Zero waste in the apparel industry: limitations and alternatives

Zero waste na indústria do vestuário: limitações e alternativas

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ABSTRACT

The Zero Waste approach applied to garment manufacturing promises the elimination of textile waste in the production process, making the process more sustainable. This article contributes to aiding textile manufacturing companies in applying more sustainable techniques to reduce waste. Therefore, the main objective is to identify critical aspects and limitations of the design and the patternmaking process using the Zero Waste approach to apply in the garment industry in large-scale production. The study initiates with zero waste bibliography research and identification and analysis of the proposals of the fashion designers who use the Zero Waste approach to garment design and pattern making. As a result, the article presents critical aspects and limitations of the approach and discusses viable alternatives for its implementation in the large-scale garment manufacturing process.

Keywords: Zero waste. Apparel. Industry. Textile sustainability.

RESUMO

A abordagem Zero Waste (ou zero resíduo), aplicada à produção do vestuário, promete a eliminação dos descartes têxteis durante o processo produtivo, promovendo ações em direção à sustentabilidade. Dentro dessa perspectiva, o presente artigo contribui para que empresas de confecção têxtil possam aplicar processos mais sustentáveis, visando à eliminação dos resíduos. Para tanto, como principal objetivo, o trabalho busca identificar aspectos críticos e limitações do processo de criação e modelagem,

usando a abordagem Zero Waste, para sua aplicação na indústria do vestuário, na produção em larga escala. Para isso, a pesquisa partiu de bibliografia relacionada ao tema e da identificação e análise das propostas dos principais designers do vestuário que utilizam as técnicas de criação e modelagem com a abordagem Zero Waste. Como resultado, o artigo apresenta uma discussão sobre os principais aspectos limitantes e alternativas viáveis para sua implementação no processo produtivo de confecção de vestuário em larga escala.

Palavras-chave: Zero resíduo. Vestuário. Indústria. Sustentabilidade têxtil.

1 INTRODUCTION

The concept of sustainable development is not new and can be defined in several ways; the World Commission gave a famous and appropriate definition of Environment and Development in 1987. According to this commission, sustainable development means development that meets the needs of the present without compromising the needs of future generations (MUTHU *et al.*, 2012).

In environmental sustainability, economist studies and environmentalists recommend avoiding waste generation in manufacturing or disposal of products after use (CUC; VIDOVIC, 2011). However, the textile industry generates about 15% of waste from what it produces between cutting and garment production. Therefore, considering the total global textile production in 2015 was about 400 billion square meters, taking into account the waste generation estimate is 15%, it estimates that the textile industry generates around 60 billion square meters of waste (RISSANEN; MCQUILLAN, 2016).

The creation of Brazilian Law No. 12,305 of 2010, which support the National Policy on Solid Waste (PNRS), led the garment industries to seek alternatives for the appropriate and responsible management of textile waste. There are several points of attention at the stages and resources used and produced by the textile and garment industry. Using renewable and biodegradable fibres, recycling alternatives, minor use of chemical substances in textile crops, and little use of energy and water, among other factors, can improve these points (FLETCHER; GROSE, 2011). Also, according to the same authors, changes in clothing design are necessary to reduce or eliminate waste and offer to the market garments with timeless concepts, greater durability and useful life. In addition, the consumer is also responsible; he should seek a more thoughtful consumption that minimises waste and support sustainable industry initiatives.

Thus, the designers are essential agents in the search for more sustainable fashion, proposing innovative alternatives in garments with style, quality, and durability, which minimise or eliminate waste from the moment of conception of the garment to the stages of its manufacture. One of the approaches that seek the total elimination of waste in the design and construction of garments is the Zero Waste approach, which acts directly on the source of waste and can be considered clean technology, with production processes modified considering the environment (PEREZ; CAVALCANTE, 2014).

Several fashion designers have been using the Zero Waste approach, in which the creative process is executed together with the steps of pattern making and marker making for the textile cut. It is worth remembering that, in the process of conventional fashion design, these steps are carried out independently and usually executed by professionals of different specialities. The sketch is generally used for creation and establishes the details, colours, and aesthetic aspects. However, it is impossible to identify and calculate the waste in the sketch phase; it is only possible to figure in the following stages when pattern making and cutting are carried out. In another way to these hierarchical patterns of the conventional process steps, the practice of creating Zero Waste fashion acts dynamically in its processes. The steps traditionally performed separately are necessarily performed together. Therefore, the patternmaking step becomes an integral part of the process and actively contributes to generating ideas. Such a change of standards highlights the designer's need to be open to the possibilities and accept the risks and challenges of this practice (RISSANEN; MCQUILLAN, 2016, p. 123).

However, despite the numerous proposals for Zero Waste creation and pattern making already presented by several designers, many questions arise about its application in the large-scale production process. The time required for the creation process increases as well as its complexity. These techniques are unconventional and unknown to most textile manufacturing professionals; applying the Zero Waste approach concepts, both in the creation and later stages, requires several adjustments in the production. The main issue, perhaps the most discussed, is related to the pattern grading stage. At this stage, the patterns produced in the base size are enlarged or reduced to meet the size grid offered by the company. Usually, a first size (base size) is produced with the concepts of the Zero Waste approach, and in grading, it is not always to keep all the grid sizes with the same idea. However, the graduation of patterns is not the only issue to be resolved by garment companies that apply this approach. There are other limiting factors in using this approach on a large scale.

Recently, other researchers have studied pattern grading. For example, ElShishtawy *et al.* (2021) conducted a systematic literature review on cutting and marker-making processes and Zero Waste apparel design. As a result, unlike the conventional process, the authors reinforce the importance of integrating processes in this approach, indicating that future research should try to incorporate the cut-and-marker algorithms in the Zero Waste design processes. In addition, Ramkalaon and Sayem (2021) investigated the application of the Zero Waste pattern cutting concept in large-scale production to optimise the production process and achieve zero waste. The authors developed a framework to implement the concept in different size grids.

After that, they tested the framework on two types of clothes in various sizes. For this process, Ramkalaon and Sayem (2021) used digital tools to cut and design the patterns; physical prototypes experimented with the fit of the clothes. As a result, the authors achieved a 98% yield in fabric usage because 85% is already considered impossible. Finally, Carrico *et al.* (2022) investigated the effectiveness of the Carrico Zero Waste Banded grading technique in the scale production of size-grade garments. The technique was taught to six designers who applied it to scale production. According to the authors, the technique was effective in reducing fabric waste.

Considering the recent research on the subject, the relevance of some limiting aspects that can disturb the implementation of the Zero Waste approach on a large scale in industries, such as grading, marking, and cutting off pieces, and the search for solutions is noticed that minimise these issues. However, the works cited are restricted to certain problems, although essential. Still, they do not care about the complete process, the issues that permeate the Zero Waste approach, from the creative process to the operational aspects. In this way, the present work proposes identifying the main critical or limitations of applying the technique of creating and cutting garments with the approach without residue (Zero Waste) applied to the clothing industry. Furthermore, seek and present alternatives to overcome these limitations, still that partially. Therefore, the relevance of this work lies in offering textile manufacturing companies alternatives to produce more sustainable fashion through Zero Waste pattern making and creation.

2 THE ZERO WASTE APPROACH APPLIED TO CLOTHING DESIGN AND MANUFACTURING

According to Rissanen and McQuillan (2016), the term Zero Waste came up in the fashion field around 2008 as a new phenomenon. However, the same authors argue that Paul Palmer, founder of the Zero Waste Institute in 1970, one of the first to use the term Zero Waste, has published many critiques about waste in modern industry.

It is worth mentioning that "although the term zero waste fashion design is new, the practice is as old as dressing the body with skins and cloth" (RISSANEN; MCQUILLAN, 2016, p.11).

In antiquity, weaving was common on looms whose dimensions were reduced, so it was woven in reduced pieces joined by seams, minimising the waste of the cut of the wide fabric. At another time, rectangular fabrics without any transformation were wrapped around the body in different ways (BOUCHER, 2012, p. 24). In later historical periods, many garments were designed on the total use of the fabric without producing waste.

After the industrial revolution, with cheaper fabrics, this practice was abandoned. Instead, fashion began to fulfil new aesthetics that could not be linked to waste-free production. However, the concept of zero waste reappears in the 20th century (YIELD EXHIBITION, 2011). It began to be remembered more intensely in the second half of the century, with the advent of the concept of sustainability, after the Stockholm Conference, in Sweden, in 1972 (BERLIN, 2012). From then on, the contemporary pioneers of zero waste appear. Firmo (2017) presents the English artist Zandra Rhodes, who, in the 1970s, brings the production of clothing using the Zero Waste approach. During this period, Rhodes worked with geometric cuts in her creations, resulting in pieces that involved the body without any seam.

Aakko and Niinimäki (2013) explain that this zero waste method comes into fashion to eliminate fabric waste in the production of clothing from the creation of the design and state that, for this approach, it is essential to integrate pattern making with the design process, in contrast to the conventional practice of pattern making after the product creation. Rizzi, Anicet, and Meurer (2017) point out that the designer must conceive a product already thinking about patternmaking that can generate no waste and if any waste is produced, used in the garment itself. Thus, the patternmaking integrated into the product creation process differentiates the Zero Waste fashion design process from the conventional process.

Several designers work on integrated creation and pattern making using the Zero Waste approach. Some names have already been mentioned, such as Holly McQuillan and Timo Rissanem. However, professionals like Yeohlee Teng, Julien Roberts, David Telfer, Caroline Briebe, Carla Fernández, Tara St. James, Mark Liu, and several others have developed experiments using the Zero Waste approach (LIU, 2017; MCQUILLAN, 2011; RISSANEN; MCQUILLAN, 2016; ROBERTS, 2013; TENG, 2018; YIELD EXHIBITION, 2011). These designers seek to create innovative garments and propose different techniques to achieve their goals. Only Rissanen and McQuillan went beyond the creative processes among the designers mentioned. They systematised the concepts and practices of the Zero Waste approach in clothing, discussing critical or limiting aspects for its application in the industry on a large scale.

3 MATERIALS AND METHODS

The developed research adopts the qualitative model, based on observation and associative analysis of data, being the study modality of recognition, a subgroup of the qualitative method. The delimitation of the research area of interest is at the intersection of fashion design concepts with sustainability concepts. Therefore, the work is inserted in the sustainable perspective of creating and patternmaking garments.

The central part of the research was based on bibliographic material, aspects related to sustainability, the Zero Waste patternmaking phenomenon, and the relationship of these concepts with fashion design. From this search, it was possible to identify how prominent designers in the market apply the Zero Waste patternmaking techniques. This analysis allowed the authors to identify a good part of the limitations of this approach. Further, we developed prototypes of some garments, reproducing the process proposed by the designers, following their instructions (when present). Two designs created by Holly McQuillan and Timo Rissanen were chosen. They are the leading designers of the Zero Waste approach. Although not detailed in this article, developing these prototypes allowed us to identify additional limiting aspects of the Zero Waste patternmaking and creative process.

The prototypes were developed using a three-dimensional patternmaking mannequin, in natural size (40) and reduced size (50% of reduction, size 40) and raw cotton fabric, of medium weight. Photographic and written records were made of the reproduced prototype. The procedure allowed the elaboration of critical analysis on the tested patternmaking techniques.

4 RESULTS AND DISCUSSIONS

The bibliographic research made it possible to identify the main critical and limitation aspects that must be observed in applying the Zero Waste approach in the industrial production of clothing, from the creative process (associated with the pattern making and marker making) to its production stages. However, the experiments with the techniques proposed by the Zero Waste designers were essential to understanding the complexity of the patternmaking process of unconventional garments. Therefore, the integrated process of creation and patternmaking was used in the experiments.

During the elaboration of the prototypes, following the creative processes proposed by the designers, relevant aspects that were not found in the literature search emerged. Hence, the two garments chosen, made by designer McQuillan, presented in Rissanen and McQuillan (2016): the "Trapeze Sleeveless Tunic" (Figure 2) and the "Spiral Trouser" (Figure 1).

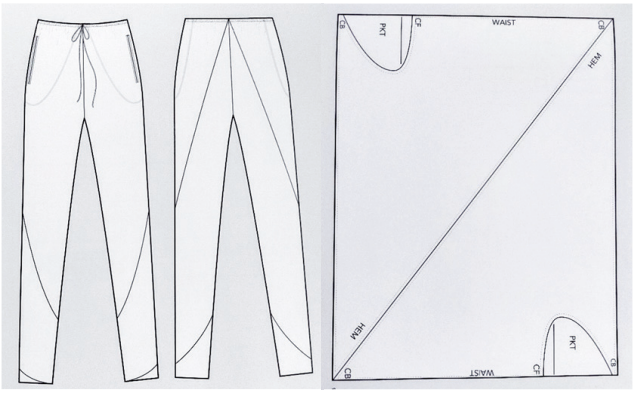

Figure 1 | Technical drawing and pattern making of the Spiral Trouser, developed by Holly McQuillan, using the Zero Waste approach.

Source: Rissanen e McQuillan (2016, p. 115).

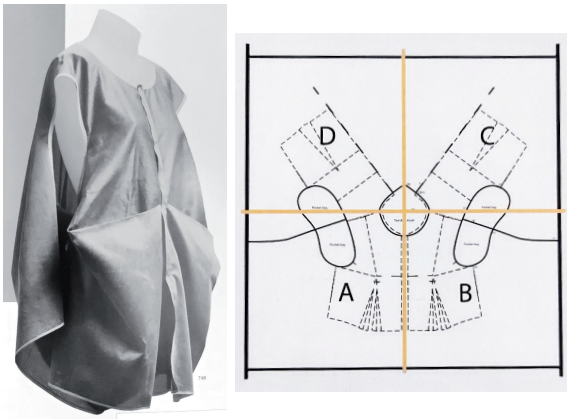

Figure 2 | Trapeze Sleeveles Tunic and its pattern making, developed by Holly McQuillan, using the Zero Waste approach.

Source: Rissanen e McQuillan (2016, p. 97-96).

In constructing the two prototypes, we observed the full use of the fabric. Despite simple pattern making, several important ramifications emerged, indicating limitations of the approach for its application in large-scale garment production.

The first aspect observed in both prototypes was the small number of instructions about the garment development process. There are several steps for elaborating each of the garments. However, many details are absent from the instructions or have dubious explanations. Because of that, the reproduction process required several tries until we could understand and replicate the garment correctly. In the case of the trapeze tunic, the publication used as a base does not present any other image of the garment, only the one shown in Figure 2, which made it difficult to understand the back of the tunic. Neither were additional images found in other publications. This is a potential problem in teaching students and professionals the Zero Waste approach in the garment manufacturing industry.

In the case of the spiral pants, three aspects showed to be necessary, which should be highlighted since they impact the results of the finished garment, such as:

1. the right and the wrong side of the fabric: when cutting and assembling one pant, according to the patternmaking diagram proposed by Holly McQuillan (Figure 1), one of the pant legs is on the right side of the fabric, other is wrong out. To avoid this problem, the pants must be cut in pairs so that the legs can be interchanged between two pants, ensuring that the fabric is straight out in all pants;

2. use of printed or textured fabric: simulations were made with the prototype with printed fabrics, which have orientation, or texture (such as velvets, for example), showed that the prints (or textures) present different directions in the resulting pieces. Figure 3 shows one of the results obtained, where the positioning and orientation of the prints on the front and back of the spiral pants can be seen. It can be observed, mainly in the backs of the pants, the diversity of orientation and direction of the simulated prints;

Figure 3 | Print orientation in spiral pants prototype (on the left, pants front view and, on the right, back view).

Source: Collection of Italiano, Kauvauti and Marcicano. Foto: Lilian S. Kauvauti, 2021.

3. variations in the fabric width and length and their influence on the size of the final garment: Given the unconventional pattern making of spiral pants, the variation in the width and length of the garment is not trivial. Thus, prototypes were developed, varying the width and length of the fabric used to understand its implications for the final size of the pieces. After several simulations, it was concluded that, for spiral pants, by fixing the width of the pattern and varying its length, the pants would change in width, producing wider or narrower pants but with the same height (Figure 4, on the left). On the other hand, by fixing the length of the pattern on the fabric and varying its width, the pants changed their height, producing longer or shorter pants, keeping the pieces the same

width (Figure 4, on the right). Likewise, the differentiated and unconventional pattern making of the spiral pants needed this type of evaluation to establish the size variations of the final garment.

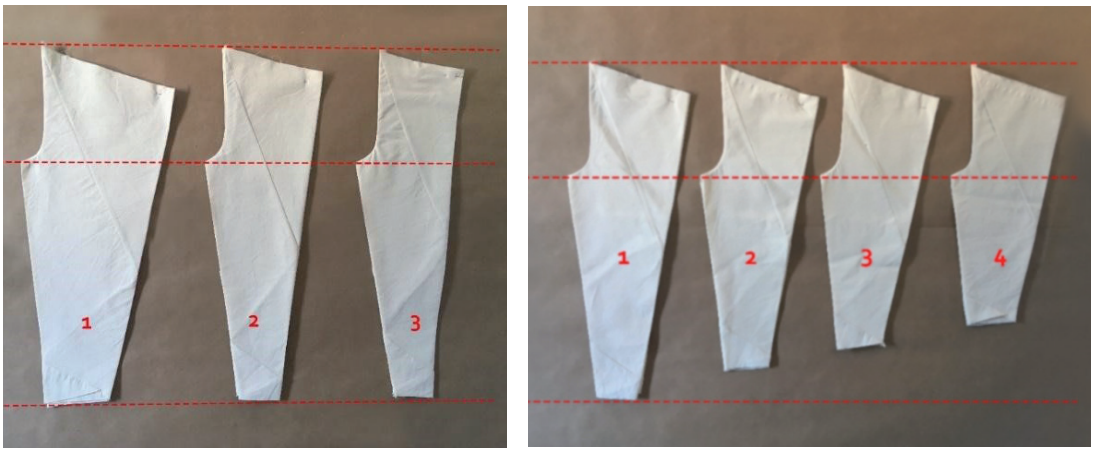

Figure 4 | Variations of the width and length of the spiral pants, design of Holly McQuillan, using the Zero Waste approach.

Source: Collection of Italiano, Kauvauti and Marcicano. Foto: Lilian S. Kauvauti, 2021.

The aspects pointed out from the development and analysis of the prototypes show that the construction of the garments in the Zero Waste approach does not follow the principles of conventional garment production and, for each garment, additional analysis are necessary to evaluate the result of each garment impacting the large-scale production process.

Thus, as a result of the bibliographic research and prototype development, it is presented the list of limiting aspects, although quite interconnected, was grouped for greater clarity:

A. ASPECTS RELATED TO DESIGN AND PATTERN MAKING WITH THE ZERO WASTE APPROACH:

A.1 - Difficulty reproducing garments developed by other designers;

A.2 - Difficulty in creating new garments with this approach;

A.3 - Difficulty in training professionals;

B. ASPECTS RELATED TO THE RAW MATERIAL USED IN THE PRODUCTION OF GARMENTS WITH ZERO WASTE APPROACH:

B.1 - Dimensions of the fabric used;

B.2 - Surface design as printis, textures, and their orientation;

C. ASPECTS RELATED TO THE SCALE OF PRODUCTION OF GARMENTS WITH A ZERO WASTE APPROACH:

C.1 - Grading and marker-making process;

C.2 - Changes in the paradigm of the production process in the clothing industry.

The discussion about the listed factors started with a set of premises. The first is related to the total use of the fabric, that is, zero waste (100% utilisation) or minimum waste in the cases where zero waste is not possible. The second premise establishes that the analysis is carried out to produce large-scale garments, either in the reproduction of a garment already created by a designer or in the creation of new garments developed by the creative team of the clothing companies.

A. Aspects related to design, reproduction, and pattern making of garments using the Zero Waste approach: *In the experiments were identified several difficulties. In addition, creating new garments, starting from the Zero Waste approach, is not trivial.*

A-1. Difficulty reproducing garments developed by other designers

- The garments made with Zero Waste pattern making, published in academic publications or virtual media, do not have instructions, measurements, or markings which facilitate their reproduction. The book by designers Timo Rissanen and Holly McQuillan, Zero Waste Fashion Design (RISSANEN; MCQUILLAN, 2016), is the only publication until the conclusion of this work. Some instructions (steps) for garments built within the Zero Waste patternmaking approach. The instructions are quite restricted, and many decisions were made based on the researcher's interpretations during the reproduction of the garments. Some of the difficulties encountered were:

- Incomplete execution instructions, with no instructions for certain elements of the garment;

- Diagram marks that are not included in the instructions;

- Absence of complete views of the garment (front, back, and side views);

- Absence of measurements (in the patterns presented by the designer) to define the size of the fabric needed to start the reproduction of the garment;

- Lack of information on how the dimensions of the fabric used (width x length) would affect the dimensions of the final product and;

- Absence of information about restrictions on the type of fabric to be used (textures and prints).

These gaps in the instructions led to interpretations during the process. Although the garments seemed, at first, simple in execution, they presented complex construction due to the absence of some instructions and detailed images. An important factor was that designer McQuillan used a piece of fabric 1.20 m wide by 1.50 m long. However, the width of 1.20 m is not standard in Brazil, which would cause a loss of material if a Brazilian-made fabric were used. Thus, it was decided the use fabric with the Brazil standard width. Other publications also do not present clear instructions that allow the reproduction of the pieces conceived by the designers. Again, in these cases, the process used must be assumed, which is often not possible, given the complexity of the garment. The lack of instruction difficulties understanding the approach and the education and training of students and professionals in the Zero Waste pattern making.

A-2. Difficulty in new designs development with the approach

In Zero Waste pattern making, new garment models can seem simple when presented in geometric diagrams or markers already developed. However, creating and developing new garments are also a challenge for designers. An important aspect to be highlighted in items c and g is that these designers must have good patternmaking training and experience. The creative process is directly linked to the patternmaking of the garment, and these two aspects are inseparable.

Another important aspect is that some applied approaches, as seen in the work of several designers, result in conceptual garments with unusual and unconventional volumes, characteristics common in Zero Waste pattern making. This method reflects its viability in the garment industry, considering commercial aspects and public acceptance. The Zero Waste approach often seeks the development of innovative pieces, which may be restricted to a specific audience.

Aakko and Niinimäki (2013, p. 73) report that the practice of Zero Waste pattern making to the full use of fabrics can limit the aesthetics of the final product, as the designs of the garment pieces share the same cut lines of the fabric. Thus, this approach becomes more challenging in carrying out a project, as it presents some unpredictability in the results.

A-3. Difficulty in training or changing the paradigm of professionals

It was noticed the importance of the designer formation with the knowledge to integrate the various sectors of production, such as pattern making, marking, cutting, and assembly, not restricted only to the aspects of creation. Rissanen and McQuillan (2016) emphasise that the steps traditionally performed separately (design, pattern making, marker, cut, etc.) must be performed together, using the Zero Waste approach. Another important aspect is that the practice of Zero Waste pattern making is not restricted only to the challenges faced with the limitations about creativity in the product's design. It also requires resources mainly, time available, for this practice to succeed. Therefore, resources such as computerised systems can help execute this work, reducing the time required.

B. Aspects related to the raw material used in garments production with Zero Waste approach:

B-1. Dimensions of the fabric used

The fabric dimensions can be considered a limiting factor in product development and the zero waste patternmaking production process. The designer Lela Jacobs mentions that in the practice of minimal or zero waste, the designer is "inherently restricted by cloth width, drape, weft, and warp, and bias" (RISSANEN; MCQUILLAN, 2016, p. 157). Thus, the designer needs to take risks and experiment because when designing garments with no waste, there is not possible to know the drape until the garment is done.

It can be said that the width of the fabric used can limit the width and length of the garments made in each design. It also depends on the position of the risk and cut (weft/warp), as was the case of the spiral pants, which used the entire width of raw cotton fabric (1.50 m), from selvage to selvage. As a result, the pants produced fit specific body sizes. An additional analysis was necessary to obtain pants with different sizes since it was not initially clear how the variation in width and length of the fabric used would influence the size of the final product. The different variations between fabric length and width resulted in narrower or shorter pants, depending on the modified parameter (width and/or fabric length), which led to questioning the full use of the fabric.

Thus, the dimensions of the raw material restrict the variety of sizes for the same model (in terms of fittings and grading of sizes for the industry) and limit the space available to design models. As a result, different approaches to fully use the fabric can be applied to large-scale production. However, the question of fidelity to the model created may change or be impossible to reproduce in certain sizes.

B-2. Adequacy of print design

The fabric's physical and visual characteristics (textures, fibre direction, prints) affected its use in the Zero Waste patternmaking approach. The direction of the cut may not follow the direction of the warp, as is conventionally done in the pattern making, fittings, and cuts of the traditional garments. Projects

with a geometric approach that use the dimension of the fabric as a whole and markers with more than one model, which also seek full use, become more challenging in their execution. These projects require greater observation of the position of pattern pairs, neckline positions, and front and back pieces when cut in fabrics with specific physical characteristics, such as prints, textures, and fibre direction.

For example, the Spiral Trousers prototype presented restrictions regarding the type of fabric used (prints and textures). Some options evaluated showed the prints were on the inside of the pants or positioned laterally or upside down.

Thus, aspects related to surface design for Zero Waste pattern making must be subject to previous tests, selecting the prints and/or textures that best fit the desired effects for the garments.

C. Aspects related to the large-scale production of garments with the Zero Waste approach:

C-1. Process of sizing (grading) and marker making

According to a measurement chart, the garment sizing (pattern grading) process used in the garment industry to produce large-scale garments increases and decreases the size of the original pattern. This process becomes a significant challenge in Zero Waste pattern making since the production of other sizes may not be obtained as directly as in the traditional approach, requiring additional analysis to assess aspects of their grading to other sizes.

Some of the Zero Waste patternmaking approaches that use conventional block patterns in their construction (e.g., the sleeveless trapeze tunic) result in a looser garment that can accommodate bodies of different sizes. However, they do not exhibit the same aesthetic and/or fit for all sizes, meaning that the garment shape, silhouette, and fit proposal may not be repeated in different sizes. Therefore, although the same model wears different body sizes, it is essential to emphasise that it is not the sizing usually applied in the industry.

Thus, the developed models need to be studied, each in its specific approach, and experimented with in its grading possibilities, which may require a particular grading process, such as the Spiral Trouser. Finally, it is worth remembering that, even with graduation, the principle of full use of fabric must be respected.

Rissanen and McQuillan (2016) suggest leaving areas of fabric that can be used flexibly according to different sizes.

All these issues were evident during the development of the spiral pants prototype since the result, in terms of dimensions, is not predictable, and variations in the dimensions of the fabric greatly alter the final garment. The possibilities of producing other garment sizes could only be estimated from the tests carried out with different widths and lengths of fabrics.

Rissanen and McQuillan (2016) list some possible paths to resolve the issue of different sizes in Zero Waste pattern making and their respective markers on the fabric. They proposed five alternatives that can be evaluated for each type of garment. The designers' proposals are reproduced below with observations and comments made by the authors of this work.

1. One-size-fits-most: "The need for grading can be eliminated by designing a garment that will fit individuals across a range of sizes" however, "this approach is mainly limited to loose, adjustable, or wrapped garments" (RISSANEN; MCQUILLAN, 2016, p.160). It is important to point out that a single size used by different bodies can change the garment's aesthetic aspects, such as fit, shape, and silhouette. When the Zero Waste model was created, the fullness planned for the garment in the original body size may not be the desired for other sizes. In addition, the limitation of the width

of the fabric can also limit the maximum size of the garment to be constructed, preventing certain garments from being produced in larger sizes.

2. Conventional grading: professionals' familiarity with the conventional grading process is a beneficial factor for its quick execution. Even if the original size of the marker is Zero Waste, the following sizes can create fabric waste (RISSANEN; MCQUILLAN, 2016). Even after each component has been graded, it is improbable that they will set up within the marker like the original size as the one designed in Zero Waste, and an important question: "Can a claim of zero waste be made of a garment if only is the sample size zero waste"? (RISSANEN; MCQUILLAN, 2016, p. 160). We understand that the answer to this question is negative. The grading and marker processes for conventional and Zero Waste patternmaking have the same limiting factor: the fabric's width. Thus, each generated size will need a different marker. With more geometric shapes, patterns built-in for Zero Waste would be easily solved in a conventional marker, with the option of dividing the marker or adding cuts; this process is possible and applicable in the industry.

3. Designing each size: different sizes can be remodelled using the original as a guide. Thus, it should ensure that each size is zero waste and is designed as similarly as possible to the original sample (RISSANEN; MCQUILLAN, 2016). However, the process can be time-consuming. Still, it fits in the context of sustainability, which emphasises "design less and design better" and that this difference is "in no way product compromised" (RISSANEN; MCQUILLAN, 2016, p.161). Thus, the designer needs to determine the components that will be graded and the grade values.

   From this first stage of the study of the components to be graded, two options occur: changing or retaining the design of the garment pieces in the marker (RISSANEN; MCQUILLAN, 2016).

   a. Changing the marker configuration: after grading the components to a specific size, a new marker is made to fit all the components, using 100% of the fabric. Keeping the original marker as possible would better assist design integrity (RISSANEN; MCQUILLAN, 2016). It is understood that this alternative is viable in terms of application, but this may not always be possible (marker making using 100% of the fabric) - it may be necessary to change some details of the original risk, adding cuttings, for example.

   b. Retaining the marker configuration: in this case, the first alternative is to change the total fullness of the garment, if possible. Pleats, tucks, darts, and gathers can be employed to control fullness through sizes. For example, in a dress with several vertical pleats across the body, a larger size will have fewer pleats than a smaller one; the different sizes contain the same total amount of fabric. The second alternative is mixing two sizes in a marker. For example, in a marker with two garments of the original size (Medium), a P and a G piece could be cut, compensating for the spaces between them. However, it must be considered that both alternatives (maintaining the marker and changing the marker) may have limitations when applied to certain garments, not to a general case (RISSANEN; MCQUILLAN, 2016).

4. Using a different fabric width for each size: an alternative would be the use of fabrics with different widths for different sizes, mentioning, as an example, tubular knit fabrics, knitted in a range of diameters to create a range of sizes (RISSANEN; MCQUILLAN, 2016).

   We understand that flat fabrics in the Brazilian market are manufactured with similar widths (1.40 m or 1.50 m), with few exceptions. Thus, this alternative, proposed by Rissanen and McQuillan (2016), appears to apply only to cases of knitted pieces.

5. A hybrid method: combining the previous four pathways (RISSANEN; MCQUILLAN, 2016).

Many solutions exist for grading, given the variability of garments, the changing size range requests of a company, and variants in grade rules. The suitable solution is based on the garment type, style, size range, fabric type, and width (RISSANEN; MCQUILLAN, 2016).

C-2. Change in the paradigm of the production process in clothing

> The Zero Waste patternmaking approach requires an integrated view of the product development process. McQuillan (2011) mentions that the current design process follows a separate hierarchy of design, creation, and pattern making, that it results in textile waste, and that there is little risk or little creativity in the fast process of today's fashion, being easier to be inspired by models with sales guarantee to take risks in creating something new. The zero-waste fashion design could help renovate the hierarchies that exist in the fashion structure, with possible constructive implications for both design and manufacturing, since the traditionally separate roles of design: pattern making, grading, marker making, and sewing are all indispensable components of fashion design (RISSANEN; MCQUILLAN, 2016, p. 153). Thus, "With manufacturing, the scope of design expands to grading and marker making" (RISSANEN; MCQUILLAN, 2016, p. 153). This does not mean eliminating one or more process functions but improving communication and integration.

Many of the limitations discussed may limit or prevent using the Zero Waste approach in apparel production. However, it can also be seen that there are alternatives to overcome the limitations presented if the company seeks the Zero Waste approach as an alternative to producing clothing; several of them are discussed here. Although the alternatives discussed here are challenging in their implementation, such as using additional resources in terms of time and materials, they prove viable.

In the course of the study and development of the prototypes, we notice the need for an integrated view of the entire design process, extending it to the more technical aspects of pattern making and marker making, requiring an essential change in the current paradigm of clothing production. This change in the industrial environment can become a difficult barrier to overcome. In addition, the issue of additional time, both to develop something new and to replicate something already existing in the Zero Waste patternmaking approach, is an important point that must also be considered. Many companies may not be interested in the zero-waste approach because, in many cases, the clothes produced with this approach are restricted to certain consumer profiles.

5 CONCLUSIONS

The study of the Zero Waste patternmaking approach is still present, mainly in the experimental scope. However, academic works and experiences have shown at events emphasising the challenge of the Zero Waste approach in clothing.

The designer McQuillan has researched the industry, teaching the Zero Waste patternmaking approach through workshops. One of the companies involved in the study said that the cost of the fabric did not compensate for the additional costs to obtain more efficient markers, although the result was satisfactory. At the end of the workshop, the designer reports: "The overall experience for myself in this project was of a forced arbitration between 'what exists' and 'what can be' – where 'what exists' won due to the massive force the scale and complexity of the industry exert on those who seek to change it" (MCQUILLAN, 2019, p. 157). However, certain technological resources can contribute to Zero Waste design being implemented in industries, such as the use of 3D modelling software, for example (MCQUILLAN, 2020).

A strong issue to be considered is the full use of the fabric (due to the marker making for cutting) of the Zero Waste pattern making compared to an equivalent conventional pattern making. Few discussions analyse the efficiency of this part of the process. Thus, an analysis of material consumption is considered

important for each model elaborated so that it can be affirmed that the Zero Waste pattern making is, in fact, more economical and maybe more attractive despite the need for more time and resources spent to create a fashion collection. It can be said that the application of Zero Waste pattern making in large-scale production is conditioned to all the limiting factors mentioned in this work, which makes its execution even more complex. It is challenging to establish the resources necessary to produce garments with the Zero Waste approach considering each project is unique, with specificities in pattern making, marker making, size grading, and type of fabric. In addition, it still requires changes in the communication and performance of the professionals involved in the process. To deal with these limiting factors, it is important to question the benefit of garment manufacturing companies in using the Zero Waste approach in their production process, even if additional resources are needed.

The comparison of conventional and Zero Waste patternmaking practices showed divergent paths. While conventional modelling can be "safe and controlled" within the current hierarchy, Zero Waste modelling can be characterised as "uncertain and challenging", requiring changes in clothing production.

From the reflections on the application of Zero Waste in pattern making discussed in this article, important aspects were not addressed and should be considered as possible future works: 1) research applied to companies – for a better analysis of feasibility and acceptance; 2) analysis of the consumption of models/fittings of other garments, to identify, in general, aspects related to the consumption of garments in the Zero Waste approach; and 3) elaboration of step-by-step analysis and scripts for other garments developed by authors in the area, aiming at teaching, professional training, and production activities.

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