A Strategic Approach to New Product Development in Smart Clothing

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Abstract: Smart clothing represents the future of both the textile/clothing industry and electronic industry. As the convergence between these two industries brings large opportunities and challenges, it draws great attention and investment from many organisations in different fields, e.g. academic institutes, governmental organisations, private companies and laboratories. Currently, none of smart clothing applications is considered a full integration of high technology and fashion design, since most research attempts are focusing on solving technical problems such as integrating microchip and computer systems into clothing or overcoming wash-and-care issues. Consequently, the current applications are unable to attract the mass market. The imbalanced contribution from electronics and fashion industries and the users is the main problem of smart clothing development at this stage. Moreover, the research reveals that the strategic thinking which helps in defining true benefits or core values of smart clothing and may lead to better outcomes is still lacking. As the approach has recently changed from the technical one to a user-centred one, strategic thinking and a New Product Development (NPD) process addressing key elements from both industries are required. As a result, the key question is identifying and optimum balancing these key elements in the new approach and the NPD process. Nevertheless, fashion design and product design are established fields of their own, it is difficult to adopt or switch to the others' work methods. Therefore, the new approach and the NPD process should encourage the development team to think in a different way and go beyond their current creative boundaries. This paper illustrates the current situation of product development in the smart clothing area and explains how strategic thinking may help towards achieving full integration of electronics into fashion – an ultimate goal of smart clothing.

***Key words*:** *New Product Development Process, Smart Clothing, Design Management*

1. Introduction

"Smart clothing" is one application of intelligent textiles. This term refers to all clothes made with intelligent textiles or in which they are applied [1]. 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. The fashion industry views it as a good opportunity to incorporate new technologies, which helps it evolve. Experts in this field suggest that smart clothing will have great impact in the near future [2]. Since smart clothing is large field, this research will cover only garments that contain intelligent functions based on electronic and computing technologies. It is a general agreement that 'smart clothes' must include intelligent functions and fashionable design.

1.1 Background of Smart Clothing Application

Smart clothing application was first developed in the wearable computing field. The idea of attaching small computer systems to garments first occurred in the late 1970s. These computer systems were developed by a group of physicists and PhD graduates to assist them in playing roulette [3]. Since these systems were designed to use in casino environment, they 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. The characteristics of its origin still have a strong effect on the current projects. Since the early projects were created merely to express advanced technologies (e.g. conductive fabric, wearable computing), the requirements of end users and fashion design were neglected. However, the concept of smart clothing became widespread in a very short period of time. It draws great attention from many organisations in different fields. A number of research studies have been carried out by many academic institutes, e.g. MIT Media Lab, Royal College of Art, University of Bristol, Central Saint Martins College of Art & Design, Brunel University and Tampere University of Technology. 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 [4]. Moreover, many high-tech companies conduct their own research or carry out collaborative work with academic institutes or sponsor external laboratories and/or design consultancy e.g. Starlab, and IDEO. Significantly, most of these organisations are multinational companies within the electronics industry, e.g. Nokia, Philips, Ericsson, Motorola, Pioneer Corporation and Infineon Technologies AG; therefore, it can be deduced that the leading companies perceive smart clothing as the next generation of electronic devices.

1.2 The Drivers behind Smart Clothing Development

It can be observed that electronics field is more proactive than the fashion one, since most of the projects are lead by the electronics development teams. (See Fig.1)

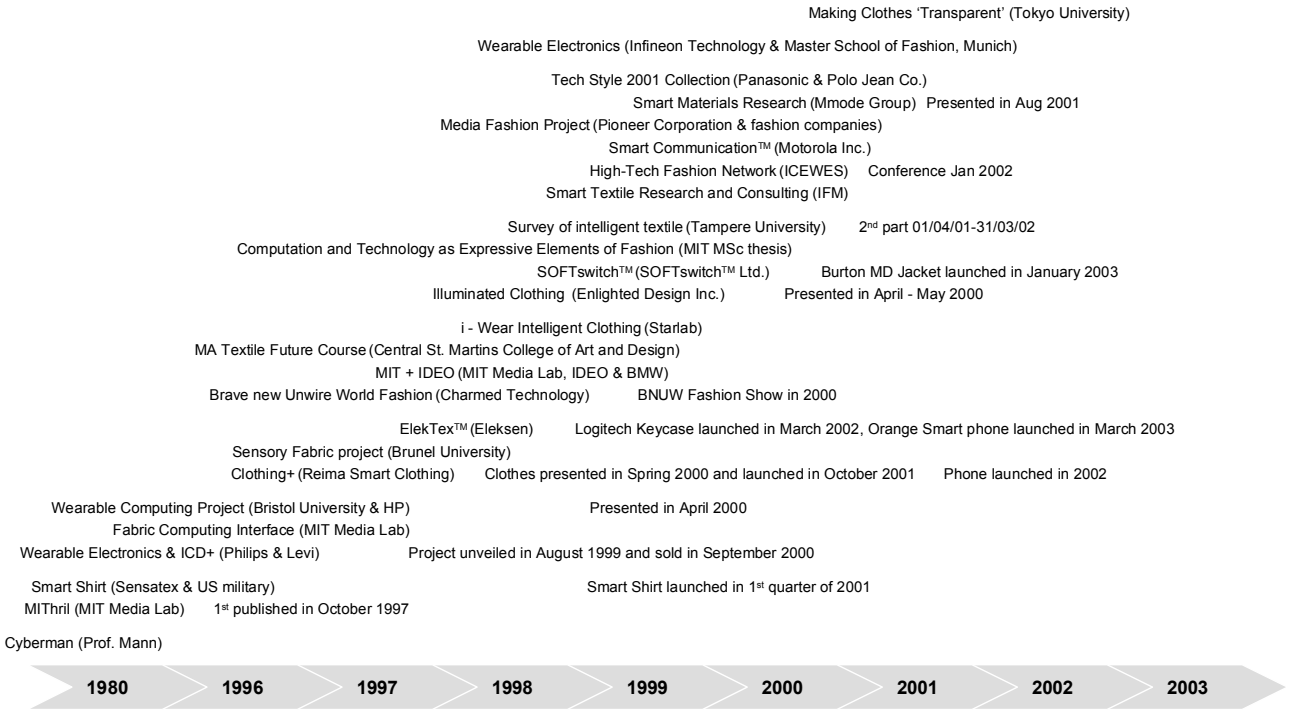

Fig. 1 Timeline of product developments in smart clothing field based on the literature research

Due to the electronic approach, most applications can be described as technology-push products. According to the literature research, there are four main drivers behind intensive developments from the electronics field.

1. The first driver is an attempt to achieve an ultimate mobility, as people want to be empowered by electronic devices in order to access required information everywhere and every time [5].

2. The second driver, product miniaturisation, results from the first driver. To achieve a highest level in term of mobility, electronic devices rapidly reduce their size. As a result, the personal electronic devices can be attached to clothes or become the accessories. But by contrast, their functions and features continually increase. The conflict between function and size leads to difficulty in term of use, as the functionality embedded in electronic devices is often complicated and inaccessible [6].

3. Derived from the previous driver, the third one is the need to solve complexity problems. Integrating electronics into garments might be an appropriate solution, since it provides many benefits such as mobility, less complexity due to a potentially bigger and/or better interface, which probably makes it easier to use.

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 experiment with conductive properties of fabrics, see [7] for example.

1.3 The Overview of the Smart Clothing Development

In the preliminary investigation, information and images of the current projects from different development teams have been collected and placed on a timeline in order to understand key trends of product development in this area. (See Fig.1) Product scenarios of these projects have been compared to identify ideas and inspirations behind the developments, since they demonstrate each team's vision of the future and how they respond to new possibilities and opportunities that smart clothing brings. The findings from this preliminary research are:

1. Currently, the research and product developments mainly focus on four areas: Healthcare, Entertainment, Sportswear and Communication. It can be deduced that the area that draws most attention is Communication and Entertainment, as the number of projects in these fields is much more than the others.

2. The approach has changed from a technical one to a user centred one, as many electronics development teams have recently realised the need for certain inputs from fashion/clothing industry and user requirements. Moreover, most product development teams create the visions and product scenarios before developing any applications to ensure that intelligent functions meet the user requirements and the future lifestyle.

3. Technical aspects still have the strong influences in smart clothing development. Since all the drivers identified come from technological side, most product developments have taken the technical approach. Besides, many development teams share the same futuristic scenario that refers to people empowered with novelty functionality like a 'cyborg', see [8-10] for example. Based on this 'cyborgian' scenario, applications emphasise heavily unconscious-operating manners. The goal is to develop a wearable computing system to enhance day-to-day activities. As the functionality is designed to be 'invisible' and embedded into ordinary everyday garments, the character of smart clothing applications becomes anonymous. Furthermore, its original character still has a strong impact on the current projects.

4. Influence from fashion design is gradually rising. There is evidence that the electronic industry must adapt itself to fashion [11-12]. For instance, 'Media Fashion', a smart clothing project lead by Japanese consumer electronic Pioneer Corporation, has worked with a hundred fashion and textile companies [13]. Due to the technical emphasis, it is difficult to incorporate fashion thinking and clothing techniques into their projects. At present fashion

designers only use their garment making skill to attach intelligent functions to the clothes. Nevertheless, it is likely that fashion designers will have more design freedom in the future, as a number of hard components reduce sizes dramatically and some are already replaced by smart fabrics.

5. Although, some smart clothing applications have proved to be feasible and already available in the market e.g. Burton Snowboard MD Jacket, Levi ICD+ Jacket, and Reima Smart Clothes, these products are offered in limited numbers and focus on the niche market. However, according 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.

2. Research Methodology

This section is divided into three parts: key issues, hypotheses and research methods, and how to handle complexity. In the first part, the situation considered problematic and the key issues for the investigation are expressed. In the following part, the hypotheses and the methods used to obtain the required information are described. In the last part, the methods used to deal with this complex information are explained.

2.1 Key Issues in Smart Clothing Development

There are a lot of issues considered problematic in smart clothing development. Moreover, the relationship of these problems is very complex. In order to express the problem situation and the relationship, the Rich Picture technique in the Soft System Methodology (SSM) [14] is employed. (See Fig.2) Each problem is examined and linked to one another. By this way, the key problems or key issues can be identified.

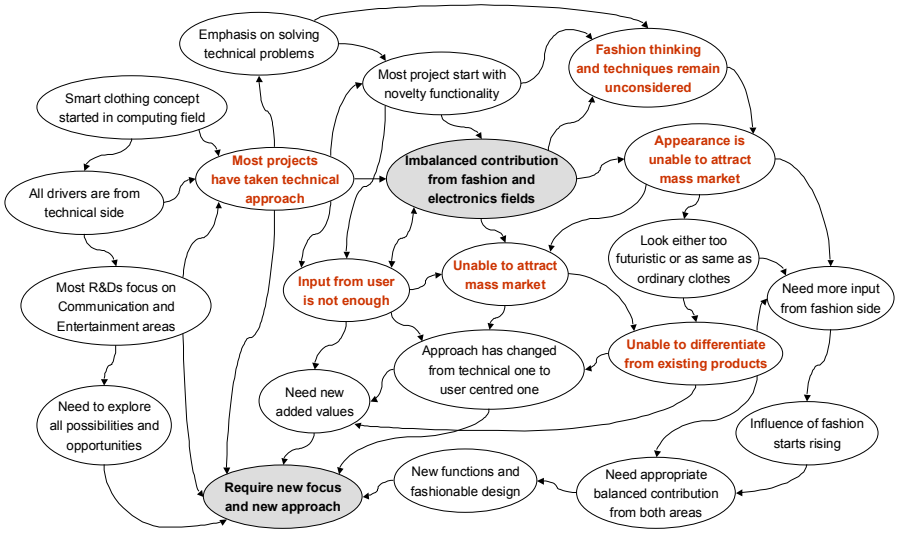

Fig.2 A rich picture of a problem situation in the smart clothing development

These key issues are:

1. The imbalanced contributions from electronic and clothing industries result in incompletely integrated applications. The electronics field still dominates the product development in this area. Consequently, most research attempts are focusing on solving technical problems such as integrating microchip and computer systems into clothing or overcoming wash-and-care issues. Application developments to date centred on the clothing industry are still uncommon and they do not take into consideration or integrate the special product development and processing techniques of this sector [1]. Moreover, the fashion industry has been slow to incorporate high technologies into clothing due to a lack of knowledge about new technology and/or an absence of motivation to use such technologies [15]. Currently, there are few clothing companies developing smart clothes e.g. Cyberdog, Levi Strauss & Co., Burton Snowboard, and Reima Smart Clothing. Nevertheless, most fashion companies have adopted the technical features rather than create the integrated fashion approach themselves.

2. Due to this imbalanced contribution, it is difficult to achieve full integration of electronics and fashion – an ultimate goal of smart clothing. Moreover, strategic thinking, added values and benefits from this integration are neglected. Without value added, it is difficult for the applications to define or differentiate themselves from the conventional clothing and existing electronic devices. This explains why the applications are unable to attract the mass market yet. Strategic thinking is therefore required, since it helps in defining true benefits and/or core values of smart clothing and may lead to better outcomes that meet consumer requirements.

3. A new approach is required for the innovation process, conception and design of smart clothing [16], as the integration of technology and fashion has created new a type of business and product range. At present, smart clothing development teams view applications as either electronics or fashion design but rarely as both. It is clear that a new way of viewing this area is required. Since fashion design, product design, and electronics design are established fields of their own, it is difficult to adopt or switch to the others' working methods. The cultural-barrier breakthrough is possibly the key challenge. Nowadays, no New Product Development (NPD) process is developed for such collaborative work. This new NPD model should not be merely the sum of each parent. It should encourage the development team to think differently, as smart clothing is an entirely new type of product not only a combination of the two.

2.2 Hypothesis and Research Methods

The research is based on two hypotheses. Firstly, in order to achieve full integration, an appropriate balanced contribution from the electronics and fashion industries is required. Secondly, to bring about an appropriate balanced contribution from both industries, a new approach is required for the strategic thinking and the NPD process. As this new approach will challenge the corporate culture, design thinking and work methods, breakthroughs in these areas are needed. Although, the user requirement is the centre of the new approach, this research concerns with addressing and utilising this information in the new approach rather than just collecting evidence and identifying it. Therefore, there are four aspects to be investigated: Corporate Culture and Work Methods, NPD Process, Smart Clothing Development, and User Requirements. (See Fig.3) The diagram in Fig.3 demonstrates the gap between the current situation and the ideal one within each issue. This research intends to find out the reasons behind these gaps and how to bridge them. There are five research tools used to collect the required information: literature research, case studies, interview, observation and questionnaire.

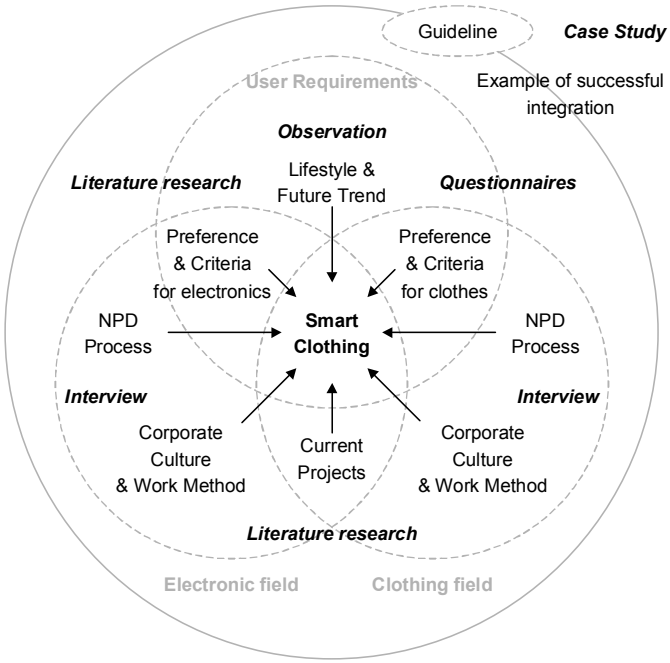

Fig.3 Diagram illustrate key aspects and the methods employed

1. The literature research is chosen to investigate all issues, since it helps build up the understanding of each topic, draw the key questions and plan the whole research. Within the literature review, the similarities and differences between NPD models employed by the fashion and electronics sectors are examined. The development processes described in research papers, articles and theses have been collected and analysed in order to obtain the

pattern of thinking and working. The images and the information about the applications, product scenarios and the development teams are analysed to find out the strategic thinking, approach, current achievements and problems. Finally, the information about future trend, lifestyle, consumer behaviour, and similarities and differences of criteria in purchasing electronics devices and fashion items are investigated.

2. To formulate a new conceptual model, an investigation of previous "integrated" models is required. Since NPD models developed for collaborative projects are uncommon, the appropriate method is examining the practical methods the organisations employed to develop similar types of product. Therefore, case studies of the companies and projects that are able to incorporate both fashion and high technology e.g. sportswear design will be sourced and evaluated. The assessment is also required to verify the new conceptual model. It includes the methods to validate the information used to formulate the model. The information from case studies can possibly be used as a guideline or recommendation, as it suggests key issues and how to address them. Since these case studies are from the different areas, their information is only a suggestion that helps to formulate the model.

3. For the secondary research, the semi-structured interview is selected to study the corporate culture, work methods and NPD process, as it allows the respondents to talk about what is important for them and ensures that all crucial topics are covered. By this way, the richness of the cultural issues can be obtained through the answers and the responses. At this stage, a number of interviews are conducted with each type of product development teams in order to find out the organisational cultures and work methods.

4. Lastly, the questionnaire and observation are employed to study consumer lifestyle and requirements. The questionnaire consisting of ranking questions is employed to collect information about user preferences and criteria for electronics goods and fashion items. Since the response to the ranking question will demonstrate the priority given to each aspect, comparison and analysis can be carried out easily. The observation will be carried out to study people's day-to-activity and lifestyle. However, this research is directed at addressing and utilising user requirement data rather than simply identifying the need. Therefore, the proposed methods to study user requirements are merely the suggestion about which type of information is required and how it can be obtained.

2.3 Handling Complexity

There are many types of information needed for the new approach and NPD process formulation as mentioned in the previous part. The complexity of the information means close attention to evaluation and synthesis. To deal with this fuzzy and complicated situation, Soft System Methodology is employed. The synthesis methods can be divided into four steps:

1. Since synthesis is considered a transformation process, its input and output needs to be identified first. In this case, the information gained in the research stage is an input of the synthetic process. (See Fig.4) Nevertheless, it is impossible to address all the findings in the new approach and NPD process. Only significant factors are selected and put into this transformation process. The method for selection will be explained in the next stage. The output is the new approach and NPD process that will lead to full integration of smart clothing, which can be obtained by addressing the key issues and balancing their proportion appropriately. The state considered as 'optimum balance' will be illustrated in the following stage.

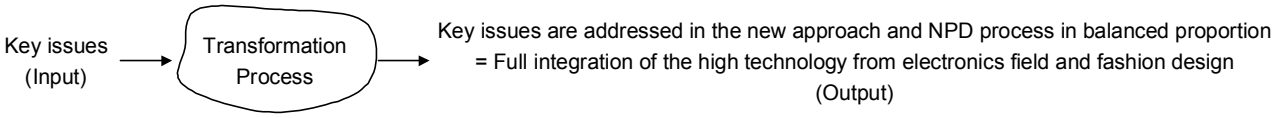

Fig.4 Diagram demonstrates inputs and output of the synthetic process

2. Secondly, for each key issue identified at the highest level in stage 1 a further level of analysis is required to find the essential characteristics at the next level of detail. Fig.5 (based on the Rich Picture techniques from Soft System Methodology [14]) shows the progression from high level strategic issues to more detailed issues and the emerging relations.

3. Thirdly, the key issues from the case studies are identified the same way as mentioned in the previous stage. (See Fig.5) The analysis is carried out in order to find the key factors that make for successful integration and how each contribution can be addressed to achieve optimum balance. For certain issues, it is difficult to demonstrate their 'optimum balance' in verbal form. Visual and probably other sensory forms can be an alternative way to describe these aspects. The conceptual model will be constructed to express how the key factors fit in the product development process and the approaches.

4. Finally, the guidelines (derived from stage 3) provide examples and help to construct the new approach and conceptual model. Key issues and the relationships of the result and the guideline will be compared. (See Fig.5) The conceptual model will be formulated and modified. Since the case studies relate to different products (as distinct from mainstream smart clothing) the findings need to be used carefully and set only as a guideline to inform the conceptual modelling process.

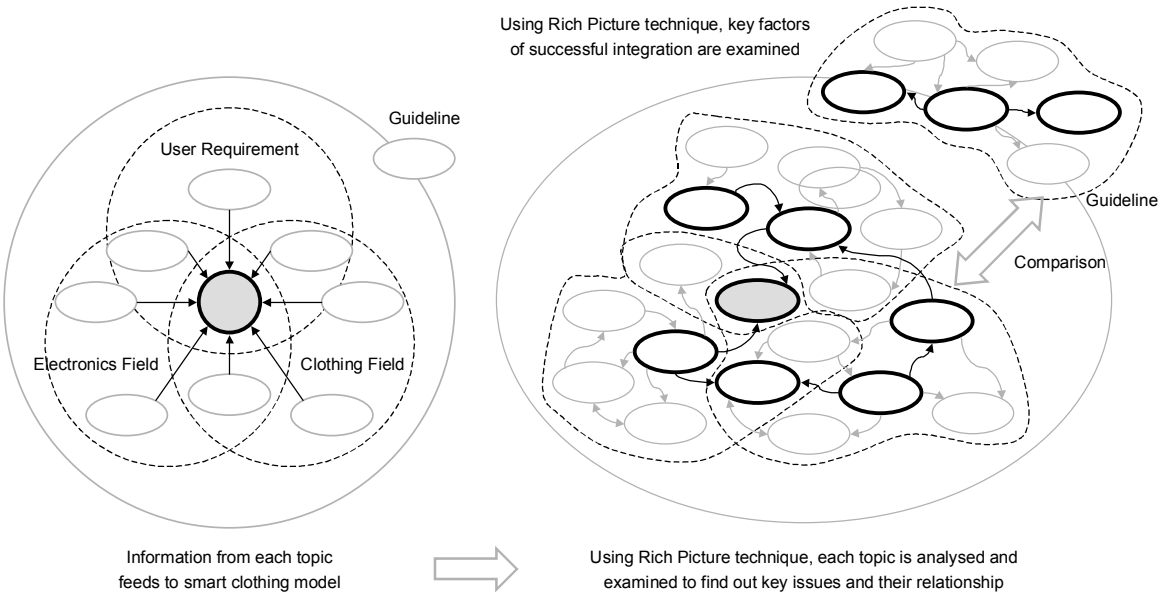

Fig.5 Diagram illustrates synthetic methods consisting Soft System Methodology, Comparison and Mapping

3. Results and Discussion

The principal findings at this stage are from the literature research. This research result can be divided into two groups: Work Methods in Smart Clothing Development and New Product Development and presented below.

3.1 Work Methods in Smart Clothing Development

Since smart clothing is a rather new area, many researchers develop new applications and their understanding at the same time through 'trial and error' method. A number of applications are developed in order to gain better understanding about smart materials and advanced technologies. In many cases, properties are explored and then applications are created based on new knowledge. By contrast, there are many projects that start with the user research and strong product scenarios and then search for appropriate technologies. This result emphasises the shift from a technical approach to a user-centred one. As smart clothing development requires knowledge and expertise

from varied disciplines, creating and maintaining the design direction is very crucial. At present, the outcomes reflect the different approaches between fashion-lead and electronic-lead projects. As mentioned earlier, the development teams view 'smart clothing' applications as electronics or fashion design not as 'smart clothing'. Consequently, most development teams try to make the new 'smart clothing' products fit into the conventional development process and methods of thinking. For instance, intelligent functions and electronic mechanisms are created as a separated part and hidden inside the new type of 'black box' – e.g. the clothes' lining or pocket. Most electronic-lead projects focus on developing intelligent functions and attaching them to the garments. In contrast, the fashion-lead projects pay attention to aesthetic exploration. Certain researchers develop new working processes themselves in order to explore and cover all issues around the smart clothing field, see [17] for example. In a computational fashion project [15], the researcher developed a number of parameters in order to outline a design space and evaluate the outcomes.

3.2 The New Product Development Process

There is a possibility to create a NPD model for the collaboration of the two sectors, since the result of the NPD models comparison indicates that they share more similarities than differences. At the highest level, both types of product are considered as assembled product, which means that the product comprises of a number of components and each component is engineered for the specific purposes or requirements. Besides, both product developments are based on the result of a previous collection and its platform. The design is described as an amendment of the previous one. Platform elements of apparel product are pattern, material, shape and style, while those of electronics are key component, and software. However it illustrates certain difficulties, as the aspects that are similar are less important than the ones that are different. For instance, the similar aspects are in the number of phases in NPD models, the order, the structure, input and output, while the different ones are the activities in each phase in the NPD model (or work methods) and disciplinary cultures (including strategic thinking, approach, strength/expertise, and environment). Since these two industries place emphasis on different issues, the major priorities are given to the different activities. The structure of conventional NPD models fails to demonstrate the differences, as the details, linkages and descriptions within each phase are hidden. As a result, unclarified works and responsibilities cause certain difficulties and confusions to the members in the collaborative teams. This result suggests the need for a new NPD process and the new way to present it in order to bring about the better understanding about works and responsibilities and enhancing communicating between team members. To identify clearly about the key issues within the NPD process, a summary is presented in Table 1.

Table 1. Summary of Key Issues Identified

Type of Issue	Key Issues
Positive issues	1. NPD processes from both sectors share more similarities than differences. This indicates the possibility to merge them and create a new model for the collaboration between two industries.
	2. As both types of product are considered as assembled and platform product, they consist of parts, components and platform elements that can be analysed and treated as their contributions.
Problematic issues	3. Since the differences are activities within each phase, details and the linkages between phases, the NPD process for collaboration cannot be drawn directly from the two existing models. Methods used to select key elements from NPD models and formulate a new conceptual model are required.
	4. As characteristics of electronics and fashion goods are different, the emphases are given to the different phases and activities. Phases and activities, which should be emphasised in smart clothing need identification.

Type of Issue	Key Issues
Problematic issues	5. Based on the analysis, the conventional structure of NPD models fails to demonstrate the different work methods of these two sectors. Therefore, a new way of presenting NPD model is needed in order to enhance better understanding about work and responsibility and the communication within collaborative teams.

4. Conclusion

Smart clothing is perceived as the next generation of both fashion and electronic products. Its influence rises dramatically, as indicated by the rapid increase in research and development projects in the last five years. It offers a large number of possibilities and opportunities for new business and new product lines. As a result, the research and product developments have been carried out by multi-national companies and leading academic institutes. Many researchers describe smart clothing as a marriage of fashion and technology. Based on this description, it can be assumed that it requires collaborative work from the fashion and electronic industries. The trends in smart clothing development suggest that technology gradually becomes an integral part of fashion. It is likely that the two identified opposing design approaches start moving closer to each other. According to the literature research, the key problem is the imbalanced contributions from the electronics and fashion industries. Besides, without a strategic and value added approach, it is difficult for smart clothing applications to differentiate themselves and expand the market. This situation indicates that the strategic approach as well as NPD process that balances all the key issues and addresses new values is required. The strategic approach should challenge development teams to think in a different way and go beyond their current creative boundaries. The challenge is to make technology become fashion and make fashion become high-tech: ultimately a fully integrated approach. Nevertheless, the new NPD model for smart clothing development cannot be drawn directly from the existing models employed by the fashion and electronic industries. The existing models were developed to a specific work methods and product context and are no longer relevant to smart clothing. Therefore, a new NPD model must be formulated based on a smart clothing context, combining the work methods from both industries and introducing new approaches (which implies many management of change challenges). Moreover, the new model should be presented in a new paradigm in order to communicate to people from different backgrounds and demonstrate the new way of thinking and working.

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