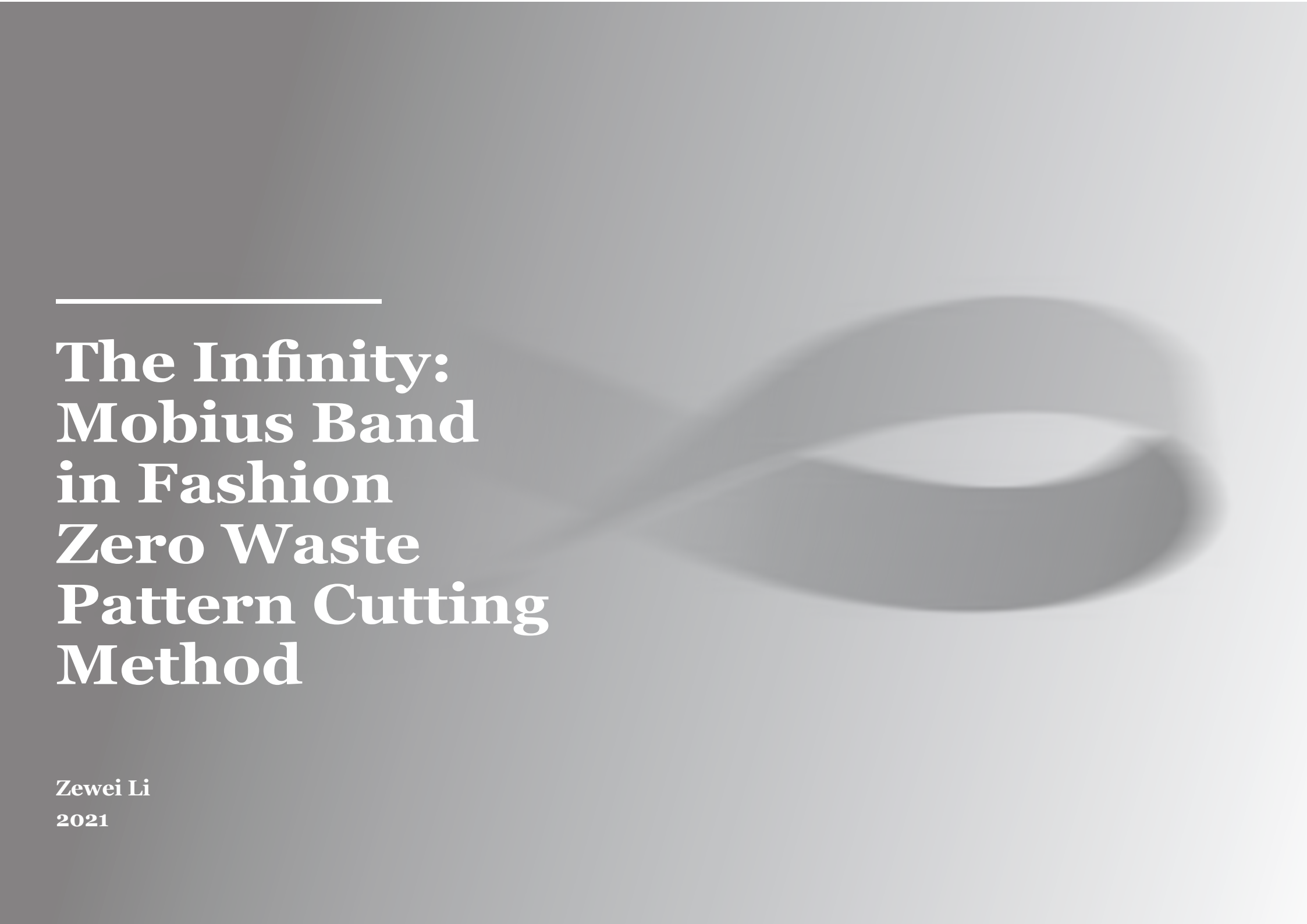
The Infinity: Mobius Band in Fashion Zero Waste Pattern Cutting Method



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Abstract

The textile and fashion manufacturing industry entered a period of rapid development after the Industrial Revolution and the ensuing environmental problems have become increasingly serious. Fabric waste made by both traditional industry production processes and consumer behaviour has contributed to these problems. In recent years, fashion design practitioners have looked to zero waste pattern cutting methods as a response to fabric waste issues today. This practice-led fashion design research project investigates zero waste pattern cutting using a Mobius band to eliminate fabric waste, reducing manufacturing with minimal cutting lines and extending the life of the fabric.

My design process, utilising action research, begins with analysing existing zero waste pattern cutting methods and explores the Mobius band to continuously develop and generate innovative garment shapes and test feasibility in varied fabrics, size, and dimension. This creative method aims to explore the design potential for innovative diverse shapes and multiple wear possibilities to meet the individual needs of the ‘new’ consumer.

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My parents and friends
For continuous love and generous support.

Content

Introduction

0.1 Experiential Motivation of This Research

Fabric waste has become a significant issue as a result of the rapid development of the fast fashion industry and overconsumption. The expansion of the fashion industry at the expense of the environment and our natural resources is not an acceptable transaction and therefore creative solutions are needed to achieve more sustainable outcomes.

The reason why I wanted to investigate this topic is related to my internship experience at a fashion trade company in Qingdao, China, which elevated my interest in sustainable fashion. This internship allowed me to spend time in the factory, technician's office, sampling studio, and the export department which gave me the chance to analyse work operations. This experience helped me gain a clearer understanding of mass production processes and the use of fabrics to reflect on the environmental impact of the fashion industry today.

Based on my observations, it became very clear that there were multiple points in the design and production process that led to fabric waste. During the creative process of sampling and design development, materials were overused. The cutting out of samples, often seen in mass production, did not adhere to minimal fabric use. There were multiple sampling requests carried out prior to mass production, focusing on the design style of the garments and the testing of the patterns for different sizes and colours. These were replicated for the sampling studio, the customer, intermediate trader, and for the foreign trade merchandiser. I also found that the skill and knowledge of the designer and sampling studio workers influenced the number of samples made and how much waste was produced.

During mass production, 85% of fabric used is considered the accepted standard for lay plan approval (Rissanen and McQuillan 11). I found that in this company, in many instances, it can be 80% or even lower, and for a brand with high-quality inspection standards or a brand with a relatively high retail price point, the use and waste of materials may be even greater in mass production. Due to the possibility of multiple reworks, the consumption of threads and recuts of a single piece of fabric may also increase. Understanding some of the causes of fabric waste and analysing the impact of different imperatives by separate departments was helpful. It became apparent during this internship that many of these processes were not recognized as a problem and were accepted as the norm in the industry. During a period of environmental crisis fabric waste issues cannot be ignored. It is the time for designers, consumers, and industry to reflect and take responsibility for the environment.

Acrylic on paper, Zewei Li, July,2020.

0.2 Reading of Exegesis Structure

For this project, I thought that a new design thinking is needed in fashion pattern making processes, by considering both pre-consumption and post-consumption waste.

The context of this exegesis is provided in Chapter One; Sustainable fashion and waste, impacts of industry overproduction and overconsumption. Zero waste pattern making methods were researched to best reduce or eliminate fabric waste in the early stage of garment making. I had a broad interest in both creative pattern cutting and zero waste pattern cutting methods, such as jigsaw puzzles, geometric garment shapes, cut-one-piece method and related apparel techniques. I have introduced these towards the end of Chapter One to explain my design precedents.

Chapter Two of this exegesis starts with the introduction of my methodology-action research in design (Swann 50-51); Creative drawing and initial pattern explorations. I analysed various cutting lines within minimal shapes in garments and investigated body measurements and proportions to explore garment multi-wear possibilities. Incorporating the concept of Mobius band solved many of my initial design aims, to create new design shapes with multiple garment variants, wear choices and different sizes. This is fully explained within my design process. Reflective practice is crucial within these design explorations and used to consider body measurements and scale in a new way and time is taken to understand the precious nature of fabric. I think it is incredibly important for fashion designers to understand fabrics, especially in sustainable fashion.

Chapter Three presents my final collection. The Infinity Mobius band combined with cut-one-piece method eliminates fabric waste in the pattern making process by consciously reducing cutting lines to ensure fabric integrity and longevity. The pattern design method is based on the human body measurements and the relationship of design parts to support garment changes and further developments of alternative garment designs from the same pattern. This not only reduces the sampling process of pattern making but also gives the wearer greater creative space and added options for gaining new garments from the 'old' garment. This Mobius band zero waste pattern-cutting method is an alternative design production system to contribute solutions to current fabric waste issues.

Chapter one: Context Review—Sustainable Fashion and Waste

In order to give a broader context to my research it was important to investigate some of the industry and societal changes. Because these large-scale and complex problems mean it is impossible to make a difference through a single change, what we need to do is to discover the different environmental responsibilities of collectives and individuals in order to implement design solutions (O'Mahony 52). Understanding consumers and their needs within new social contexts is key to developing relevant and creative technical design applications.

1.1 The Development of Fashion: Overproduction and Overconsumption

Historically, industrial technologies have shown significant impact on the overproduction and overconsumption of clothing. After the Industrial Revolution, the increased popularization of mechanisation accelerated the speed of manufacturing clothes. Previously, the production of fabrics was time-consuming and raw materials were scarce, and as such, clothes were expensive and highly valued (Rissanen "From 15% to 0" 1; Tarrant 10). There was a cherishing of cloth in the agricultural era. With the improvement of human living standards, people's requirements for material life have gradually risen (Series 14-31). As Crafts states "human development is seen as a process of expanding people's choices"(302), such as from people eating for survival to eating well, from wearing clothes to keep warm to having different and multiple styles of clothing, satisfying a complex array of fashion needs (Richardson 2-3). Rising demand exacerbates environmental problems (Richardson 2-3). Overconsumption and waste fabric today is partly caused by these changes in people's perceptions of fabric and clothing. The decrease in material costs due to the advance in technology, fuels people's desire to buy more clothes. This issue is highly complex and involves many factors, but it can be argued that the advancement of science and technology has contributed to fabrics and garments being perceived as no longer "precious".

The fast fashion industry and people's enthusiasm for excessive consumption was additionally influenced by the internet era. First of all, the arrival of the Information Age is an incentive that cannot be ignored, and it caused an important change in the fashion financial market (Abnett 1). During the Internet era, the popularity of computers and the development of modern communication technologies have provided nourishment for economic globalisation (Khiabany 139-141). The advent of this has brought global trade closer, and network marketing and promotion have achieved remarkable success. Fast fashion also began to grow in this period (Abnett 2). For example, from 2013 to 2017, American consumers' spending on clothing and footwear increased from $250 billion to $380 billion (Maloney 1). The internet effect allows products that were not previously appreciated to be quickly noticed or to receive a wider market.

Overconsumption of fashion products is closely related to the rapid development of online shopping platforms, which have also contributed to increasing the frequency of purchases. Analysis of consumer data has allowed shopping platforms and online companies to target products to likely interested individuals in order to stimulate consumption (Abnett 3). Attractive pictures beautify clothing with low prices. No one can escape the charm of fashion (Farrer 27), especially when the business has a better understanding of what everyone is interested in. Besides, convenient payment methods like After pay and Alipay have made shopping easier, further increasing consumption.

In addition, the shortened service life of clothing has also accelerated the frequency of people buying clothes. This is not only because people's pursuit of clothes continues to grow, but also because companies purposely shorten the life of the garment (Yang and Zhang 590). Fashion design production methods that extend garment longevity are therefore necessary for a more sustainable fashion ethos and business accountability.

In order to quickly obtain profits, apparel companies tend to prefer the fast fashion business mode. The reason that led the majority of businesses to join the "party" of fast fashion was due to "capitalism itself being based on the ideals of growth – the need for more, faster and cheaper"(McQuillan "Zero-Waste Design Practice: Strategies and Risk Taking for Garment Design" 86). It is because fashion is a profit-oriented industry. "Cheaper goods mean more consumption, which in turn means cheaper goods, which means more consumption"(Farrer 20). Fashion design and production cycles have gradually shortened (Abnett 4).

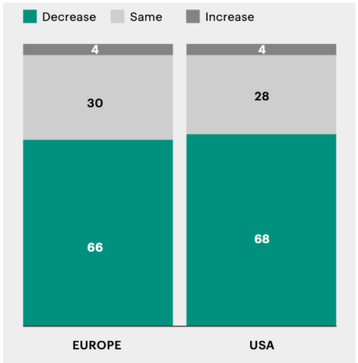
The overproduction and overconsumption within the apparel industry have produced more textile waste than originally planned, which creates new difficulties in how to deal with the garbage (Downs and Acevedo). In the era of globalisation, cross-border and cross-region transactions are becoming more and more common, the development of e-commerce platforms has pushed the fast fashion industry to a new climax, which indirectly leads to excessive production and excessive consumption (Giuffrida et al. 163-165; Smales). The current consumption concept and the business model of most garment brands and industry have also led to the generation of large-scale clothing and fabric waste (Amed et al. 17-18). The rate of decomposition is limited. Burning fabrics containing chemical and metal components causes air pollution and even exacerbate global warming and other problems (Napier and Sanguineti 160-163). The vicious circle of buying–using–disposing of–buying, has exacerbated this problem (Gwilt and Rissanen 13).

1.2 Sustainable Needs of 'New Consumer'

While most people have intentionally or unintentionally neglected the issue of fabric waste for many years, the new sustainable revolution may bring hope of solving the problem. In the Anthropocene, the growth of human power made us ignore the changes in the surrounding environment and even react indifferently to our negative environmental impacts (LeCain 3-6). If the traditional apparel industry operation and make a profit of based on ensuring quality, aesthetics, and meeting market expectations under low-risk and compliance conditions (McQuillan "Zero-Waste Design Practice: Strategies and Risk Taking for Garment Design" 87). If older industry models prioritised profit, then today's industry should foreground environment considerations. The fourth Industrial Revolution, which is "powered by a constellation of new innovations across the physical, digital and biological worlds, from 3D printing and artificial intelligence to advances in biomaterials"(Abnett 2), may help grow the new fashion system and reduce fabric waste as well.

A new generation of consumers is giving up the pursuit of fast fashion, and sustainable fashion is entering the public eye. The good news from the Thredup 2019 resales report shows consumers are beginning to pay more attention to the meaning and concept behind the brand, especially in terms of sustainability. The consumption mindset of the younger generation in this respect is worthy of appreciation. Seventy four per cent of people between the ages of 18 and 29 prefer to buy goods from sustainable brands (Thredup 12). And in a survey of consumers' expectations for clothing, 59% want companies to create and produce more ethical and sustainable fashion products (Thredup 11). This will allow the development of sustainable fashion strategies to be valued by capital while reducing their operational resistance. This highlights that consumer consciousness has begun to change and with the next major consumer group demanding new practices.

In addition, this year the most serious global economic crisis after the second world war (Guterres 1), COVID-19, has provided the conditions and opportunity for the continuous growth of sustainable fashion and the cultivation of new consumer awareness. The epidemic has hit the economy hard, and the apparel industry has exposed its vulnerability in this crisis (Amed et al. 11). The number of company bankruptcies has increased sharply, therefore the unemployment rate has also risen dramatically (Amed et al. 6). People's financial difficulties and the anxiety caused by the epidemic are all affecting their consumption behaviours, which indicates "consumer instinct to prioritise necessary over discretionary goods" (Amed et al. 6). As the table shows (Fig. 1), 66% of Europeans and 68% of Americans decreased their spending on apparel. Just as the shift in Gen-Z and Millennial consumer intentions mentioned above was happening quietly before the pandemic (Amed et al. 19), the pandemic does also make "sustainable first" more appealing to the general public (Amed et al. 8). "The pandemic will bring values around sustainability into sharp focus, intensifying discussions and further polarising views around materialism, over-consumption and irresponsible business practices" (Amed et al. 18). The process of reshaping the apparel industry or finding new value opens the door for companies to accept the penetration of sustainable fashion, because it will help to attract "increasingly frugal and disillusioned consumers"(Amed et al. 17-19).



(Fig. 1) Spending on apparel (Amed et al. 19).

"The crisis is a catalyst that will shock the industry into change—now is the time to get ready for a post-coronavirus world. " (Amed et al. 8).

1.3 What is Sustainability and Why Zero Waste Pattern Cutting?

The definition of sustainability in the past 50 years has been controversial, and its meaning has gradually changed to meet the needs of development in the fashion industry (Farrer 20). In the 1950s, the word emerged to describe issues related to social change and poverty, but now it is more representative of environmental protection and recycling (Farrer 20), as well as the need for social equity (Diesendorf 23). To ensure the sustainable and healthy development of human society is to ensure that everyone's life and safety are based on the rational use of environmental resources (Lewis and Gertsakis 4).

Sustainable fashion is the apparel industry's response strategy to environmental and social issues. In addition, it is also important to ensure the healthy development of animal and plant species, because this will indirectly affect human society. So how are we to determine whether the current model is sustainable? Herman Daly's three conditions give a clear answer:

> "Its rates of use of renewable resources do not exceed their rates of regeneration; Its rates of use of non-renewable resources do not exceed the rate at which sustainable renewable substitutes are developed; and Its rates of pollution emission do not exceed the assimilative capacity of the environment"(Meadows et al. 209).

Unfortunately, the current state of society's operations has exceeded the renewable rate of resources and the degree of decomposition of pollutants. This consumption of resources and the speed of waste production are clearly unsustainable (Lewis and Gertsakis 6).

However, sustainable design strategies give designers the opportunity to reassess the value of raw materials and products, and respond in a more comprehensive way (McQuillan "Zero-Waste Design Practice: Strategies and Risk Taking for Garment Design" 85). Today, the methods and decisions adopted by designers should also be based on environmental, economic, social and future development considerations, and aim at improving the social environment (Lewis and Gertsakis 5). Therefore, in response to the problem of fabric waste production in the apparel industry, zero waste could be one of many effective methods. Although fabric scraps can be made into small ornaments or objects, and waste can also be recycled into blankets, felts, cotton, etc, reducing waste from the source is always the better solution and it is more effective (Rissanen "From 15% to 0" 3). This is demonstrated in the table (Fig. 2) shown below:

Goal	Attribute[1]	Outcomes
Reduce	Preventative	Most desirable ↕ Least desirable
Reuse	Predominantly ameliorative Part preventative	
Recycle	Predominantly ameliorative Part preventative	
Treatment	Predominantly assimilative Partially ameliorative	
Disposal	Assimilative	

(Fig. 2) Waste management (Lewis and Gertsakis 7).

According to this table, reducing waste is the most desirable way to solve the waste issue. To avoid waste and reduce waste is to reduce the environmental impact of textiles throughout their life cycle such as the impact of crops on the water, chemicals in the soil and rivers when making fabrics, the emission of carbon dioxide during transportation, and finally impact on the soil when it is disposed of in the landfill. This is a fundamental solution to the overexploitation of resources, and it will also be the most cost-effective method (Lewis and Gertsakis 11). Therefore, zero waste pattern cutting could be a good method to respond to the fabric waste issue, because it controls waste at the beginning of the clothing making process. Although reducing waste in design and production is only the tip of the iceberg for complex sustainable apparel strategies, the contribution from reducing the impact of fabric waste on the environment will be significant (Rissanen "From 15% to 0" 7-8). Thus, my Mobius band zero waste pattern cutting approach is primarily aimed at reducing fabric waste at the design stage and taking into consideration multiple pattern and garment derivatives from the fabric and postconsumer waste.

1.4 Fabric Waste and Impact

Investigations of fabric waste highlights the importance of the designer's fabric choice (Aakko and Koskennurmi-Sivonen 16-17). The composition of waste is complex, including not only by-products and surpluses of different production activities, but also commodities that are no longer used (Lewis and Gertsakis 10). The different waste materials determine how they will be disposed of. For example, the production of fabrics containing heavy metals should be avoided, because it not only affects the air and soil, but also affects the human skin and nervous system (Teli 185-186). The use of polyester fabric should be reduced because the ultra-fine fibres it produces are harming marine animals and indirectly affecting humans. Natural fibre fabrics that consume a lot of resources in production like cotton (Teli 184), should be recycled as much as possible. As Lewis and Gertsakis state, waste is "made up of different materials that should be treated differently – some shouldn't be produced, some should be reused, some recycled or composted, some should be burnt and others buried"(Lewis and Gertsakis 7).

Approximately one thousand fifty million tonnes of textile waste is sent to landfills every year in the United States alone (Abnett 3). Textile waste can be divided into two sections, one is pre-consumer waste, the other is postconsumer waste (Gwilt and Rissanen 35). Pre-consumer waste literally means waste before the goods are purchased, that is, textile waste during the production process of clothes. According to an investigation by Gugnami and Mishra, 15 to 20 percent of fabric is wasted in the process of cutting and making the garment (Rissanen and McQuillan 11). Take 2018 as an example, the fashion industry created 92 million tons of fabric waste (Rudenko). Part of the reason for the waste is the current mainstream clothing production model. Often designers will only focus on design and the finished effect. The patternmaker will only consider how to meet the design requirements, and the constructor will only think about how to sew a piece of clothing.

Secondly, "Post-consumer waste is thought of as pre-worn, manufactured garments that are sourced through second-hand clothing merchants and charities" (Gwilt and Rissanen 35). The control of post-consumer waste is mainly decided and influenced by the consumer themselves (Farrer 21). Take the UK fashion industry as an example, consumers donate clothes to charities, second-hand stores or clothes banks, but more clothes stay in their wardrobe (Farrer 21). A large amount of clothing waste left the UK and was traded as recyclable fabric in other countries, this is so called "green waste"(Farrer 20). Some of the better-quality clothes will be re-sold in some countries, and the rest will enter waste disposal factories that can shred the clothes and make them into cotton again or dump them in the landfill. Even if designers and factory employees make every effort to reduce waste in production, the end products can still be discarded as "unfashionable" products in favour of a new trend (McQuillan "Zero-Waste Design Practice: Strategies and Risk Taking for Garment Design" 87). Therefore, today's huge fabric waste is caused by both the fashion industry and consumers (Rissanen and McQuillan 10). It is meaningful for me in my zero waste pattern cutting and design process to think about consumers' use of garments and the reuse of fabrics after consumption. In my project, there are multiple ways to wear a piece of garment, and new garments have been obtained by re-cutting and re-constructing the same piece of garment.

Fabric is precious. Although the current technology makes it easy to produce, we are paying a more expensive price, even an irreversible one. Therefore, we must not only spend our thoughts on fabric waste disposal and recycling, but also try at the design source to ensure that all decisions and methods are within the scope of sustainable development (McQuillan "Zero-Waste Design Practice: Strategies and Risk Taking for Garment Design" 86). A sustainable fashion strategy aims, overall, to speak to the multiple issues within the fashion industry today. Zero waste fashion design brings an alternative, fabric-centric process.

1.5 Creative Pattern Cutting and Zero Waste Pattern Cutting

> "Zero-waste, recycling, up cycling and working with advanced materials present pattern cutters with new challenges through which to develop more creative practice; a critical component of contemporary fashion design" (Townsend and Mills 104).

The development of fashion design is inseparable from pattern making (Sharma 13), as the method of pattern making affects the design trend intentionally or unintentionally. Fashion pattern making, which involves a process of constructing 3D from 2D, requires an understanding of the three-dimensional relationship between shape and body. This integrated association of the "pattern, the fabric, the shape, the body"(Townsend and Mills 105) to create garments is applicable to zero waste pattern cutting and my own pattern design research using the Mobius band.

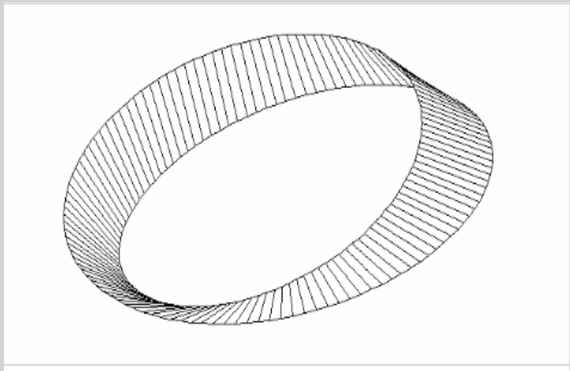
It would be meaningless to discuss the problem of fabric waste if a discussion of the pattern making process is avoided. Creative pattern cutting (CPC) is the process of designing and cutting fabrics, and this process requires designers to fully understand the relationship between the body and its covering (Townsend and Mills 104). This is a dialogue between visual and fabric forms, designers constantly explore shapes and forms to discover more potential possibilities for fabrics in fashion design (Townsend and Mills 104). Creative pattern cutting has become more valued in the development of contemporary fashion design. Fashion pattern making is not just a process of obeying instructions and commands, it is also a part of the design (Rissanen "From 15% to 0" 6). When we pay more attention to the relationship between each piece of fabric, the fabric will interact more fully with the human body in the most natural form (Townsend and Mills 104).

Zero waste fashion is "the design and manufacture of fashion that aims to eliminate the production of textile waste"(Rissanen and McQuillan 212). Zero waste pattern cutting is the process of cutting and creating garments by making full use of the length and width of the fabric. This process helps to avoid 15%–20% of textile waste generated in the traditional fashion patterning process (Townsend and Mills 104). Applying creative pattern cutting as a means to zero waste pattern cutting may enrich its knowledge system and create new possibilities (Townsend and Mills 110). However, if the pattern cutter neglects the control of clothing performance, quality, technique, and design in cutting, it will bring about unknown or unresolved problems (Townsend and Mills 105), which may lead to dull and repeated garments. Finding a balance between the aesthetic appeal of apparel and the environment is an issue that cannot be ignored. As introduced earlier, young consumers are concerned about sustainability but also prefer beautiful garments. Therefore, my goal is not only to reduce the cutting line while ensuring fabric zero waste, but also to ensure aesthetic appeal.

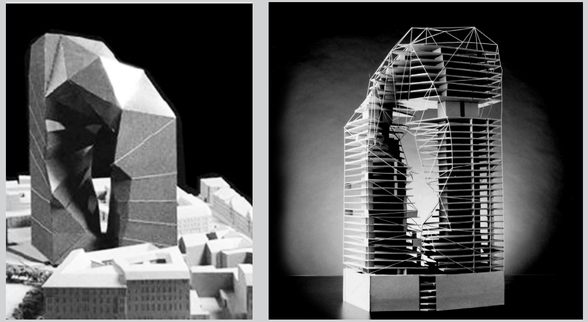
The integrated relationship of the "pattern, the fabric, the shape, the body" to create garments (Townsend and Mills 105) was my primary focus throughout my research of designer precedents and my own zero waste practice-based design research.

1.6 Designer Precedents: Case Studies

The discovery of the Mobius band (Fig. 3) is attributed originally to the German mathematicians Johann Benedict Listing and August Ferdinand Möbius in 1858 (Thulaseedas and Krawczyck 1). This structure can be easily made by using paper tape to rotate a half circle and then gluing the two ends. Since the discovery of the mobius band, it has appeared in different fields including mathematics, engineering, science, and even art and magic (Thulaseedas and Krawczyck 1). The Mobius band is more often used in architectural design, such as Peter Eisenman's Max Reinhardt Haus (Fig. 4) (Hodge et al. 90; Thulaseedas and Krawczyck 1) which is a 34-story multi-purpose tower (Hodge et al. 90). Although the building is divided by the ground plane and does not form a complete Mobius band visually, it is the product of a design iteration starting from Mobius (Thulaseedas and Krawczyck 2). The characteristics of Mobius itself can provide penetration with space and visual production in architecture (Thulaseedas and Krawczyck 2). For example, the infinite feature can make people experience wonderful spatial and visual changes when walking around without being turned upside down. Additionally, its transformation character can make the external and internal space intermingle (Thulaseedas and Krawczyck 2). The infinite feature will also help in achieving zero waste fashion pattern making so that the fabric will have a certain fluidity on the human body that realises the possibility of varied wearing.



(Fig. 3) The Mobius band (Thulaseedas and Krawczyck 1).

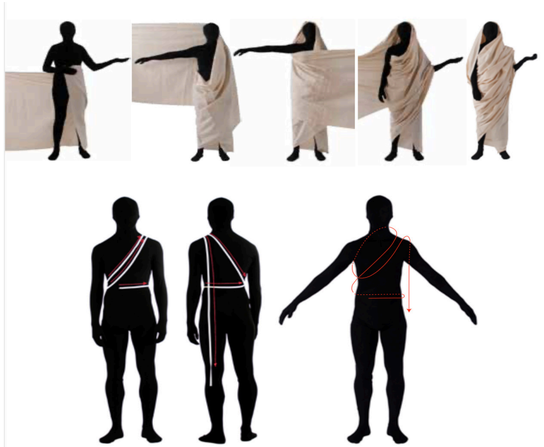


(Fig. 4) Left: Max Reinhardt Haus (Thulaseedas and Krawczyck 2).
Right: Max Reinhardt Haus model (Hodge et al. 91).

(Fig. 5) The Mobius (Hodge et al. 256-257).

Fashion designer J. Meejin Yoon's conceptual project the Mobius (Fig. 5) takes the shape of the Mobius strip to create a felt A-line shape dress (Hodge et al. 256-257). The wearer could zip up the Mobius to create the dress around the body, and when unzipped it becomes a structured fabric loop on the floor (Hodge et al. 256-257). This was a simple use of the mobius theory to construct clothes without cutting and solve the issue of excess fabric waste. However, the functionality of this garment is bit weak, and the use of this felt fabric let this dress look too heavy and stiff, not allowing the fabric be fully utilised. In addition, the width of the fabric increases the difficulty of winding the fabric around the body, so the fluidity of the fabric is also reduced.

1.6.1 CPC precedents – not 100% zero waste but inspired



(Fig. 6) Reconstruction of an Indian sari (Lindqvist 60).

There are many designers' creative pattern cutting methods or theories that influence my ideas and open up my vision of fashion pattern making. For example, Rickard Lindqvist states, "pattern cutting is one of the activities that constitute fashion design" (Rissanen and McQuillan 54). His kinetic construction theory focuses on the relationship between body movement and joint points, balance directions, and garment (Lindqvist 7). In addition, he used traditional clothing styles like the Roman toga and Indian sari to conduct wrap clothing experiments in order to understand the movement and shape of the human body (Fig. 6) (Lindqvist 57-59). This research influenced some of my early toiles as these traditional garments are oriented to fabric dimensions and draped in response to the body.

Lindqvist's analysis of the traditional garment influenced current thinking about the balance direction and key biomechanical points (Lindqvist 7). He explored human dynamic lines from early clothes, and combined patterns/blocks with these dynamic lines to create a pattern cutting method based on body movement. Compared to the traditional garments he studies, the kinetic construction theory reduces the fabric dimension and makes it more convenient for the wearer to move. However, his one-piece-cut pattern shapes reduce the versatile usage of fabric compared with the traditional method and increases fabric waste.

Julian Roberts' Subtraction Cutting method is another alternative process that cleverly focuses on the negative space between the cloth and the body (Roberts 12). It does however retain the use of a conventional pattern/block, rather than creating a new one. The advantage of the Subtraction Cutting process is that it increases the opportunities in the final shape pattern making for innovative outcomes and reduces the dependence and restrictions on pattern piece numbers and sizing (Roberts 13). The 'Tunnel' technique is integral to the Subtraction Cutting method (Roberts 34), and involves constructing a tubular body with the cloth, and then leaving holes through which the body can pass. These holes can be connected and stacked in varying order, and then based on this, the designer can start adjusting the design. During the design process, Roberts focuses on analysing the shape in front of him. It allows the designer to rethink the relationship between fabric, human body, and pattern. This process also makes the design result uncertain and unknown, where risks and opportunities co-exist. These risks can develop new positive possibilities in zero waste pattern cutting. A critical outcome is a spatial relationship between the garment and the body with the potential for changeable and transformable garments. His Sub-Cut dress (Fig. 7) is made of seven-meters-long white and red cotton fabric, and this dress has no less than five kinds of wearing modes (Rissanen and McQuillan 67). This feature allows consumers to own 'multiple pieces' of clothing while only buying one piece of clothing (McQuillan and Rissanen 30). This will not only have the potential to reduce the amount of fabric people purchase but also extend the useful life of the precious fabric. However, this approach substantially increases the amount of fabric used, more than usual lengths for comparable garment types.

(Fig. 7)
Above: Sub-cut dress front view (McQuillan and Rissanen 31).
Below: pattern of sub-cut dress (McQuillan and Rissanen 35).

1.6.2 Zero waste fashion practitioners and methods.

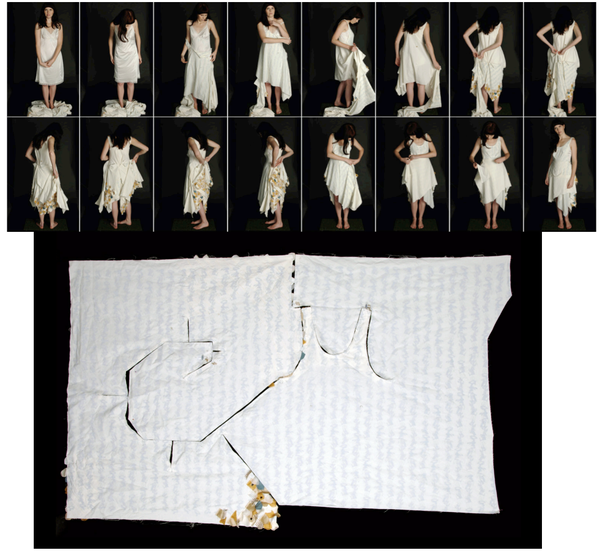
(Fig. 8) Left: Muse dress back view
Middle: Muse dress front view
Right:Muse dress pattern
(Townsend and Mills 109).

Mills' design method is based on using an existing garment as a design prototype. After thinking and analysing it, she transforms it into a zero waste garment. For example, her Muse dress (Fig. 8) was designed with reference to the black Greek dress from the 2009 Inbar Spector AW collection (Townsend and Mills 107). She used the traditional drape method to start experimenting with a half-scale mannequin. When the design was basically shaped, she continued to develop it using the full-scale mannequin. After that, the fabric is defined and a preliminary 2D pattern is produced. Mills believes this step helped her understand the relationship between 3D and 2D, and helped to clarify the most important part of the current design. After that, she placed the preliminary pattern under the framework of zero waste pattern cutting (Townsend and Mills 108), and continued to develop the remaining unidentified parts while maintaining the stability of important parts. The main purpose of Mills' method is to focus on the design first, and then study the pattern of the design, and then think about how to mix the two to achieve the final product (Townsend and Mills 108). This provides a useful base for learning more about zero waste shapes when the end garment design is preferred.

Mills not only pays attention to the fluidity of the fabric in the development of design, but also retains the shapes of the fabric itself as much as possible, in an attempt to integrate these shapes into the overall design of the clothes. In Mills' design, she tries to reduce the interference with the natural state of the fabric while retaining the design prototype as much as possible (Townsend and Mills 108). During the entire development process of the Muse dress, drape is used as the main method, and the flat pattern making method is added after the initial design and toiles, and the final outcome is achieved with comprehensive analysis and improvement. Mills' method is time-consuming in the short term. By determining the design of the garment first, then making it zero waste, the finished garments are more directional. This method helps to reduce the unpredictability and uncontrollability of earlier precedents methods discussed but designs may not be as innovative, and it is a time-consuming process.

(Fig. 9) Gauze coat with pattern (Cumming and McQuillan).

Deb Cumming and Holly Mcquillan's project "Zero + One"(Fig. 9), is a product of zero waste design combined with one-piece cutting technology, it is the method of making a piece of clothing with a continuous fabric. This project includes the design of three coats and shows the application process in various fabrics. The research goal of this project is to reduce fabric waste and allow for post-consumer design disassembly and pattern reconstruction by fusing minimal cut lines for textile recycling. The one-piece cutting method can reduce the cutting and stitching while ensuring new aesthetics of the clothing, which is a manifestation of minimalism (Cumming and McQuillan). This project pays attention to the internal space between the body and clothes, especially to observe and consider fit and functional body movement primarily in the double sleeves. The goal is to enable clothes to meet people's increasing demands for clothes, in terms of both aesthetics and functionality. Cumming and McQuillan achieved this goal by draping on the live body (Cumming and McQuillan). In addition, there are pattern and construction methods adapted for the alternative design process for example; alternative double fabric folds in areas to compensate for no interfacing and seam and pocket stabilization, retention of the selevage, applied tape to the original fabric shape on lines to be stitched to eliminate overlocking giving the garment a clean finish and graphic textile quality. However, the location of cutting lines were scattered throughout, this reduced the integrity of the fabric (the fabric area between the cutting lines is small and irregular). Although these cut lines can be refused, the effect on the fabric is irreversible.



(Fig. 10) First Son. 2004-2005. Holly McQuillan.
Above: garment changes
Below: pattern

The design of First Son (Fig. 10) by Holly McQuillan mainly adopted the one-piece cutting method. This garment can be assembled into different styles of dresses. The flexible and custom design can meet the user's pursuit of different styles of clothes (McQuillan "Zero-Waste Design Practice: Strategies and Risk Taking for Garment Design" 86). McQuillan's creative pattern cutting process takes a piece of fabric and a size chart as the beginning of the story. She explained her process as a careful dialogue with the fabric to feel the changes in the fabric in each collision with the scissors (McQuillan "Zero-Waste Design Practice: Strategies and Risk Taking for Garment Design" 87). Risks, errors, and even failures are the negative aspects of this process. Although, as McQuillan states, "my design practice and research has been actively to pursue the development of an accidental or intuitive design generation process" (McQuillan "Zero-Waste Design Practice: Strategies and Risk Taking for Garment Design" 87). In exploring zero waste pattern cutting, she constantly challenges various risks, not involved in traditional pattern making.

McQuillan's methods along with other designers discussed are commendable in that they are not afraid to deviate from the procedures of mainstream clothing design and are not affected by the so-called fashion trends. However, the bottom line is to make the clothes under zero waste pattern cutting have the look of 'rightness' and looking 'timeless' (McQuillan "Zero-Waste Design Practice: Strategies and Risk Taking for Garment Design" 87).

1.7 Sustainable Fabric and the New Fibre—To Understand the Fabric

More and more types of fabric have been discovered and utilized by designers with the advance in technology (Hallett and Johnston 10). To distinguish a fabric is actually to distinguish its constituent fibres and its characters. Fibre is mainly divided into the natural fibre, man-made fibre (Sinclair 5), and hybrid fibre (O'Mahony 51). The principle of judging whether a fabric is a sustainable fabric also changes with human cognition. The sustainability of fibre is related to the production process and also how to carry out the laundry care process (O'Mahony 45). Therefore, this section will explain the impact of fibre on the environment and the designer's responsibility in this process. It will illuminate the research behind my careful selection of fabrics in the design of this project.

Natural fibre does not necessarily mean that it is sustainable (Fletcher 11). Natural fibre includes plant fibres and animal fibres, such as cotton, linen, sisal, hemp, silk, wool, and so on (Hallett and Johnston 62-181). Also, some new plant fibres have recently been applied to textiles, such as lyocell, Tencel, and bamboo (O'Mahony 43-45). The fabrics made from natural fibres have always been stereotyped as the sustainable fabric (Fletcher 11; O'Mahony 43), mainly because most natural fibres not only require shorter decomposition time but are also made from fast renewable resources. However, natural fibres have the problems of short service life and large water consumption during raw material growth. Therefore, in my design process, I try to ensure the integrity of the natural fibre fabric for reuse.

Man-made fibre is not always harmful to the environment and can be environmentally friendly depending on the materials (Fletcher 11; Hallett and Johnston 182). Synthetic fibres are gaining more and more advantages in saving water and extending the life of clothing (O'Mahony 44; Turley et al. 6). Although synthetic fibres are fibres synthesized through chemical processes, such as polyester, nylon, acrylic, and so on, the raw materials of synthetic fibres are mostly made of petroleum (Hallett and Johnston 183), and petroleum itself is not a fast renewable resource. Such materials are mostly considered to be harmful to the environment. However, some new synthetic fibres are believed to help solve environmental problems, they are new fibres made from recycled resources or that use less water (Hallett and Johnston 182). For example, polyester PET fibre is a fibre made by Wellman International GmbH through recycling PET bottles (O'Mahony 48). Thus, more and more evidence shows that the fabrics made of natural crops cannot be simply defined to be more environmentally friendly, and man-made materials are not necessarily more harmful to the environment. In my design, instead of buying new synthetic fibre fabric I have used leftover fabric from my past years' collection, it will become "fabric waste" if I do not use it.

With the development of technology and new materials, hybrid fabrics may be the future of sustainable fashion, although hybrid fibres are not perfect (Gwilt and Rissanen 17; O'Mahony 44). As its name suggests, a hybrid fabric is a mixture of multiple fibres (O'Mahony 51). The advantages of hybrid fibre are mainly reflected in its service life due to its lower requirements in terms of washing temperature, frequency, and method. However, its shortcomings are also obvious, because it is a fusion of natural fibres and synthetic fibres its raw materials are not unitary, which also increases its difficulty in recycling (Turley et al. 5). In particular, most of the mixed materials have high-performance elements such as metals and liquid crystal polymers (O'Mahony 51), which makes it difficult for these materials to be recycled. It is precisely because the reconstruction of the fibre and fabric is complicated that it is important to ensure the integrity of the fabric, as this can make the fabric after deconstructing the clothes more direct and effective for secondary creation.

The complex characteristics and production process of fabrics make it more difficult to achieve and define to be sustainable (Tomaney 547) and therefore this requires more input from designers. The current problem is that most designers will not ask whether the production process of fabric or materials causes serious harm to the environment (Gwilt and Rissanen 17). "It is uncommon in current fashion design practice for the designer to be concerned with the efficiency of fabric usage"(Rissanen "From 15% to 0" 7). The occurrence of this situation is also affected by the cost of time and money to a certain extent. However, during the production process of zero waste pattern cutting, the designer is required to improve their pattern making skills and their knowledge of the fabric (Abnett 4). Understanding the growth environment of textile crops, the production of fibres, the process of dyeing fabrics, and the production and disposal of clothes will help designers to minimize negative impacts on the environment. While focusing on sustainable design practice, fashion designers must also consider the process of clothing from raw materials to consumers, because different stages of production influence each other (Van Kopplen 3), and this will be a challenge to designers that guarantee aesthetics in limited resources (Tomaney 549). Therefore, my zero waste project starts with carefully choosing fabric, using deadstock fabrics, and fabric I made from wool.

Understanding the production process of fabric is not only beneficial to promoting the development of sustainable fashion, but also helpful to design innovation from a designer's perspective (Calderin 171). If a designer considers the sustainable value and durability of the fabric when choosing it, and understands the whole construction process of the garments, the designer demonstrates a sustainable strategy intake before consumption that can help to eliminate fabric waste and positively impact the environment at the design stage (Rissanen "Zero-Waste Fashion Design" 19). In addition, this will largely avoid contamination caused by consumers during cleaning and drying. Additionally "it is more effective to avoid problems from the outset, than to invest in reactive solutions once the problem has presented"(Lewis and Gertsakis 7). The contemporary designer needs to work hard on evaluating the existing technology and research, in order to find methods that suit the current social and environmental conditions (Rissanen "Zero-Waste Fashion Design" 19). However, because of the pollution and waste of fabrics worldwide there is urgent need for reform, which also reserves space for innovative designs (Rissanen and McQuillan 8) that appear in many creative pattern cutting methods including zero waste pattern cutting.

Chapter Two: Method—Design Thinking and Pattern Development Process with Reflection

“The design process is a research process“ (Swann 55).

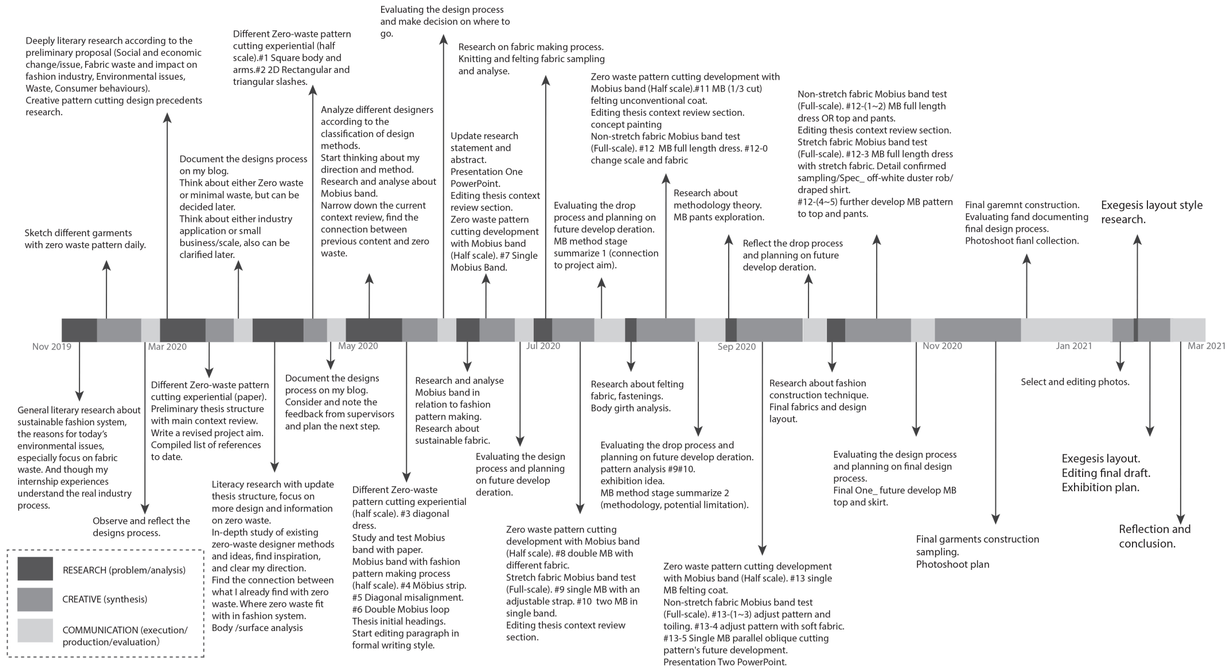
2.1 Methodology

(Fig. 11) The action research in design (Swann 53).

The method in this practice-based design project is framed by an action research process, with analysis through reflective insights (Swann 50-51). The action research (Fig. 11) can be divided into three stages: Research, Creative, and Communication (Swann 53). I began with secondary research on related aspects of fabric waste issues and creative pattern cutting methods, defined the aims and scope, to then experiment with a number of pattern developments, sample processes, refining my garment design decisions and outcomes throughout the process. Both the project development and design process were iterative processes that were constantly evaluated to find and solve problems and make plans for the next stage. They followed the “spiral of cycles of action” composed of “plan, act, observe, and reflect” in the design process described by Ortrun Zuber-Skerritt (Swann 55-56; Zuber-Skerritt 11-13). An outline of my specific design process and iteration (Fig. 12) is detailed below.

The design development process was led by the following criteria:

- considered fabric choice
- zero waste fabric usage
- pattern planning responds to fabric and body dimensions
- pattern can create multiple garment designs
- patterns and garment designs are innovative in shape
- garment designs are multi-sized and worn in multiple ways
- patterns and garments facilitate recycled designs to extend fabric life



(Fig. 12) My design process and iteration,Zewei Li,2021

2.2 Creative Drawing and Initial Pattern Explorations:

My initial concept board (Fig. 13) explains the fabric waste situation, which shows the light and dark side of the apparel industry. People wear fancy garments everyday imaging the light side, but there are in fact tons of fabric waste in the dark side of the industry. Therefore, my collection "The infinity" used black and off-white as my colour palate to encourage reflection on this issue. The pattern in black pleated fabric and wool felt fabric were all like black, falling and broken leaves which reflects the impact to the environment from both the fabric production process and the post-consumption period.

(Fig. 13) Initial concept board painting, Zewei Li,2020.

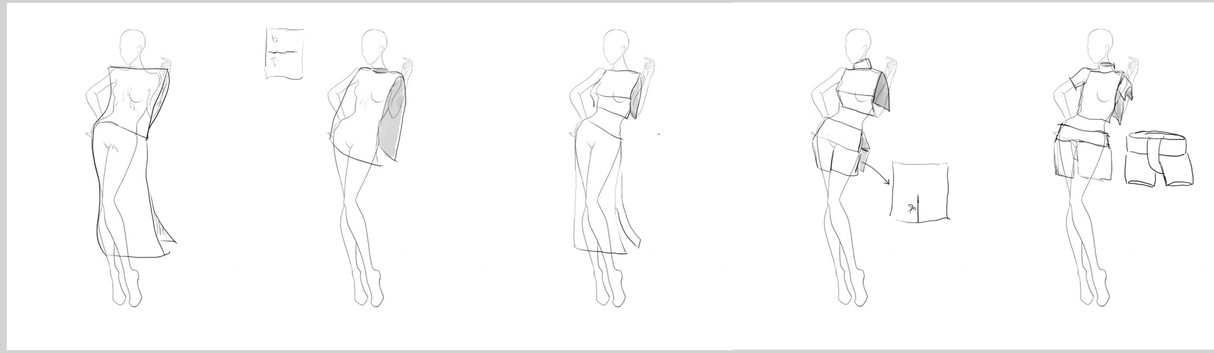
“Reflection and theorising”(Cross 27).

My design process started with a lot of sketches, mainly analysing the patterns of existing clothes, and thinking divergently to achieve zero waste. This process not only enriched my understanding of different garment patterns but also began the exploration of my zero waste pattern cutting methods.

The relationship between garments, fabrics, and the human body is inseparable (Carufel and Bye 6). As shown in the figures, the clothes can be assembled using squares or triangles (Fig. 14). I could foresee that there would be an excessive number of cutting lines (Fig. 15), so I started to analyse how many cutting lines are necessary when constructing various types of garments.

Initial half-scale toiles were used to extend my learning of different zero waste pattern cutting methods which had potential to achieve my aims. The potential of multiple pattern use and wear of garments was important in my design thinking in response to extending the serving life of the fabric and in the reduction of textile waste. In most of my design process, I took the selection and use of fabric as the starting point, establishing a fabric-centred focus. In addition, during my exploration process all fabric I used was recycled, deadstock with the exception of the felt fabric constructed by myself.

(Fig. 14) Geometric body form, Zewei Li.



(Fig. 15) Cutting lines analysis, Zewei Li.

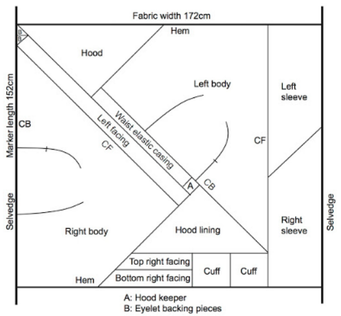
2.2.1 The geometric figure

#1 2D Square body and arms shirt.

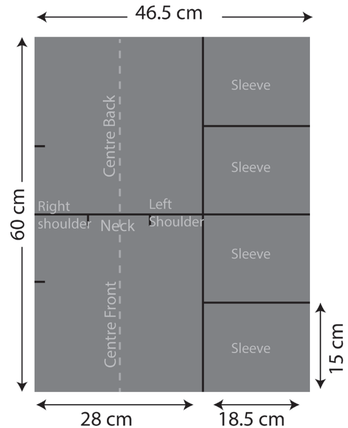
The pattern and method of this toile is mainly inspired by both the historical medieval shirt (Fig. 16) (Scott 67) and the Jigsaw puzzle methodology (Rissanen “Zero-Waste Fashion Design” 86). The outline of the medieval shirt is neat and rectangular from the sleeve to the main body, it did not waste fabric except for the neck area. Although it can be easily fit to different body shapes, the drape of the fabric is influenced by the people who wear it.

(Fig. 16) Dalmatia by Rodrigo Ximenez de Rada, Spain, before 1247, Soria, Cistercian abbey of Santa, Maria de Huerta.

In the hoodie pattern from Timo Rissanen (Fig. 17), the main content on the left side consists of the main body pieces, the sleeves are on the right side and the remaining part is filled by the inner lining, facing, and other pieces. Those pattern pieces are all geometric shapes and are ultimately put together to become a rectangle. This demonstrated to and inspired me on how to divide the fabrics in different positions within a rectangle (Fig. 18). My attempt at zero waste pattern cutting starts with square fabric pieces of different sizes. Corresponding sets of edges in the square piece formed cylinders corresponding to body dimensions. I kept developing shapes with varied additions and details to show different looks (Fig. 19). This process gave me some understanding of the use and limitations of rectangular shapes. It was difficult to make a close fit shape to the body without having a cutting line in a single square piece. Exploring trims increased the diversity of the garment, an important consideration for consumer appeal, but these did not necessarily respond to the design criteria.



(Fig. 17) Jigsaw puzzle methodology—hoodie pattern, Timo Rissanen.

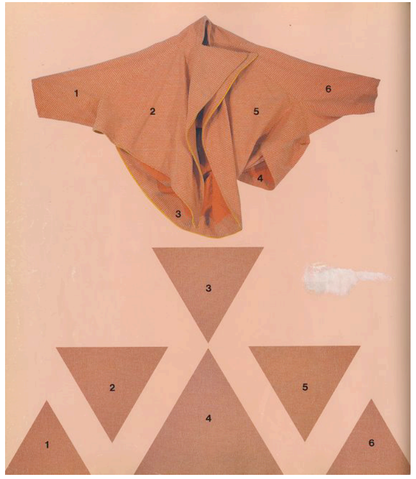


(Fig. 18) #1 2D Square body and arms shirt pattern, Zewei Li.

(Fig. 19) #1 2D Square body and arms shirt: front and side views.

#2 2D Dissected triangular and polygon coat

"Geometric figures can produce beautiful shapes" (Nakamichi Pattern Magic 2 12).



(Fig. 20) Six triangles coat (Hishinuma 162).

I was also inspired by Yoshika Hishinuma's six triangles coat (Fig. 20) (Hishinuma 162). Generally, the fabric is rectangular, it can be divided into multiple squares, and the square can be divided into multiple triangles (Rissanen "Zero-Waste Fashion Design" 40). Although the pattern of this dress is made up of geometric figures, it presents a more contoured silhouette. However, from the perspective of reducing the cutting lines, I thought 18 cutting lines to build a loose fit coat added unnecessary fabric dissection. I explored dissecting the rectangular shape into varied shapes. Unlike the designs of Hishinuma the cut shapes were irregular and asymmetrical. My coat pattern (Fig. 21) reduces cutting lines and integrates jigsaw puzzle methodology and triangles as well.

First of all, I used paper, scissors, and tape to carry out experiments, a method I repeated throughout to quickly visualise the evolving shapes. When the design of the quarter-scale was formed, I scaled up this pattern to half-scale in order to make the fabric toile to drape on the half-scale body form. This helped to further develop the shape details and check the making process. When the toile was basically determined, I explored the multiple wear possibilities by rotating or folding the clothes, but I was not very satisfied with the results. Generally, I like this coat, especially the shape of the lapel, as it can be worn differently. However, its back and side body are more exposed which is not suitable for a wide range of markets. Although I greatly reduced the cutting lines, I did create unnecessary cutting lines in the pursuit of triangles. For example, the length of the upper cutting line of the pattern can be shortened to ensure the integrity of the fabric to a greater extent. This method was generally feasible for visual interest, but the large use of multi-sided shaped patterns resulted in random and unnecessary cutting lines, which are not conducive to a repeated process or extending the service life of the fabric.

(Fig. 21) #2 Initial pattern, left-side, back, and front garment views, sequentially, Zewei Li.

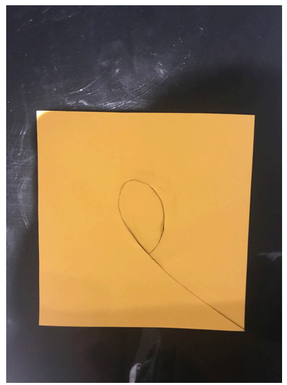
2.2.2Diagonal drape

#3 Diagonal dress and mobius top

"Taking the fabric to the dress form is a good way to gauge how the fabric breaks, folds, and drapes."(Calderin 171).

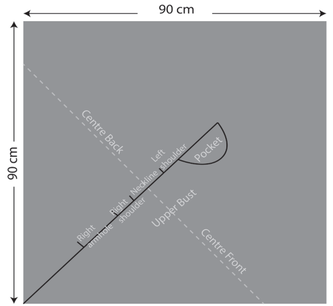
In my drape design process, I tried to "forget" my previous knowledge about pattern making and let the fabric in hand lead me to design and explore the shape of a human body once again through the process of draping on the form. This way I was able to pay attention to the precious fabric itself. The usable area of the fabric affects the creative space of the design, in both traditional pattern making and the creative pattern cutting process. A large initial area of the fabric provides more possibilities for multiple re-creations. I found the action that affected the fabric area during pattern making was the cutting line: "cutting was the most delicate and demanding aspect of the garment trades; stitches were easily removed and replaced, but a mistake in cutting would destroy the cloth"(Crowston 150). This also required me to carefully consider the direction, position, and length of each cutting line and whether it is necessary in my zero waste cutting.

The idea of starting this design was to explore the possibilities of variable grainlines and the bias-cut inspired by Madeleine Vionnet (Bryant 28-29), so I placed the primary cut-line based on the 45-degree diagonal of the square. My goal was to minimize the use of cutting lines. As Cross states "design is opportunistic, and so the path of exploration cannot be predicted in advance"(Cross 30). Firstly, I selected a piece of fabric I would use for toiling which was a black velvet with medium weight, thickness, shear, stretch, and high-medium drape. I conducted a preliminary experiment with a paper pattern, cut the paper with the diagonal as the split point, and finished with an ellipse (the cut line looked like a forward-sloping letter P)(Fig. 22), which was initially inspired by Holly McQuillan's work, the War and Peace dress (Rissanen and McQuillan 75-77). In my design the space of this ellipse matches the size of the upper circumference of the chest. After the elastic band is added, it can effectively ensure the stability of clothes on the body. The oval cut-out became a pocket. As in the steps of the previous toiles, I scaled up the pattern and started draping on the half-scale body form. This is a simple but elegant dress (Fig. 23), the dress hem falls from high to low, showing the charm of the fabric itself. In addition, I found that I may not need to cut the fabric diagonally, but only to cut the location of the bust and a shape cut out to allow the body to pass through (Roberts 34). Further analysis involved minimising the cutting line for textile preservation and garment stability and the effect of balance for the drape of the design. These were crucial aspects I explored in the subsequent process.



(Fig. 22) #3 Diagonal dress: initial pattern and side view.

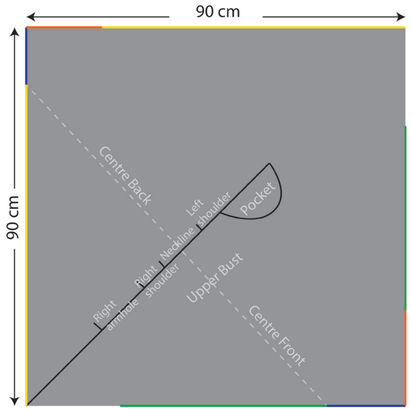
In order to explore more possibilities of this same pattern, I continued to drape and discovered the potential for further garments and wear. I decided to pin the different edges of the fabric together to see what would happen. Then I found that the edges of the squares were connected in dislocation, and sometimes a loop-like structure appeared. This structure somewhat confused me because it is like another 3D structure independent but still connected to the body section. I used drawing to drive my analysis of this structure (Fig. 24).



(Fig. 23) #3 Diagonal dress: final pattern and front view.

(Fig. 24) Further development of Diagonal dress sketch analysis.

After stitching diagonally, the loop structure allowed the cloth to flow around the human body while constantly changing. If the line is drawn from the outside of the fabric as a starting point, you can enter the internal structure without turning over the fabric. I found that I needed to understand the principle of this phenomenon to help me understand more about the structure. “Design is not a search for the optimum solution to the given problem, but that design is exploratory” (Cross 29). This research led me to the Mobius band.



(Fig. 26) Further development of Diagonal dress: final pattern.

(Fig. 25) Further development of Diagonal dress: front and back views.

2.2.3 Mobius band

After the accidental discovery of the last design, I started to study the theory of the Mobius band. I used paper to learn how the mobius loop worked. What excited me most about this theory is that the endless infinite loop it creates is a non-orientable surface and achieved by starting from a 3D fabric to shape a 3D body. This is how I started my journey with the Mobius band (Fig. 27).

(Fig. 27) Paper Mobius band test, Zewei Li.

#4 Single mobius top

I explored cutting pieces of fabric to make mobius loops in different sizes and draped these around the body to learn more about the process potential. “Design is risky - it is not comfortable, and it is not easy” (Cross 31). Although it was paper, I could still feel the fluidity it brought during the draping process. The single mobius top (Fig. 28) made by simply wrapping the mobius bands on the human body is changeable and disorderly. I hoped that clothes could be changed within a controllable range. In short, I created a design parameter that must first look like a “commercial” garment. After this experiment, I looked for further transformational potential.

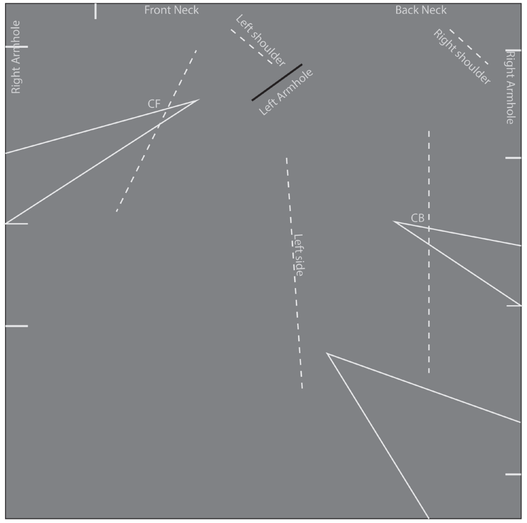
(Fig. 28) #4 Single mobius top: front, left-side, and back views, Zewei Li.

(Fig. 29) #4 Single mobius top pattern, Zewei Li.

#5 Single mobius angular dress (square)

I labelled the four corners of the front and back of the strip and compared the difference between a normal circle and a Mobius band. I found that a common circle meets two parallel points, but mobius band meets two opposite corners, that is, along the diagonal of a rectangle. I tried to use this diagonal as a benchmark to build on the Mobius Band in drape, at this point, the mobius band structure was still not clear to me. There were extensive explorations that were not satisfactory in relation to my design aims and criteria, but these were analysed and refined as I learnt more about this mobius zero waste pattern cutting process. I started to simplify my thinking, trying to think only about the diagonal. The following toile (Fig. 30) was created after this period of exploration, its structure is formed by intersecting diagonal lines. Compared with the previous toile, this fabric has a larger area and width and is closer to a square, so its contour is flatter. No other cutting lines are added except for the armhole. This increases the difficulty of developing it into a variety of garment types, but the advantage is that the integrity of the fabric is guaranteed to the greatest extent. On analysing these samples, I felt there was potential for further development with better consideration of fabric quality.

(Fig. 30) #5 Single mobius angular dress (square): front, back, and side views, Zewei Li.



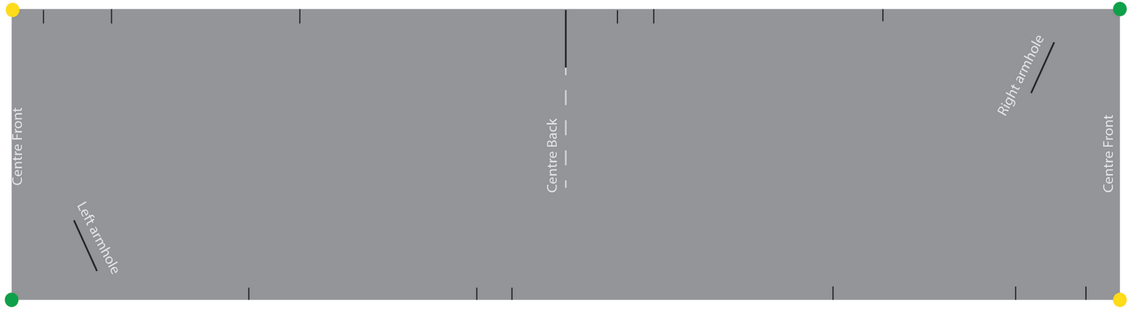
(Fig. 31) #5 Single mobius angular dress (square) pattern, Zewei Li.

#6 Single mobius angular dress (rectangle)

I started again with a rectangular fabric 110 cm long and 25 cm wide. This was my leftover velvet (medium weight and thickness, no stretch, high-medium drape, and medium-low shear). Firstly, I made this fabric into a mobius band. I placed the fabric join line on the centre front; here, the dividing line can clearly be seen between the front and back of the fabric. In order to cover this, I folded the fabric from the top, then pulled up the bottom right fabric under the centre front (CF). During this process I found that when I focused on drape on one part, it was difficult for me to take care of other parts. Changes made in one section will affect other places.

I cross-connected the fabric at the centre back (CB) (Fig. 32), creating the structure while incorporating a facing. Using the weight and drape of the fabric itself, I created a V-shaped neckline on the back. I used fabric layering to obscure the appearance of holes exposing the body. In addition, I also rotated the garment in order to get other looks, but not very successfully, as multi-layered sewing on the back reduced the fluidity of the fabric. This attempt at mobius band was more visually effective compared to the previous toile. Misalignment and flipping were complexities I needed to master when converting to a pattern.

(Fig. 32) #6 Single mobius angular dress (rectangle): front, back, and side views, Zewei Li



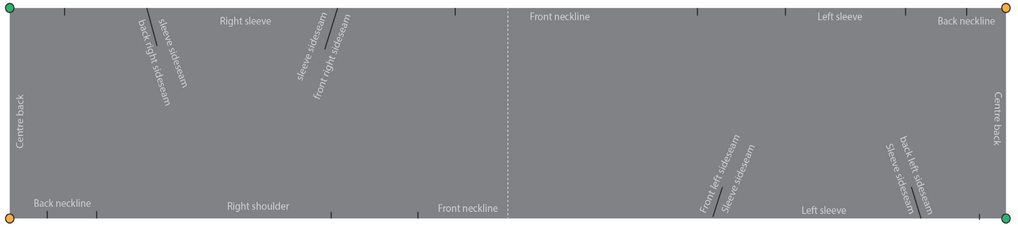
(Fig. 33) #6 Single mobius angular dress pattern (rectangle), Zewei Li.

#7 Single mobius multi-wear top (rectangle)

I soon progressed to experiment draping the Mobius on a full-sized dress form for a clearer understanding of the relationship between the Mobius band method, the fabric and body, and designing for multiple wear possibilities. The fabric I used this time was deadstock 100% Merino knit fabric (medium weight, thickness, drape, shear, and high-medium stretch). The width of this fabric was 152cm including the selvedge. I retained the use of selvedge in the design, because it not only ensures the zero waste fabric integrity, but it also reduces the use of overlock threads. As found in previous toiles, the length of the clothes would be affected by the width of the MB and use of the horizontal orientation.

In the process, I discovered that there are several possibilities for sleeves, making the pattern conducive to my goal to make a changeable garment. The designs were enhanced by the one-piece-cut method which reduced the number of cutting lines (Fig. 34). Concentrating details and sewing lines on the edge of the fabric, allowing more space in the centre of the fabric, facilitated its reuse and transformation. In addition, if the hem and neckline of this top are exchanged, or the front and back are exchanged, this will also change the shape of the top. It can be led by the preference of the wearer, for example the buttonhole around the edge facilitates flexibility of wear with the use of ties.

(Fig. 34) #7 Single mobius multi-wear top (rectangle): front and back views, Zewei Li.

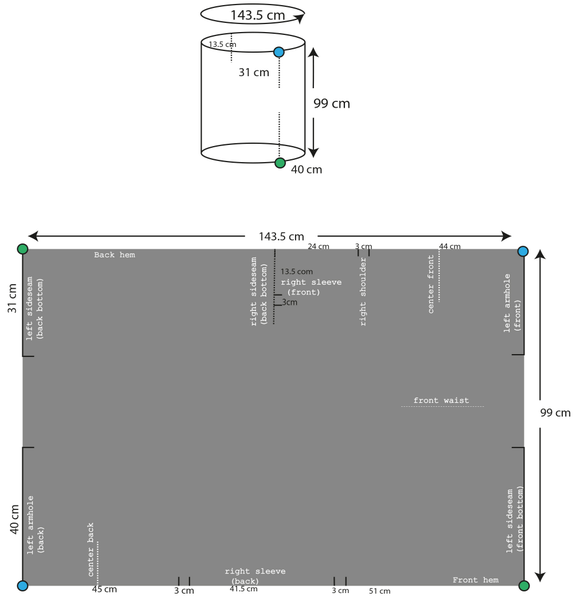


(Fig. 35) #7 Single mobius multi-wear top pattern (rectangle), Zewei Li.

#8 Single mobius vertical dissected: dress

As I wanted to try different types of fabric to test this Mobius band method, I used a tube knit fabric. Taking the vertical dimension 99cm of the cylinder as a reference line, I cut a certain distance from both ends of the fabric to the middle but ensured that a part of the middle is connected. After that, the cut fabric is turned over and made to become a mobius band. Because a defined distance is planned in the middle, two mobius bands appear in this fabric shape, and therefore two twists appear. There are five holes of different sizes in this garment including two holes whose size can be changed without adding other trims because of the effect of the mobius band. This helps achieve variety without adding fastenings. During the construction process, attention should be paid to the treatment of the fabric turning area, which is a common construction issue in this method that I needed to resolve.

(Fig. 35) #8 Single mobius vertical dissected: pants and dress, Zewei Li.



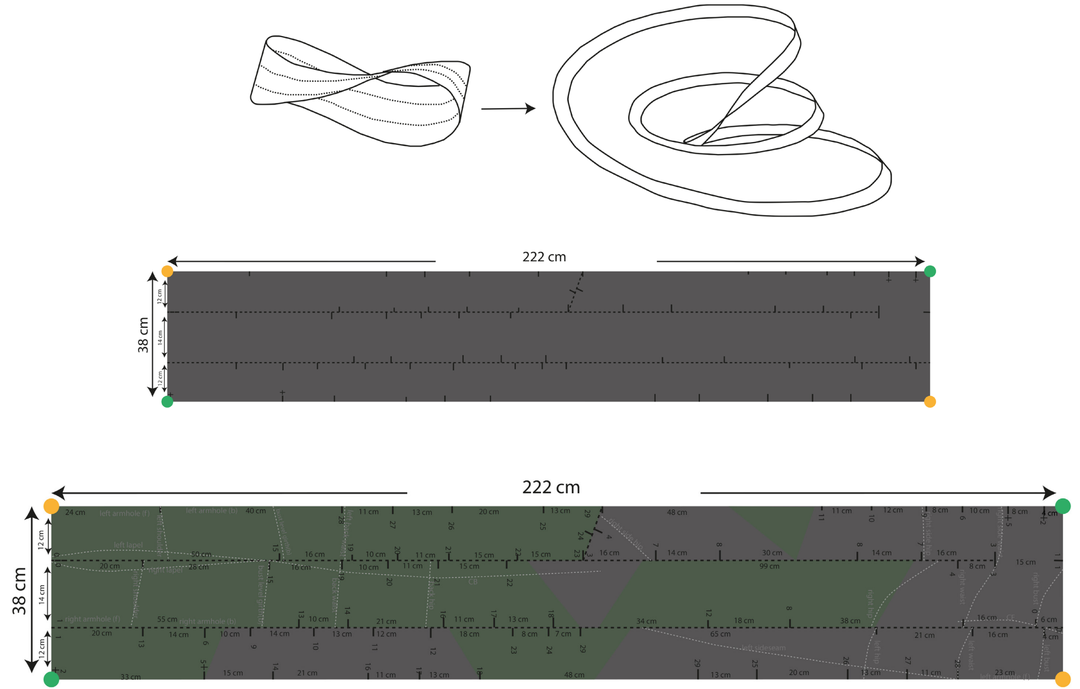
(Fig. 36) #8 Single mobius vertical dissected: dress pattern, Zewei Li.

#9 Single mobius horizontal dissected: coat

In order to further explore the Mobius band method for varied fabrics, I made samples in felt for the consideration of creating new fabric to dimension for zero waste. This sample was made with two colours of wool (low drape, medium-high thickness, medium weight, low shear, and low stretch). I started with testing the position of the cut-line, and then moved to draping. I tested its variability, taking the measurement of the holes in the garment and other important body lines such as the waistline and neckline. These are there to create potential variability of wear.

The more difficult part of the pattern making process is at the beginning, because the Mobius band connection is connected after flipping and being connected diagonally. When it is displayed as the paper pattern, it is still a simple rectangle. Therefore, in order to understand the pattern more easily, it is essential to label the corners so that they are connected with the same colour. Compared with single Mobius bands, the thrice cut mobius band can increase its length when reducing the width of the fabric, which helps to improve the drape quality of the felt fabric in the Mobius band method. It is inevitable that the increased cutting lines limit further uses of the fabric. There was also the issue of body exposure which needed further attention.

(Fig. 37) #9 Single mobius horizontal dissected coat: front, side, and back views, Zewei Li.

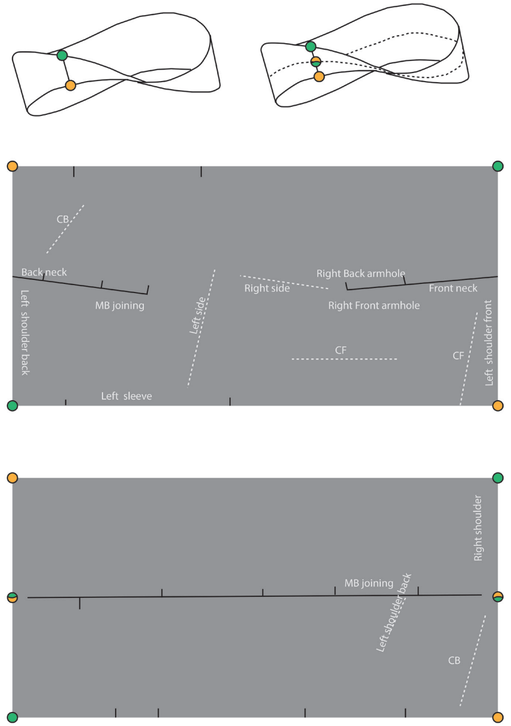


(Fig. 38) #9 Single mobius horizontal dissected: coat pattern, Zewei Li.

#10 Double mobius coat

While researching the Mobius band further, I was inspired by the video topology of Mobius cuts (Math-Constructed 2:28). I pinned two Mobius Bands vertically, and placed the join point around the neck, slashing an opening at the middle of the first MB so the head may go through. Then I let the left arm go through the loop and closed the edge of the loop to create a sleeve, slashing an opening at the back MB, so this could give a curve finishing on the back of the left sleeve. After that, I thought about the right sleeve and armhole, I extended the first slash a little bit more to provide space and was able to button it at the right shoulder. Later I found out the majority of the second loop was still not used, yet I was still able to create a garment using only one loop (without fully cutting open the loop)(Fig. 39). Thinking about different entry points for the body inspired by this concept of Julian Roberts (Roberts 29-34) was an interesting application. However, in this sample using two Mobius bands to make a piece of clothing was considered redundant. It not only increases unnecessary complexity in pattern making, but it also increases unnecessary fabric usage. This goes against my original intention.

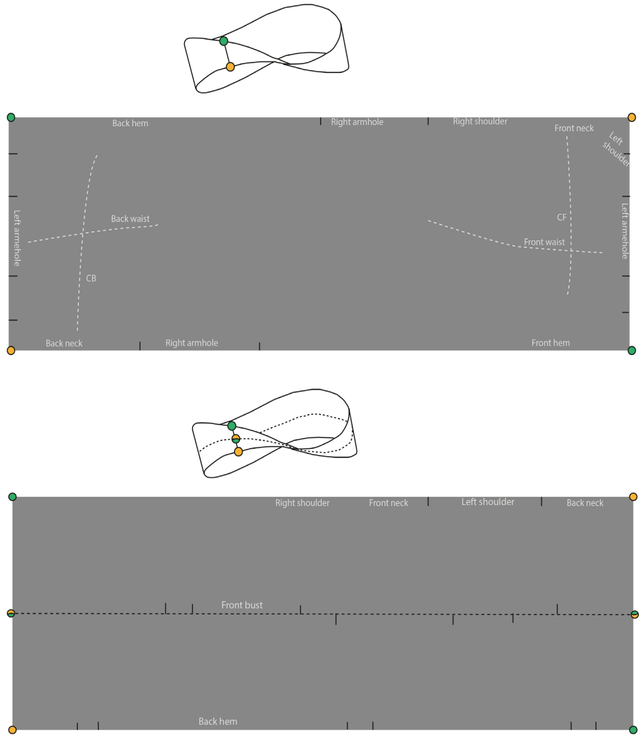
(Fig. 39) #10 Double mobius coat: side and front views with pattern, Zewei Li.



#11 Double mobius joined: coat (bi-colour)

The definition of MB in mathematics is that it is one-sided and has no end (Barrow 219). Fabric, however, often has a right and wrong side. However, many monochromatic fabrics on the market make it difficult to distinguish the right and wrong from a distance, and functionality is not impacted. The deadstock Merino knit fabric I used this time has two sides of colour; red and skin, which helped enrich the design. An inherent quality of the Mobius Band is the use of both sides of the fabric, which in this case created a contrast between the front and back of this garment (Fig. 40). In order to make the clothes meet more needs of customers and adapt to different occasions, I explored adding fabric of different texture on one side. It is a counter-clockwise Mobius band. This garment has contrast not only in the texture of the fabric, but also in the colour. Moreover, the overall outline of the warm side is round, while the dark side has angular lines creating alternative silhouettes within.

(Fig. 40) #11 Double mobius joined: coat (bi-colour) right and reverse look views, Zewei Li.



(Fig. 41) #11 Double mobius joined: coat (bi-colour) pattern, Zewei Li.

2.3 Mobius Band Exploratory Methods: A Stage to Reflect

"Design is abductive: a type of reasoning different from the more familiar concepts of inductive and deductive reasoning, but which is the necessary logic of design - the necessary step from function to form" (Cross 30).

The primary aim of this technical design pattern project is to eliminate fabric waste and reduce cutting lines during the pre-consumption phase. This method also aims to extend the service life of the fabric, allowing re-creation more easily without multiple cut pieces and cutting lines. This involved the process of producing zero waste from 3D fabric and rethinking the relationship between fabric and body. If 2D fabric is a straight line, then the Mobius Band is a circle with an angular tilt, and this tilt angle is one of the main factors that produces variables. If the foundation fabric itself is 3D, it can help reduce some of the cutting lines and sewing lines which are produced in the normative processes of transforming 2D fabric into a 3D garment. Reducing cutting lines in zero waste pattern cutting, especially one-piece cutting, means that the integrity of the fabric is retained to a greater extent.

In addition, the "endless" feature of Mobius Band adds a certain degree of fluidity to the fabric of the garments, thereby creating more possibilities for transformation. By using the approach of zero waste pattern cutting from a Mobius band I explored the variability of women's garment designs to meet the diverse needs of consumers. I needed to create designs that were commercially viable and provided multi-wear functionality.

This fluidity of process helps to achieve design goals while reducing cutting lines.

The structural feature of the Mobius band also helps to blur the traditional definitions of right and wrong sides of the fabric. Mobius band zero waste pattern cutting helps to liberate more creative space, but in order to take aesthetics into account, it has certain requirements for the use of cloth. As the case with all draped garment designs, the fabric qualities are extremely important for the design outcome. This demands strong consideration for further design development to meet the sustainable, aesthetic and technical design criteria. When reflecting on the sample process, I found that there was an intuitive response to the design in relation to the body forms. I wanted to consider, in greater depth, pattern planning, responding to fabric, and body dimensions.

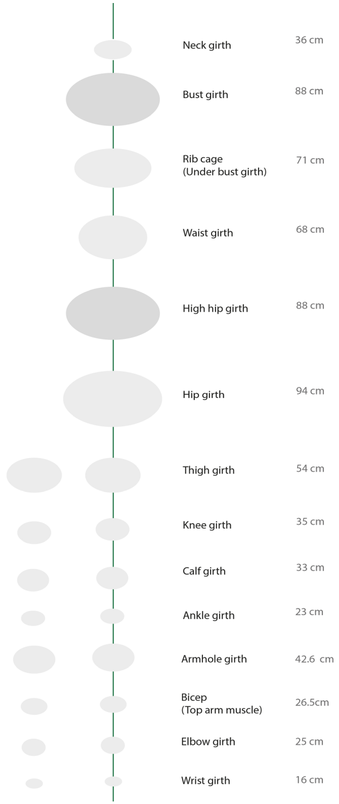
2.4 Body Analysis: A Dimensional System

"Traditional anthropometry provides researchers with the ability to describe the body via linear measurements"(Carufel and Bye 2).

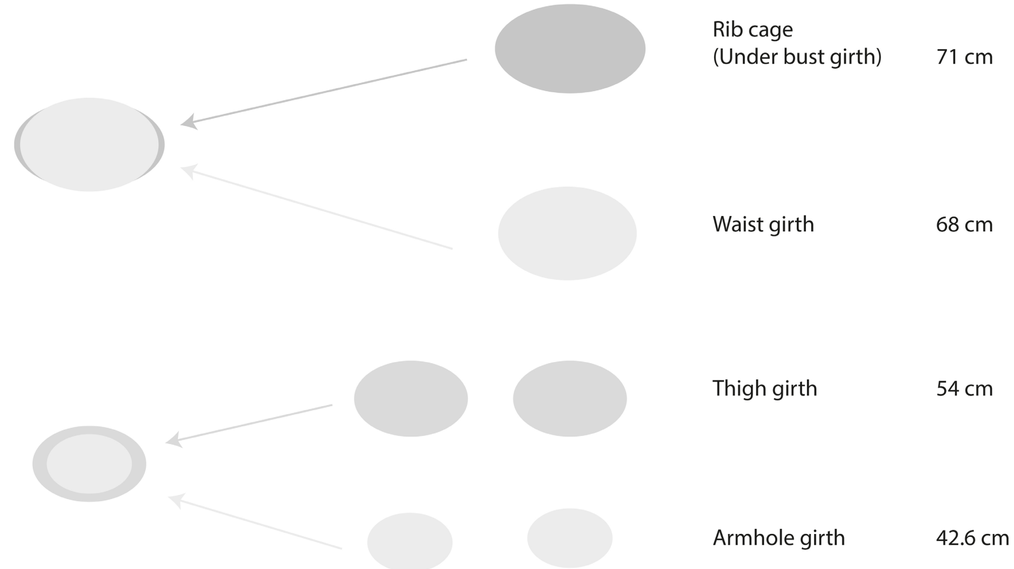
The shape of the human body is complicated. In order to better design and develop clothing, it is necessary to consider the body form and structure in pattern making (Carufel and Bye 5). This is also applicable in the process of developing the Mobius band method. "Body component classification focuses on breaking the body into its component parts and evaluating each part separately from the others"(Carufel and Bye 4). I grouped body measurement dimensions to allow positional changes of a garment for multiple designs from a mobius pattern. Carufel and Bye state that "body form can vary across similar volumes, indicating that it may also vary within a single size" (Carufel and Bye 4).

2.4.1 Girth dimensions

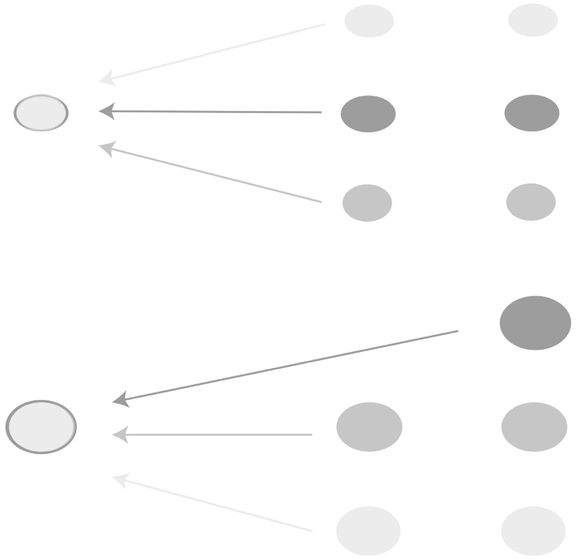
This was analysed according to the size 12 data in the size table. Firstly, I extracted all the circumference measurements, such as bust, waist, hip, knee, bicep girth, and so on. Some of them are singular, some are a pair. After that, I classified them according to the circumference and divided them into a group. These classifications mean that there is a possibility of positional displacement between the same group when designing and wearing clothes. Transposition between different groups is also achievable, but obviously, I can replace a small circle with a large circle. The circles are superimposed according to the grouping through the diagram, which helps me to understand the size changes and connections between different circles of the human body more clearly. The gap between each circle guarantees the possibility of design change, and also helps define the circumference of different parts of the garment.



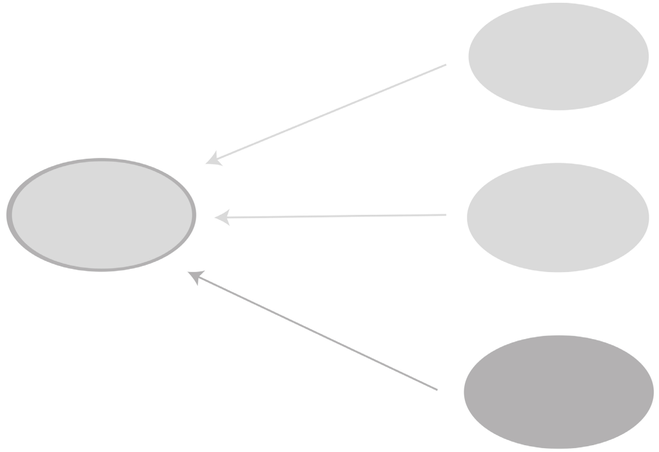
(Fig. 42) Circumference measurements, Zewei Li, size chart reference from Cloake Dawn (Cloake 10-13).



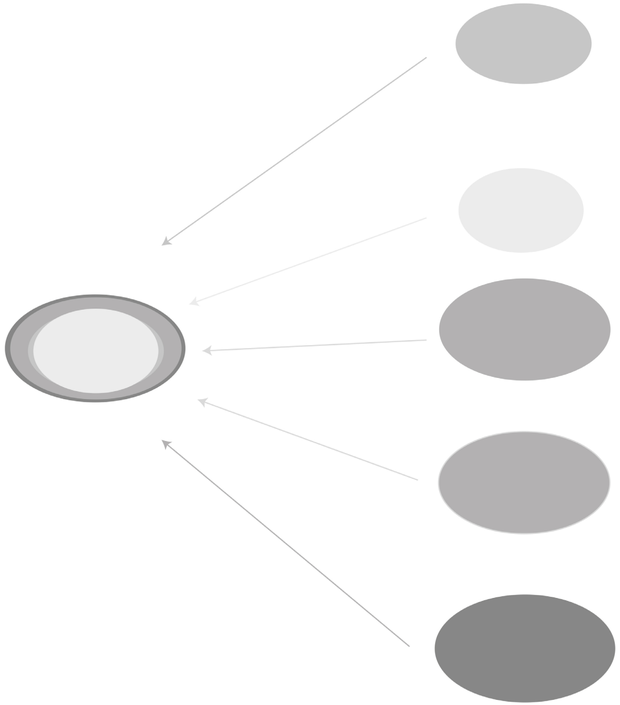
(Fig. 43) Group circumference measurements, Zewei Li, size chart reference from Cloake Dawn (Cloake 10-13).



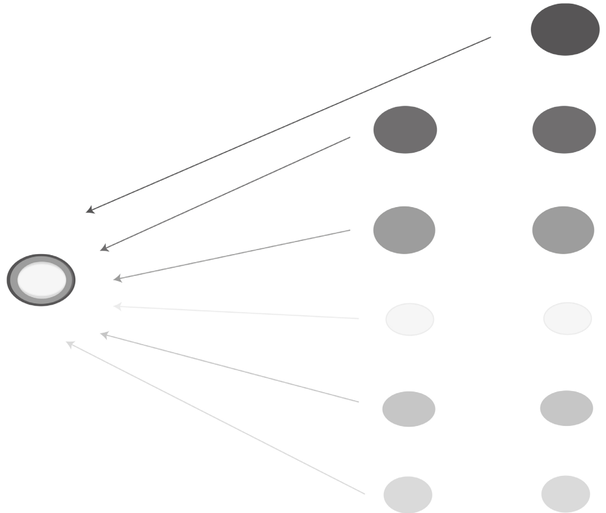
Ankle girth	23 cm
Bicep (Top arm muscle)	26.5 cm
Elbow girth	25 cm
Neck girth	36 cm
Calf girth	35 cm
Knee girth	33 cm



Bust girth	88 cm
High hip girth	88 cm
Hip girth	94 cm



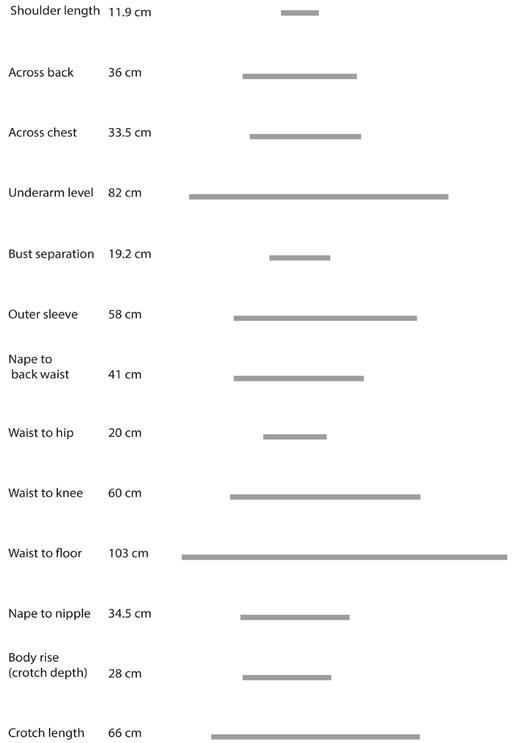
Rib cage (Under bust girth)	71 cm
Waist girth	68 cm
Bust girth	88 cm
High hip girth	88 cm
Hip girth	94 cm



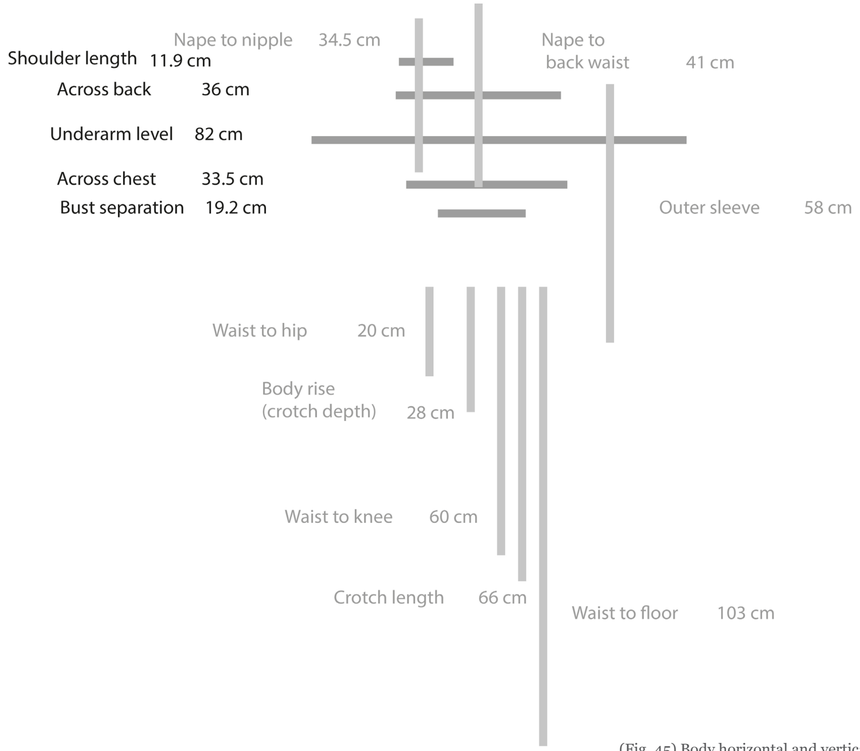
Neck girth	36 cm
Calf girth	35 cm
Knee girth	33 cm
Ankle girth	23 cm
Bicep (Top arm muscle)	26.5 cm
Elbow girth	25 cm

2.4.2 Line dimensions

Distinguishing the horizontal and vertical dimensions, as shown in the figure, helps me to understand the layout of these sizes more intuitively. I also tried to incorporate some circles, from which the outline of a human body can appear. I found that these girth and lines are not independent. There seems to be some connections between them. After analysing the lines, I merged and synthesized these together.



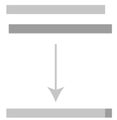
(Fig. 44) Body lines dimensions, Zewei Li, size chart reference from Cloake Dawn (Cloake 10-13).



(Fig. 45) Body horizontal and vertical dimensions, Zewei Li, size chart reference from Cloake Dawn (Cloake 10-13).

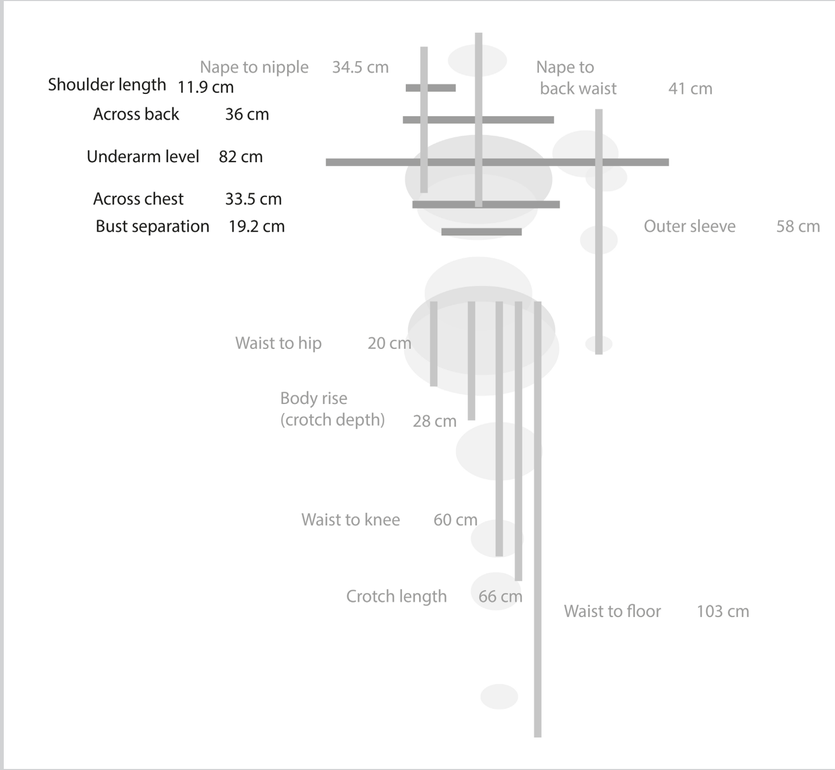
Outer sleeve 58 cm
Waist to knee 60 cm

Bust separation 19.2 cm
Waist to hip 20 cm



Nape to back waist 41 cm
Across back 36 cm
Nape to nipple 34.5 cm
Across chest 33.5 cm

(Fig. 46) Group lines dimensions, Zewei Li, size chart reference from Cloake Dawn (Cloake 10-13).

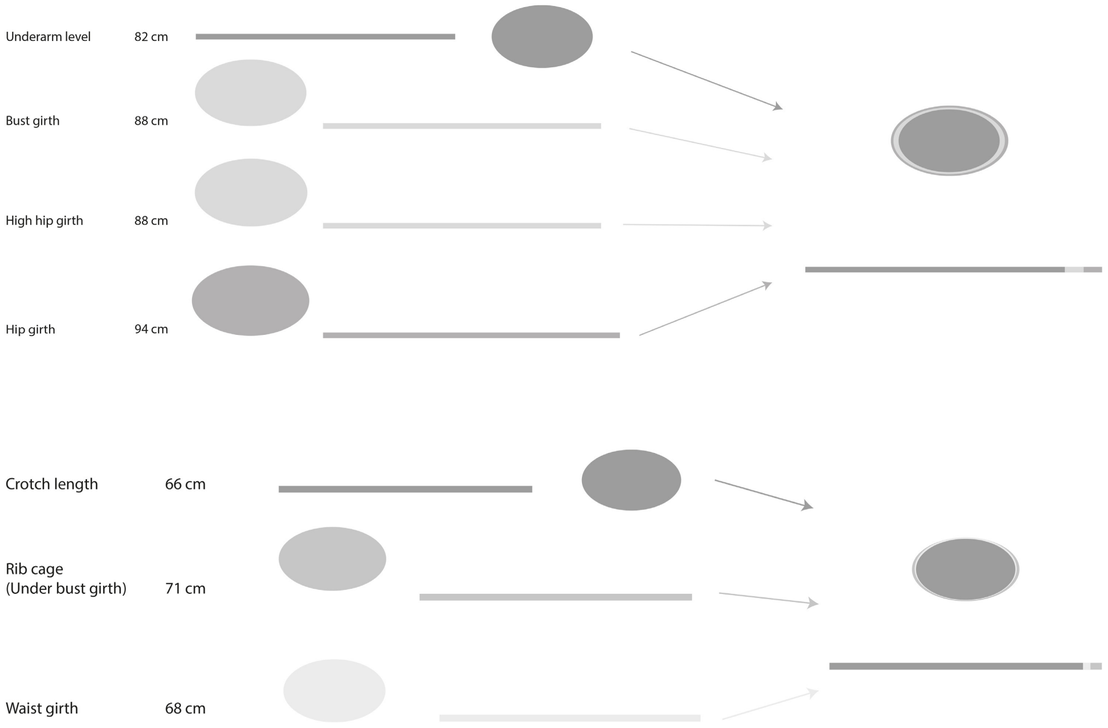


2.4.3 Combination

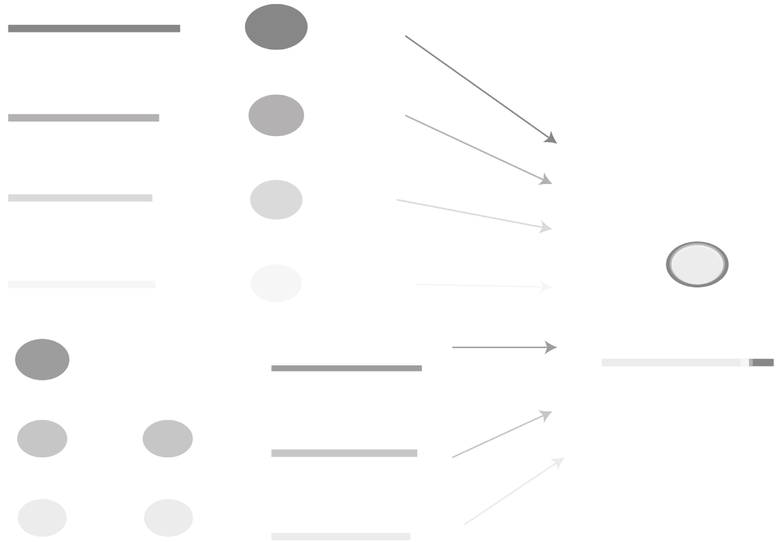
Mixing the girth and lines into groups means that the girth and lines in the same group may also be replaced. For example, I can turn the girth into a line or connect the lines end-to-end into a girth.

(Fig. 47) Body girths and lines dimension combination, Zewei Li, size chart reference from Cloake Dawn (Cloake 10-13).

(Fig. 48) Group body girths and lines dimension combination, Zewei Li, size chart reference from Cloake Dawn (Cloake 10-13).



Nape to back waist	41 cm
Across back	36 cm
Nape to nipple	34.5 cm
Across chest	33.5 cm
Neck girth	36 cm
Calf girth	35 cm
Knee girth	33 cm

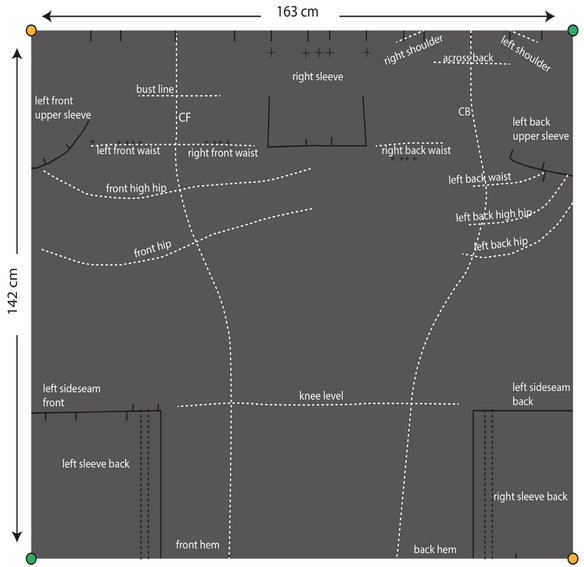


Chapter Three: Final Design Development

The final design process is similar to the development process but with stronger conviction to the design criteria. It is composed of multiple design iterations starting from draping of the mobius band and then working on toiles and patterns with the choice of fabric based on the consideration of sustainability and dimensional relationship to the body and garment designs.

3.1.1 Mobius Pattern 1a: full-length dress

Process



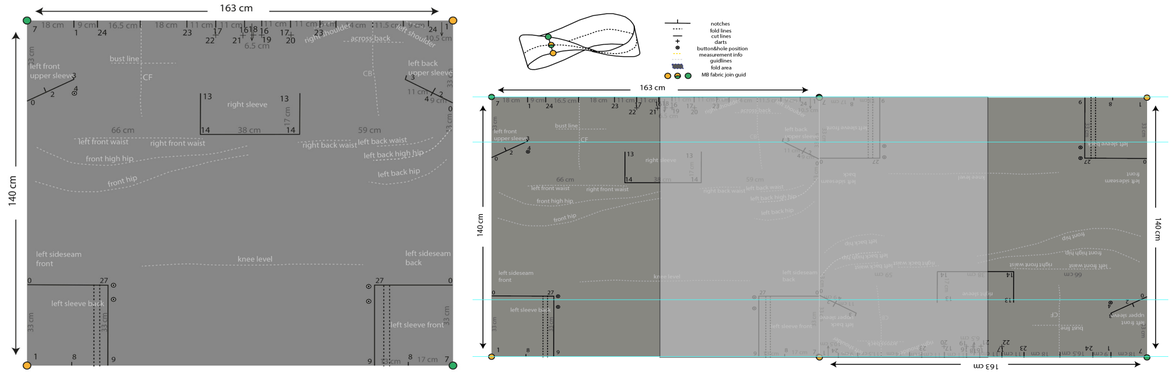
(Fig. 49) Full-length dress: initial pattern and small toile, Zewei Li.

The goal this time was to design a garment that can cover the entire body, by considering the dimension of the bust, hip, and bicep girth, and length of the nape to back waist, waist to knee and floor. The fabric width was 163 cm including the selvedge, and the length was 142 cm. I horizontally used this Mobius band with the human body, this means that the fabric grainline is horizontal in the final garment and the width of the fabric is close to the length of the garment. In addition, I considered how to construct the garment while draping, because it would also influence design, especially when it came to the different fit of the garment with different types of fastenings. In order to help myself in pattern making and construction, I labelled notches with numbers. After creating an initial pattern, I always sewed a small-scale cotton garment to test the pattern (Fig. 49), especially to check whether the marks and numbers could guide me to achieve the garment.

After initially constructing this garment, I moved it onto the mannequin to feel the changes in the direction of the fabric and the fit, in order to confirm whether and where it is necessary to add trims or details that could make this garment changeable. For example, opening the shoulder line and neckline (Fig. 50), the left and right bicep girth are the same so sleeves are interchangeable, the back of this dress can also be worn as the front. In addition, it is possible to change the length of the garment, due to the hem length being bigger than the waist and hip girth. The fabric is pulled back to the waist area to change the shape and reduce the length of the dress with added fastenings to maintain this form.

Fabric: a medium weight and drape, low stretch viscose and polyester fabric which I found from the textile recycle bin at the University.

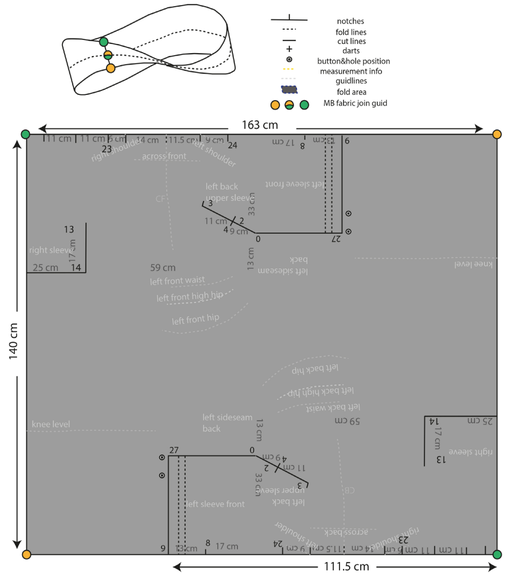
(Fig. 50) Initial full-length dress—possible dressing methods, Zewei Li.



(Fig. 51) Full-length dress: pattern development process, Zewei Li.

I am satisfied with the dress presented by this pattern, but the cutting line of its right sleeve is not positioned from the edge, and the bottom of the right sleeve pieces will not allow the pattern to become a one-piece pattern (Fig. 51), which does not fit my criteria. As the picture shows, I modified the pattern to correct this without changing the effect of this dress. I did this by copying the original pattern, then splicing and pasting it on its right side, rotating it at 90 degrees, and finally taking its middle part to form a new pattern. In the new pattern, the number of cutting lines was reduced, and they all cut from the edge to the centre, and the integrity of the fabric is acceptable. Moreover, I changed the curve cutting line to a straight line because it helps reduce the difficulty of cutting and sewing in the one-piece-cut method. The positions corresponding to the cutting line are armhole, sleeve, and leg side opening, these are necessary cuttings to ensure that the wearer can move with ease.

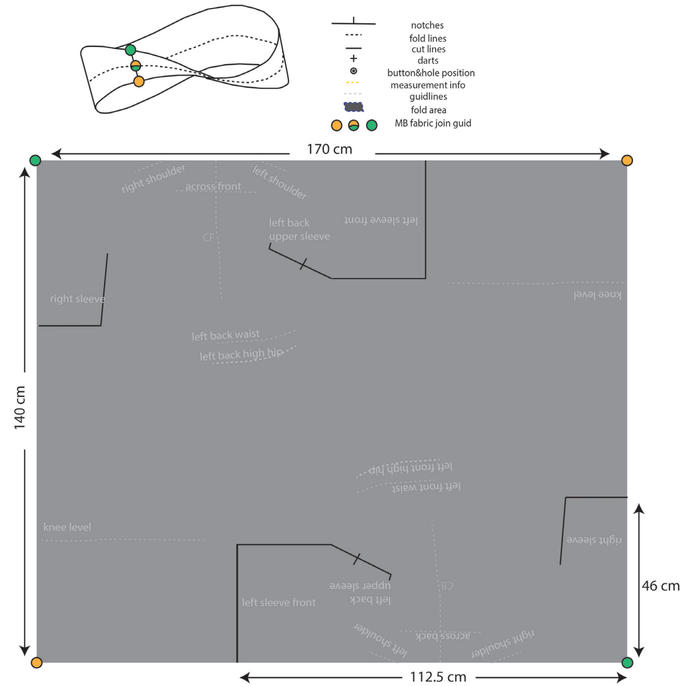
I also constructed this pattern in stretch cotton fabric as applying the same pattern to different fabrics will make the garments look and feel different for the wearer (Fig. 52). This not only provides opportunities for enterprises to use the same pattern in different collections, but also reduces fabric waste in the pattern making and sampling process. I also found out this garment could be worn upside down as the bust girth, waist girth, hip girth, and hem length was able to change position with aesthetic appeal. Of course, the different styles of target clothes will also affect choices of different fastenings and stitch types. The strap attached at the left side could be used as a waist belt, and it also plays a role in changing garment appearance.



(Fig. 52) Knit full-length dress, Zewei Li.

Fabric: medium drape and weight, medium to high stretch cotton fabric from textile recycle bin at the University.

Outcome

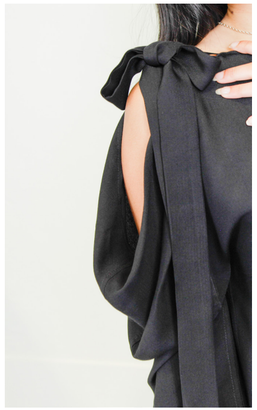


(Fig. 53) Full-length dress: final pattern, Zewei Li.

Fabric: low stretch, medium weight, and drape deadstock viscose fabric from local fabric store.

(Fig. 54) Full-length dress: final photos.

As this Mobius band one-piece-cut method is different from traditional pattern making, the construction decisions and details are slightly different as well. First of all, because this method blurs the definition of the front and back side of the fabric, affected by the Mobius band structure, the edge and cutting line of the fabric may appear from the inside to outside, or from front to back (Fig. 54), so it is necessary to ensure that both look professional and clean. To achieve this, I mostly used self-cover stitch and double turn stitching to construct this garment. In addition, in order to reduce using sewing thread, I avoided using overlock stitch for this project. I reinforced the cut points by hand stitching to help strengthen the corner instead of using fusing, because the fusing tape consists of hot glue on the fabric and is not removable, which is inconsistent with my goal of maximizing the integrity of the fabric. The same reasoning explains why I used a thread chain and fabric straps as a button loop instead of buttonholing.



(Fig. 55) Full-length dress details.

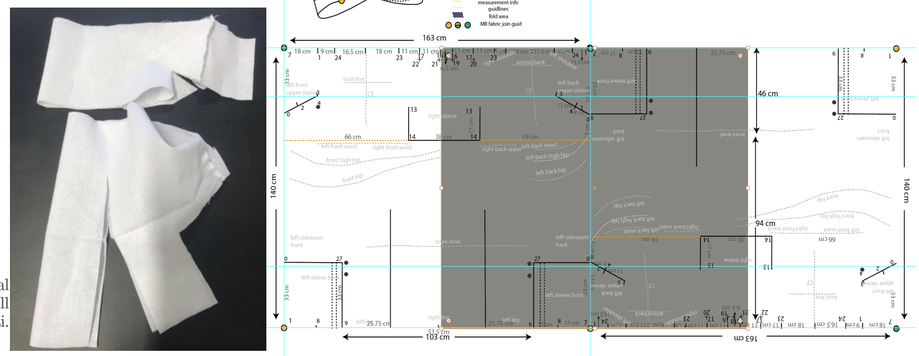
This black viscose dress can also be worn upside down (Fig. 56). The appearance changes by adding belt loops on the neckline and sleeves and using a strap to connect these loops and holes in the garment, such as the holes on the right sleeve and the side waist. A long fabric strap achieves the variations in the garments. The strap and loop I added are all straight cut, instead of bias-cut which is normally used in the industry. The wearers can decide how to adjust the dress according to their own preferences, to fully close the sleeve crown or drop the shoulder. The wear suggestions I give are here for inspiration, provided as a designer. I believe that the interaction between the garment and the wearer can create more possibilities.

(Fig. 56) Full-length dress: other wear options.

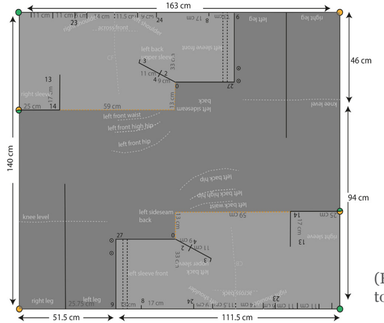
3.1.2 Mobius Pattern 1b: Palazzo Pant and Asymmetrical Top

Process

This is the same pattern, however, added cut lines create alternative garment designs so that the designer or consumer can choose the pattern at the beginning of the design process or it can be used as regenerated designs extending the service of the fabric. In order to get a top and pants from the original dress pattern (1a) I separated the pattern from the waist area. The method of division is to re-divide the layout of the fabric by extending the existing cutting line. The added cut lines for legs are also based on the original leg position in the dress pattern. This does not change the use of the Mobius band pattern positioned horizontally to the body. The length and position of the new four cutting lines is also based on the consideration of hip girth, waist girth, knee girth, body rise, and waist to floor length. Preliminary experiments were carried out by cutting mini-size patterns (Fig. 57). This saved time and effectively reduced the waste of fabric in the design and development process.

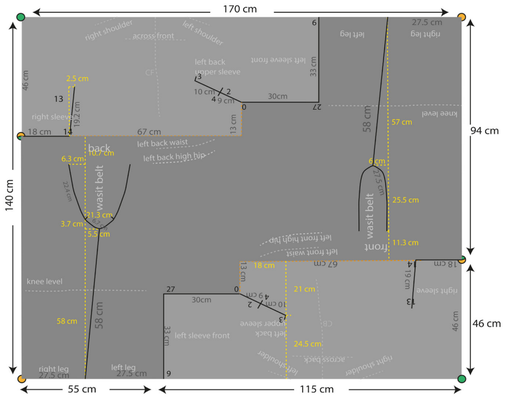


(Fig. 57) Palazzo pant and asymmetrical top: pattern development and small toile, Zewei Li.



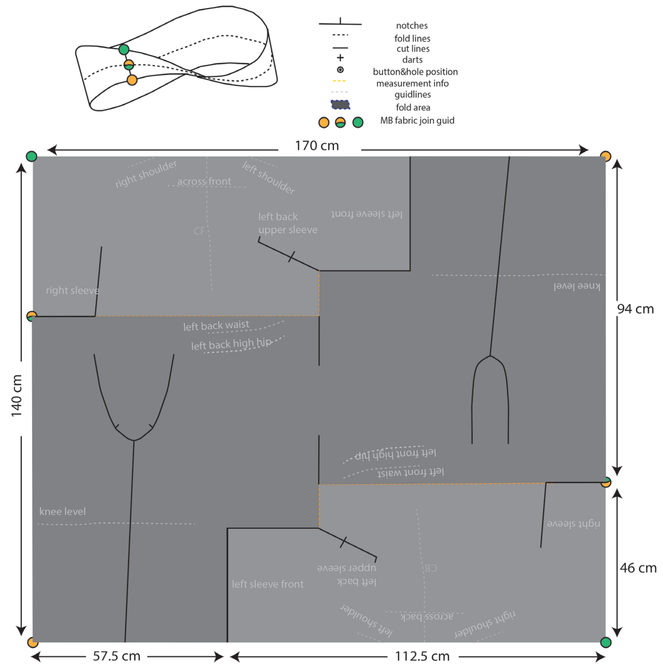
(Fig. 58) Palazzo pant and asymmetrical top: initial pattern, Zewei Li.

In the first toile, I realised that a simple straight line to divide the pattern of the legs cannot solve the problem of the crotch area. The pants look tight, especially when stepping, squatting and sitting down. In traditional pattern making, a semi-elliptical fabric is cut to ensure the fit of the crotch area. In most zero waste pattern cutting, this area of fabric is used as a pocket (Rissanen “Zero-Waste Fashion Design” 95). However, in the one-piece-cut method this is difficult to achieve. After many attempts, I finally solved this problem by adding two new curved cutting lines, which also created a belt by lifting and gathering. In addition, I added two short straight cutting lines to ensure the balance of pulling the fabric on the right side of the left leg. This is also to balance the fabric grainline near the Mobius band twist, and better shape the lines of the legs.



(Fig. 59) Palazzo pant and asymmetrical top: pattern and second toile, Zewei Li.

Outcome



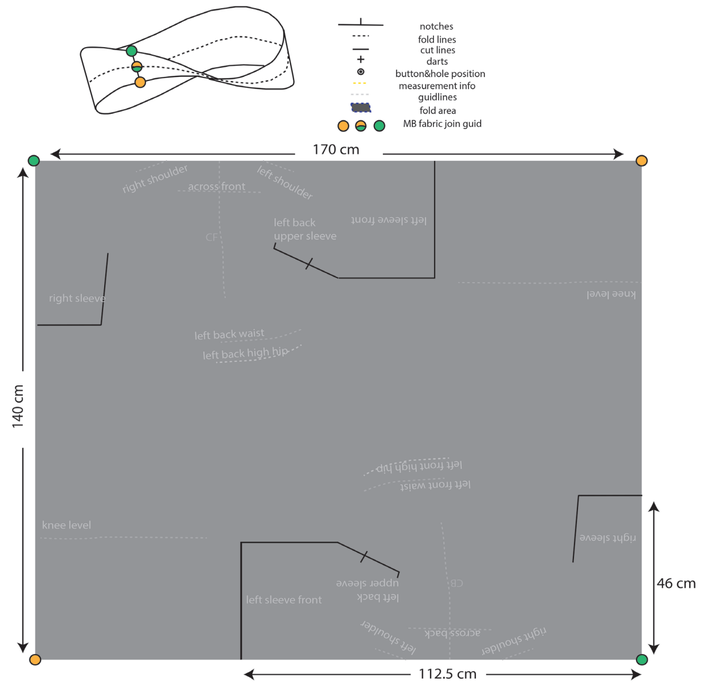
(Fig. 60) Palazzo pant and asymmetrical top: final pattern, Zewei Li.

Fabric: low stretch, medium weight, and drape deadstock viscose fabric from local fabric store.

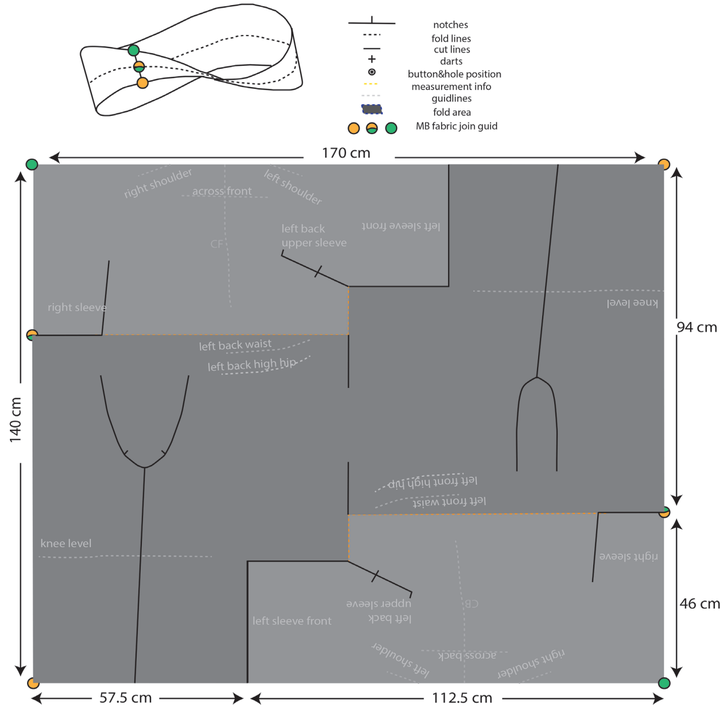
(Fig. 61) Palazzo pant and asymmetrical top: final photos.

This construction detail and process for the full-length dress and pants are similar as the strip in the dress can be used as a strap and a waistbelt to create different looks. There are two tunnels I left around the waist to provide fit changes for the wearer; two recycle cotton buttons on the left waist of the pants will support this adjustment. The button on the right shoulder of the top also has the function of adjusting the size of the neckline opening. I used the rectangle formed from the pattern on the left side of the top and folded it inward to form a pocket, which enriched the functionality of this garment. All stitch lines were aimed at providing a clean finish to both sides of the garment.

(Fig. 62) Palazzo pant and asymmetrical top details.



(Fig. 63) Mobius Pattern 1a: full-length dress.



(Fig. 64) Mobius Pattern 1b version: palazzo pant and asymmetrical top.

3.2.1 Mobius Pattern 2a: Felting Coat

Process

In response to the chosen colour palette of this collection, I made the felt fabric from black and off-white wool. It has a natural and timeless aesthetic and is suitable for a wide range of customers. I decided to make the felt fabric because it can achieve complete zero waste, cutting lines could be re-felted together without adding other material. In addition, the edges do not fray. The front and back of the fabric has the same appearance which reduces the difficulty in construction, especially in the reinforcement of cutting points.

> "The natural properties of wool make it flexible, resilient, insulative, absorbent, hygienic, and mouldable" (Hallett and Johnston 66).

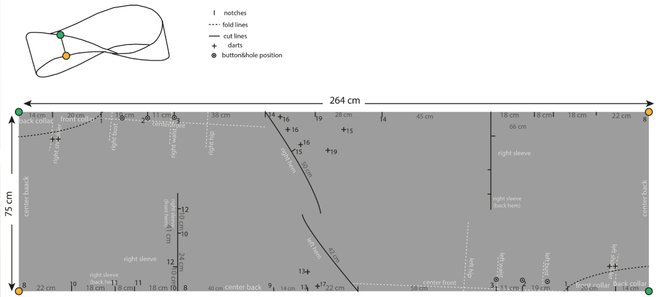
For the long coat, I used the Mobius band vertically. Firstly, I made a piece of felt fabric with a length based on the measurement of the mannequin and my target garment shape and length. The bust girth, shoulder length, hip, and waist girth were used for deciding the fabric width and the length of nape to back waist, front waist to knee, and the outer sleeve for deciding fabric length. In the process of draping, I used the Mobius band connection as the upper centre back, because fabric itself provides natural contrast for this garment (Fig. 65). I also tried to create the same treatment on the front side of this garment. The position of the cutting lines was planned in order to manage the fabric for sleeves and the hem of the garment.

Next was the stage of experimenting which created the possibilities of various sleeves. The cut line on the left is longer than the cutting line on the right, so the lower part of the left sleeve can be relatively separated from the main part of the garment (Fig. 66). After that, the remaining fabric was folded, and a cutting line was added, as the aim was to continue the contrast formed by the back fabric. The making of the felt created a unique design I

(Fig. 65) Felting coat half-scale process photos, Zewei Li.

found the fluidity of the felt fabric to be poor (heavy weight, medium to high thickness, low shear, drape, and stretch), which created difficulties to achieve diverse ways of wearing the garment. If I used more cutting lines, or a half-cut, or a third-cut Mobius band method, diverse wearing may be improved. However, in order to test the feasibility of this pattern, I explored this pattern on other fabrics and it worked well.

(Fig. 66) Felting coat half-scale toile, Zewei Li.

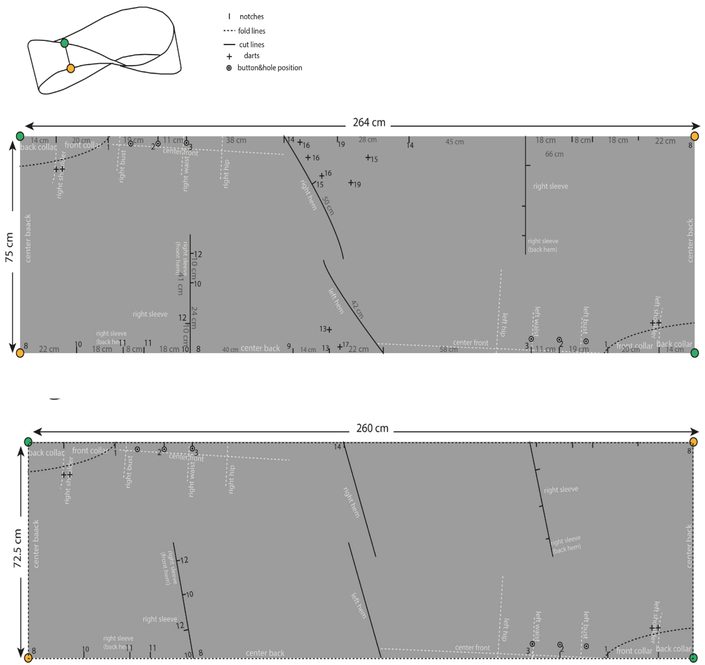


(Fig. 67) Felting coat foundation pattern 2a, Zewei Li.

3.3.1 Same pattern (2a) but with design variations: duster robe and draped shirt

Process

This pattern was also found to be suitable for mass-production fabric. As the 2a pattern width is 75 cm, it could make a pair of garments (duster robe or shirt designs) by using the full width of the 150 cm fabric, or could use half of the fabric to be the main piece and another half of the fabric to become the lining of the garment. For the duster robe, I unified the sleeve style, corrected and reduced the cutting line (Fig 68), which made the garment symmetrical and eliminated the extra fabric hanging at the back hem of the garment. The four cutting lines correspond to sleeves and hems. For movement of the arm and body, I inclined the two sleeve cutting lines that were originally perpendicular to the fabric edge. I tested the pattern on both medium weight calico and light weight silk. It is evident that the same pattern has varied effects on different fabrics and requires different construction methods.



(Fig. 68) Duster robe and draped shirt pattern iteration, Zewei Li.

(Fig. 69) Duster robe full-scale toile—cotton, Zewei Li.

(Fig. 70) Duster robe full-scale toile—silk, Zewei Li.

(Fig. 71) Draped shirt full-scale toile—cotton, Zewei Li.

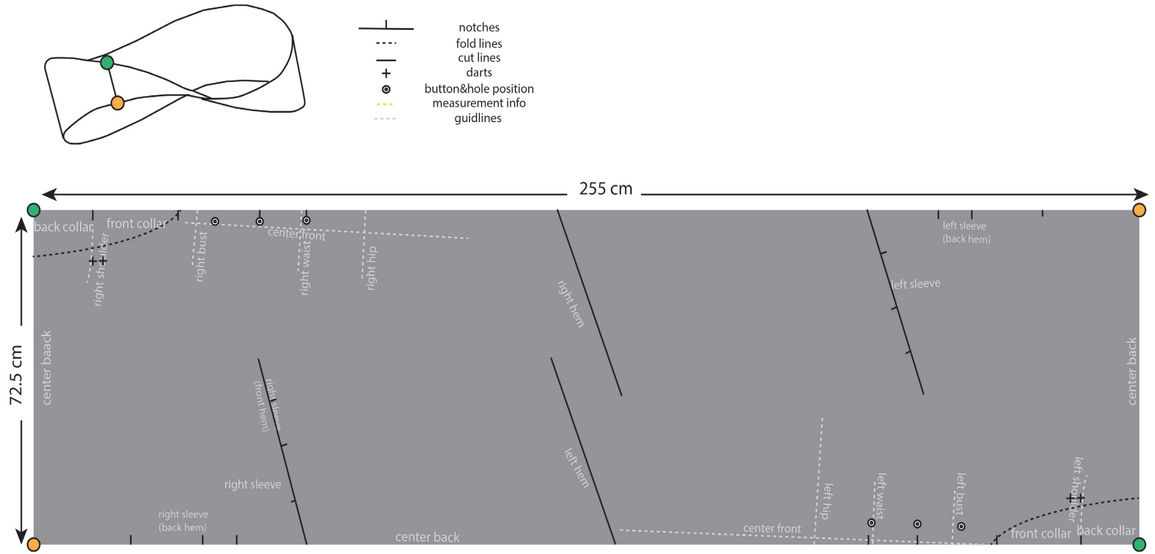
(Fig. 72) Draped shirt full-scale toile—silk, Zewei Li.

The change from duster robe to draped shirt is based on the position swap between bust girth and hip girth, across back and neck girth, waist to knee and nape to back waist, and upside-down armhole and elbow girth. The length of the shirt is approximately half that of the robe. The inclined cutting line increases the drape of the fabric, especially when the shirt is worn. However, this also brings some construction problems. Using a double turn with top stitch for the back opening of the robe without using fusing and a facing piece is difficult, as it can create roping especially on light weight fabric. Through increasing the folded width, I reduced this effect. For sustainability concerns most of my fastenings are fabric made, but I also use wood, coconut and river shell buttons. Compared with calico and felt fabric, the silk fabric has a certain fluidity creating another aesthetic.

(Fig. 73) Duster robe and draped shirt fastening exploration—cotton, Zewei Li.

(Fig. 74) Duster robe and draped shirt fastening exploration—recycled polyester, Zewei Li.

Outcome



(Fig. 75) Felting coat, duster robe, and draped shirt final pattern, Zewei Li.

(Fig. 76) Felting coat final photos.

The main body of the felting coat presents an arc-shaped silhouette, and there are fabric contrasts between the left and right side of the fabric. The cuffs are located around the elbows and connected with the main body of the garment. The exaggerated lapel is separated at the centre back to make it appear to be composed of two triangles. The buttons on the front of the garment are also made by felting and attached with wool thread, which unified the raw materials and is easily recycled. The twist made from the Mobius band is hidden inside the back hem. The shape of the sleeve transitions from the curve at the shoulder line to the right angle at the elbow, together with the garment hem, balances the use of the curve and arc of the garment.

(Fig. 77) Felting coat details.

Fabric: light weight, low thickness, medium shear, and high drape off-white silk and polyester fabric I had left over from my early works, which were sourced from a local fabric store.
Fabric: light weight, low thickness, medium shear and stretch, medium to high drape black silk and polyester deadstock fabric from a local fabric store.

(Fig. 78) Duster robe final photos.

The design detail that is different from the coat is mainly the fastening application. There are no buttons on the front of the garment, however these were used for the thread loops for holding the strap and were added to the cuffs. The cutting points at the cuff are secured by a rectangular facing and the Mobius twist cutting points are strengthened by hand embroidery. Button pleats were added to the shoulder to protect the clothes from slipping off easily. The buttons were attached to both sides of the fabric on the off-white garment, and thread looped inside the pleated fabric functions to combine two garments. A hidden button closes the off-white robe opening at the back and there is a tie provided for the black robe giving more creative variations to the wearer.

(Fig. 79) Duster robe details.

(Fig. 80) Other ways of wearing the duster robe.

(Fig. 81) Draped shirt final photos.

(Fig 82) double layer draped tops

3.2.2 Mobius Pattern 2b: Double Layer Skirt and Top

Process

Continuous experimentation on the Mobius band pattern and divergent pattern possibilities based on an original pattern both help to explore the advantages and disadvantages of the Mobius band zero waste method. For example, the prototype of this pattern was planned for a wool coat from my self-made felt fabric. During the process, I saw the possibility of using other fabrics (cotton and silk) and the potential for variants and changeable clothes. Because of this, the width of this pattern does not fully use the width of the fabric for the manufacturing fabric. After minimal pattern adjustments based on the width of 140 cm to 150 cm for most fabrics on the market, the pattern utilised half of the fabric. This means that two items of clothing can be produced at the same time in order to use this piece of fabric completely. This is highly feasible for mass production, and different sizes can be realised.

More design variants became evident after taking into account body dimensions and repositioning the fabric. Considering the further development of this pattern (Fig. 83), it could become a skirt and changeable top by simply extending two cutting lines. The original fabric positions of the shoulders, sleeves, and upper back at both ends of the fabric have become two pieces that make up the skirt. This is based on the position exchange of nape to waist and waist to knee, nape to bust point and waist girth. The middle of the fabric becomes the top, this is based on the position change between knee girth and neck girth, waist to knee and nape to waist, knee girth and across the back. Thus, the top still vertically uses the Mobius band but the skirt changes to be horizontal. In addition, the different way of wearing the top is supported by the exchange between the armhole and neck girth. There remain four cutting lines, the middle two are to ensure the accessibility of the neck and head, combined with stitch lines to create armholes as well. The two cutting lines at the side create the torso access of the top piece and make a side seam for the skirt.

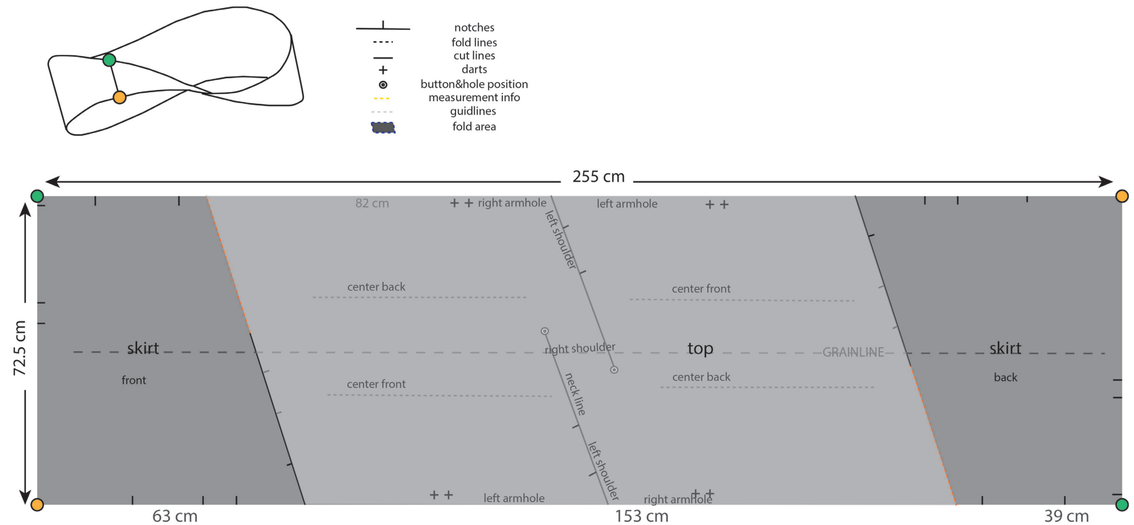
(Fig. 83) Double layer skirt and top initial pattern, Zewei Li.
(Fig. 84) Double layer skirt and top toile, Zewei Li.

During the skirt construction process, I attached the lining piece to the main fabric to provide support for the drape and fabric weight. An invisible zip for the skirt was used as the fabric length which was insufficient for the workings of a wrapped skirt, but the original cutting lines could be moved to accommodate this.

For the top garment, I made the two pieces separately to free up space for the wearer to make their own adjustments for wear. In considering the stability when the two pieces are worn together, I added buttons and loops on the front and back necklines. The cutting line creates a V-neckline and the cut points are strengthened by the button placement and hand stitched thread loop. The slit of the skirt is located on the inclined cutting lines (bias grainline), which shows a rippled effect. This shortcoming did not alter the effect of the clothes too much as it becomes part of the flow of the fabric. Thread loops (Fig. 85) were made and tested for different colours and the thickness of thread.

(Fig. 85) Double layer skirt and top construction exploration, Zewei Li.

Outcome



(Fig. 86) Double layer skirt and top final pattern, Zewei Li.

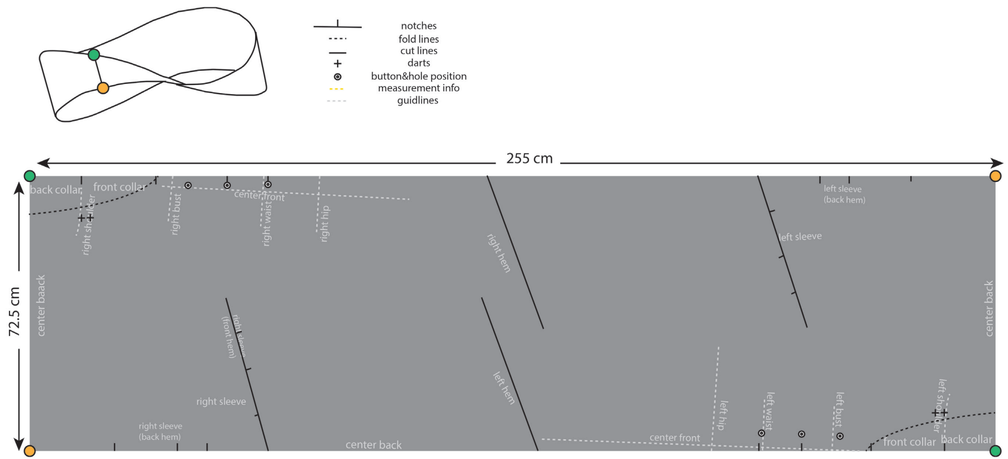
Fabric: light weight, low thickness, medium shear, and high drape off-white silk and polyester fabric I had left over from my early works, which were sourced from a local fabric store.
Fabric: light weight, low thickness, medium shear and stretch, medium to high drape black silk and a polyester deadstock fabric from a local fabric store.

(Fig. 87) Double layer skirt and top final photos.

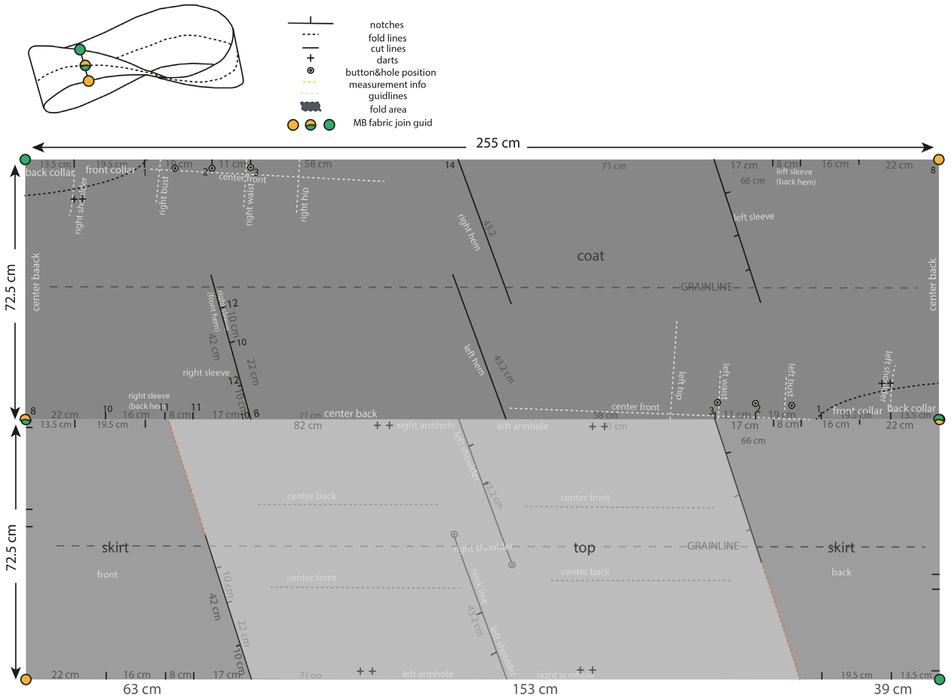
This final look is composed of a double-layered close-fitted skirt and a loose fitted top. The Mobius twist sits at the right shoulder which allows for changing the garment wear between the armhole and neckline. As it is loose fitted it can also be worn on both front facing and back facing. There are two holes at the right side of the off-white top which provide different ways to access the arm. The drape of the fabric is positioned on the right front chest and right back. The button at the hem corner, which can button up to the neckline, not only provides the ability to fold back and reduce the length of the garment, but can twist the fabric together when wearing two-layers to create a different look. The closure of the skirt used with a strap around the waist helps to adjust the size fit. The wearer can decide the position of the split when wearing it.

(Fig. 88) Double layer skirt and top details.

(Fig. 89) Other ways of wearing double layer skirt and top.



(Fig. 90) Mobius pattern 2a: felting coat.



(Fig. 91) Mobius pattern 2b: Double layer skirt, top and robe.

Reflection and Conclusion

“Although its name is new, the idea is much older: for example the traditional Japanese kimonos or Indian saris both make use of one complete piece of a fabric without wasting any of it” (Aakko and Koskennurmi-Sivonen 17). The value of traditional thinking about fabric is worth recalling.

In this Anthropocene age, we should now show greater responsibility to the environment we live in. After investigating the problems of fabric waste in traditional fashion industries, I feel strongly that both designers and consumers should change their behaviours and shift their mind to a more sustainable future. It is a complex and challenging task but as a future fashion designer in the fashion industry my contribution to this challenge is to rethink the traditional methods of apparel design and production. My aims in this technical design research project are realised through exploration of the Mobius band zero waste patterns with minimal cutting lines to respond to the fabric waste issue. This one-piece-cut method not only provides a new pattern making approach for designers to eliminate fabric waste at the pattern making stage, but also takes into consideration the extension of post-consumption textile life. The ‘new consumer’ is looking to alternative ways to satisfy their needs for ‘newness’ in clothing while maintaining a sustainable conscience. These design developments can meet wearers’ demands by providing changeable garments and further developing garment options.

My Mobius band zero waste collection ‘The Infinity’ is mainly composed of two Mobius pattern foundations. Patterns 1a and 2a used minimal cutting lines to ensure fabric integrity and reduce manufacturing. The adopted pattern on fabric types, different construction ways and fastenings help provide different garment looks from the same pattern. Patterns 1b and 2b extended fabric usage life and met consumers’ ‘new garment’ requirements by adding necessary cutting lines to further develop the original patterns and garments.

The alternative pattern design process highlights the continued development of existing patterns and the re-cutting of clothes to obtain new garments, which extends the service life of fabrics. The design process comprised of multiple design iterations starting from the Mobius band, considering body and fabric dimensions, draping and the refining of patterns and toiles. I analysed the main body measurements, girths and lengths, in order to find the relationship between body, fabric, and garment. This helped me to define the size of the fabric in my zero waste pattern cutting process and think about the proportions and dimensions of design lines spanning the body in order to create transformative pattern designs for different garment types and flexible wear possibilities.

The selection of fabrics was based on sustainable choices. I made and chose the fabric colour palette of black and shades of white for this collection because they are timeless and therefore target a larger market. Fabric is considered a precious resource in garment creation. In many existing pattern making methods, whether mainstream or creative pattern cutting and zero waste, multiple cutting lines are distributed across the fabric. This problem affects the service life of the fabric and increases the difficulty of reuse, because the cutting line is irreversible, especially for woven and knit fabrics.

All my toiling fabrics are deadstock fabrics, except for the wool felt fabric that was self-made to pattern dimension. The fabric I used in the final collection is a combination of deadstock fabrics from local fabric stores and wool felt fabric made by myself. Understanding and selecting the fabric was important especially when aiming to use minimal cutting lines to achieve longevity. The outcomes of the Mobius band method vary on the drape qualities of the fabric. In addition, this method blurs the traditional definition of the right and wrong sides of the fabric and frees more space in the draping process to achieve the varied types of garments to respond to my aims.

Compared with the traditional garments production model, it does not increase difficulty in the construction process. This not only provides opportunities for enterprises to use the same pattern in different collections, but also reduces fabric waste in the pattern making and sampling process. This approach might be used in the industry for smaller agile design companies. My collection is not an industry-ready project, but it exemplifies a process and designs which are ready to be refined for production purposes to meet a company’s price point and target group. Additionally, this pattern innovation process has potential for application in the whole garment knitting process to create seamless Mobius band garments.

There were extensive explorations that were not satisfactory in meeting my design aims and criteria, but these were analysed and refined as I learnt more about this Mobius zero waste pattern cutting process. I did not deliberately cater to popular fashion trends and the pursuit of pre-determined clothing silhouettes. The final creative designs in this research project are the products of the collision between the Mobius band and zero waste pattern processes. There are many possibilities for the development of the Mobius band method. Overall, the process of creating these designs was quite challenging but joyful for me, and I would like to keep exploring the use of the Mobius band for zero waste pattern cutting in the future.

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List of images

Appendices

1.Fibre impact on environment

Cotton
- Moderate energy demand during preparation and production
- High water requirement
- High amount of chemicals used in finishing
- Moderate water waste
- Moderate greenhouse gas emissions
- Relatively high land requirement

Organic Cottton
- Low energy demands
- Low pesticide use
- Low production and large demand for land area

Silk
- Low energy demands during preparation and production
- High energy demand in dyeing
- High water requirement
- Moderate water waste
- Low greenhouse gas emissions

Wool
- Low energy demands during preparation and production
- Moderate water requirements in clearing
- High water waste
- Low greenhouse gas emissions
- High land use

Viscose
- Moderate energy demands during preparation and production
- High water requirement
- Low water waste
- Low greenhouse gas emissions
- Low land use

Polyester
- Moderate energy demands
- Low water requirement
- Low water waste
- High greenhouse gas emissions
- Low land use

Hybrid fibre
- Difficult to recycle
- Improved durability and resistance to washing

Information based on the tables in the Summary Report to the Department for Environment, Food and Rural Affairs (Turley et al. 6-18)

'The Infinity' collection fabric content
Recycling polyester, silk, viscose, wool fabric
- Reduced energy use
- Reduced greenhouse gas emissions
- Reduced resource consumption
- Reduced water requirement
- Reduced water waste
- Extended usage life

2. Model/photos release form

Advertising & Illustrative Photographers Association — AIPA

Standard Photographic Licence & Order Confirmation

Licence granted to: (Agency/Client)	Photographer: Emily Fei
	Licence Number:
	Date of Licence:
Advertiser: (if any)	Return Date:
Product: (if any)	☐ Exclusive Licence ☐ Non-Exclusive Licence

DESCRIPTION OF JOB/PHOTOGRAPH(S) COVERED BY THIS LICENCE
MDes Final garments Photoshoot

Please Note: This is not a commission. Please read clause 1 of the Standard Photographic Terms and Conditions of Engagement (v2006) available from www.aipa.org.nz

LICENSED PURPOSE

Non-Advertising	Advertising		
☐ Editorial (newspaper, magazine, periodical)	☐ Magazine/Newspaper/Periodical	☐ Billboard	
☐ PR (Public Relations)	☐ Poster	☐ Catalogue	
☐ Press (news)	☐ Brochure	☐ Point of Sale	
☐ Book (single publication)	☐ Packaging	☐ TV/Cinema Commercial	
☑ Any Non-Advertising Use	☐ Promotion	☑ Any Advertising Use	
☐ Other Use (specify)	☐ Internet (specify URL)		
☐ Internet (specify URL)	☐ Other Advertising (specify)		

LICENSED TERRITORY
☑ New Zealand ☐ Australia ☐ Australasia ☐ Worldwide ☐ Other (specify)

LICENSED PERIOD
☐ 1 year ☐ 2 years ☑ 5 years ☐ In Perpetuity ☐ Other (specify)

OTHER LICENCE DETAILS
☐ Special conditions of licence: (if any)
☐ No right to alter image (see clause 1.1.3)
☐ Photographer to act as agent (refer to clause 13.3)
☐ Weather permitting booking (refer to clause 17.1)
☐ The Photographer waives attribution rights (see clause 4); or
☐ Attribution required as follows:

IMPORTANT NOTE
The Photographer has accepted this order on Standard Photographic Terms and Conditions of Engagement as previously supplied to you. Please read and check this order confirmation carefully as the work will proceed according to these instructions. Please request our Standard Photographic Terms and Conditions of Engagement (v2006) if you require a further copy.

CLIENT SIGNATURE:
PHOTOGRAPHER SIGNATURE:

AIPA Advertising & Illustrative Photographers Association of New Zealand | PO Box 9218 | Newmarket | Auckland | www.aipa.org.nz | © AIPA 2006

Advertising & Illustrative Photographers Association — AIPA

Model Release

Model's Name: CHRISTINE HUANG
Model's Address: 13 HORNER STREET, NEWTOWN 6021
Model's Email: CHRISTINEHUANGBUNNY@GMAIL.COM
Model's Phone: 0223651997
Photographer's Name: Emily Fei
Photographer's Email: emily20 marsey @ gmail.com
Photographer's Phone: 027 648 1508
Shoot Description [and Shoot Reference if applicable]: MDes Final garments photoshoot
Shoot Date: 21/01/21
Special Conditions [if any]:

MODEL'S CONSENT

For valuable consideration which I hereby acknowledge, I grant the person or entity photographing or recording me ("Photographer") and its licensees and assignees full permission to license and/or use any photographs, film or recording ("Works") taken of me (including my appearance, likeness and form), for any purpose whatsoever (including, but not limited to, advertising, packaging, marketing, and promotion, for any product or service). The Works may be cropped, altered, transformed or reproduced in any way, in any current or future media (including, but not limited to, print, TV, film, digital and the Internet), and may also be combined with any other works or text.

I agree that I have no rights or copyright in the Works (and any derivative works). I hereby release the Photographer and its licensees and assignees from any and all claims and demands in connection with the Works or their future use.

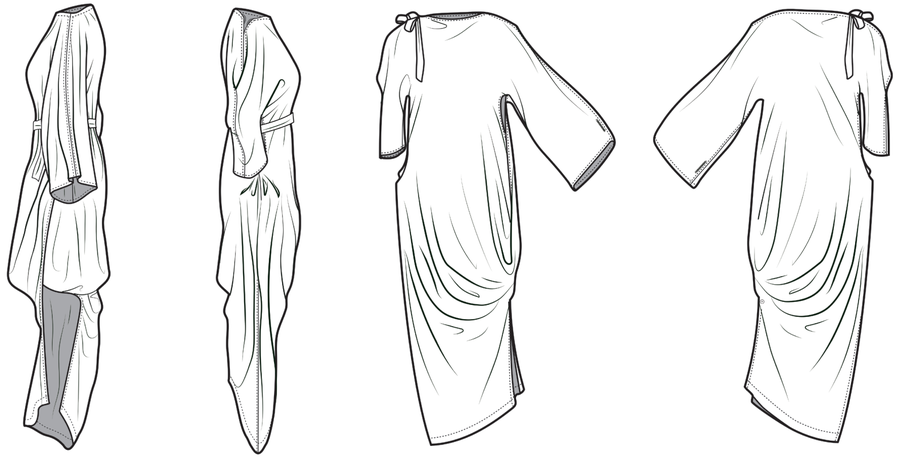
I understand that where readily retrievable, I may access any personal information of mine and may correct any personal details provided by me.

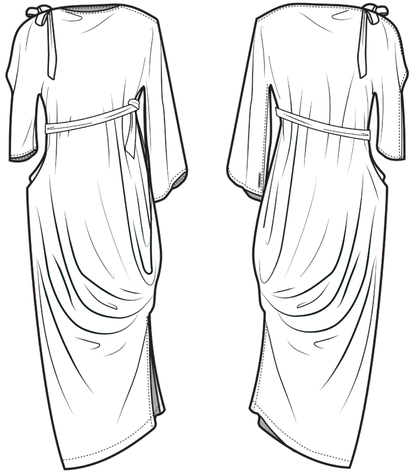
I am over 18 years of age and legally entitled to grant this consent.

Model's Signature: CHR **Date:** 21/01/21
Photographer's Signature:

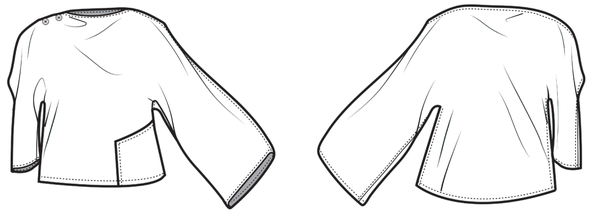
AIPA www.aipa.org.nz

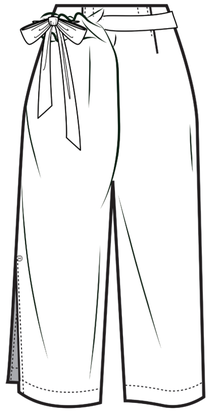
3.Technical drawings



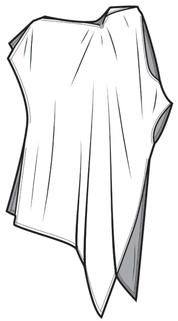


Full length dress

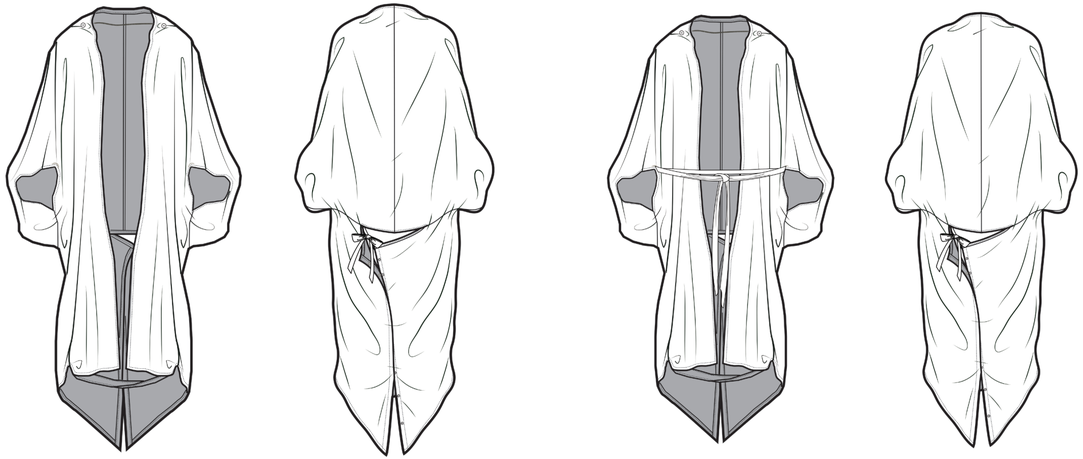


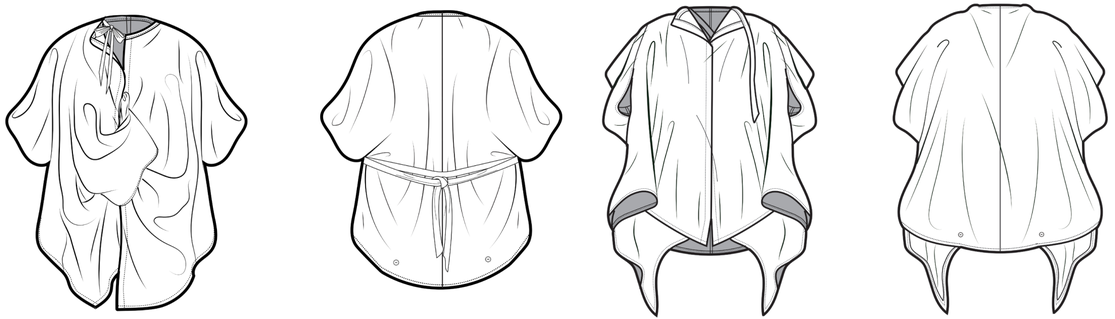


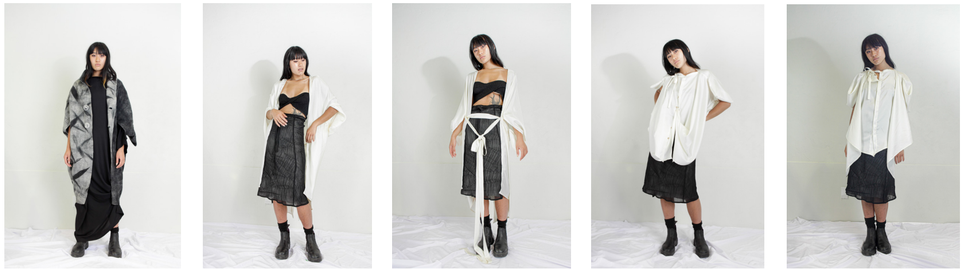
Palazzo pant and asymmetrical top



Double layer skirt and top



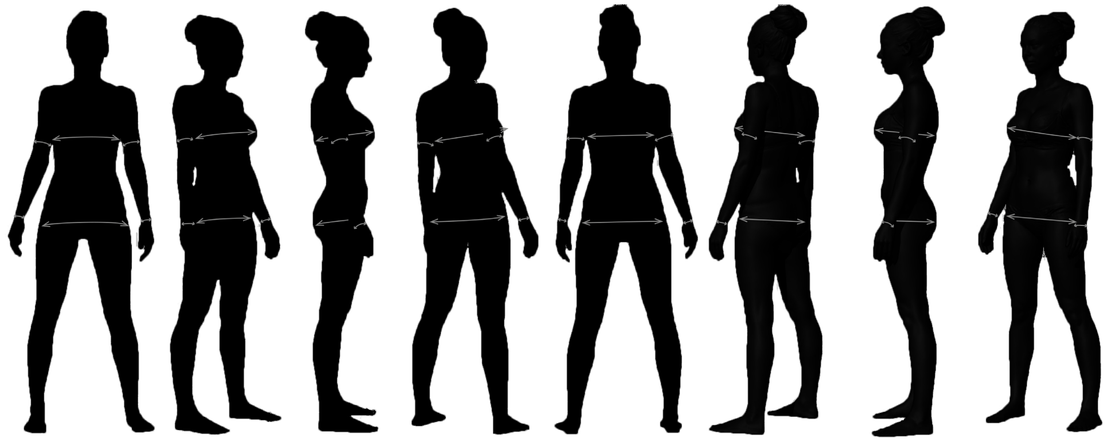




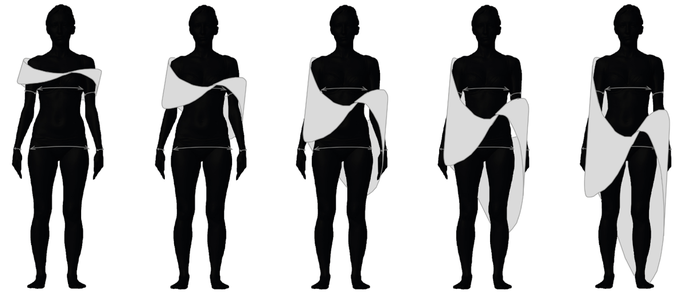
Felting coat,duster robe and draped shirt

4. Mobius band with body

Horizontal Mobius Band



Horizontal Mobius Band- width change



Horizontal Mobius Band- length change