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11th Inclusive Design Conference
Helen Hamlyn Centre for Design

Conference Proceedings (Online)

Royal College of Art, London, UK
22-23 September 2022

Royal College of Art
THE HELEN HAMLYN CENTRE FOR DESIGN

INCLUDE. Unheard Voices is a global conference that focuses on inclusive design and its people-centred, creative approaches. It is hosted by the Helen Hamlyn Centre for Design at the Royal College of Art.

The Helen Hamlyn Centre for Design (HHCD) is a globally recognised centre of excellence with a 30-year history of applying inclusive design and design thinking to improve people's lives. The term 'inclusive design' was framed by HHCD's founding co-director Roger Coleman in 1994, as a people-centred, comprehensive and integrated design approach to ensure that people with diverse abilities and needs are included in mainstream design consideration for products, services, technologies, and environments. The HHCD is the largest and longest-running design research centre of the Royal College of Art (RCA). The RCA was established in 1837 and in 1967 was granted Royal Charter and University status. It is a wholly postgraduate university institution of art and design, offering MA, MPhil and PhD degrees, and to this day, remains the world's leading university for art and design education, having received the #1 QS Ranking for the eighth consecutive year since 2015.

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Inclusive and Sustainable Fashion Product-Service System for Evolving Bodies during / after Pregnancy

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Media and fashion systems have shaped ideal and stereotyped female bodies, imposing an unattainable aesthetic image based on extreme slenderness, perfection, and tone, thus causing social anxieties, and unhealthy self-relationships. In 2019, Mental Health Foundation showed that 66% of UK women were affected by body dissatisfaction due to their bodies' changes during maternity.

This paper investigates mothers' relation with their body image during/after pregnancy through a user-centred design approach. We surveyed 97 mothers and interviewed 2 perinatal psychologists and 2 body experts to understand methods of confidence-building during pregnancy and experience with maternity clothes. Based on the received feedback, we designed and empirically tested Nawale, an inclusive fitting garment adaptable to female bodies during/after pregnancy via (i) flexible auxetic textile patterns, (ii) lacing, and (iii) interlocking systems (connectors) from laser-cutting technologies. Users can co-design the garments customising on body shapes and preferences at the online virtual fashion platform. It allows users to preview the custom garments in a virtual fitting room and set a networked on-demand production.

The resulting project aims at (i) tackling body image change and dissatisfaction of pregnant women, (ii) boosting self-confidence, and (iii) increasing diversity in fashion, toward inclusivity, and social/environmental sustainability.

Keywords: *fashion design; social sustainability; auxetic textile; product service system design; inclusive design*

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Introduction

Body image and dissatisfaction during/after pregnancy

Body dissatisfaction is a person's negative thoughts and feelings about his or her body (Grogan, 2016). It refers to the perceptions people have of their physical appearance and the emotions caused by these perceptions. The media and society promote the idealisation of slenderness and beauty portraiture and stipulate that everything that manages to look like those beauty standards is good (Grogan, 2016). Thinspiration and fitspiration media contents contain guilt-inducing messages regarding the weight of the body, fat stigmatisation, the presence of objectifying phrases, and dieting messages (Cohen et al., 2019). These messages change women's perception of themselves by teaching them socially acceptable ways in which they should behave. Therefore, women were found to have more body dissatisfaction than men (Kostanski & Gullone, 1998), presenting dissatisfaction with their bodies due to an idealised beauty benchmark that they wanted to achieve (Charles and Kerr, 1986). Specialists have found that since the age of eight years old women feel insecure about their bodies and that this feeling lasts throughout all their life (Grogan, 2016).

Pregnancy and postpartum represent a critical risk period for developing and exacerbating anxieties caused by body dissatisfaction (Johnson, et al., 2004). During pregnancy, women are vulnerable to mood and anxiety disorders due to the significant physical and emotional changes that occur during this period. Pregnancy-related anxiety is associated with the fears and worries centred around pregnancy (Bayrampour, et al., 2016). Women feel concerned about the process and health of the unborn baby. Within this disorder, women can experience poor psychological adjustment and self-care, low self-esteem, increased weight gain and nausea, and negative views of motherhood. Even when they have a health reason to not fulfill the beauty stereotypes, they are judged and pressured to return to their previous shape as soon as possible to ensure to be a good mother (Malatzky, 2017). Earle (2003) found that women indicate three main concerns in relation to their bodies: how they would look when their pregnancy began to show, where the changes in their bodies would occur and how easy it would be to return to their old shape. Furthermore, women indicate that they feel more concerned about their bodies during the last trimester as compared to the onset of pregnancy and pre-pregnant phase, particularly in the breast and the stomach (Breda et al., 2015). Other alterations like stretch marks, acne, skin pigmentation, and varicose veins cause serious problems of confidence that are generated mainly by a strong social comparison created by the media and the friends and family nucleus (Dryer et al.,2020), along with the fashion system producing standardised sizing clothes that does not fit everybody (Grogan, 2016). Ogle et al. (2013) found that maternity clothes were considered expensive, ugly, and unattractive, causing anxiety in women because they symbolised someone that they did not want to be associated with. Since clothes are considered a way to satisfy the individual, social and physical human needs, as well as the cultural representations and art forms (Kaiser, 1997), reflecting their identity and being directly linked to the way people look and feel about their image (Tiggemann & Lacey, 2009), new clothing systems should address the needs and concerns of pregnant women becuase they could affect their personality and behaviours (Lennon et al., 2017).

Methodology of the research

Aim of the research

The research focused on creating a product-service system to promote mothers' body satisfaction and reduce anxiety during/after pregnancy, meanwhile implementing a circular fashion process to promote sustainable maternity products. The aim is to explore and design a product-service system that can eliminate the standardisation of sizes and reduce body dissatisfaction caused by clothes anxieties. In addition, its aim is also to create a more inclusive service in which users can feel integrated and where the body can be evaluated for what it can do and not so much for its appearance. The system wants to promote the creation of products that can be adjusted to the different stages of pregnancy, as well as the customization of the garment so that women are in control. To define the project/system requirements, two main research methodologies were adopted: (i) user-centred research through qualitative and quantitative mixed research strategies to understand the users' fears and needs and their experiences during pregnancy; (ii) material experimentation with research through design approach to investigate how to implement flexible, adaptable, and sustainable solutions for garment design through the application of new technologies such as laser-cutting techniques.

Materials and Methods

1) User-centred research

1 quantitative/qualitative survey (28 questions in Spanish, Italian, and English) and 2 qualitative interviews were developed and administered online. The survey was delivered to 97 women (11% pregnant women, 86% mothers at the time of the survey; average age 35 years old; Nationality: 80% from Mexico, 15% from Italy, 1% from Brazil, 2% from Venezuela, 1% Colombia, and 1% Norway) to collect experiences about: (i) body image during and after pregnancy, and (ii) women's relationship with maternity products (clothes and accessories) on the current market. The semi-structured interviews were directed to 2 perinatal psychologists and 2 body experts (a nurse and yoga instructor and a massage therapist, experienced in working with pregnant women) about (iii) methods to build confidence. Data were collected and treated with the consent of the participants and elaborated by aggregating and anonymizing the results.

2) Material experimentation

The empirical testing of laser-cutting technologies on fabrics materials was useful to iteratively design and test flexible, adaptable, and sustainable garments based on the zero-waste pattern-making logic to offer a custom, inclusive, circular service that could be accessible worldwide. The experimentation focused on three different adaptable solutions (e.g., auxetic structures, interlocking systems - connectors and lacing) and was developed on Rasone (100% polyester woven fabric weigh 0.0186 gr/cm2), Mollettoni (65% polyester + 35% viscose non-woven fabric weight 0.0329 gr/cm2, and Cotton Neoprene (92% polyester + 8% spandex knit fabric weight 0.0385 gr/cm2).

Auxetic structures can expand and shrink in all directions when stretched and compressed, thus adapting to the precise shape of the user's body (Papadopoulou, et al., 2017), creating comfortable and adaptable clothes for different maternity stages (Hu, et al., 2019). For the research, 11 different auxetic structures were

laser-cut into 10x10 cm synthetic fabrics swatches to test their behaviour in terms of expandability and flexibility, aesthetic, texture, and manufacturing difficulty on a three points scale (see Table 1). Swatches were also digitally tested using CLO3D software with the intention to compare the physical and digital behaviours with the intention to make them visible on an online platform.

Table 1. Evaluation criteria for the experiments of auxetic structures

PROPERTY	VALUE		
	1	2	3
EXPANDABILITY AND FLEXIBILITY	It does not have great flexibility.	It has medium flexibility.	It has great flexibility.
AESTHETIC	It does not look good when it comes to expanding. There exists to mush deformation of the figures.	It looks nice when it expands but it presents some deformation.	It does not present a great deformation. The figures look nice and clean.
TEXTURE	It creates a scratchy and unpleasant texture to the touch.	It has a good feel texture, but it is not comfortable.	The texture created is soft and pleasant to the touch.
MANUFACTURING DIFFICULTY	It breaks, it frays, it burns. It cannot be used on laser cut machine.	It does not break; it does not fray. But it still requires special adjust-ments to be used on laser cut machine.	It does not break, it does not fray, and it does not have any complication of been produced on laser cut machine.
DIGITAL BEHAVIOR	It does not change. The visualization is not well developed. It seems to be static.	It behaves a bit like the physical sample, but it is still not 100% accuracy.	It behaves like the physical sample. It looks real.

Interlocking systems/connectors allow the creation of a modular design of parts that can be detached, modified, relocated, and replaced for upgrading, repair, recycling, or reuse (Gu, et al., 2009). This system decreases shipping pollution and impulses local production. For the research, 19 different interlocking system samples were designed, laser-cut, and tested to evaluate stretch resistance, aesthetic, manufacturing difficulty, and assembly difficulty (on a three points scale) and to select the most suitable ones to be applied on zero waste garments and accessories (see table 2).

Table 2. Evaluation criteria for the experiments of interlocking systems/connectors

PROPERTY	VALUE		
	1	2	3
STRETCH RESISTANCE	The union does not resist, it opens very easily when stretching the fabric.	The joint resists a little when stretching the fabric, but it opens with the frequency of stretching.	The union remains intact when stretching the fabric, it does not break.
AESTHETIC	They do not look good, it generates lumps.	They look good, but they generate deformations.	They look good. They help to generate design details, or they are not visible at all.
MANUFACTURING DIFFICULTY	It breaks, it frays it burns. It does not good to be used with laser cut machine.	It does not break; it does not fray. But it still requires special adjustments to be used on laser cut machine.	It does not break, it does not fray, and it does not have any complication of been produced on laser cut machine.
ASSEMBLY DIFFICULTY	It is not easy to assemble, it takes a lot of time.	It is more or less easy and quick to assemble.	It is easy and quick to assemble, it is intuitive.

Lacing is a fastening method used in clothes that allows garments adaptability to new requirements, garments' reuse when circumstances change in time (Gu, et al., 2004), and opening adjustability (Sarina, 2022) to different bodies and sizes, in particular for pregnant women (Rybarczyk, 2020). It was also used as a decorative element in western ladies' clothing of the 20th century (Rogers, 2020). In this research, lacing technique was explored through the sole use of laser-cutting techniques by developing a 10x10 cm sample of perforated holes with a constant distance of 2x2cm spacing. Likewise, digital prototypes through CLO3D were made to observe the size and the adequate distance of the perforations in different areas of the body.

Results

Physical and psychological during/after pregnancy needs

60% of the surveyed women admitted having suffered insecurity about their appearance during pregnancy and postpartum and fear of being unable to lose weight. Most of them consider pregnancy as a body *"deformation"* that results in discomfort and resignation. Despite this, they did not consider it necessary to take a specific therapy to treat body dissatisfaction during pregnancy. However, they perform physical activities such as walking to stay toned and do relaxation practices such as yoga, stretching exercises, massage, and physiotherapies during pregnancy and post-pregnancy. These practices belong to the functionality theory (Wood-Barcalow *et al.,* 2010). Women look for support groups of other mothers, in family and outside (e.g., motherhood counseling). In relation to clothes, pregnant women need maternity clothes that do not limit their movement. Current maternity clothes and accessories are considered ugly, with a not-unique and customised design, expensive and disposable: at childbirth, they are thrown away or donated.

The experts argued that body dissatisfaction in women during pregnancy is linked to the lack of knowledge and full awareness of what it means to have a baby. The experts use functionality (Alleva & Tylka, 2020) to construct psychological confidence and security and physical activity to decrease the feeling of anxiety. In addition, they use the feminism theory (Peterson *et al.,* 2006) to question gender roles and to put patients' expectations and problems into visible words. Experts consider that it is essential to design functional tools to promote the bonds of motherhood and to rebuild women's new identities during and after pregnancy to help them feel free and independent.

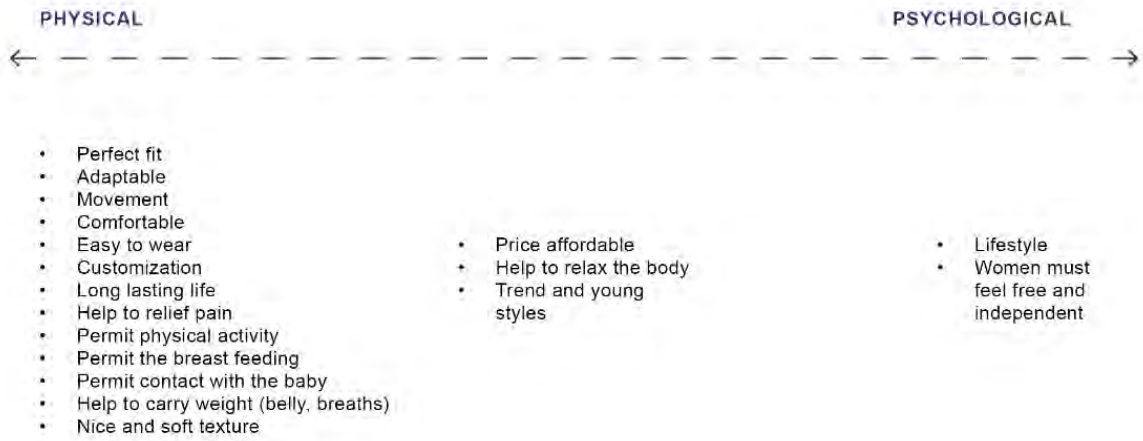


Figure 1. Physical and psychological needs emerged from the user-centred research

Connection, flexibility, and adaptability: empirical results

To respond to the emerging functionality and physical needs, a series of experiments on materials and shapes were performed thanks to the use of laser-cutting technologies to test the adaptability to movement, comfort, perfect fit, and easiness of wear during and after maternity.

In particular, 11 auxetic structures were designed and tested to check expandability, aesthetics, resistance, and difficulty/simplicity in laser-cutting (see table 3). The expandability of auxetic structures depends on the design of the cuts (bigger cuts, higher expansion) and materials (higher flexibility of the material, higher expansion). The size of the cuts is also linked to the transparency that the piece could have (larger cuts, wider openings, higher expansion, more transparency). Several samples (e.g. hexagon) scored low due to the fragility of joints derived from low cut tolerances. The digital and physical expansion of the materials was not the same due to the impossibility of the CLO3d software to simulate real behaviours. This means that physical samples are required to understand the real behaviour of the auxetic structures to be further applied to the visual representation of digital fabrics in the virtual world

Table 3. Evaluation processes of auxetic figures

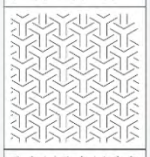
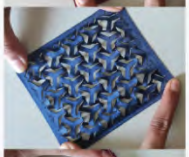
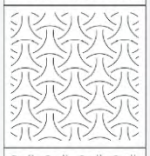
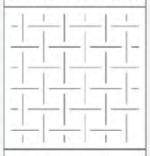
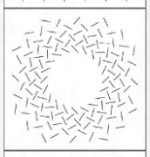
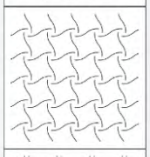
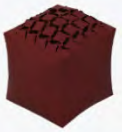
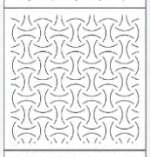
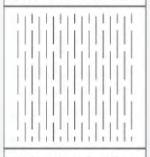
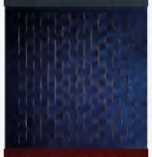
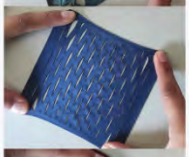
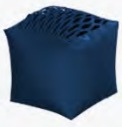
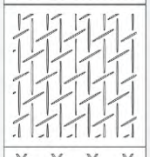
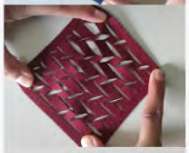
NOMENCLATURE	TECHNICAL DRAWING FOR LASERCUTTING	TEXTILE CUT	CHECK ON STRETCHABILITY	SIMULATION ON CLO3D	COMMENTS
FIGURE: 1 WAVES					Large cuts greater flexibility. Extra volume and texture are formed with the expansion
FIGURE: 2 Y					Greater number of cuts more flexibility, less tolerance to breakage
FIGURE: 3 TRIANGLE					Thick materials less flexibility
FIGURE: 4 BOWS					Greater number of cuts more flexibility, less tolerance to breakage, and rough texture
FIGURE: 5 SQUARE					Higher flexibility of the material, higher expansion
FIGURE: 6 SWIRL					Smaller cuts less flexibility and less transparency
FIGURE: 7 PINWHEEL					Thick materials less flexibility
FIGURE: 8 PINCHES					Higher flexibility of the material, higher expansion, more transparency
FIGURE: 9 LINES					Higher volume and better aesthetics on curved surfaces
FIGURE: 10 RHOMBUS					Thick materials less flexibility
FIGURE: 11 HEXAGON					Consider tolerance and distance between cuts

Table 4. Evaluation processes of interlocking systems

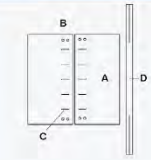
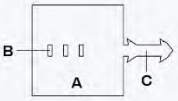
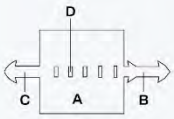
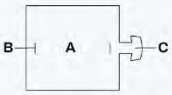
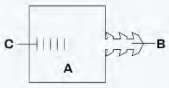
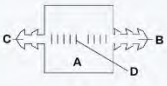
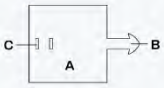
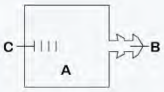
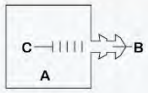
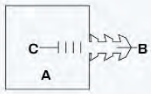
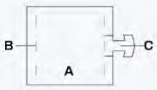
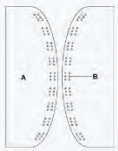
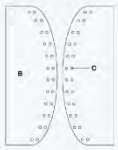
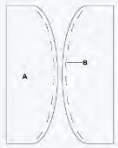
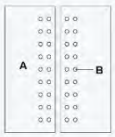
NOMENCLATURE	TECHNICAL DRAWING FOR LASERCUTTING	SIZE SAMPLE	DISASSEMBLED CONNECTOR	ASSEMBLED CONNECTOR	COMMENTS
CONNECTOR: 1		A: 6x12 cm, B: 1.5 cm r, C: 1cm, D: 0.9x20 cm			In light materials use mechanisms with strings and slots
CONNECTOR: 2		A: 5x5cm B:.2x.6cm C: 1.5x2.8cm			Considered tolerance of joints and material thickness
CONNECTOR: 3		A: 5x5cm B: 2.7x1.2cm C: 2.1x1.2cm D: .1x.6cm			Considered tolerance of joints and material thickness y structure.
CONNECTOR: 4		A: 4X20cm B: .9cm C: 2cm			The interlocking systems with the connector on one side and slot on the other are less resistant than the ones with connectors and slots on both sides
CONNECTOR: 5		A: 6X10cm B: 1cm C: .9x20cm D: .3 cm r E: 4.5x1.8cm			Connectors can be used as fasteners.
CONNECTOR: 6		A: 65.5x5cm B: .6cm C: 1.3x1.5cm			In light materials without structure the joints break. In light materials it is better to use mechanisms that seal completely (strings and slots)
CONNECTOR: 7		A: 5X5cm B: 2.5x1.6cm C: .6cm			In light materials without structure the joints break. In light materials it is better to use mechanisms that seal completely (strings and slots)
CONNECTOR: 8		A: 5x5cm B: 2.5x1.6cm C: 2x1.5cm D: .7cm			More points contact more difficult to open, although it takes longer to assemble.
CONNECTOR: 9		A: 5x5 cm B: 2x1.3cm C: .1x.6cm			Connectors made in unstructured fabrics do not resist
CONNECTOR: 10		A: 5x5cm B: 2x1.5cm C:.6cm			In light materials without structure the joints break. In light materials it is better to use mechanisms that seal completely (strings and slots)

Table 4 (continued). Evaluation processes of interlocking systems

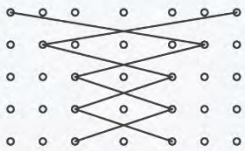
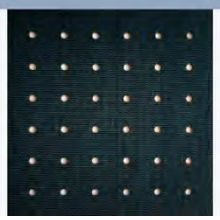
NOMENCLATURE	TECHNICAL DRAWING FOR LASERCUTTING	SIZE SAMPLE	DISASSEMBLED CONNECTOR	ASSEMBLED CONNECTOR	COMMENTS
CONNECTOR: 11		A: 5.5cm B: 2x1.5cm C: .6cm			The best fabrics in terms of aesthetics and resistance present structure and friction useful to maintain the shape and sustain a stronger locking system
CONNECTOR: 12		A: 5x5cm B: 2.5x1.5cm C: .6cm			Although the interlocking systems have many points of contact, if the fabric does not have structure and friction, the interlocking systems will break.
CONNECTOR: 13		A: 5x5cm B: .6cm C: 1.3X1.4cm			In light materials without structure the joints break. In light materials it is better to use mechanisms that seal completely (strings and slots)
CONNECTOR: 14		A: 4x20cm B: .9cm C: 2cm			The interlocking systems with the connector on one side and slot on the other are less resistant than the ones with connectors and slots on both sides
CONNECTOR: 15		A: 5.5x17.5cm B: .1 cm r			Strings and slots have good strength on lightweight fabrics (non-knitted), but they take more time to assemble them
CONNECTOR: 16		A: 6.5x17.5cm B: 15cm			Connectors work better on straight patterns than on curves. Deformations in the joints occur when there is an accumulation of material and a pronounced curve.
CONNECTOR: 17		A: 6.5x17.5cm B: 1cm			Connectors work better on straight patterns than on curves. Deformations in the joints occur when there is an accumulation of material and a pronounced curve.
CONNECTOR: 18		A: 4x10cm B: .15cm			Strings and slots good resistance. Consider knot volume
CONNECTOR: 19		A: 4X3cm B: 4.5x3cm C: 3.5x3cm			The best fabrics in terms of aesthetics and resistance present structure and friction useful to maintain the shape and sustain a stronger locking system

For the interlocking systems, we designed and tested 19 connector samples (see table 4) on three different materials to test the stretch resistance, aesthetics, functionality, ease of use, and manufacturing through laser-cutting. The stretch resistance of the connectors derives from the fabric structure and the design of the

lock. The best fabrics in terms of aesthetics and resistance present structure and friction useful to maintain the shape and sustain a stronger locking system. Furthermore, the more contact points an interlocking has, the less likely it is to break, although it takes longer to assemble. Although it was observed that the connectors composed of strings and slots were the best option for soft materials, these also took more time to assemble. During the design process, it is necessary to consider the tolerance of joints and material thickness, allowing friction and resistance but also ease of assembly. On the samples, it was evident that the interlocking system with connectors and slots on both sides worked better and had better resistance than the ones with the connector on one side and slot on the other (e.g. connector 4). Connectors work better on straight patterns than on curves (e.g. connector 17), since deformations in the joints occur when there is an accumulation of material and a pronounced curve (e.g. connectors 15, 16, 17). It is necessary to calculate the precise distance of the connectors to create a more defined round figure.

A physical sample and a digital sample of the lacing mechanism were developed (see table 5) through laser cutting circles with different distances to create a grid where a cord can cross and thus generate the adjustment of the garment. The test showed that it is possible to realise the lacing fastener by a single production process (laser cutting) and that this technique could be used in different parts of the body without causing discomfort and unwanted alterations in the silhouette. Likewise, the digital sample prototype with CLO3D showed that the circles could be personalised and adjusted to the user's measurements and silhouette.

Table 5. Evaluation lacing mechanism

MECHANISM EXAMPLE	TEXTILE CUT	SIMULATION ON CLO3D	COMMENTS
			It is possible to realize the lacing fastener by laser cutting, and it could be used in different parts of the body without causing discomfort. Circles could be personalised and adjusted to the user's measurements and silhouette.

Inclusive and sustainable fashion product-service system for evolving bodies during/after pregnancy

The previously carried out research was used to design Nawale, a product-service system that allows pregnant women to customise garments based on their style and particular body shape, changeable during different pregnancy stages. The system is composed of (i) two adaptable zero-waste dresses that could be personalised by the user thanks to a (ii) digital platform that allows sustainable on-demand production.

The two dresses include both auxetic structures on the abdominal, central back, and breast area that present more significant changes during pregnancy, and lacing mechanisms were implemented on the front and back to make the garment's adjustment easier. One of the dresses (Figure 2) could be produced on-demand using the traditional approach of product manufactured and assembled in the company workshop and sent to the clients once it's finished. The second dress (Figure 3) could be produced through networking on-demand production that relies on digital drawings sent to the user to be produced by the worldwide network of

fablab using laser-cutting and to be assembled by the user. This dress also includes interlocking systems in place of sawing on the edges of the pattern to allow the self-assembly of the piece at home by non-expert users.

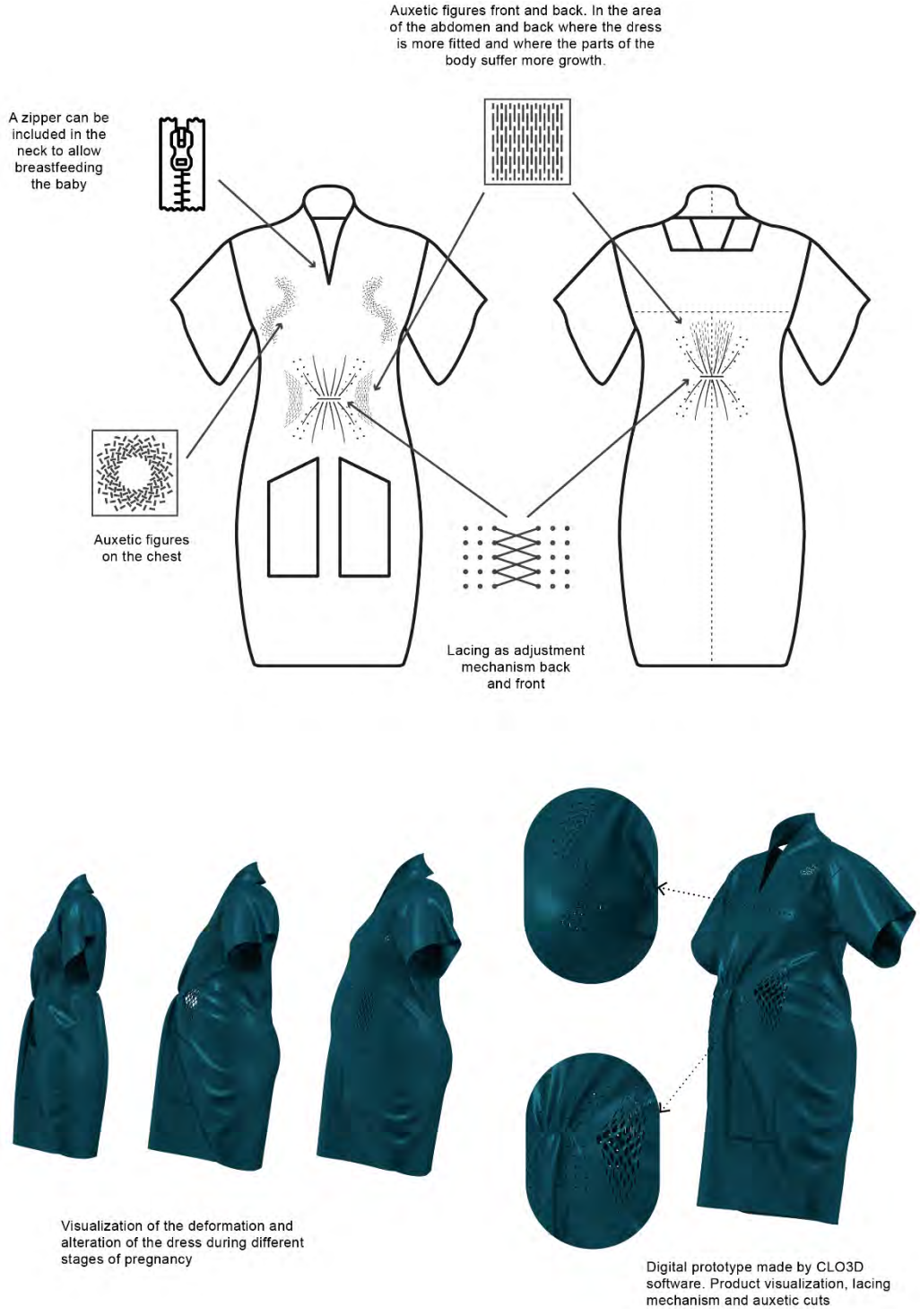


Figure 2. Dress to be produced by traditional production without connectors

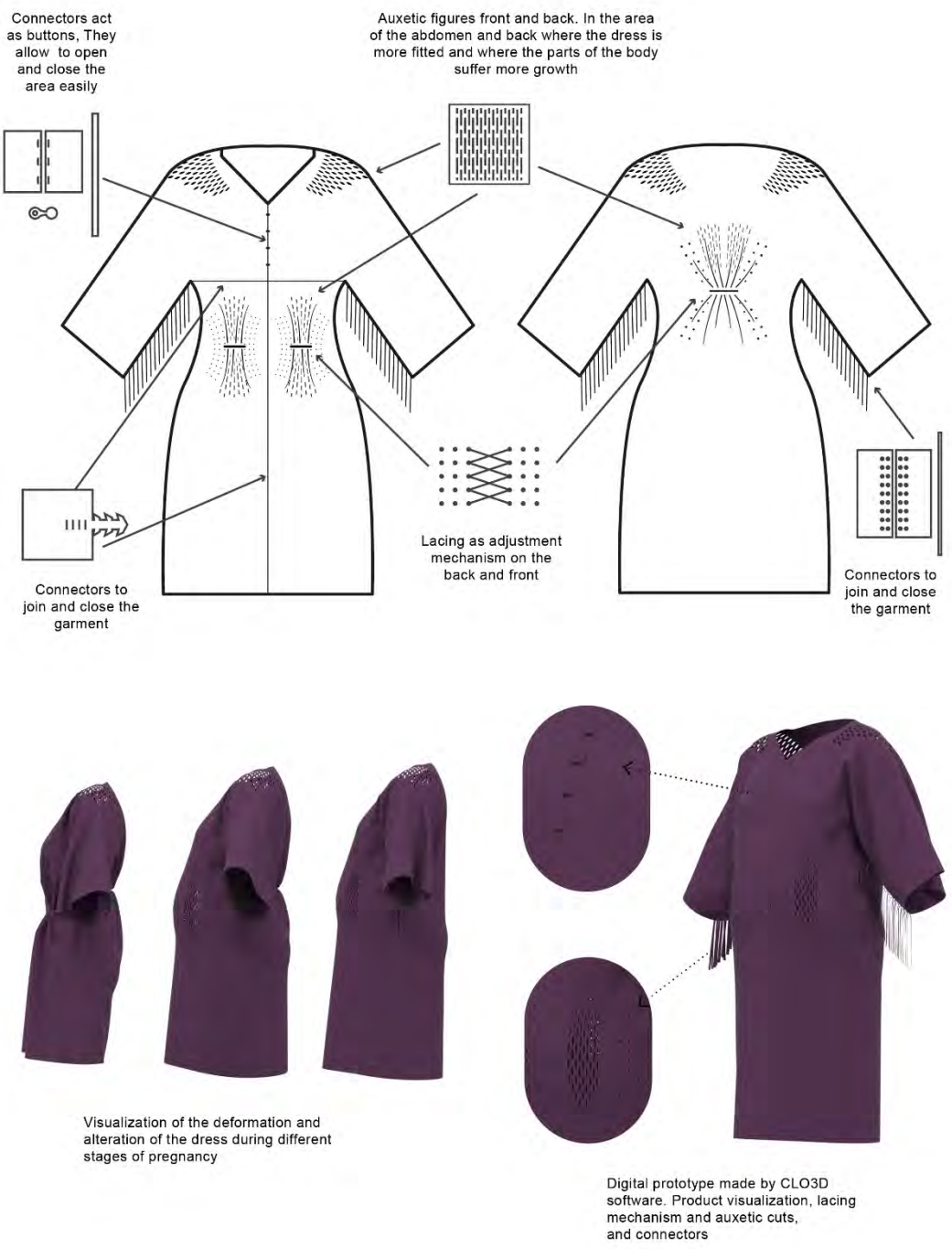


Figure 3. Dress to be produced by networking production with connectors

Both dresses are based on a zero-waste design created by the Make/Use tool (McQuillan, et al., 2018). This tool is adaptable to an extensive range of sizes and can include vast body diversity (McQuillan, et al., 2018). The pattern and design of the dresses are intended to be simple to be adaptable to different occasions. The dresses were developed through virtual prototyping technology, using CLO3D software that allows to test and modify the prototypes, visualise the garment fitting through the different stages of the pregnancy, and could be also exploited to offer a virtual tailoring experience on the service (Jankoska, 2021). We designed both dresses to be produced by laser-cut technology that reduces the garment production to only one step through a technology that is accessible worldwide in Fablabs laboratories (Nayak & Padhye, 2016). These two features make the

customization of the garments by the user feasible in terms of production costs and product lifecycle management.

The traditional model of serial production of finished products is replaced by the on-demand co-design model through a digital platform that allows a semi-finished designed product to be modified, customised, and finished by the consumers (Ambrosio & Vezzoli, 2019). Based on the user-centred research that highlighted the need for women to search for alternatives to feel more comfortable when buying clothes and accessories during pregnancy, we designed a user experience that intends to improve the purchase experience through the personalization of the product and the visualisation of the product on the user's avatars. The user experience consists of implementing a digital customer journey on a digital platform (Figure 4) allowing the user to co-design (selecting the zero-waste dress of their choice, choosing the type of production, and selecting predetermined alterations in terms of colours, materials, auxetic structure typology), customise the garment based on their measurements and preferences (through a questionnaire about their measurements) visualise and test (on a digital personal avatar through a virtual fitting session with the help of a real-time 3D rendered image) test and finally produce the customised product in a traditional or networking modality.

Figure 4. Platform design to customize the dresses.

Conclusion and Discussion

The study highlights the importance of producing adaptable, flexible, and sustainable garments for pregnancy through an inclusive approach at the design and manufacturing levels. The majority of surveyed women indicated the need of finding evolutionary garments that could fit their bodies in every stage of the pregnancy. The found alternatives such as oversized, loose, and shapeless clothing were found to negatively influence their self-esteem and body appreciation. The developed dresses with auxetic structures and lacing mechanisms can follow body changes during/after pregnancy with the ability both to control the garment and adjust the fabric during the different stages of pregnancy and also after, both feeling comfortable and perfecting the fit to their dynamic body changes with an excellent aesthetic appearance, thus allowing increased confidence and body satisfaction.

The manufacturing and co-design service through the digital platform allows a more democratic and inclusive process, allowing accessibility and customizability with a certain degree of freedom. The platform helps to create a no discriminatory product that includes the user as a cocreator toward a garment design and production that can create an attachment between people and garment, thus ensuring the product life extension (Maldini,2016). In addition to this, virtual size and fit platform technologies can help women have a better customer experience, through an interactive protected virtual space that allows custom fitting in a secure way, contributing to feeling more comfortable and gaining confidence and self-esteem.

In terms of environmental sustainability, the adaptable design also reduces the waste of clothes and prolongs their use not only during but also after pregnancy. In addition to this, the implementation of connectors on maternity clothes can decrease the ecological impact of the traditional production based on sewing and accessories inclusions. Connectors help to disassemble the product easily (without any mechanical or chemical process required) and also to eventually substitute some parts with a modularity logic. However, real environmental sustainability can be reached only when thinking in terms of systems, including innovative ways of manufacturing and selling. Here the on-demand networking production is a winning solution since it significantly allows a reduction of the garments' impact on the environment. On-demand self-production (Ambrosio & Vezzoli, 2019) minimises the number of resources needed, the cost of production, packaging, transport, and the waste from unsold finished goods. Furthermore, the diffused networking production on micro-urban scales promotes social interaction in local communities and creates local employment thanks to reshoring through a 0-km diffused production. However networked production needs further to be studied to overcome design limitations, logistics implementation, supply chain organisation, and users' involvement feedback.

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