of all people and resources used in NPD process (Crawford, 1997). Although strategic approach provides a guideline for product development, it should not be too prescriptive that it restricts creativity in NPD process. The product strategies can be categorised into certain groups. For instance, Freeman (1982, cited in Walsh *et al,* 1992) classifies them into six groups: 1) Offensive strategy, 2) Defensive strategy, 3) Imitative strategy, 4) Dependent strategy, 5) Traditional strategy, and 6) Opportunist strategy. Similar idea is proposed by Baxter (1995), as the researcher categorised product strategies into four types: 1) Pioneering strategy 2) Responsive strategy, 3) Traditional strategy, and 4) Dependent strategy. To summarise, the company has to identify its *'area of excellence'*, choose a strategic approach accordingly and apply it into the NPD process.

Key Elements of Strategic Approach in NPD Process

There are many proposed theories describing the content of a product strategy. For instance, Boike and Staley (1996) state that a strategic approach addresses seven key elements: 1) statement of consumer needs, 2) market conditions and response, 3) product attributes and specifications, 4) development schedule and milestones, 5) resource requirement and purchasing, 6) product financials, and 7) key interfaces both internal and external. Another researcher, Crawford (1997), suggests that strategic approach comprises of four elements: 1) background including key ideas from the situation analysis; 2) focus containing at least one clear technology dimension and one clear market dimension that are matched and have good potential; 3) goals-objectives; and 4) guidelines. Based on the literature research, it can be summarised that strategic approach consists of three main elements. Firstly, product strategy addresses background research in term of consumer requirements, market condition, core competencies of a corporate, competition, etc. Secondly, it contains strategic directions such as technology/market opportunities. Finally, it includes goal and objectives of NPD process such as benefits from product development and essential features/functions new products need to achieve.

Definition of the New Product Development (NPD) Process

Many definitions from different points of view are proposed for the NPD process. Nevertheless, it is a general agreement that the NPD process is essential for every company, as it helps a company survive and compete in the marketplace by introducing new products and/or services. This process consists of a number of activities, which can be grouped into certain steps. It transforms user requirements, opportunities, and a company's physical and intellectual assets (e.g. expertises, innovative ideas, technologies, etc) into tangible and profitable products and services (Walsh *et al*, 1992; Wheelwright and Clark, 1992; Bruce and Cooper, 2000). The outcome of the process ranges from an incremental improvement to a radical innovation. Although, there is no standard NPD process for all companies, the basic principles are the same, regardless of the company's specific character and environment (Folyd, Levy, and Wolfman, 1997). The process is carried out by three key disciplines: marketing, design and engineering/manufacturing.

Generic Models of the New Product Development (NPD) Process

The NPD process is regarded as a sequence of activities to be completed. One of the most well known conceptual models is the Stage-Gate system (Cooper, 1993), which breaks the process into typically four to six stages (figure 1.8). Each stage consists of a set of parallel activities undertaken by a multidisciplinary team. These activities are designed to gather information and reduce uncertainties. Between stages are gates, which function as quality control and go/kill check points. The six stages are: 1) preliminary investigation, 2) detailed investigation, 3) development, 4) testing and validation and 5) full production and 6) market launch. A number of conceptual models are developed based on Stage-Gate's principles such as Risk Management Funnel (Baxter, 1995). Despite of its common use, Stage-Gate system may not be useful for a ‘new-to-the-world’ product development because it is unclear what needs to be done in order to succeed (Rosenau, 1996).

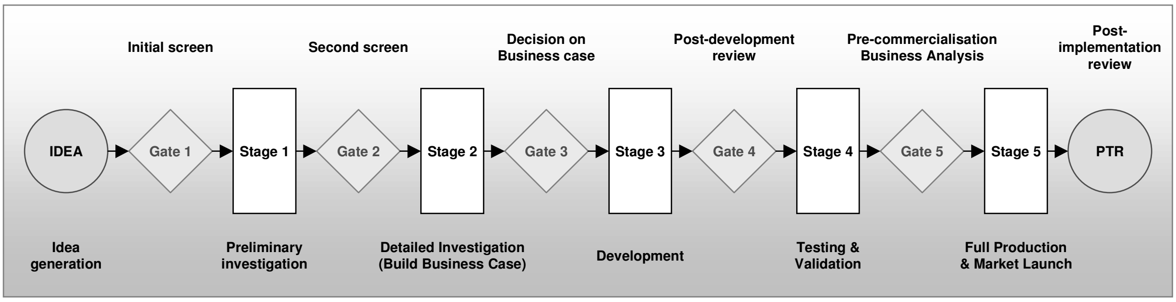

Figure 1.8: A generic Stage-Gate New Product Process (Cooper, 1993)

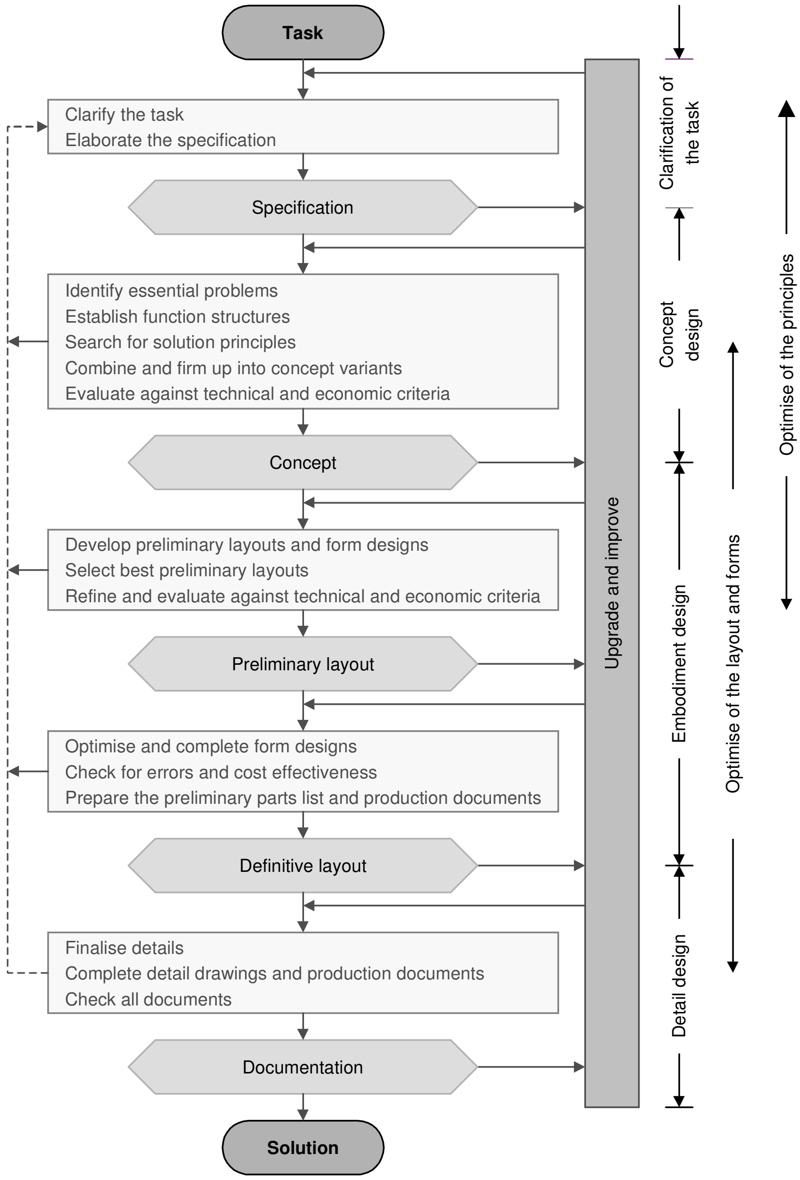

Figure 1.9: Steps of the design process (Pahl and Beitz, 1984)

Despite many differences in details of the NPD processes across different industries and types of product, there is a similar pattern of stages (Cross, 1989, cited in Walsh *et al*, 1992; Otto and Wood, 2001). The generic NPD process usually comprises of five or six phases as follows: strategic planning and/or specification, concept development, embodiment design, detail design, testing and refinement, and production and commercialisation (Pahl and Beitz, 1984; Crawford, 1997; Sinha, 2000; Ulrich and Eppinger, 2000). An example of the generic model is shown in figure 1.9.

Relationship between the Strategic Approach and the Conceptual Model

A number of researchers suggest that the generic model of the NPD process must be adapted to fit the different types of company, product line and strategic approach. This is because the relationship between the corporate strategy and NPD activities has a great influence on the outcomes of the NPD process. Moreover, Robert (1995) comments that the best product development is one that leverages upon the company's strategic capabilities and fit the strategy of business. The company attempting to innovate outside its strategic parameters usually fails. Based on this comment each conceptual model should be presented differently according to the characteristic of the project and its strategic approach. However, a conceptual model developed for a specific approach is not common (Studd, 2002). In addition, most generic models rarely explain how they can be altered by the development teams. Currently, the main difference between each model is the description, not the structure of the model. Therefore, it is difficult to identify the strategic approach or project's characteristic from the conceptual model alone. There is evidence that demonstrates attempts to capture the 'fuzzy' character of the NPD process (see Pugh, 1996 for example). The main reason is to provide a clear idea of the process to all participants in order to enhance the performance of the whole team. The recent NPD models become more complex due to the large number of issues they address, e.g. the disciplines involved, their responsibilities, communication route, etc. Although, the issues addressed in the NPD model have changed significantly, the structure is still similar to the early ones. This complexity of the NPD models results from the limitation of the 'linear structure'.

Based on the literature review, it is assumed that there are four types of conceptual model:

1. Sequence: The model emphasis is on sequence of stages and activities
2. Multidisciplinary: The model focuses on the multidisciplinary team and their roles
3. Key-element: The model concentrates on the elements influenced NPD process
4. Combination: The model is a combination between at least two types of model

Three examples of NPD models are given to show the impact of the different approaches.

1. An example of the first type is *Fashion Design cycle* (Rhodes, 1995) focusing on the activities within the process (see figure 1.10). As a result, the NPD model is presented in a linear structure. Although, it is able to address many key elements, e.g. input from all participants and relationships between tasks and disciplines, the linear structure prevents it from capturing the active interaction and influence of each key element.
2. An example of the second type is *Fusion style of product development* (Hughes, 1995) concentrating on the relationships between the sets of activities and responsibilities of each function involved in the NPD process (see figure 1.11). Although, the model still demonstrates the task in 'sequence structure' to some extent, the cross-functional collaboration is clearly expressed. However, it is unable to describe the key elements and the activities that actually need to be carried out.

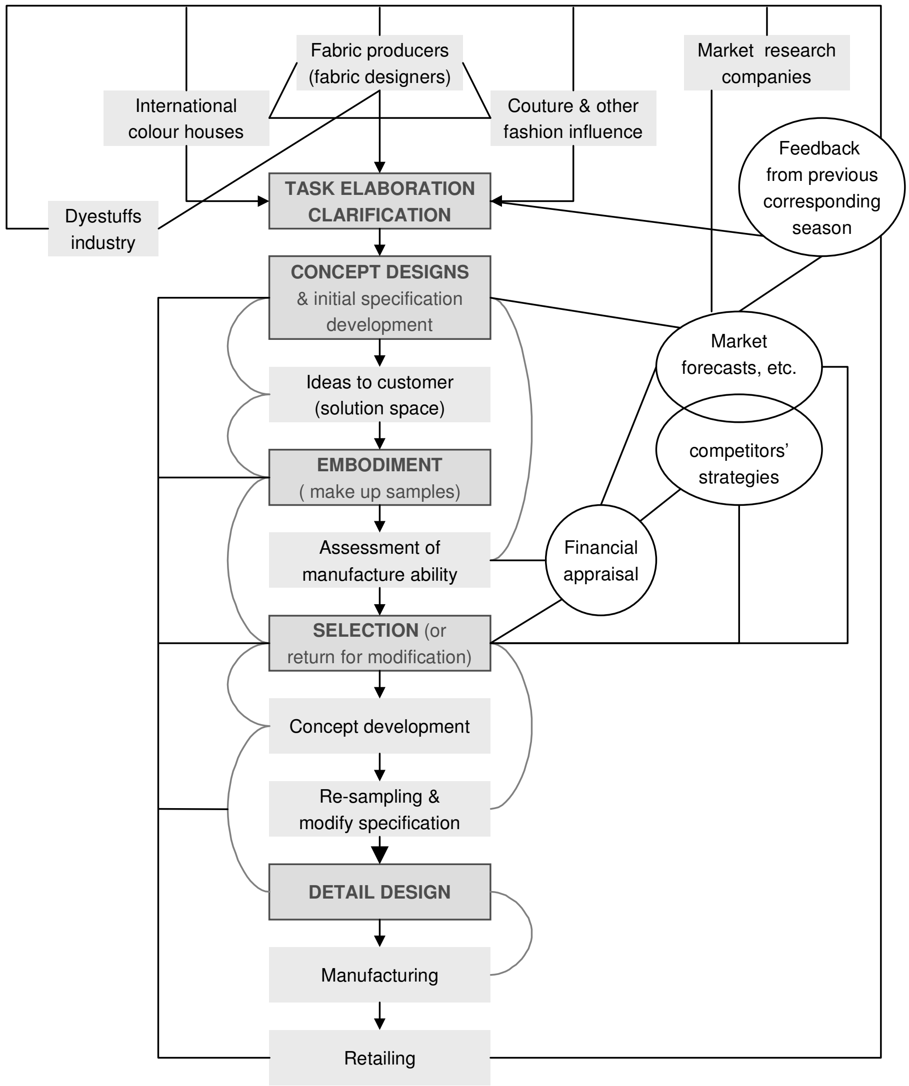

Figure 1.10: Fashion Design cycle (Rhodes, 1995)

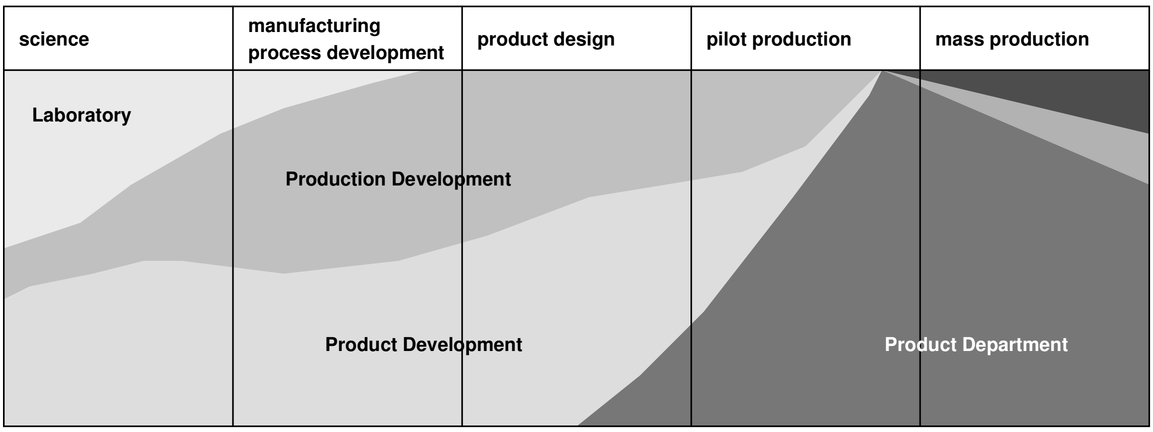

Figure 1.11: Matsushita Industrial's Fusion style of NPD process (Hughes, 1995)

3. An example of the third type is *Product development framework* (Kallal and Lamb, 1993 cited in Le Pechoux, Little, and Istook, 2001) emphasising the key elements affecting NPD process, e.g. brand, market response, competition, etc (see figure 1.12). Therefore, all the elements and their relationship are addressed and clearly presented. However, it is unable to demonstrate which discipline is responsible for which aspect.

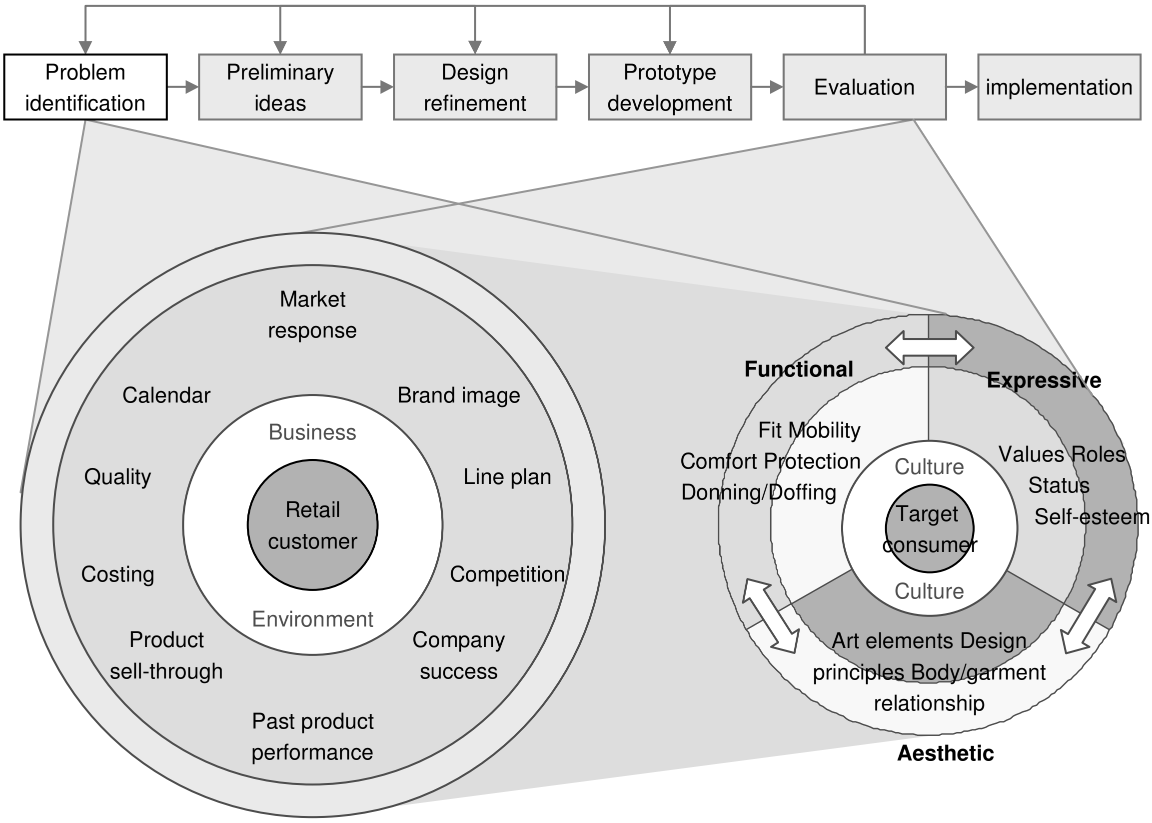

Figure 1.12: Product development framework emphasising retailers' influence (Kallal and Lamb, 1993, cited in Le Pechoux, Little, and Istook, 2001)

Since Smart Clothing development is very new area and requires a radical approach, it is important that the developers get a clear idea of 1) necessary tasks/activities required in the NPD process, 2) key elements of the NPD process and their relationships, 3) responsibilities of all the disciplines involved, and 4) how they collaborate with each other.

In other words, the new conceptual model needs to combine the strength of these three types of NPD models together. In order to avoid the limitation of the 'linear structure', a new way to present the conceptual model is needed.

Summary of Strategic Approach and Conceptual Models of NPD Process

The generic NPD models describing a basic transformation process of the intellectual and physical resources of a company into the competitive product/service, recently encountered the problems caused by a conflict between the increase in number of the elements needed to be addressed in the conceptual model, and the limitation of the linear structure. Currently, none of the models is able to capture the real 'fuzzy' situation of the NPD process. Therefore, it is unlikely that these models can explain the complexity of the collaborative NPD process. Moreover, they are unable to address the strategic approach and represent special characteristics of the project. These two issues are crucial, as they not only gives a clear idea of the process, but also make sure that all participants think and work in the same direction. To overcome these problems, the new conceptual model for Smart Clothing development must illustrate its specific context, address the strategic approach and be presented in the new structure in order to avoid the current limitations.

1.2.2 Collaborative Approach for NPD Process

As the Smart Clothing NPD process requires a high level of multidisciplinary collaboration from very different industries, it is important to investigate the existing collaborative approaches in NPD processes in order to discover the underlying theories and conceptual models, and identify potential problems of a collaborative approach in NPD process. Therefore, this part presents three key issues: 1) definition of collaborative approach in

NPD process, 2) current situation of the collaborative approach in NPD process, and 3) proposed theories to improve collaboration in NPD process.

Definition of Collaborative Approach in NPD Process

Littler, Leverick, and Bruce (1995) note that collaborative product development has been promoted as a means to reduce problems of the product development process, which includes 1) organising teamwork, 2) co-ordinating of contributions from all participants involved, 3) overcoming inter-functional boundaries and 4) reducing rework, time and cost. Jassawalla and Sashittal (1998) suggest that the collaborative approach is not only a means to solve inter-functional problems, but also enhance the performance of the NPD process. The researchers describe collaboration as a condition that all the participants' concerns are viewed as equally important. Besides, multiple perspectives and experiences from all participants are incorporated equally in decision-making. They propose that the cross-functional collaboration in the NPD process includes four key features as follows:

1. **At-stakeness**: An equal stake in the agenda, implementation and NPD outcome.
2. **Transparency**: A high level of awareness in terms of motivation, agendas and constraints among participants, which is achieved through communication.
3. **Mindfulness**: A condition where new product decisions and participants' actions reflect an integrated understanding and divergent motivations, agendas and constraints
4. **Synergy**: The outcome of the cross-functional NPD expressing 'capacities significantly beyond those participants individually bring to the process'

To summarise, collaboration refers to a condition, which all the participants of the NPD process understand and accept the differences, focus on the shared objectives, explore the new opportunities, enhance their creativity, and open their minds to new and innovative ways of thinking and taking action. Based on their research, Jassawalla and Sashittal (1998) found that the level of collaboration was notably low when the emphasis was placed on defensive responses to competitor activities, cost reducing and shortening time to market. In contrast, the level of collaboration was considered higher when the management interest was focused on *'creative utilisation'* of every participant's potentials.

Current Situation of Collaborative Approach in NPD Process

The survey carried out by the Product Development and Management Association (PDMA) indicates that, despite the breakthrough of rigid inter-functional boundaries and linear-sequential workflow, and the broadly use of multifunctional teams, the overall success rate and NPD performance are unchanged or are even slightly improved (Griffin, 1997). In order to achieve more effective NPD, Jassawalla and Sashittal (1998) comment that the organisations need to go beyond the cross-functional approaches and start thinking in terms of collaboration. In other words, the organisations need to pursue *'creative utilisation'* rather than *'task co-ordination'* or *'task co-operation.'*

The intensive research conducted by Littler, Leverick, and Bruce (1995) demonstrates that the main reasons of collaborative product development are to respond to the customer's need, market opportunity, technology changes, and reduce the research and development risks and costs. It is noted that developing a more innovative product is rated at number ten in the total of fifteen. Nevertheless, this research reveals a high proportion of respondents who felt that collaboration could have a negative effect on the process of product development. For instance, the design specification may be compromised in order to meet the requirements of all parties; therefore, the final outcome of the NPD process cannot satisfy the customer. Moreover, collaborative product development can complicate the NPD process and make it difficult to control and manage the NPD process. The main risks are leakage of information, loss of control or ownership, and conflict due to different aims and objectives. The risk that a partner is unable to contribute as expected and pulls out of the collaborative project or becomes less committed is also considered significant.

Littler, Leverick, and Bruce (1995) note that there are some overlaps between factors affecting a successful NPD process and factors contributing to successful collaborative product development, such as establishing ground rules of the project, having a product or collaboration champion, and frequent communication. However, there are certain factors that are only relevant to the collaborative product development process: 1) ensuring partners contributes as expected, 2) perception of even benefits between partners, and 3) building trust between partners. The researchers conclude that *'effective product development collaboration management is concerned with balancing diverse and sometimes contradictory influences.'* Nevertheless, Sethi and Nichoson (2000) comment that although the factors affecting the collaboration are precisely identified, the method to improve it is hardly ever mentioned. The study at Stanford University illustrates a similar problem, as the result reveals the engineering design students commenting on the usefulness of the design process model 'while the models and methods told them *what* to do, they provide little insight into *how* to do it' (Brereton *et al*, 1996).

Proposed Theories to Improve Collaboration in NPD Process

Most theories and conceptual models tend to contribute to the related areas, as they aim to improve *'cross-functional cooperation'* or *'design coordination'* in the NPD process. However, design collaboration is more than overcoming functional boundaries and linear-sequential workflow, as it requires an exploration and utilisation of the potential creativity of all participants to create a radical outcome (Sonnenwald, 1996). A number of theories concentrate on the co-development between a company and its suppliers, or the design alliance between a company and external designers (see Jevnaker, and Bruce, 1998), but not the collaboration of companies from different industries. Hence, most existing theories and models only contribute to certain parts of collaboration. Many theories share the same idea, as they suggest that successful cross-functional cooperation relies on the ability to build a shared set of goals and synchronise the activities (Valkenburg and Dorst, 1998). The examples of existing theories and models are demonstrated as follows:

Improving team management and concurrent engineering: Hollins and Hollins (2003) stress that although allowing every participant to make a contribution to the improvement of the design is important, it can cause problems. For instance, the design team can become too big to function or organise efficiently. Moreover, there are potentially communication problems. As a result, the researchers propose a new system called the 'Design Circle', which can work through the whole design process. According to their concepts, the participants are divided into two groups: members who only need to be involved at certain stages and others who must be involved at all times, such as a product champion. Subsequently, the participants continue to change throughout the process. For example, new disciplines join whilst others leave, with a view to rejoining at a later stage if their expertise is required or relevant (figure 1.13). Since the number of participants is kept to a workable size (nine or ten), cross-functional teams can be organised and managed.

Improving communication and knowledge exchange: Boujut and Laureillard (2000) state that the actions of the participants in the design process occurred in three levels: 1) objects, 2) organisation, and 3) actor (figure 1.13). The researchers claimed that these three levels must be addressed concurrently in order to develop design cooperation. Based on this theory, the researchers developed a design tool to enhance each level. For example, a new medium of presentation suitable for every participant. As it represents the attributes of the product not components, it allows all participants to discuss and exchange idea according to their areas of expertise. For the other levels, the researchers suggest the development of internal regulation procedure that is deeply linked to the changes in participants' attitudes. This reflective process helps participants build a common understanding of the problems and allows the assessment at the end of the project.

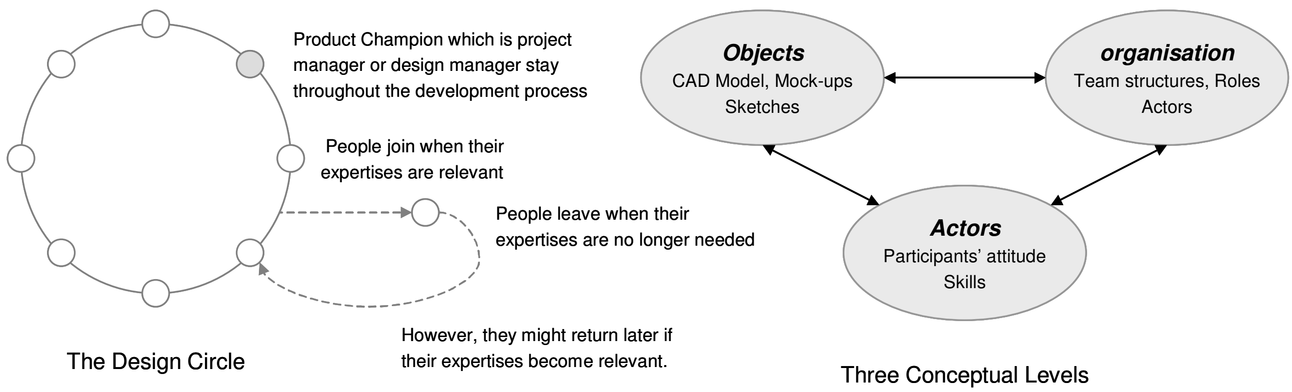

Figure 1.13: Conceptual models proposed to improve cross-functional cooperation

Model on left-hand side: The Design Circle (Hollins and Hollins, 2003)

Model on right-hand side: Three conceptual levels (Boujut and Laureillard, 2002)

Improving an understanding of all the participants: Johnson and Evans (1999) propose a method called *'transparency'* to aid the management of co-development or joint-product development. In this case, transparency means allowing every participant to see through the development process and making the management systems easy to understand. In this way, the performance of the co-development between a company and its suppliers can be monitored and continuously improved. The transparency of the process and contributions required from each discipline are emphasised by Sims and Cane (cited in Rassam, 1995) at the Technology Partnership as follows: *'if you set up the product development on a team basis and everybody understands the objective is and what their contribution is, then you are more likely to end up with a set of ideas and proposals that converge. The problems arise if people have an incomplete picture in the beginning.'* Rassam (1995) points out that the product development team must be well-balanced, which means having the right representative mixture of different professional skills (see figure 1.14) to ensure the best possible solution. The researcher stresses that the input from all disciplines should be obtained from the front-end, right through the whole NPD process, as shown below:

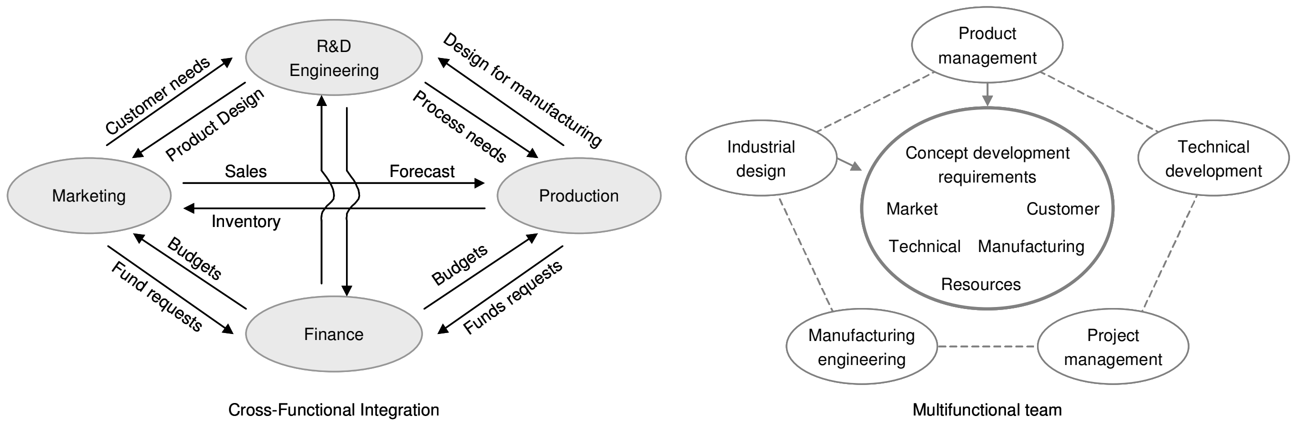

Figure 1.14: Model on left-hand side: Cross-functional integration (Urban and Hauser, 1993 cited in Song, Montoya-Weiss and Schmidt, 1997)

Model on right-hand side: Multifunctional team (Rassam, 1995)

<u>Improving knowledge exploration:</u> To gain a high level of collaboration, Sonnenwald (1996) suggests that all participants need to explore new knowledge and integrate the differences in terms of pre-existing patterns of work activities, perception of quality and success, specialised work language and organisational constraints and priorities. Nevertheless, the researcher points out that knowledge exploration can be difficult for design participants because their experiences, specialised work languages, and different work patterns, and so on may lead to 'contested collaboration' which is referred to the situation where the participants challenge the contribution from one another. The researcher stresses that the most important role in the knowledge exploration and collaboration in design is the 'boundary spanning' role defined as *'communication and information processing behaviour between two or more networks or groups'* (figure 1.15). In this case, the boundaries are classified into five groups: 1) organisation, 2) task, 3) discipline, 4) personal, and 5) roles that span multiple boundaries. The researcher investigates each type of boundary spanning and identifies specific roles for each of them.

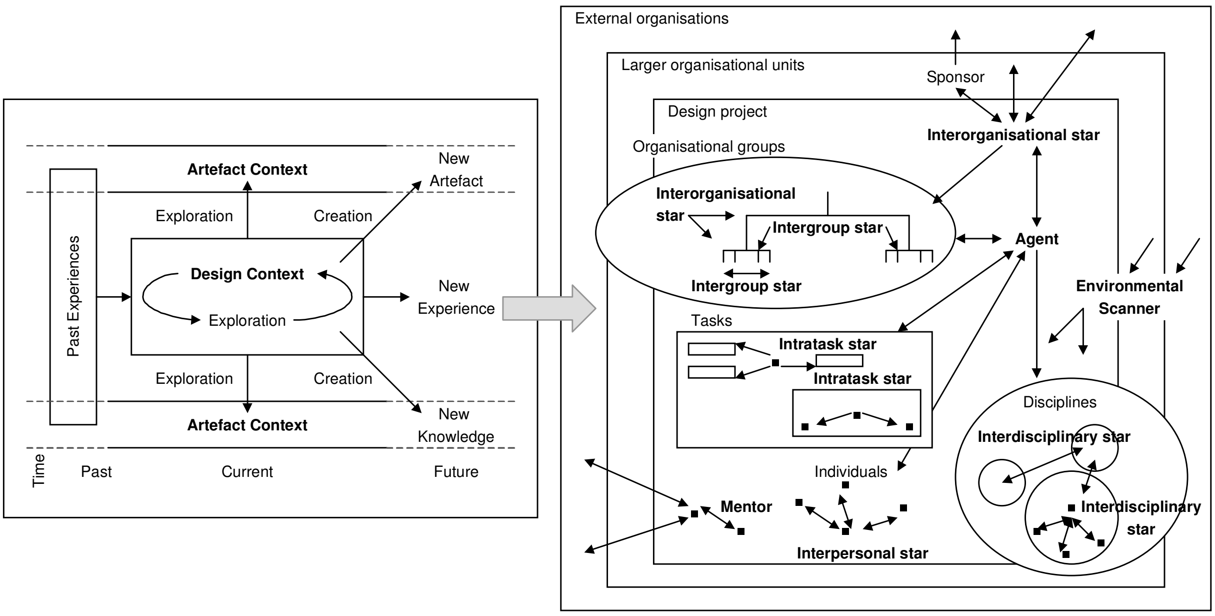

Figure 1.15: Sonnenwald's conceptual models:

Model on left-hand side: Knowledge exploration during the design process

Model on right-hand side: Knowledge exploration roles in design and their relationships

<u>Improve collaborative behaviour and quality of an outcome:</u> Sethi and Nicholson (2000) argue that the processes that make the product development team excel are richer and more complex than cooperation and integration. As a result, they introduce a concept of 'charged behaviour' including drive, collaborative behaviour, commitment and joy of team members. In this case, 'collaborative behaviour' refers to a condition that team members are *'intensely involved in their tasks, strongly believe that they are working to achieve something superior, openly exchange ideas, forcefully debate and challenge these ideas, and feel a great sense of joy and excitement.'* The researchers hypothesise that these behaviours are affected by team structure, e.g. physical proximity and team longevity, and contextual factors, such as the firm's approach. According to their research, the factors that directly and indirectly influence the charged behaviour are identified (figure 1.16). As a result, the factors that are significant to the charged behaviour must be addressed in the cross-functional team in order to increase performance of the outcome in the market.

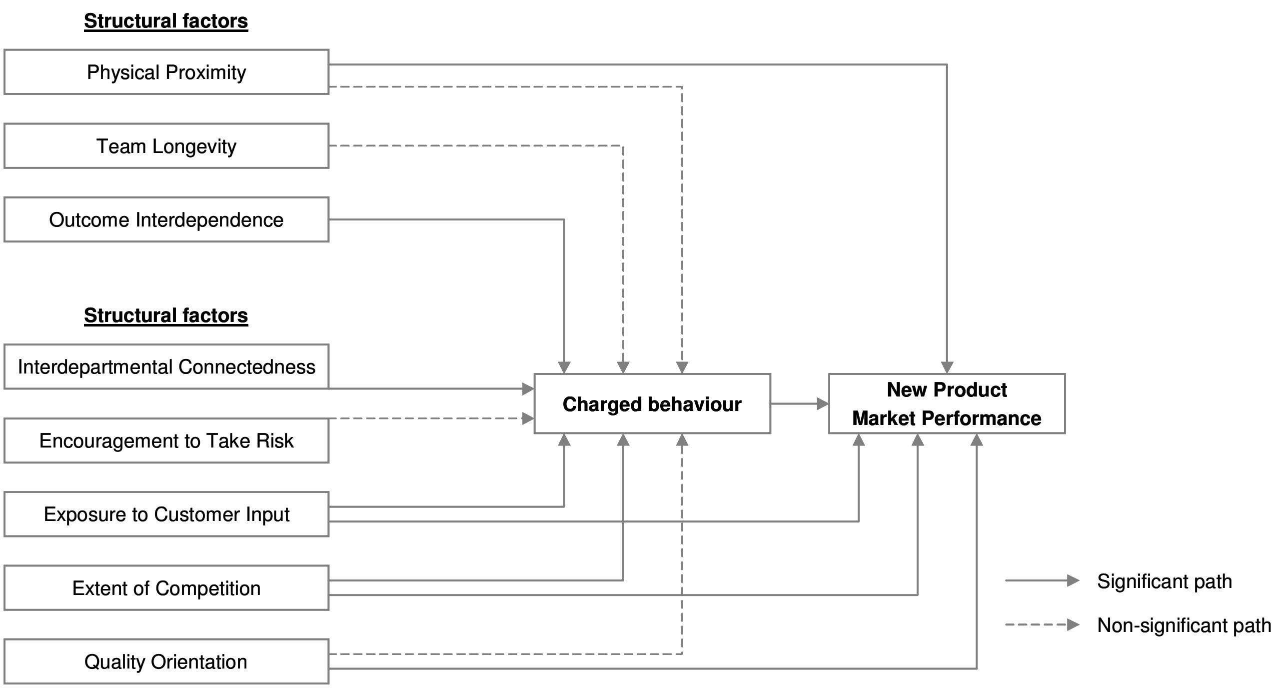

Figure 1.16: Factors influencing charged behaviour (Sethi and Nicholson, 2000)

Literature review demonstrates that the conceptual models of the design collaboration and the NPD process are often presented separately, although these models are proposed to enhance collaboration in NPD process. Despite its clear explanation, it is difficult for the developers to apply or link the collaborative approach to the NPD process themselves.

Summary of the Collaborative Approach for NPD Process

Most experts state that the NPD process has moved towards multifunctional and collaborative approaches. Although the literatures report that multifunctional team and collaborative NPD process have been broadly adopted, many researchers comment that only parts of collaborative approaches, such as task coordination, have been employed. As the essential part of design collaboration, creative and knowledge exploration, has not been utilised, the full potential of design collaboration has not been achieved. In addition, the means to achieve successful collaborative product development have not been clearly described and recommended. Currently, most theories and conceptual models tend to present design collaboration and NPD process separately. Conceptual models of the NPD process are commonly presented in linear structure (see figure 1.8-9), while those of the collaborative approaches are demonstrated in the form of a linkage between different disciplines (see figure 1.14). As a result, it is difficult for the development team to apply a collaborative approach to the NPD process. This situation expresses a pressing need for an explicit explanation of how collaboration can enhance the NPD process and vice versa.

1.3 Problem Statement and Hypotheses

Based on the literature review, the main problems in Smart Clothing development are:

1. The current outcomes of Smart Clothing development have not achieved the full

integration between fashion design and electronic technology. One of the main reasons is that the product context of Smart Clothing development is still unclear.

2. The strategic approach and core value of Smart Clothing applications are still lacking. As a result, it is difficult for the applications to differentiate themselves and expand the target market in order to justify the development costs.
3. The method to optimise the contributions from all participants is still limited; thus, the knowledge and expertise of each discipline has not been efficiently used.
4. There is a need for a conceptual framework as a means to enhance the performance of the collaboration and optimise the input from different disciplines involved.

To respond to the problem statement, the assumptions on how to solve the problems have been drawn. As a result, this research is based on two hypotheses shown below.

1. Since the conceptual model of the NPD process has an influence on the performance of the product development, it can be used to enhance the performance of the process.
2. To enhance the performance of the collaborative NPD process and solve the current problems of Smart Clothing development, the conceptual model must address:
   - **Strategic approach** to guide the participants and synchronise the development effort into the commercial outcomes identified by the potential consumers.
   - **Smart Clothing development's context** to distinguish Smart Clothing design from the conventional clothing design and traditional electronic product design.
   - **Clearly described NPD process** in order to make all essential tasks visible and clarify the responsibilities of each participant as well as explain the relationships and the collaborations between different disciplines involved in the process.

- **Means to increase the creative and knowledge exploration** among the participants, which is the essential part of the collaborative NPD process and is required for the innovation development like Smart Clothing development.

There is plenty of evidences to support the first hypothesis, as large number of researchers propose new models or redesign the existing models to improve and/or accelerate the development process, e.g. 3 Stage-3 Gate System (Cooper, 2001) and Reverse Engineering Theory (Otto and Wood, 2001). Currently, the means of improvement are: 1) providing a clear idea of the development process (see Hart and Baker, 1994; Pugh, 1996 for example), 2) changing the perception of the development process, e.g. Concurrent Engineering Theory (Hollins and Hollins, 1995), 3) improving managerial decision making (Smith and Morrow, 1999), 4) using product platform and product families to reduce development time (Meltzer, 1996), etc. Nevertheless, the existing NPD models do not aim to tackle the problems of creative and knowledge exploration, which are considered the significant issues in a project that requires a radical innovation like the Smart Clothing development. Besides, the multidisciplinary collaboration in this process is far more complicated, since it involves the participants not only from different disciplines but also different industries. This situation leads to the second hypothesis which aims to identify what needs to be enhanced in Smart Clothing NPD process and how conceptual models of the NPD process can influence and enhance the performance of Smart Clothing NPD process.

1.4 Research Scope

The research focuses on four areas: 1) Smart Clothing development, 2) NPD process, 3) strategic approach in NPD process, and 4) collaborative approach in NPD process.

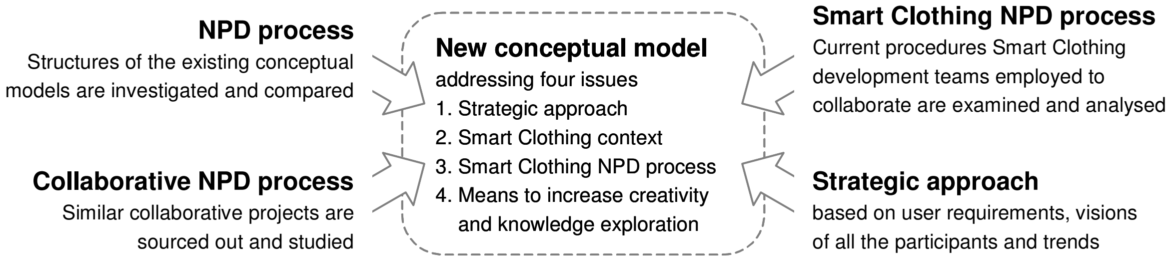

Figure 1.17: Diagram showing focus of the research

- **Smart Clothing development**: Although this research studies Smart Clothing development as a whole to gain the holistic view of its context, the emphasis is placed on development teams and the NPD process that the developers employ currently, especially their ways of thinking and working. Since Smart Clothing development is a collaboration of electronic industry and apparel industry, it is important to investigate the development teams and the NPD models employed in both industries as well.
- **The NPD process**: This research will concentrate on the conceptual models, especially how they address and present all key elements (e.g. essential tasks, responsibilities, etc), and enhance the performance of the NPD process. This research concentrates on the structure of the conceptual model because it provides the first impression of the applied NPD process. Moreover, the clearer the context provided by the conceptual model, the better understanding the participants have about the process. In this case, the conceptual model is the integration between the collaborative approach and NPD process and between electronic and fashion designs. Since this conceptual model aims to overcome the imbalanced contribution caused by restricted creative boundary and conventional thinking, it focuses on the activities at the front end of the NPD process, such as researching, strategic planning and concept development. As a result, this

model will not cover the problems of the later stages, e.g. commercialisation or production. Furthermore, it will not cover business and technical issues, such as design tools, business models and team management.

- **Strategic approach in the NPD process**: This research investigates user requirements and their visions of the future lifestyle as well as the visions of Smart Clothing developers in order to identify several potential strategic approaches, which can be recommended to the developers and addressed in the new conceptual model.
- **Collaborative approach in the NPD process**: Since certain theoretical models have already been studied in the background research. In the next stage, the methods employed to achieve the high level of collaboration in practice and the successful collaborative projects will be explored and analysed.

1.5 Aim and Objectives

This research aims to investigate and develop a conceptual model of the NPD process for the Smart Clothing that addresses four key issues: 1) Smart Clothing development's context, 2) explicit explanation of the NPD process focusing on the responsibilities of all participants and their relationships, 3) strategic approach, and 4) means to increase the creative and knowledge exploration among the participants. The objectives are:

1. **To understand existing conceptual models**: Identify and evaluate the established NPD conceptual models in three areas: electronics, clothing and Smart Clothing
2. **To discover similarities and differences**: Identify the similarities and differences between Smart Clothing development and the established approaches in electronic and clothing fields in order to discover a specific context of Smart Clothing.

3. **To study how development tasks are carried out in practice**: Identify the existing creative methods and work procedures of each discipline involved in Smart Clothing development process and then contrast them with the models in order to examine how accurate the key issues, such as responsibility of each discipline, are described.
4. **To find out what to improve**: Identify what are considered the problems, benefits and challenges of the collaboration between fashion design and advanced technology.
5. **To identify appropriate strategic approach**: Discover how the participants and the end user see the future and design direction of Smart Clothing applications.
6. **To learn how the collaborative NPD process can be done successfully**: Identify and evaluate the key factors affecting an integration between fashion design and advanced technology and examine how these factors are implemented in practice.
7. **To utilise all information together to formulate a new conceptual model**.
8. **To check if the new proposed model works as intended to**: Evaluate the impact of the conceptual model on the participants in terms of the perception of the NPD process and whether it can encourage creative and knowledge exploration.

1.6 Research Contributions

This research aims to provide two key contributions:

1. **An insight into the collaborative NPD process of Smart Clothing Development:** The trend in design and product development indicates a rapid increase of collaborative work, merging between industries and crossing between the disciplines (Griffin, 1997; Thompson, 2001). Nevertheless, the methods to optimise contributions from different disciplines have not been commonly described (Jassawalla and Sashita, 1998). Therefore, this research aims to provide an insight into the collaborative NPD process,

which involves not only the problems, benefits and challenges the participants' encounter but is also a means to achieve successful collaborative approach in the NPD process. Smart Clothing is chosen as an extreme case because it requires the collaboration from the very different areas, electronics and clothing. The information from this research may be potentially useful for other NPD processes, which need collaboration from very different disciplines and seeks a radical outcome.

2. **A conceptual model of the NPD process as a means to enhance creative and knowledge exploration among the participants:** It is generally accepted that the NPD model has an influence on the performance of the development process. However, the NPD models and existing theories are very much about providing a guidance or checklist of a process (Brereton *et al*, 1996) and accelerating the speed (see Smith and Reinertsen, 1998; Cooper, 2001; McGrath, 2001 for example). This research proposes the conceptual model of the NPD process as a mean/method to help the development team not only to gain the clear understanding of the development process and its context, but also encourage and challenge them to think and work in the different ways, which is crucial for a collaborative project that requires a radical outcome. Moreover, the researcher suggests that this new conceptual model can be employed strategically, for instance, use it for project planning or team managing.

1.7 Structure of the Thesis

This thesis consists of seven chapters as shown below. The contents of each part are:

1. **Introduction**: This chapter introduces the key subject areas, namely Smart Clothing development and collaborative NPD process, summarise the key problems and

hypotheses, and explains the purpose of this research including goal and objectives.

2. **Literature Review**: This chapter mainly investigates the NPD process in practice of three different fields: Smart Clothing, Apparel Industry and Electronic Industry.
3. **Research Methods**: This chapter focuses on the primary research. It describes the criteria of the research tools and selected subjects, and how all the primary researches are conducted. Furthermore, it explains the methods employed to analyse the findings.
4. **Key Findings and Discussion**: This chapter presents the results of the primary research. The information is analysed and discussed in order to answer the seven research objectives. In addition, it summarises the requirements of the new models.
5. **Model Formulation**: This chapter illustrates the formulation process, the relationship of key issues addressed, and the new conceptual model and its implementation.
6. **Feedback and Modification**: This chapter explains the criteria employed to select the validating methods, the criteria used to choose the subjects to validate the new model, how the validating process are conducted, results of the validation, and the final conceptual model modified according to the responses of the subjects.
7. **Conclusion and Recommendation**: This last chapter provides a summary and discussion about the whole research including methods, findings and outcomes, and the recommendation on how to use the new conceptual model and this research.