Jing Zheng[1, 2, *],
Li Li[1, **],
Wen Gu[1],
Gang Xiao Liu[1, ***]

Sustainable Apparel Product Design Methods: a Fashion Brand Company Case Study

[1] **Donghua University, College of Fashion & Design,** Shanghai 200051, China, ** e-mail: Lili@dhu.edu.cn, *** e-mail: liuxg@dhu.edu.cn

[2] **Xiamen University of Technology, School of Design & Art,** Xiamen 361024, China, * e-mail: zhengjing@xmut.edu.cn

Abstract

Fashion brand companies must fully consider all the three following aspects in apparel product design: perspectives, method and model (the key research questions proposed by this study), and practise in a sustainable way, with a focus on the combination of enterprise practices and sustainable development. In this paper, we make full use of the key elements of clothing design to establish a user-friendly theoretical model based on the concept of "clothing series design" and conducted the first trial at an appropriate company (Burberry). Then we applied this method derived from our model to the new products released as part of the 2019 Spring and Summer collection at a Chinese apparel company to test the stability of the method. The study proposed a new sustainable design method and received positive application results through the tests at Burberry and at a Chinese apparel company, which can be considered as one of the major contributions of this study.

Key words: *sustainability, sustainable apparel product design, clothing series design, fashion brand company.*

Introduction

Environmental impact is one of the most important aspects that should be considered during sustainable apparel product development (SAPD) [1]. Many decisions in terms of SAPD, are made during the design stage [2]. Therefore, fashion brand companies (FBCs) and designers must return to the initial stages of product development to think systematically about the environmental attributes of the product and process. A strong product layout, deeply-distributed product elements, competitive product design, and the introduction of different product development models could gradually improve and partially replace traditional production models to achieve sustainability [3]. The development of a conceptual model led us to formulate the following research questions for this study:

(1) Are there avenues that could be further explored in seeking opportunities for sustainability in the configuration of the elements of apparel products?

(2) Can a sustainable clothing design model help FBCs develop new products while reducing their negative environmental impacts?

FBCs come in all types and sizes, the major types of which can be grouped into manufacturers, licensors, and retailers which sell private label fashion, including SPAs (specialty store retailers of private label apparel) [4]. In this paper, the FBCs which are our research objects are the retailers, which are businesses that sell products to the final consumer and may include a vast range of brick-and-mortar stores (e.g., department stores, mass merchants, specialty stores, boutiques, discount stores, and outlet stores), as well as catalogues, brick-and-click stores, and online stores [5].

This paper is organised as follows. In the first part we review relatedand recent literature. Next, we employ a case study to describe the model, and then verify it in new product development for a real company. The significance and contributions of the article are discussed afterwards. In the last part we conclude the limitations as well as directions for future research.

Literature review

Clothing design key elements and SAPD

The key elements (KEs) are the essential components of the art form, and the building blocks for designing products. We comprehensively checked the clothing design KEs included in the literature and merged similar expressions [6-12]. The purpose for this was to strengthen the overall understanding of KEs. For example, value (the lightness or darkness of a colour), as an attribute of a colour, can be considered as a colour element, while texture (different types and combinations of fibres, yarns, and methods of construction, as well as colourings and finishes), as an attribute of a fabric, can be regarded as a fabric element. In this study, the KEs of clothing design are defined as silhouette, colour, fabric, styles, details, and theme. The definitions of KEs are provided in *Appendix A* for this study.

SAPD tools, such as the design for X, where X represents a specific activity, feature, or goal, should be considered during the product design phase, seeking sustainability through a specific KE of the clothing design [13]. For example, a design for waste minimisation (DfWM) and one for recycling (DfR) are more focused on the fabric (materials) of clothing products [14]. Zero-waste clothing design (a method of DfWM) is related to the fabric width and pattern cut [15]. A design for assembly (DfA) and for disassembly (DfD) provide tools focused on garment product details or components [16]. No matter which method we use in SAPD, the KEs are the focus. Therefore, there are avenues that could be further explored in seeking opportunities for sustainability in the configuration of the elements of apparel products.

Sustainable clothing design model

The second question we wanted to answer was whether existing models could provide more convenience for sustainable clothing product design. Although the classic theory of 'cradle to cradle' (C2C) redefines the value of materials in the manufacturing system cycle [17], the contribution of this model is not outstanding in any aspect other than requiring materials to be maintainable, repairable, recyclable, and reusable. Gam et al. proposed a sustainable model, cradle to cradle apparel design (C2CAD), by integrating the

'cradle to cradle' model into existing apparel design and production models [18]. In this model, material selection, testing, and production provide important contributions to sustainable design; however, the material selection and evaluation introduce strict requirements for suppliers in the enterprise supply chain.

DfA and DfD products are offered as kits and create an opportunity to provide a creative experience for consumers, where modular construction allows for the rapid disassembly and reassembly of modules [16]. In clothing, this means detachable parts. This design model provides the possibility of upgrading a product or modifying a personalised one [19]. However, the upcycling, modularity, and co-creation models [20] are based on user choices, and the final results cannot be upscaled to mass production. The key problem to be solved in this study was the identification of a model that is simpler to operate and fully considers the actual conditions and capabilities of most FBCs.

Approach adopted for the research project

Case study

Case study triangulation was adopted to reduce prejudice and contribute to providing a more holistic perspective on SAPD. Triangulation means the use of two or more approaches in the research aspect so as to strengthen the research findings, theoretical perspectives, methodological approaches, data analysis methods, and investigators, which are examples of aspects that are usually triangulated [21].

Theoretical perspectives

Some FBCs, especially large FBCs, including but not limited to H&M (2010), Gap Inc. (2010), Burberry (2014), Gucci (2016), and Giorgio Armani (2017), have implemented corporate social responsibility (CSR) strategies. This implies that large FBCs practice sustainability in many creative ways to respond positively to the growing consumer demand for green products and more sustainable choices. Although the majority of small FBCs often have financial restraints that prevent them from adopting proactive sustainable strategies, they are increasingly under pressure to adopt more sustainable production models to cater for upgrades or transformation [22].

We selected Burberry as a case study, based mainly on three considerations. First, Burberry conforms to the definition and attributes of the research object (FBCs) in this study. Second, Burberry has a wide influence in the field of sustainable fashion, and its sustainable practices are of some reference value. Third, Burberry has never been absent from the twice-yearly product release of London Fashion Week. We were able to obtain the latest product images from fashion trend service providers (FTSP) in a timely manner, which provided stable data support for our research.

In this study, although Burberry has been defined as a large-scale fashion brand, from the marketing perspective Burberry is still widely known as a luxury brand. According to an AFP report (2008), luxury apparel companies have both the opportunity and responsibility to promote the sustainable development of the entire fashion industry and are capable of becoming sustainability leaders [23]. Being a pioneering leader means that luxury companies play critical roles in developing professional knowledge, helping mature cutting-edge technologies, and providing practical solutions [24]. Sustainable development is a challenge faced by the entire fashion industry, and no individual or single organisation can claim to be an expert in all the aspects. Regardless of the type or size of the business, any progress made during its sustainable practices is worth sharing and being studied. Therefore, according to Stella McCartney, the exchange of sustainability lessons learned and values among brands should not be limited by any conditions [25]. Based on this, the article aims at studying Burberry as a large-scale fashion brand, or should say luxury brand, which has made noticeable progress in sustainable development to see if we can find effective solutions that are applicable to apparel companies of different types and sizes.

Burberry was the leading fashion company on the 2017 and 2018 Dow Jones Sustainability Index (DJSI). In December 2018, in Katowice, Poland, a fashion industry charter for climate action was formally launched at the UN climate change conference, COP24. Burberry, Stella McCartney, Adidas, and PVH Corp. were included in the list of 43 signatories [26]. As a result of the company's contributions in the field of sustainability, the company was awarded the

'Bronze Class' in RobecoSAM's 2018 Sustainability Yearbook. The highlights of Burberry since 2012 include 77% of its leather being manufactured by certified tanneries, 33% energy savings, and an 18% reduction in water use at key mills. The company has also stated that it will use, reuse, repair, donate, or recycle unsaleable products, and continue to expand these efforts [27]. Burberry's responsibility agenda states that the company will focus not only on economic growth but also on strictly controlling and reducing their market-based emissions, committing to 100% renewable electricity by 2022 and immediately ending the practice of destroying unsaleable finished products. With regards to enterprise products, in addition to improving raw materials, such as improving the sustainability and performance of the cotton and leather supply chain, the most interest and attention has been paid to the statement that 100% of their products will have at least one positive attribute by 2022 with respect to product sustainability [27].

Methodological approaches

Scholarly research projects on SAPD have more often taken a 'single product' as the study object pertaining to development models [28], whereas the closely-related product series (range) development model has not received much attention. The term 'collection', applied to fashion design, refers to a compilation of clothing or accessories that are interlinked in a limited way. Each collection may consist of several ranges or series, and they may be linked through a combination of factors usually associated with a theme or season. A 'series' refers to more specific sets of clothing connected by KEs. Although this approach has an important role for the independent designer who creates their reputation through the design of such series of clothing [29] and is considered a design code of luxury fashion brands [30], the application of series design in SAPD has rarely been studied. Clothing series design (CSD) methods have been successfully attempted in Burberry and other FBCs with the same status, market, and positioning. For example, from October 2018, the B series, designed by Burberry's Chief Creative Officer R. Tisci, was released monthly through Burberry's Instagram and WeChat accounts as well as, for the first time, through the LINE and Kakao platforms [31].

(1) Clothing series design method concept

A series may be used to describe a more specific grouping of clothing products that are aligned to a commercial sales or marketing plan [32]; and may also refer to the relationships between the garments. CSD is based on the quantification of styles (≥3) as a premise for matching the wants of specific market segments and meeting consumer demand. A similar design method has been adopted to establish an equivalent connection between products through the KEs of clothing design to express a unified style tendency [33], as shown in **Figure 1**.

As Eames once said, 'design is a plan for arranging elements in such a way as to best accomplish a particular pur-

Figure 1. *A series design by Burberry, fall/winter, ready-to-wear, 2012.*

Table 1. *Clothing series design model (CSDM) based on key elements (KEs).*

Theme (T)	Silhouette (S)	Colour (C)	Styles(S')	Fabric (F)	Detail (D)
YTNS	YSNT	YCNT	YS'NT	YFNT	YDNT
YTNS'	YSNS'	YCNS	YS'NS	YFNS	YDNS
YTNC	YSNC	YCNS'	YS'NC	YFNS'	YDNS'
YTNF	YSNF	YCNF	YS'NF	YFNC	YDNC
YTND	YSND	YCND	YS'ND	YFND	YDNF

Figure 2. *2012 Burberry spring and summer women's ready-to-wear collection.*

Theme	Silhouette	Colour	Styles	Fabric	Detail
0	0	0	0	0	0
2	0	0	0	1	0
1	0	0	1	4	1
0	1	0	1	0	0
0	0	0	0	0	0

pose' [11]. Product design revolves around KEs, and the application of the same KE in different clothing products is an important feature of CSD.

(2) Clothing series design methods and model

The concept of CSD is determined by the class and genus of the clothing design KEs. According to the definition of clothing design KEs in this study (the definitions are listed in ***Appendix A***), these KEs are represented by different symbols to better identify them: theme (T), silhouette (S), styles (S'), colour (C), fabric (F), and details (D). Every product is inseparable from the participation of all the KEs, but in the process of CSD, a designer must plan which element is to be used as the main one. In order to enable consumers to identify KEs more accurately, we developed the following rules:

(1) The CSD must ensure that products in a series have one KE that is the same throughout;

(2) Once the same KE has been identified, the remaining five KEs appear, in different forms, as auxiliary elements in the series design process; and

(3) The design should follow the rules from abstract elements to concrete elements, from overall modelling to local detail. In general, the theme and silhouette are relatively more abstract among all the KEs, which are also the common starting point of the series product design. Take silhouette as an example, designers often use the shape of letters (such as A-line, T-line, and so on) to outline, and when the silhouette planning is completed for the product series, they will fill in other elements such as styles, fabric, colour, and details. Once the design draft is done, designers will clarify the KEs one by one and make adjustments from the overall design to the design of different parts and from the different parts back to the overall design to make sure those

elements are well implemented until the specific design ideas and product development objectives are achieved.

In the theoretical model, combining the basic methods of clothing design with consumer purchasing decisions [34], we compiled the order of the KEs to suit the rules we had developed. In ***Table 1***, Y indicates the same KE and N a different KE. For example, a series with the same theme (YT) but different silhouette (NS) is expressed as YTNS, whereas one with the same silhouette (YS) but a different fabric (NF) is expressed as YSNF. A clothing series design model (CSDM) was constructed by dividing relevant KEs into 30 different modules. In the theoretical model, the same elements are the necessary conditions for the CSD. They bring a sense of unity to the series of products, and other auxiliary elements (besides the same ones) bring diversity to the series. In a category element module, there are five small modules. In the process of sorting out brand products or developing new ones, a designer can fully plan according to these modules.

Data collection and analysis

We chose the 2012 Burberry spring and summer women's ready-to-wear products for observation, with data from the World's Global Style Network (WGSN), as shown in ***Figure 2***.

Table 3. *Series design of the Burberry Spring and Summer women's ready-to-wear collection, 2012.*

Series 1: A series of YTNS' (same theme but different styles).

Series 2: A series of YTNS' (same theme but different styles).

Series 3: A series of YTNC (same theme but different colours).
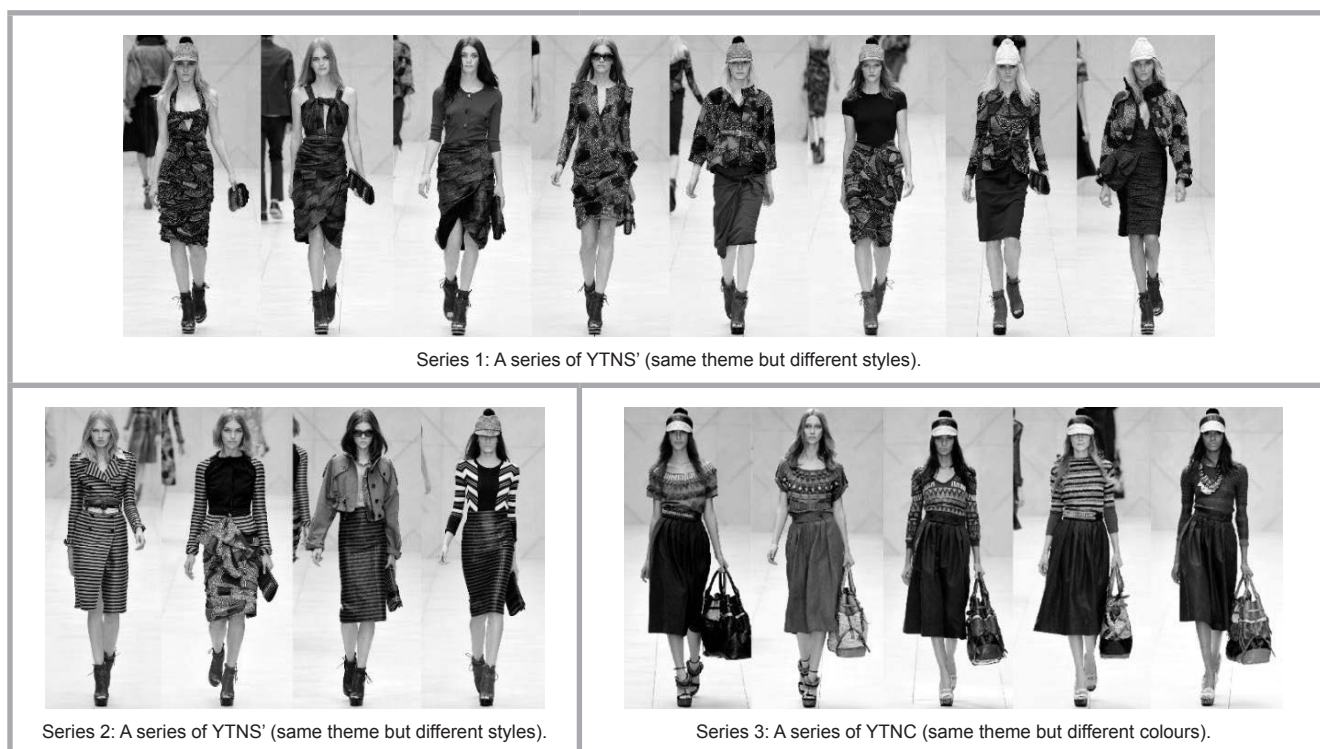
Table 3. *Continued.*

Series 4: A series of YS'NC (same styles but different colours).

Series 5: A series of YSNF (same silhouette but different fabrics).

Series 6: A series of YFNS (same fabric but different silhouette).

Series 7: A series of YS'NF (same styles but different fabrics).

Series 8: A series of YFNS' (same fabric but different styles).

Series 9: A series of YFNS' (same fabric but different styles).

Series 10: A series of YFNS' (same fabric but different styles).

Series 11: A series of YFNS' (same fabric but different styles).

Series 12: A series of YDNS' (same detail but different styles).

2009		2010		2011		2012		2013		2014		2015		2016		2017		2018		Total
S/S	F/W	S/S	F/W	S/S	F/W	S/S	F/W	S/S	F/W	S/S	F/W	S/S	F/W	S/S	F/W	S/S	F/W	S/S	F/W	
Number of products released by the brand each season																				
47	41	42	48	43	50	46	47	45	45	42	46	43	50	40	47	47	48	47	51	915
Series product data analysed by CSDM																				
9	11	10	12	11	13	12	10	8	10	10	12	10	13	9	13	14	10	12	14	223

Table 5. Analysis of Burberry clothing series data from 2009-2018.

		Theme	Silhouette	Colour	Syles	Fabric	Detail
		6	4	2	17	0	4
		2	15	6	0	19	6
		0	0	2	9	26	1
		10	11	1	19	12	2
		6	6	0	16	13	7
Total	223	24	36	11	61	70	20
	100%	10.8%	16.1%	4.9%	27.4%	31.8%	9%

By understanding the function of KEs and following the rules above, our goal was to retrieve each product from a whole collection and identify the relationships between the corresponding KEs. As we adopted the cluster analysis method [35], we divided all 46 products in *Figure 2* according to the KEs (products with the same silhouette were grouped, for example), and then selected products with different themes, styles, colours, fabrics, and details by applying principal component analysis (PCA). Following this, according to the series design module in CSDM, we reorganised the classified clusters. Twelve series were ultimately obtained (*Table 2*); *Table 3* shows each specific clothing series analysed based on the CSDM model.

The clothing series reorganised by CSDM looks more specific and easier to understand due to the connection with the same KEs. Next, we expanded the scope of research to branded products released by Burberry from 2009-2018, including two seasons per year – spring and summer (S/S) and fall and winter (F/W) – with all data from the WGSN, as shown in *Table 4*. *Table 5* shows the distribution of all series data.

The analysis results of the 2009-2018 products show that the methods used in the development of a series of products were distributed intensively in the CSDM, thus we focus on the analysis and discussion of the fabrics (31.8%) and styles (27.4%) in the following paragraphs. We also observed a certain amount of silhouette (16.1%), theme (10.8%), detail (9%), and colour (4.9%), which we do not examine in depth in this study.

Verification

One case study is exploratory and represents the first attempt to try to test the model suggestedl even the verification is just one test, and further empirical study is needed. Choosing a particular geographic context for a qualitative study was facilitated by connections established by one of the authors, who was able to gain access to a number of FBCs in Xiamen, China. This approach was supported by a large body of literature [36, 37]. The RF Company was established in 2016, with headquarters in Xiamen, Fujian, China. As a growing retailer, the company currently owns stores in more than 30 cities in China, with annual sales of 100 million yuan (RMB) in 2018. Since 2016, the sales volume of the company has recorded a 20% growth rate. The RF company meets the definition of an FBC in this study. Therefore, we chose to conduct empirical research in co-operation with this company.

Selection of design options

Our collaboration with the company was responsible for part of the new product development (14/40) for the spring and summer season of 2019. In the product development process, CSDM led to the completion of four series, for a total of 14 styles. In particular, three of the series were specifically targeted using the same fabric module, as shown in *Table 6*.

Sample production

Mass clothing production has been criticised for its low sustainability, mainly due to the waste of raw materials and other resources (such as water and electric-
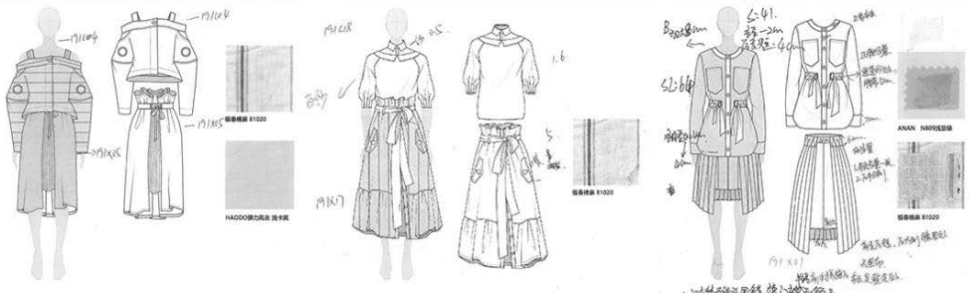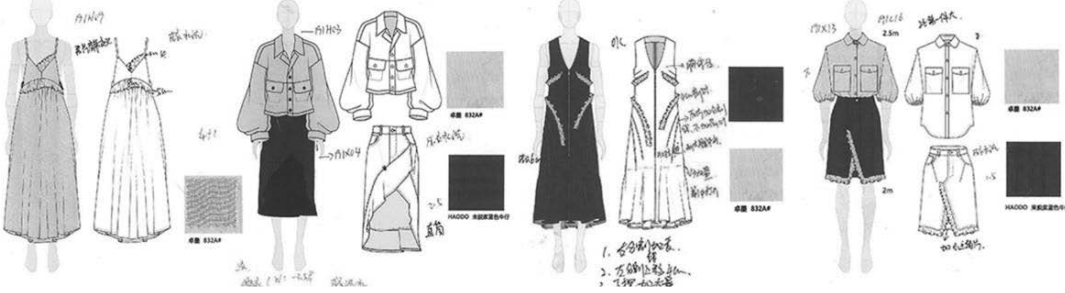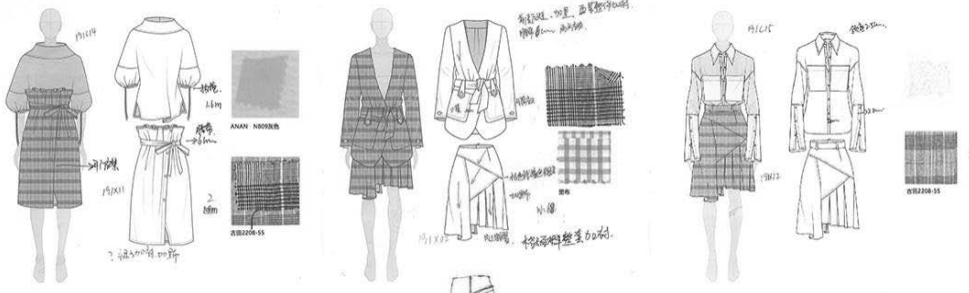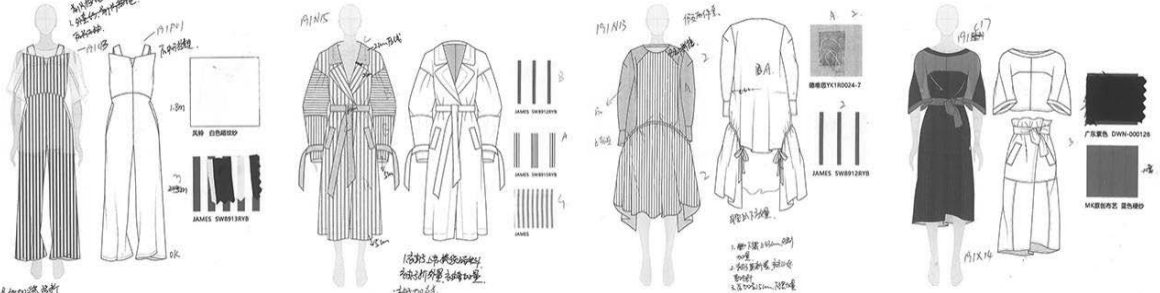
ity) in the manufacturing process [38]. Traditional mass production of clothing is based on the mixed typesetting of different sizes in the same style, and a use rate of fabric cutting $\geq 80\%$ is considered to be an ideal result [39]. Taking series 3 in *Table 6* as an example, the three styles used the same plaid fabric, and the fabric width was 150 cm. In single-pattern cutting, the fabric use rates were 80.3%, 79.5%, and 75.6%, and the amounts of fabric used were 1.341 m, 2.867 m, and 1.265 m, respectively, for a total of 5.473 m, with data calculated using CAD/CAM software (Modaris V7R2 for pattern design, and Diamino V6R2 for material typesetting, LECTRA, France).

CSD can also be used to unify the technological process and the pattern cutting of multiple styles using a CAD/CAM tool. This provided important information in this study; that is, material loss can be controlled through intensive production to create a more efficient design output and provide support for SAPD. In this study, patterns using the same fabric were combined in typesetting to replace the typesetting of different sizes of the same style with S, M, L & XL. The fabric use rate of this series was 85.2% after mixed pattern typesetting, and the fabric consumption was 4.88 m, which saved 0.593 m when compared to the fabric consumed by single-pattern cutting, as shown in *Figure 3*. The completed collection including the four series, which were released at RF's fashion show during Xiamen International Fashion Week (26 November 2018), is shown in *Figure 4*.

Results and discussion

For series 1 and 2 in *Figure 4*, the same pattern-cutting method was used. One fabric was used in series 1 (a coat and two skirts), where the fabric use rate was 86.2%. Two fabrics were used alternately in series 2, where the fabric use rates were 85.5% and 84.9%. Series 1-3 used the same method, where the fabric use rate reached or exceeded the industry's ideal standard ($\geq 80\%$). Mixed pattern

Series 1: A series of YFNS'; (the same fabric ((striped linen)) but a different style).

Series 2: A series of YFNS'; (the same fabric ((blue denim and plain cotton)) but a different style).

Series 3: A series of YFNS'; (the same fabric ((plaid)) but a different style).

Series 4: A series of YTNS'; (the same theme ((vacation in Santorini)) but different styles).

cutting in the proofing stage could easily achieve this goal, with a fabric use rate increase of about 5% in at least three series in this research; if different sizes of the styles had been incorporated into the mass production, the increase would have been greater. Due to the different design modules (YTNS') used in series 4, the fabric use was not as efficient as that of the other three series.

In terms of fabrics, when the same fabric is used in a clothing series, its width should be considered, as some differences may exist as a result of mixed pattern-cutting in the same clothing series. In the development of a series of products dominated by fabrics, attention should be paid to combining the advantages of CAD/CAM mixed typesetting; considering this, designers have the op-

portunity to partially modify or redesign every style in a series, and strive for more sustainable fabric consumption on the premise that the design is fully expressed.

In terms of styles, by using the same style in a clothing series, methods based on rapid prototyping products or styles have been applied in previous studies to improve the efficiency of product
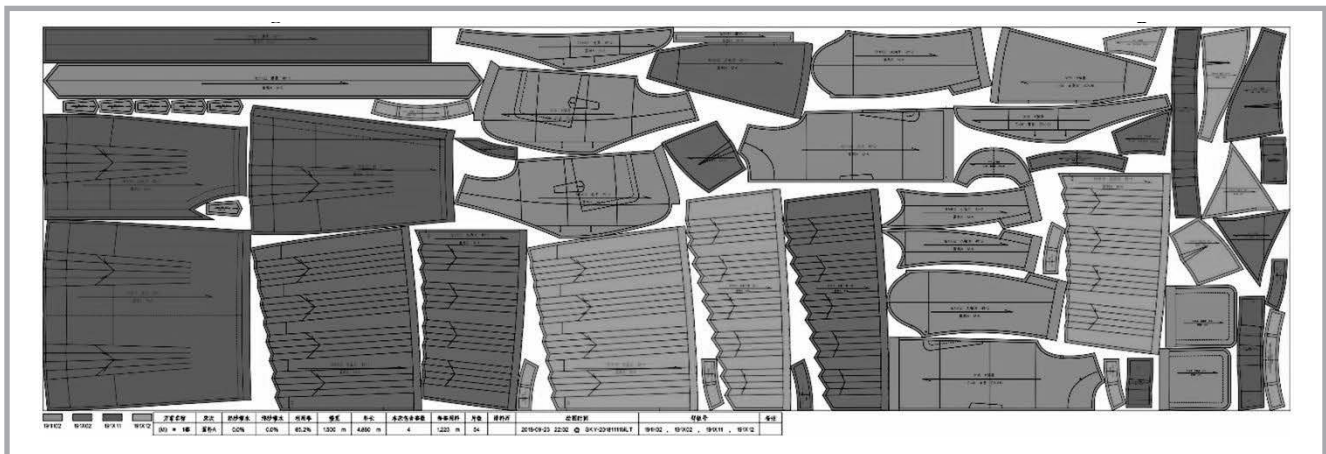
Figure 3. *Fabric layout of series 3 (see **Table 6**).*

Series 1: A series of YFNS'.

Series 2: A series of YFNS'.

Series 3: A series of YFNS'.

Series 4: A series of YTNS'.

Figure 4. *Four series completed in this research and presented at a fashion show.*

development through the reuse of product prototypes [40]; however, the waste material control was not remarkable. In clothing product development, the reuse of styles not only reduces the repeated development of clothing patterns but also the extra investment necessitated by repeated adjustments. The advantage of style reuse lies in using the same pattern combined with different fabrics or adding more details to achieve the purpose of improving the diversity of a brand of

products [41]. For example, in series 7, shown in ***Table 3***, the style known as the "trench coat" appears in almost every season. As an iconic Burberry product, it is no longer subject to fashion trends. For consumers, this means a longer product life cycle i.e. a product that does not become obsolete due to changes in fashion trends. Time-honoured classic styles like this can also be found in other well-known fashion brands, such as Chanel's tweed suit and little black dress. There-

fore, from an economical perspective, when brands organise a series of products with the same style, high sustainability performance can be achieved.

The information we utilised for the analysis and research comes from Burberry's 2016-2018 Spring and Summer Collection. This study has successfully helped its brand with new product design, and their Brand Design Director, Ms. Lin, has provided the following feedback: "Our

suppliers and distributors are satisfied with the research results. A big systematic improvement in the product organisation can be seen from the newly released products. In particular, taking advantage of the series product design method to organise fabrics has demonstrated a huge potential for controlling fabric cutting waste, which the company did not realised prior. This will help our company establish a more complete system for sustainable product development."

Discussion and conclusion

Concluding remarks

SAPD tools, such as design for X, have often taken only a single product as the study object pertaining to the development of models; these tools also only being aimed at a single element of clothing design. The development of a CSD approach linking all KEs in clothing products has been neglected [28]. Therefore, in-depth research on the CSD not only answers the first question raised by this study but can also be seen as a significant and unique contribution to the CSD literature.

An effective theoretical model is the focus of this study and also the key to answering the second question raised in this study. Our main contribution was building a user-friendly CSDM based on the definition of CSD. In addition, we employed a large FBC for a case study. After understanding the real situation of the enterprise though the model we developed, we chose a small FBC in China as our experimental object for a robustness check. The verification results show that the model has good performance in SAPD.

Theoretical and practical contributions

1. Theoretical contributions: This study theoretically contributes to the introduction of CSD methods into the deeper SAPD research field, which can be used to develop a more robust and comprehensive CSD theory. The sustainable clothing design "toolbox" strategy developed by Fletcher was expanded and enriched in order to increase material efficiency and reduce the environmental impact across a product's lifecycle, including both the economical (cost reduction) and the environmental (energy and material savings) [42]. In this paper,

our research not only combined the sustainable views of naturalism and rationalism, as proposed by Ehrenfeld [43], but also took into full account humanism with respect to the needs of various countries and regions at different socio-economic levels as well as the individual enterprise requirements at each level of the economy in a sustainable world. Moreover, our research positively responded to the viewpoint that "sustainability initiatives must contend with the fashion influence" [44].

2. Practical contributions: the outstanding practical contribution of the CSDM model lies in the completely open choice of fabrics. Most SAPD models only require organic or ecological fabrics, but they also put forward strict requirements for material suppliers [18]. To some extent, it provides a more comprehensive support for the C2CAD. This model was developed without fabric restrictions and, thus, is more aligned with the actual situation of a majority of FBCs. We claim that this model is competitive, even for companies that produce clothing entirely from ecological and organic fabrics, as it provides an effective solution for controlling fabric waste. We identified methods to effectively control fabric cutting waste through the combination of CSD and software tools. Therefore, in the context of mass production, maximising the use of fabrics and reducing their waste should be one of the most valuable contributions to SAPD.

Our research conclusions come from a case study of a large FBC. The case study method is particularly suitable for observing and studying the serial transformation of enterprises; and is good for seeking out new ideas and thoughts, potentially even resulting in the creation of a theory. In our analysis, Burberry has recently made a lot of positive contributions in the field of sustainable development, which is worthy of reference for socially responsible enterprises. The CSDM developed by this research is the result of an analysis of the product design and organisation modes of enterprises. Compared with other means of sustainable innovation, this model has significantly lower requirements for the technical conditions and capital investment of enterprises. It is a simple and humanised model framework which can

start from any module for product series development. We even combined the observation angles of ordinary consumers to optimise the compiled order of the modules, which makes the company more in line with market expectations when using the model for new product development. Therefore, it is more suitable for some small enterprises with insufficient experience to imitate and learn from.

Managerial implications and insights

Facing social and environmental pressures, FBCs need to adjust their product development strategies in a timely manner to meet the requirements of sustainable development. For many FBCs which are willing to transform, the introduction of CSD not only means adjustment for their own corporate image but also winning the favour of consumers and even becoming a hot topic on social platforms; such as accomplished by Burberry's B series. For some economically restricted FBCs, making full use of CSD not only means gradually increasing the number and types of sustainable clothing products in a product collection (or in multiple product collections) and gradually upgrading [45] but also avoiding the huge investments and risks required for a comprehensive consideration of the replacement of a sustainable system over a short time period.

Limitations and future research

The paper is just an exploratory piece of research, a first step of a research line which is trying to innovate theory and practical tools. Although the model proposed in this study positively affects SAPD, enterprises will face some challenges in accepting this method, mainly due to the dependence on traditional product development models. The object used for our case study was that of retail enterprises, which only represents certain FBCs. As the development of products in wholesale enterprises, original equipment manufacturer (OEM) enterprises, and other enterprises are related to the conditions and positioning of the company itself, not all FBCs can fully adopt this method.

For the CSDM proposed in this study, only the sustainability value of the same fabric in a series design was considered in the empirical study; and the other modules in the model were not demon-

Appendix A. Interpretation and clarification of concepts.

Explanation of the key elements of clothing design	
Silhouettes	The silhouette of a garment refers to the outline or shape.
Colour	Colour refers to the components into which white light, or the full spectrum, may be separated. Every colour embodies three dimensions: hue (the name given to a particular colour family, with its integral degree of warmness or coolness "visual temperature"; for example, warm hues and cool hues. Black, white, and gray are without hue), value (value refers to the degree of lightness or darkness of a hue), and intensity (intensity, also referred to as chroma, is the degree of brightness or dullness of a hue, "visual clarity").
Fabric	Fabric is determined by the fibre, yarn, and method of fabrication, which supports the structural design of a garment. Texture is an attribute of fabric, which describes the surface characteristics of fabric or material: the way it looks, tactile impression, hangs or drapes, and possibly the sounds made when rubbed together.
Styles	Styles refers to the clothing forms, specific features, and also to the 'cut' in menswear; such as Single-breasted, Bodice, Trench Coat, Cheongsam, and so on.
Details	The lines on the inside of a garment provide details such as collars, necklines, sleeves, pleats, darts, pockets, and contour seaming. A line encloses and divides space, indicates direction, and leads the eye throughout the design (e.g., Structural Lines, Decorative Lines, and so on.).
Theme	A theme can, loosely, be defined as a visual or literary reference which directly influences the look of the clothes. A theme is a topic for a fashion concept that has a unifying, dominant idea. The process from concept through theme can be described as the journey from culture to product. It involves the contents of art, culture, lifestyle and other aspects, such as fonts (style of lettering) and symbols, printing patterns, garment combinations, and so on. It conveys the prediction of future trends through products.

strated, which will be the focus of our future research. For example, in a series of products of the same colour, when a popular colour is used for a predetermined fabric and yarn, the production efficiency of printing and dyeing and the sustainability of water resource consumption are involved. In addition, we did not combine multiple identical KEs for a series of clothes with the same silhouette and colour, or for a series of clothes with the same theme and fabric. A certain elasticity exists in the combination of multiple KEs in CSD, but whether this can produce superior sustainability performance in SAPD, as compared to using a single KE, still needs to be further examined with more empirical research. In addition, we can study and compare the sustainability of five different small modules under the same category of element modules; In this case, determining which module provides optimal sustainability will be interesting and challenging.

This paper represents an attempt to improve upon the traditional models and to make just one test of the model with one case study. We are trying to cooperate with FBCs of different types and sizes; further companies for verification will be added and the same experiments replicated to understand if the model really works.

Author contributions

J.Z. and L.L. collected data, G.X.L conducted the analysis, J.Z wrote the paper, and W.G checked and revised the manuscript. The clothing collection was designed by J.Z.

Conflict of interest

The authors declare no conflicts of interest.

References

1. Bogue R. Sustainable manufacturing: a critical discipline for the twenty-first century. *Assem Autom* 2014; 34: 117-122.
2. Shapira H, Ketchie A, Nehe M. The integration of design thinking and strategic sustainable development. *J Clean. Prod* 2017; 140: 277-287.
3. Niinimaki K, Hassi L. Emerging design strategies in sustainable production and consumption of textiles and clothing. *J Clean Prod* 2011; 19: 1876-1883.
4. Mills DE. Why retailers sell private labels. *J Econ & Manag Strategy* 1995; 4: 509-528.
5. Dyer B, Ha-Brookshire J. Apparel import intermediaries' secrets to success: Redefining success in a hyper-dynamic environment. *J Fash Mark & Manag* 2008; 12: 51-67.
6. Amaden-Crawford C. Draping Principles and Skills. In The *Art of Fashion Draping* (pp. 3-20). New York: Fairchild Books, 2018.
7. Cadigan E. Conceptualizing the Collection. In *Sourcing and Selecting Textiles for Fashion* (pp. 108-131). London: Fairchild Publications, 2014.
8. Rousso C, Ostroff NK. The look. In *Fashion Forward: A Guide to Fashion Forecasting* (pp. 158-169). New York: Fairchild Books, 2018.
9. Sorger R, Udale J. Research. In *The Fundamentals of Fashion Design* (pp. 10-35). London: Bloomsbury Visual Arts, 2017.
10. Brannon EL. Designing the Line. In *Designer's Guide to Fashion Apparel* (pp. 112-139). London: Fairchild Publications, 2011.
11. Liechty E, Rasband J, Pottberg-Steineckert D. Using the Elements and Principles of Design in Apparel Design and Style Selection. In *Fitting & Pattern Alteration: A Multi-Method Approach to The Art of Style Selection, Fitting, and Alteration* (pp. 17-45). New York: Fairchild Books, 2016.
12. Tain L. Presentation Concepts. In *Portfolio Presentation for Fashion Designers* (pp. 88-109). (4th Edition), New York: Fairchild Books, 2018.
13. Meerkamm H, Koch M. *Design for X. Design Process Improvement*. Springer London, 2005.
14. Ghosh D, Shah J. A comparative analysis of greening policies across supply chain structures. *Int J Prod Econ* 2012; 135: 568-583.
15. James AM, Roberts BM, Kuznia A. Transforming the sequential process of fashion production: where zero-waste pattern cutting takes the lead in creative design. *Int J Fash Des Tech Educ* 2016; 9: 142-152.
16. Fontana M, Carubelli A, Rizzi C, et al. Cloth assembler: a CAD module for feature-based garment pattern assembly. *Comput Aided Des Appl* 2005; 2: 795-804.
17. Cao H, Frey LV, Farr CA, et al. An environmental sustainability course for design and merchandising students. *J Fam Consum Sci* 2006; 98: 75-80.
18. Gam HJ, Cao H, Farr C, Heine L. C2CAD: A sustainable apparel design and production model. *Int J Cloth Sci Tech* 2009; 21: 166-179.
19. Paras MK, Wang LC, Chen Y, et al. A Sustainable application based on grouping genetic algorithm for modularized redesign model in apparel reverse supply chain. *Sustainability* 2018; 10: 3013-3032.
20. Roser T, DeFillippi R, Goga Cooke J. Co-creation in design: How the UK company own label combines openness and ownership to manage talent. *Strategy & Leadership* 2014; 42: 34-40.
21. Rodrigues M, Franco M. Importance of living labs in urban Entrepreneurship: A Portuguese case study. *J Clean Prod* 2018; 180: 780-789.
22. Preuss L, Perschke J. Slipstreaming the Larger Boats: Social Responsibility in Medium-Sized Businesses. *J Busi Ethic* 2010; 92: 531-551.

23. Achabou MA, Dekhili S. Luxury and sustainable development: Is there a match? *J Bus Res* 2013; 66: 1896-1903.

24. Nunes B, Bennett D, Shaw D. Green operations strategy of a luxury car manufacturer. *Technol Anal Strateg* 2016; 28: 24-39.

25. Yang YF, Han H, Lee PKC. An exploratory study of the mechanism of sustainable value creation in the luxury fashion industry. *Sustainability* 2017; 9: 483-499.

26. UNFCC. Milestone Fashion Industry Charter for Climate Action Launched. Available online: https://www.un.org/sustainabledevelopment/blog/2018/12/milestone-fashion-industry-charter-for-climate-action-launched/ (accessed on August 23, 2019).

27. Burberry. Creating tomorrow's heritage, our responsibility goals to 2022. Available online: https://www.burberryplc.com/en/responsibility/creating-tomorrow-s-heritage.html#item-undefined (accessed on February 15, 2019).

28. Kim S, Moon SK. Sustainable platform identification for product family design. *J Clean Prod* 2017; 143: 567-581.

29. Leslie D, Brail S, Hunt M. Crafting an antidote to fast fashion: The case of Toronto's independent fashion design sector. *Growth Change* 2014; 45: 222-239.

30. Angelis MD, Adıgüzel F, Amatulli C. The role of design similarity in consumers' evaluation of new green products: an investigation of luxury fashion brands. *J Clean Prod* 2017; 141: 1515-1527.

31. Burberry News. Burberry introduces the first of its series of monthly product releases. Available online: https://www.burberryplc.com/en/news/news/corporate/2018/b-series.html (accessed on August 23, 2019).

32. Hopkins J. *Developing a Collection. In Fashion Design: The Complete Guide*. London: Fairchild Books (UK). 2012, pp. 140-171.

33. Xu J. The study of rules about product form based on the user's preference image. *Light Industry Machinery* 2004; 4: 4-6.

34. Kim Y, Krishnan R. On Product-Level Uncertainty and Online Purchase Behavior: An Empirical Analysis. *Manag Sci* 2015; 61: 2449-2467.

35. Su J, Gargeya VB, Richter SJ. Global sourcing shifts in the u.s. textile and apparel industry: a cluster analysis. *J Text Inst* 2005; 96: 261-276.

36. Li Y, Liu Y, Li M, et al. Transformational offshore outsourcing: empirical evidence from alliances in China. *J Oper Manag* 2008; 26: 257-274.

37. Sinha P, Akoorie Michèle EM, Ding Q, et al. What motivates manufacturing smes to outsource offshore in china? *Strategic Outsourcing* 2011; 4: 67-88.

38. Bhatia D, Sharma A, Malhotra U. Recycled fibers: an overview. *Int J Fiber and Text Res* 2014; 4: 77-82.

39. Parish P. Sustainability and fashion. In pattern cutting: The architecture of fashion, 204-225. London: Bloomsbury Visual Arts, 2018. Available online: http://dx.doi.org/10.5040/9781474272407.ch-007 (accessed on January 08, 2019).

40. Broega AC, Jordão C, Martins SB. Textile sustainability: reuse of clean waste from the textile and apparel industry. *IOP Conference Series: Materials Science and Engineering* 2017; 254: 192006.

41. Skov L. Hong Kong fashion designers as cultural intermediaries: out of global garment production. *Cult Stud* 2002; 16: 553-569.

42. Fletcher K. Exploring demand reduction through design, durability and 'usership'of fashion clothes. *Philos Trans A Math Phys Eng Sci* 2017; 375(2095), 20160366.

43. Ehrenfeld J. Designing sustainable product/service systems. In *Proceedings Second International Symposium on Environmentally Conscious Design and Inverse Manufacturing* (pp. 12-23). IEEE, 2001.

44. Gill A, Lopes AM, Kaye-Smith H. Practicing sustainability: Illuminating 'use' in wearing clothes. *Cult Stud Rev* 2016; 22: 32-58.

45. Aspers P. Using design for upgrading in the fashion industry. *J Econ Geogr* 2010; 10: 189-207.