The Gap & How to Bridge It

Attempts at Reconciling Weaving & Garment-Making

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Contents

Introduction

When I tell people that I am a textile designer, I often find myself in the position of having to explain myself. "Nice, so you make clothes!" is an expression I have heard rather frequently in my relatively short life. Others ask me whether I could fix their clothes or stitch their curtains, which are challenges I am happy to accept but which I am not exactly trained for. I blame these persons in no way, for from the outside the disciplines of textile and fashion design are closely linked, or at least it would seem logical that they are. They are centred around the same material, textiles, and one sector could not exist without the other. Yet there is a striking distance between them that becomes apparent upon closer scrutiny, and that is the central topic of this thesis.

Today's Western textile industry largely focuses on the production of long rectangular fabrics according to an internationally standardized system. It ensures the weaving or knitting of these fabrics, as well as their dyeing and printing. The apparel industry, then, uses these panels to produce garments. In order to do so, it designs two-dimensional patterns that are cut out of the fabric and then assembled by means of sewing to form three-dimensional garments. While this description is utterly simplistic and does not include all the complex links between the two industries, it serves as a means of describing the basic functioning of the industry.

This clear separation of tasks engenders an array of problems that together lead to a gap between the two disciplines. The most striking issue is a lack of knowledge about the other field. Fashion designers do not necessarily have a concrete fabric in mind when designing the shape of a garment. Following a basic drawing, their first step is usually a prototype in calico fabric. It is often only after this stage that the research for fabrics that the garment could be realized in begins. In many cases, these steps are fragmented and not necessarily carried out by the same person. Textile designers, on the other hand, often only have a vague idea of what the fabrics they make might become. This lack of mutual understanding is an important contributor to the problem that large stocks of fabric are being produced and proposed to fashion designers without assurance that they will ever be used and without a clear idea of what will be made from them.

This thesis, however, argues that the disconnection, or gap, between the textile and fashion sectors is by no means insurmountable. It calls for a larger cooperation between the disciplines and a greater openness towards the innovation of production techniques. It also seeks to stimulate new ways of thinking about textiles and garments that go beyond their perception as dichotomous entities. In other words:

Can we find ways to conceive textiles and garments simultaneously? Is it possible to design a garment at the same time as its fabric?

A substantial focus has been laid on weaving in this work. This emphasis is neither fully arbitrary nor does it intend to show an incomplete picture of the gap between textiles and garments. But while it is true that important progress has been made in the industrial production of seamless knitted garments in recent years, conventional woven garments are still far from seamlessness. To put it differently, the gap is currently being bridged in knitting, but not in weaving. Meanwile, it is striking that we have optimised weaving looms to produce flat, two-dimensional and rectangular pieces of cloth that we try to fit on our round, three-dimensional and flexible bodies by the intermediary technique of sewing. The aim of this thesis is thus to show that there is much more potential to the technique of weaving than is commonly assumed and that the presumed limits to the technique are mostly due to our limited use of the tools at hand. The question should not be whether it is at all possible to produce seamless woven garments directly in the loom, but why we do not adapt the tools we have to do so. This leads to another goal of this thesis, which is to provide a rough repertoire of different looms and weaving techniques that already exist in order to stimulate a reconception of the loom.

At first sight, the basic idea of weaving is rather simple, consisting of crossing one row of parallel fibres orthogonally with another row of parallel fibres in order to obtain a stable textile surface. However, this is where the simplicity ends and where a myriad of possibilities present themselves to the weaver. Not only do the materials and tools to weave the fabric need to be chosen carefully, but also the exact way in which the fibres should be intersected must be decided upon. This leads to the fact that weaving quickly turns into a rather complex and intricate activity, which may be part of the reason why the full potential of this technique is rarely acknowledged, and especially so in today's textile industry.

Unfortunately, the scope of this thesis does not allow for providing its reader with a detailed introduction to weaving and a small degree of prior knowledge about tools and techniques needs to be presupposed. But since it is written in English by a German native speaker studying at a French institution, translations into French and German and short explanations of crucial technical terms have been marked with an asterisk (*)

when first mentioned and have been included in a glossary at the end of this thesis to facilitate reading. Most of the sources used here were published in English. In-text citations from sources in other languages have been translated, while longer quotes were left in their original language.

With the help of an historical analysis of the relationship between garments and the fabrics they are made from in the Western tradition, the first chapter of this thesis shows that fabrics and garments have not always been as disconnected as they are today. It relates the development of Western clothing to that of the weaving loom and also sheds light on the development of the techniques of sewing and tailoring and makes attempts at explaining the origins of the gap.

The second chapter critically reflects on the burdens that the gap between the textile and fashion sectors poses on garment production today, especially in terms of sustainability. It presents the problem of waste that the current Western system produces and reflects on the excessive need for transport in the globalized fashion industry. Furthermore, it addresses the lack of interdisciplinarity in the education of textile and fashion designers today and the difficulties that large parts of the industry face when it comes to changing their way of production.

The third chapter presents examples of techniques from different cultural and temporal contexts that aim at producing garments at the same time as their fabrics or at least facilitate this. With this analysis, it aims to show that alternative ways of garment production exist whose merits are still not sufficiently explored. Furthermore, the chapter highlights recent ideas for overcoming the separation of the sectors. It introduces innovative approaches by fashion designers like Issey Miyake, Timo Rissanen and Jeanne Vicerial. While trained in the current system of garment manufacturing, these designers have come up with new ways to reconcile the processes of garment and fabric production whose potential impact will be assessed.

In the fourth chapter, I will present my project *No Cuts No Seams*, which aims at producing woven garments directly on the loom by omitting any cutting or sewing after the garment has been taken off the loom. Based on the theoretical analysis from the previous chapters I will critically reflect which of the presented elements to use in my practical work as a textile designer and about the tools at my disposal to realise garments directly on the loom.

It is my hope that this thesis will be read as an invitation to see the relationship between a garment and the fabric it is made of from a new angle and to further explore the unrealised potential of the weaving technique.

Part I

The Gap

1. Historical Relationships Between Garments and Their Fabrics and the Development of the Weaving Loom

This chapter aims to highlight crucial events in the development of weaving and garment-making throughout European sartorial history. It will illustrate the different degrees of distance between garments and the fabrics they are made of. If a garment is directly manufactured on the loom, as is the case in many draped garments, this distance could be considered inexistant. If, however, a fabric is produced and only later cut into pieces and sewn together again, the distance between the textile and garment production forms a rather large gap. It will be argued that the gap between textiles and garments has continuously been widened in the course of European history, and especially so since the invention of the notion of fashion and the introduction of capitalist thinking into the production process.

The origins of sewing and weaving in pre-history

It is common practice in historical analyses to commence with our earliest ancestors in the Stone Age. As costume historian Jean-Noël Vigoureux-Loridon points out, sewing is a very ancient technique that dates back to around 17500-16000 BC (Vigoureux-Loridon, 2006, p. 16). It largely precedes weaving, which is mostly due to the fact that our prehistoric ancestors first used animal skins to cover themselves, which they needed to cut in pieces and reassemble according to their needs. They could not choose the size and shape of the skins and needed to develop tools to adapt them, which led to

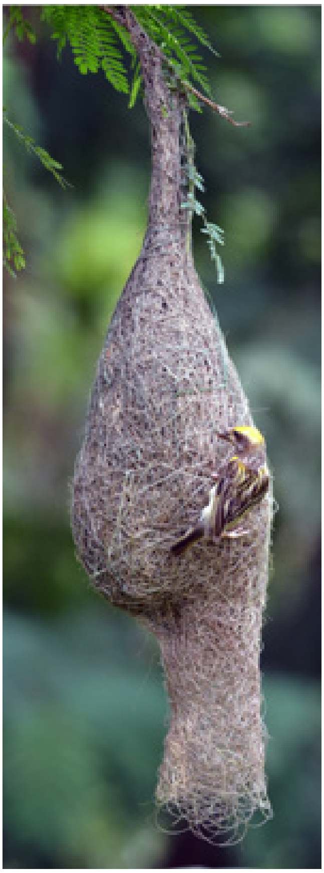


Fig. 1: Weaver bird with its nest in Karnataka, India

the invention of needles from animal bones. Vigoureux-Loridon therefore reminds his readers that 'clothing does not automatically imply a fitted and tailored garment made from fabric' (ibid.).

As a consequence of this use of animal skins for clothing, felting was invented, since it only required water and the hair obtained from the leather-making process. This can be seen as an intermediary step in the development of human-made fabrics. The advent of sedentism in the Neolithic period around 8000-3000 BC also marked the beginning of agriculture and cattle breeding, which meant that new plant and animal fibres were cultivated and led to the discovery of spinning. Textile historian Eric Broudy suggests that one possible inspiration for the weaving technique lay in the nests of weaver birds (Fig. 1) or in the observation of other natural phenomena like spider webs and silk cocoons (Broudy, 1979, p. 10f.).

However, the development of woven fabrics took much longer and passed by the intermediary techniques of braiding and basket-weaving. Indeed, as Broudy points out, 'plaiting baskets was a preliminary step to weaving cloth [... and] many weaving patterns are derived from these techniques' (Broudy, 1979, p. 11). To 19th century architect and historian Gottfried Semper, 'the origins of building coincide with the origins of the textrine art' (Semper, 1878, p. 213). He frequently uses the term textrine to refer to weaving, which is a direct translation from the the Latin adjective *textrinus* (i.e. related to weaving). Semper therefore sees the stable pen as well as fence-building techniques as bases for the development of woven textiles. Vigoureux-Loridon further underlines that it was only after mastering basketry and fence-building that 'man sought to reproduce his technology with other, finer plant fibres such as papyrus' (Vigoureux-Loridon, 2006, p. 17). As Broudy points out, the earliest fragments of plain-woven cloth were found in Central Anatolia and date from around 6000 BC (Broudy, 1979, p. 13), which to him is evidence that from this time onwards, 'basketry and weaving were heading in different directions' (ibid.).

These intermediary steps led to the invention of first rudimentary weaving looms that basically consisted of a frame to stretch the warp* fibres and a thick bone needle serving as the shuttle* (Vigoureux-Loridon, 2006, p. 17). Broudy, however, specifies that the development of the earliest looms was heavily dependent on the available resources in each geographic region, and especially on the fibres employed. He further suggests that the first looms could have been similar to the North American Ojibway bag loom (Fig. 2). These looms consisted of a cord stretched between two vertical sticks or trees. The warp fibres were then freely suspended from this cord and were not tied to another frame. Broudy emphasises that this technique required the warp fibres to be 'stiff enough to hang relatively parallel by themselves' (Broudy, 1979, p. 15). This specification is important since it further shows the transition process from basketry to weaving.

Broudy further underlines that while vertical looms were predominant in Europe in the Neolithic age, the weaving technique was developed differently in other cultural contexts. For example, a pottery bowl found in Badari (Egypt) and dated back to around 5000 BC shows a loom with a warp stretched horizontally between two bars attached to the ground. According to Broudy, this system is still appreciated today by Bedouin nomads for its great simplicity: '[I]f they

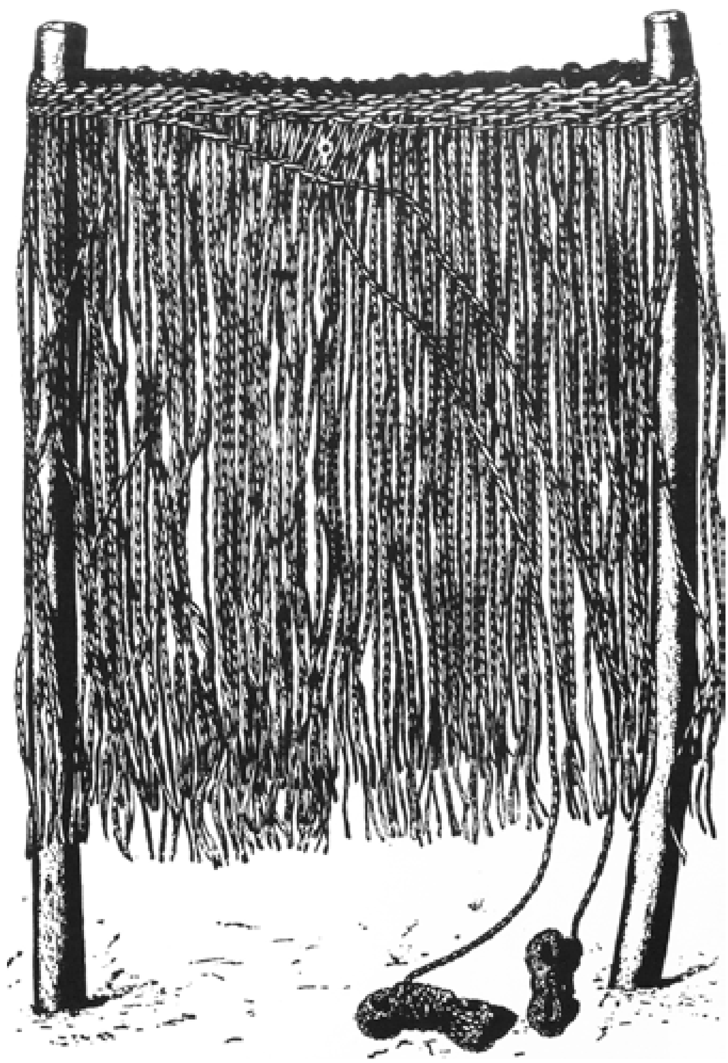


Fig. 2: Ojibway weaving frame

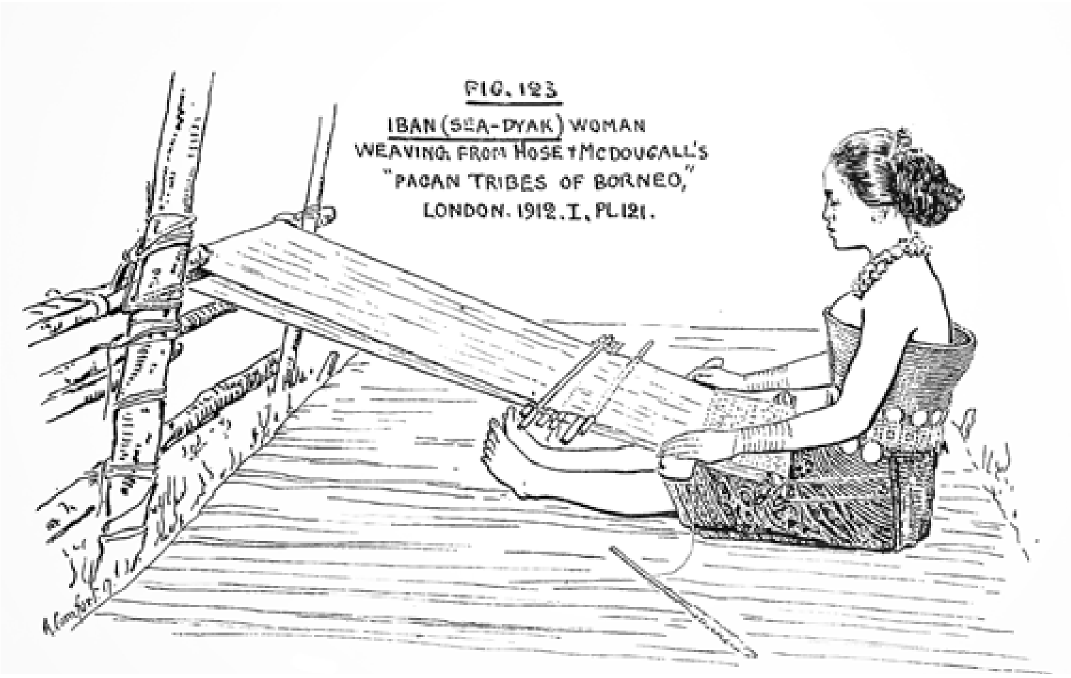


Fig. 3: Backstrap loom from Borneo

have to move in midweave, they simply pull up the pegs and roll up the loom - cloth, warp*, heddles*, batten*, and all' (Broudy, 1979, p. 14).

A third type of loom whose origins are much more difficult to trace is the backstrap loom* (Fig. 3). In this type, the warp beam* is fixed to a stationary object while the cloth beam* is attached to the weaver's back with the help of a sort of belt. The weaver therefore constantly controls the tension of the warp fibres with their body. Broudy points out that while this technique is mostly associated with Peruvian and Mexican weaving traditions, it can also be found in many regions of Asia (Broudy, 1979, p. 76).

This basic repertoire of looms was further developed in subsequent centuries and millennia as will be explained in the following. While they became more and more intricate and even automatised in the course of history, the basic set-up of these looms has remained essentially the same until the present day in the Western world. The loom is mainly considered a tool to produce rectangular woven surfaces that can be cut into pieces if necessary.

Draped fabrics and draped garments in European Antiquity

In European Antiquity, the technique of weaving became increasingly sophisticated. The sartorial code often associated with this period is that of draped garments, which essentially consist of a rectangular piece of woven fabric wrapped around the body in various ways. The Greek *chlamys* or the Roman *toga* are frequently mentioned examples of these Ancient garments (Fig. 4/5). Vigoureux-Loridon points out that the rectangular shape of these garments is directly connected to the set-up of the weaving loom and to the technique of weaving in general (Vigoreux-Loridon, 2006, p. 21). The case of the *toga*, however, is interesting since its basic pattern is semi-circular, hence indicating the need for tailoring since the woven rectangle had to be cut and hemmed. Nevertheless, Vigoureux-Loridon underlines that 'a beautiful toga mostly stemmed from the talent of the person draping it, more so than from the skill of the tailor or weaver' (ibid., p. 22), meaning that much more attention was paid to the way the folds were executed than to the pattern of the garment. Nowadays, examples of draped garments can mostly be found in non-Western clothing, with prominent examples being the Indian sari or the sarong worn in many countries in Southeast Asia and some Pacific islands.

Vigoureux-Loridon classifies further types of clothing worn in Antiquity that were developments of draped garments (Fig. 6). One of these is the *costume enfilé* (Fig. 7) which consists of a rectangular piece of fabric without sleeves that has an

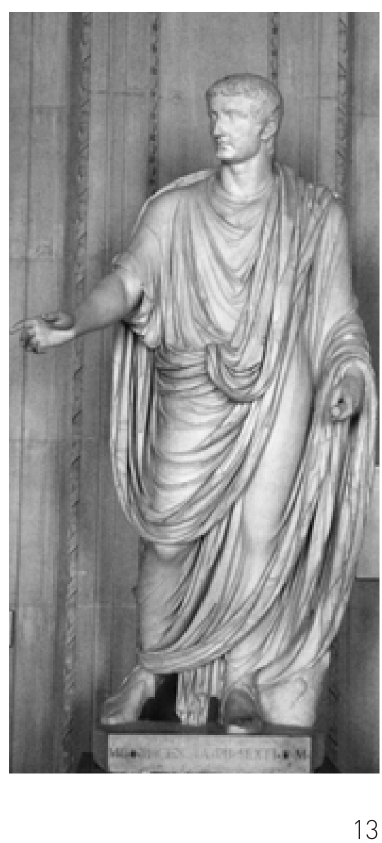


Fig. 4/5: Ancient Greek *chlamys* (left), statue of Tiberius wearing a *toga* (right).

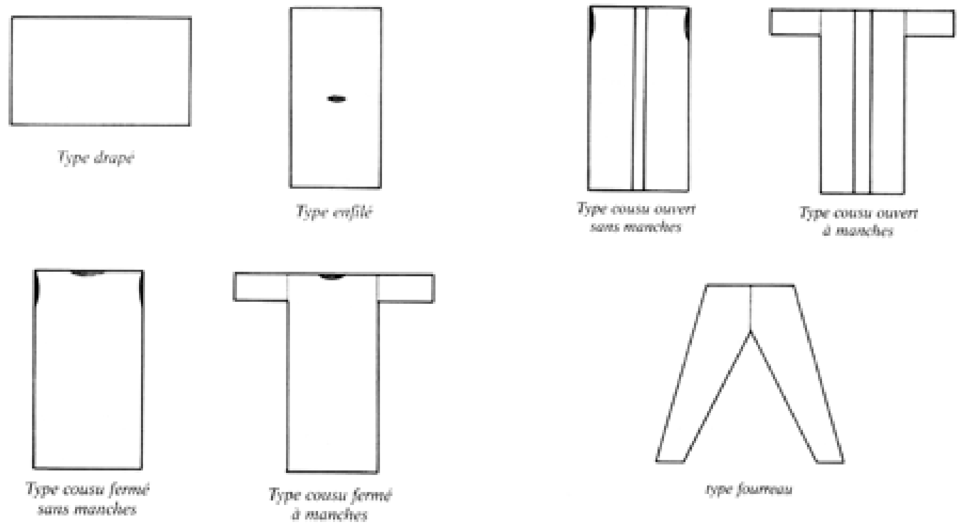


Fig. 6: Ancient clothing types
according to Vigoreux-Lauridon

Fig. 7: Ancient Roman *paenula*

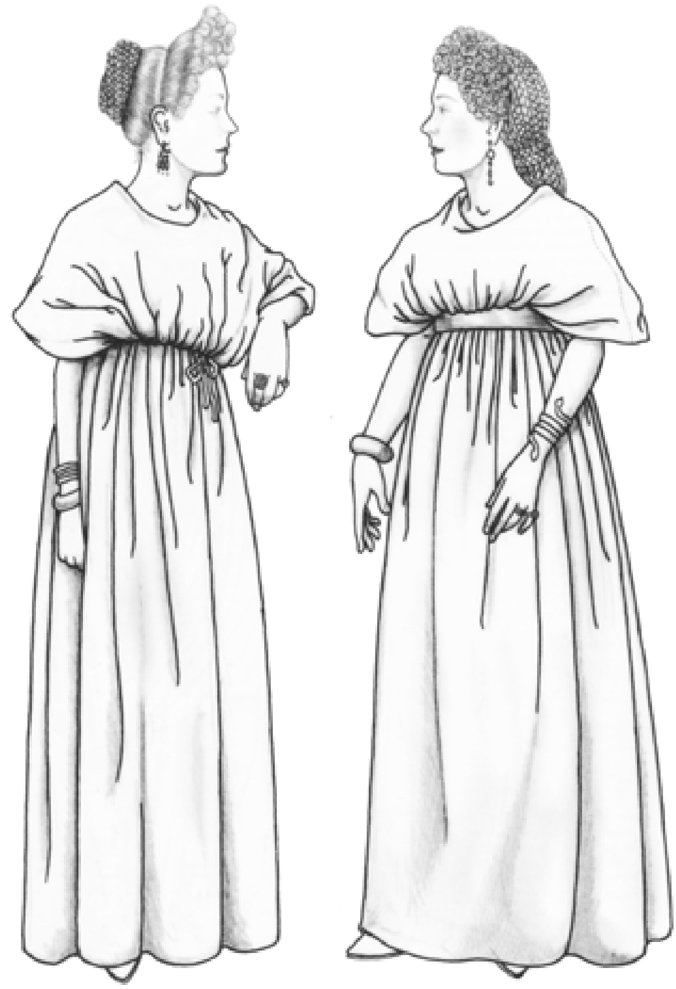


Fig. 8: Ancient Roman tunic

opening in the middle serving as a neckline. Examples for this are the *paenula* that became popular in Rome from 200 AD (Vigoureux-Loridon, 2006, p. 32) or the South American poncho.

Another type he presents is the *costume cousu et fermé* (Fig. 8), which is obtained by folding a panel of fabric in half and sewing the edges together with the exception of holes for the arms. A hole for the head can be obtained by leaving out weft threads during weaving if the garment is folded along the warp threads or by cutting if it is folded along the weft threads. The garment obtained in this way is called tunic. Sleeves can be added to this basic shape by folding additional fabric panels in half and sewing them on the edges to obtain a T-shaped garment (ibid., p. 22, pp. 33-39).

Fig. 9: Ancient Persian *kandys* and trousers

Being similar in shape to the tunic, the *costume cousu et ouvert* (Fig. 9) is open at the front, quite similar to a jacket. An example for this is the Persian *kandys*, which later developed into the *caftan* (ibid., p. 40).

As a last type, Vigoureux-Loridon presents the *costume fourreau* (Fig. 9), a predecessor of the modern trousers consisting of two tubes for the legs that were developed by so-called "barbaric" peoples like the Persians, Scyths, Gauls and Teutons to facilitate horseriding. Initially ridiculed by the Greek and Roman civilizations, they gained widespread popularity in Rome from 200 AD onwards.

It is remarkable that while some of these Ancient garments needed a certain degree of sewing, their basic shape was constructed from rectangular panels of fabric that were sewn together. There was thus very little waste of material since the woven fabric could be turned into a garment with a few relatively simple seams. This indicates that the gap between textile and garment production was still relatively small at this time.

The loom most associated with the period of Greek Antiquity is the warp-weighted loom* (Fig. 10). It is similar to the Ojibway loom presented earlier since it is a vertical loom whose warp threads are suspended from an upper beam. Stone weights are attached to the lower part of the warp threads to assure the right tension. This type of loom remained in use in different parts of Europe, notably in the Northern countries. Broudy estimates that it was common in Iceland until the late 18th century and points out that it is still in use in parts of western Norway today (Broudy, 1979, p. 28) (Fig. 11). 19th century textile historian Alfred Barlow remarks that in this type of loom, the cloth is woven upwards. He further notes that it did not yet include a reed* to beat the weft* fibres into place. They were rather combed upwards, 'and the blow was given to drive them together by the use of a flat sword-shaped

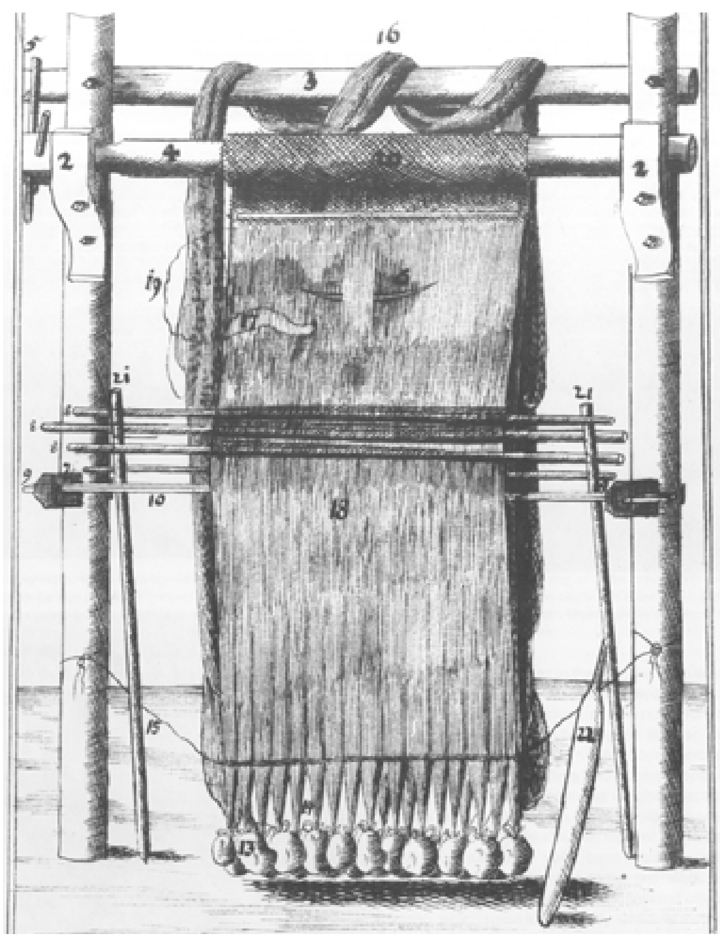


Fig. 11: Icelandic warp-weighted loom, c. 1778

Fig. 10: Depiction of Circe and Odysseus with an Ancient Greek warp-weighted loom, 4th century AD

Fig. 12: Ancient Roman two-beam loom, wall painting from the Hypogeum Aurelii

piece of wood, which was introduced into the shed* for that purpose [... and] called the "spatha"' (Barlow, 1878, p. 58). A special type of this loom will be discussed in the third chapter of this thesis.

Broudy suggests that a different type of loom was used in Rome, namely the two-bar vertical loom (Fig. 12) (Broudy, 1979, p. 47). In this type, the warp was stretched vertically between two beams attached to two uprights. This system was probably imported from Syria or Egypt where it is likely to have been in use since the period of the New Kingdom (ca. 1570-1085 BC). The particularity of this loom was that '[t]he top beam [...] did not revolve but could be lowered through slots in the uprights as the weaving progressed and was wound on the lower beam' (ibid.). This organization of the Roman loom can be seen as a predecessor to the modern loom, which contains a warp beam and a cloth beam. However, it also indicates that the quantities of fabric that could be produced on this loom were relatively low. On a modern loom, kilometres of warp threads can be rolled on the warp beam and then unrolled as the weaving progresses. If the warp beam cannot revolve but only be lowered, the length of the produced cloth is limited to the length of the weaving frame.

The advent of fashion and horizontal looms in the European Middle Ages

Many scholars of European sartorial history divide the Middle Ages in two. While the silhouette retained the rather large and basic construction of Antique garments in the early Middle Ages, it is in the mid-fourteenth century that most of them locate the birth of the concept of fashion, which will be explained in more detail in the following. However, it will also be argued that trying to give an exact date for the emergence of an idea is rarely without problems. This holds especially true given the large time span and the many changing factors that the European Middle Ages encompass.

Historians Giorgio Riello and Peter McNeil point out the fact that the social system in the early Middle Ages imposed certain dress codes on the different classes. Wearing a certain type of clothing was more a sign of belonging to a certain group or profession than an expression of the wearer's individual taste. Indeed, as they further note, the 'static nature [of medieval society] prevented any playful engagement with clothing, including its most ludic expression called "fashion"' (Riello & McNeil, 2010, p. 20). They also point out that clothing was barely affordable at this time due to the high price of fabrics 'woven with simple looms and from fibres that were hand-spun, making the emergence of fashion even more improbable' (ibid.). The vast majority of people simply lacked the means to afford the luxury of sartorial playfulness.

Fig. 13: Early medieval tunic

According to Riello & McNeil, it was only in the twelfth to the fourteenth century that the economy began to flourish, especially in Italian cities like Venice and Genoa, and that wealth could be accumulated by the fortunate classes and displayed in luxurious and varying dress. Fashion historian Douglas Gorsline also associates the advent of fashion with the economic development of European societies in the Middle Ages. He points out that relatively simple rectangular shapes persisted in European clothing until the fifteenth century, which only then 'abandoned simple lines and assumed the fantastic richness and elaborateness associated with the later medieval period' (p. 20). However, it should be made very clear that even in the later Middle Ages, fashion was by no means a mass phenomenon, especially since most people were 'still far too poor and socially excluded to be able to savour any of the pleasure of sartorial consumption' (Riello & McNeil, 2010, p. 21).

Fig. 14: Pourpoint, c. 1340-1520

As medieval garment historians Françoise Piponnier and Perrine Mane have pointed out, the early medieval dress of the popular classes underwent very few changes for several centuries and 'always belongs to the category of the sleeved tunic, reaching at least the calves for women and sometimes only the knees for men' (Piponnier & Mane, 1995, p. 52) (Fig. 13). Trousers, which had already been introduced in Europe in late Antiquity, were restricted to male wearers (ibid., pp. 53-54) and were mostly worn under the long tunic. Even though slight nuances existed, Jean-Noël Vigoureux-Loridon explains that this basic silhouette formed by the tunic was common to both men and women, leading to a unisex shape of clothing (Vigoureux-Loridon, 2006, p. 44).

After the long persistence of this unisex silhouette, Piponnier & Mane relate the birth of the concept of fashion to the definition of a new and distinctly male silhouette in the mid-14th

century. According to them, a decisive factor in this development was the wearing of metallic armour on the battlefield, which needed suitable undergarments that closely followed the actual contours of the human body. This led to the invention of the pourpoint or doublet (Fig. 14) in the twelfth century, literally meaning 'overstitched' (Piponnier & Mane, 1995, p. 80). This name stems from the technique of assembling several layers of fabric by stitching them together to create a solid and protective undergarment (ibid.). They further give a rather technical explanation for the new way the sleeves are assembled in this garment:

> Le montage de la manche en arrondi a dû être inventé pour éviter les inconvénients de la coupe habituelle, en T, dans le prolongement de l'épaule. De telles manches, forcément larges et formant des plis sous l'aisselle lorsque le bras est baissé, seraient importables sous la brigandine et, à plus forte raison, sous le 'harnois plain'. (Piponnier & Mane, 1995, p. 80)

Piponnier & Mane further explain that from the late thirteenth century onwards, these pourpoints were also realised in precious materials such as embroidered velvet and that from the late 1330s onwards, 'young warriors showed themselves in public in such tight-fitting clothes' (ibid., p. 81). This development shows that the pourpoint was disconnected from its original protective function and reappropriated for use outside the battlefield to mark the origin of the modern male and nowadays also female silhouette. The new tailored garment was subject to many playful variations in the following decades and frequently combined with an overgarment called jaquette (Fig. 15).

Textile historian Jennifer Harris also sees the development of tight-fitted garments as a major turning point in European sartorial history and explains that these were, according to her, largely influenced by new tailoring techniques that replaced the former more rectangular cuts:

> Methods of constructing clothing in the early Middle Ages were relatively unsophisticated by modern standards. Based on the cutting and dividing of a basic rectangle into further rectangles and triangles, they reflected a traditional unwillingness to waste cloth by cutting out curved shapes. Not until the early fourteenth century do we observe the development of cutting-to-fit proper, the process whereby fabric is cut and shaped to fit the contours of the individual body. The increasing

Fig. 15: Jaquette, c. 1340-1520

> use of buttons, which appear to have been introduced into Northern European clothing during the thirteenth century, greatly facilitated the development of modern tailoring techniques [...]. (Harris, 1998, p. 90)

Nevertheless, Harris points out a number of tailoring techniques like sleeve construction, pleating and smocking that were already present earlier. According to her, these largely facilitated the development of tailored, tight-fitted garments. She therefore locates the birth of fashion rather in the twelfth than in the fourteenth century, since these techniques 'called for a good deal of ingenuity on the part of the tailor and provided the impetus which led, over the next century or so, to cutting-to-fit and functional buttons' (Harris, 1998, p. 99).

In her literature review on the dating of the birth of fashion, historian Sarah-Grace Heller criticizes Harris' approach as one-sided. To her, 'dating fashion's advent to the appearance of any given type of technology neglects the societal forces that brought about such a development' (Heller, 2010, p. 30). Heller further generally criticizes the attempt by many historians to point down a particular date for the birth of the concept of fashion. According to her:

> Fashion systems constantly reject the immediate past. Every new wave of innovation presents itself [...] as newly born, even while it may be situated along what is really an unbroken (but constantly bending) thread of evolution. (Heller, 2010, p. 25)

In other words, fashion was not born out of the blue, even though it often likes to present itself in this way. Heller therefore argues that '[t]he radical change in male dress that was staged by the young men of the wealthy fourteenth-century Burgundian court could only have happened because a fashion system was already in place' (ibid., p. 35). She further explains that the desire to identify a specific date for the birth of sartorial modernity often stems from considering the early Middle Ages as the opposite of this modernity, namely the Dark Ages, 'when everyone lived in squalor, wore rough homespun, lived a life of obscure oblivion due to illiteracy, suffered oppression by theological dogma, spurned classical art and literature, and never washed' (ibid., p. 26). Such a simplistic way of thinking about the early Middle Ages makes it easy to let following eras appear like times of sartorial splendour. It is, however, far from being historically accurate.

There is another problem in Harris' way of presenting the birth of fashion, which is somewhat related to Heller's criticism. When Harris praises the advent of new tailoring techniques in the late Middle Ages as 'ingenious' or 'providing impetus', she implies that they were a step in the right direction, and even more so, an inevitable necessity for progress. This becomes even clearer when considering that she qualifies earlier methods of garment construction as 'unsophisticated by modern standards' and 'reflecting a traditional unwillingness to waste cloth'. It would be far-fetched to qualify Harris as a follower of technological determinism on the basis of a few small quotes and it would go beyond the scope of this thesis. However, her way of contrasting the early and late Middle Ages in this way implies that the new techniques were necessarily better and more advanced and that people in the early Middle Ages were not yet as far because they were 'traditional' and 'unwilling' to discover the technological novelties. She does not explain that the 'unwillingness to waste cloth' must have persisted for specific reasons, for example the high price of fabric mentioned previously. Furthermore, it is not clear why a system that tries not to waste its resources would be an unsophisticated one. Is this to imply that wastefulness is wise? This criticism does not intend to discredit the value of technological innovations, but rather seeks to underline that they always need to be put into perspective and that the mere fact that we still use them today does not make them more advanced than other techniques.

While it is undeniable that the advent of the tight-fitted silhouette marked a turning point in European sartorial history, it is curious that the weaving loom did not follow suit and was not adapted to this new way of manufacturing garments. While it underwent considerable changes, it was not reshaped as drastically as the male silhouette. This is even more surprising as the latter roughly coincided with the introduction of new loom technology as will be explained in the following. This development could therefore be seen as a widening of the gap since the shapes the loom could produce began to be quite far removed from the shapes needed to construct the new garments.

Broudy points out that vertical looms, specifically the Ancient Greek warp-weighted loom as well as the Roman two-bar loom, continued to be used in the early European Middle Ages (Fig. 16). Like Heller, he questions the stigmatization of this period as the "Dark Ages" by pointing out that there were many technological innovations in cloth manufacturing during this time. However, these did not concern the loom. While sources from this time are scarce and lack detail, they indicate that the Ancient vertical looms did not undergo any major changes during this time (Broudy, 1979, p. 138).

Significant changes in loom design came about in the 11th century with the introduction of the horizontal treadle loom* in Europe (Fig. 17). Broudy points out that this type of loom has its origin in Eastern or Southern Asia, where silk and fine cotton weaving needed a much more careful handling than was possible with backstrap looms. In this loom, the weaver changes the shed* with the help of foot treadles (Fig. 18). This 'freed the hands for the more delicate work of inserting the weft and beating it in' (Broudy, 1979, p. 102), and gave weavers the possibility to put more focus on the delicate fibres they were working with. Another characteristic feature is this loom's compact structure, which combines many functions in one loom frame:

Fig. 16: Loom depicted in the Hrabanus Maurus manuscript, 11th century

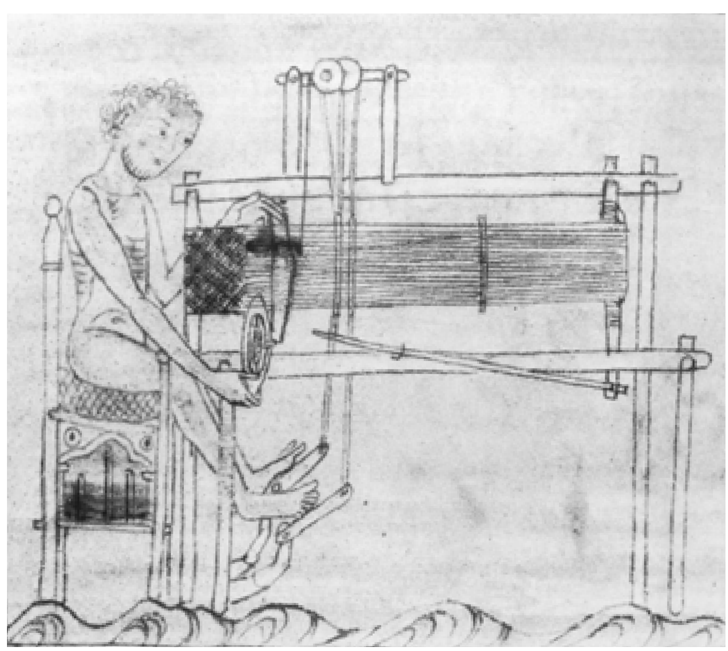


Fig. 17: Medieval treadle loom, c. 1200

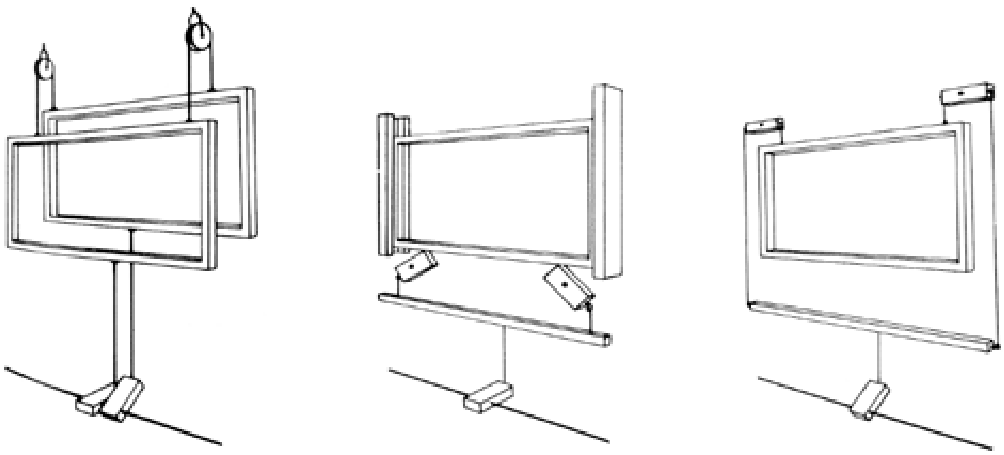


Fig. 18: Different variants of treadle looms

> It supports the warp and cloth beams*; the reed beater*; the heddle harnesses*, treadles, and various lams, pulleys, or jacks that connect them; the ratchets and pawls; the levers and brakes that control the advancing of the warp; and occasionally a footrest or even a bench for the weaver. (Broudy, 1979, pp. 102-103)

Broudy further points out that this new loom technology 'was not a western invention at all but probably an import from the Near East' (Broudy, 1979, p. 138). Along with it came a vast array of tools already in use elsewhere, such as warping mills*, spool racks*, and sectional warp beams* (ibid., p. 142).

According to Broudy, some sources suggest that the new horizontal looms were predominantly used by men, while women continued to produce cloth on vertical ones. To him, '[t]he appearance of men at the looms signals the birth of European weaving as a commercial enterprise [... since it] was now possible to weave long lenghs of cloth at a speed that made the warp-weighted loom appear primitive by comparison' (Broudy, 1979, p. 138). In other words, with this new tool weaving became interesting commercially, and since women were not judged capable of doing business, men started to enter the previously female-dominated field of weaving. This development also marked the emergence of professional workshops owned by men, since female weavers had previously mostly worked in the domestic sphere (Kibler & Zinn, 1995, p. 1704).

The introduction of the horizontal loom also occurred in a time of increased urbanization and pan-European trade.

Woven cloth was a central commodity in this time and led to the prosperity of a large number of production centres, predominantly in Flanders. Their wealth, however, was dependent on a steady supply of raw materials, mainly wool imported from England (Broudy, 1979, p. 140). This micro-scale globalization reflects a pattern that has persisted in the textile industry ever since, namely the dislocation of different production steps.

Another related factor that can still be found in today's organisation of the industry is specialisation, which was heavily facilitated by urbanisation. By the late Middle Ages, many professions had evolved that were directly linked to the production of textiles, although they were less concerned with the weaving process itself than the subsequent production steps:

> The brayer pounded and scoured the cloth to remove the oil and dirt; the burler picked out the loose threads and knots. The tramping by the fuller matted the fibers together in a kind of felting that softened the cloth and obscured the weave. The rower teased a nap up on the cloth with teasles set in a frame, and the shearman cut the nap even and smooth. The drawer mended any holes in the cloth caused by broken threads. (Broudy, 1979, p. 140)

This enumeration does not yet include the steps required to make garments out of the fabrics produced in this way. It becomes clear, however, that this separation of tasks, even though it might have contributed to innovations in certain fields, also further removed the production of garments from that of their textiles as more and more intermediary people were involved in the production process.

The increasing separation of tasks was reflected in the development of guilds in the late Middle Ages. Their tasks, among many others, were to protect their members' economic welfare, to organize the training of new apprentices, and even to regulate working hours and procedures. However, they mainly served to preserve the system as it was. Broudy remarks that '[g]uild regulations, while they hampered innovation and tended to retard guild technology compared to developments outside the guild, probably had little effect on the development of looms' (Broudy, 1979, p. 140). However, it could also be assumed that the loom did not evolve drastically to accomodate the changes in garment-making precisely because of the highly regulated environment designed to keep up the separation of tasks that it was operated in.

Another factor to consider in this context is that cities were relatively wealthy, especially compared to rural areas or to the early Middle Ages. For the new tight-fitted garments, this meant that the textile waste that their tailoring produced probably became much less of a concern, since there were more and more people who could simply afford it. In the early Middle Ages, fabric was far too precious to be wasted, so the advent of a new silhouette whose construction necessarily generates waste implies that more people had the means to pay for the excess fabric that was left after cutting out the patterns and that would not be used for their garments. It could therefore be argued that the gap between textiles and garments is intrinsically linked to wealth and also to the emerging capitalist system that we continue to operate in today. This will be further elaborated on in the following section.

Industrialised weaving and garment-making

The textile industry is generally considered as one of the driving forces in the industrialisation of Western Europe, and especially England. Its growth and success was based on a number of technological innovations, as well as the full integration of capitalist thinking and rationalisation into the production process.

The treadle loom discussed earlier remained relatively unchanged over several centuries. It was only at the dawn of the industrial revolution in the 18th century that considerable innovations occurred that had a long-lasting impact on the textile industry. There had been a general tendency towards mechanisation and automatisation of textile production processes before this time, but since handweavers feared for their employment many cities issued ordinances against the use of automatic looms in the seventeenth century (Broudy, 1979, p. 147). However, one important innovation was John Kay's flying shuttle, which he presented in 1733 and which quadrupled a weaver's output. It consisted of a cord with a handle that was connected to two boxes to the left and right of the cloth that the shuttle could be stowed in. By pulling on the handle, the shuttle was propelled at a high speed from one side to the other and caught in the opposite box. Broudy points out that the 'effect [of the introduction of the flying shuttle] was to widen [...] the disparity between the spinner's and the weaver's production' (Broudy, 1979, p. 148). This disparity, among other factors, stimulated the development of the automatic spinning jenny by James Hargreaves in 1764.

At the same time, considerable efforts were made to fully automatise the loom itself. In 1784, the English cleric Edmond Cartwright presented his first fully automated power loom (Fig. 19), which was originally powered by oxen and subsequently by a steam engine that James Watt had patented in 1769 (Broudy, 1979, p. 153). Cartwright's principle was further developed over the following years, leading to the fully automated power loom that formed the backbone of the 19th century textile industry (Fig. 20). Historian Alfred Barlow estimated that between 1820 and 1833, the number of power looms in England and Scotland septupled, reaching 100,000 operational looms in 1833 (Barlow, 1878, p. 243). He further states that by 1878, 1,215,000 were in use worldwide (ibid., p. 244). Barlow also pointed out the extreme changes that the introduction of this machine must have meant to the weaving profession:

> The advantages that the power loom possesses over the hand loom is in its greater productiveness, and the complete saving of manual labour, for while the irksome and laborious part of the work is being done by power, the weaver is occupied in attending to the replenishment of the shuttles, and keeping the warp in order. By this means one weaver may in most cases attend to more than one loom [...]. (Barlow, 1878, p. 244)

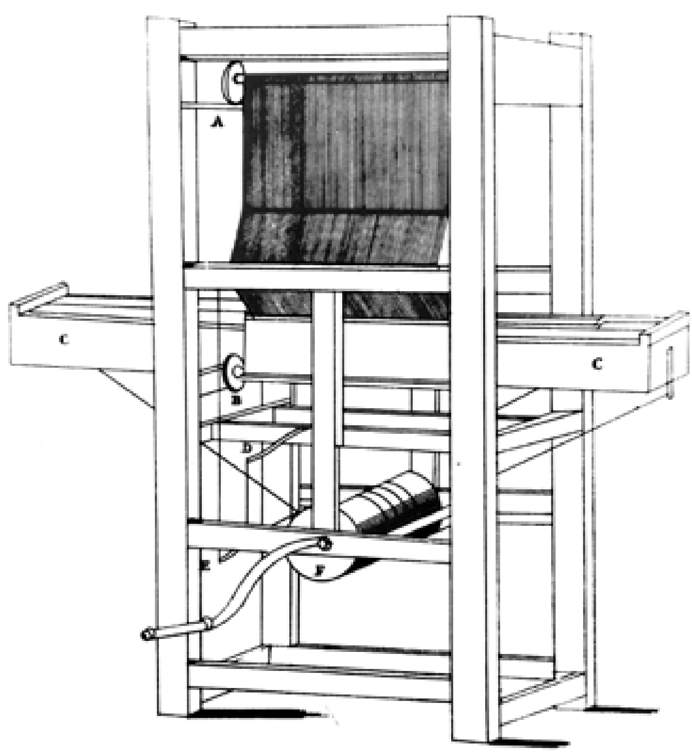


Fig. 19: Edmond Cartwright's first power loom, c. 1784

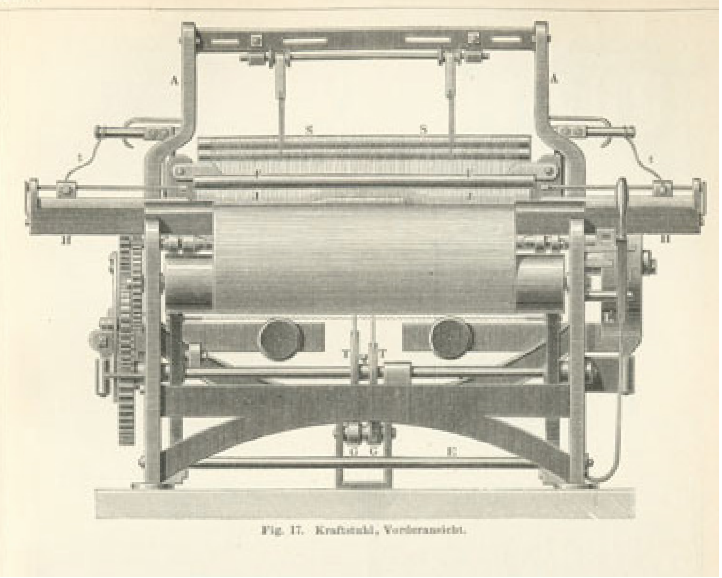


Fig. 20: Industrial power loom, c. 1885-1890

Until today, most wovens are produced on fully automated weaving machines, which have been developed further to increase the speed of production even more. One important step in this development was the introduction of shuttleless looms in 1927, which place the weft threads with the help of rapiers or air-jets.

However, it was not only in England that mechanisation and automatisation occurred in the 18th century. In the late Middle Ages, a silk weaving industry had developed in Northern Italy and later also in and around the French city of Lyon. To weave complicated figured patterns such as damasks, drawlooms* (Fig. 21) were introduced in the seventeenth century. These had their origins in Eastern Asia and were already widely used throughout Persia and the Middle East at this time. These horizontal looms had separate figure harnesses that could be activated by pulling cords. To do this, a "drawboy" or "drawgirl" had to sit on top of the loom and activate the different constallations of the pattern at each weft shot (Broudy, 1979, p. 127).

This type of loom saw a tremendous development in the 18th century with the introduction of punched cards. The original idea for this method stemmed from Basile Bouchon, a textile worker from Lyon. He conceived a device that could read a weaving pattern punched into paper cards and was thus able to lift every single warp thread separately without the need for repetition in the design. Bouchon's design was improved by Jean Baptiste Falcon in 1728, and by Jacques de Vaucanson in 1740, and ultimately completed by Joseph Marie Jacquard

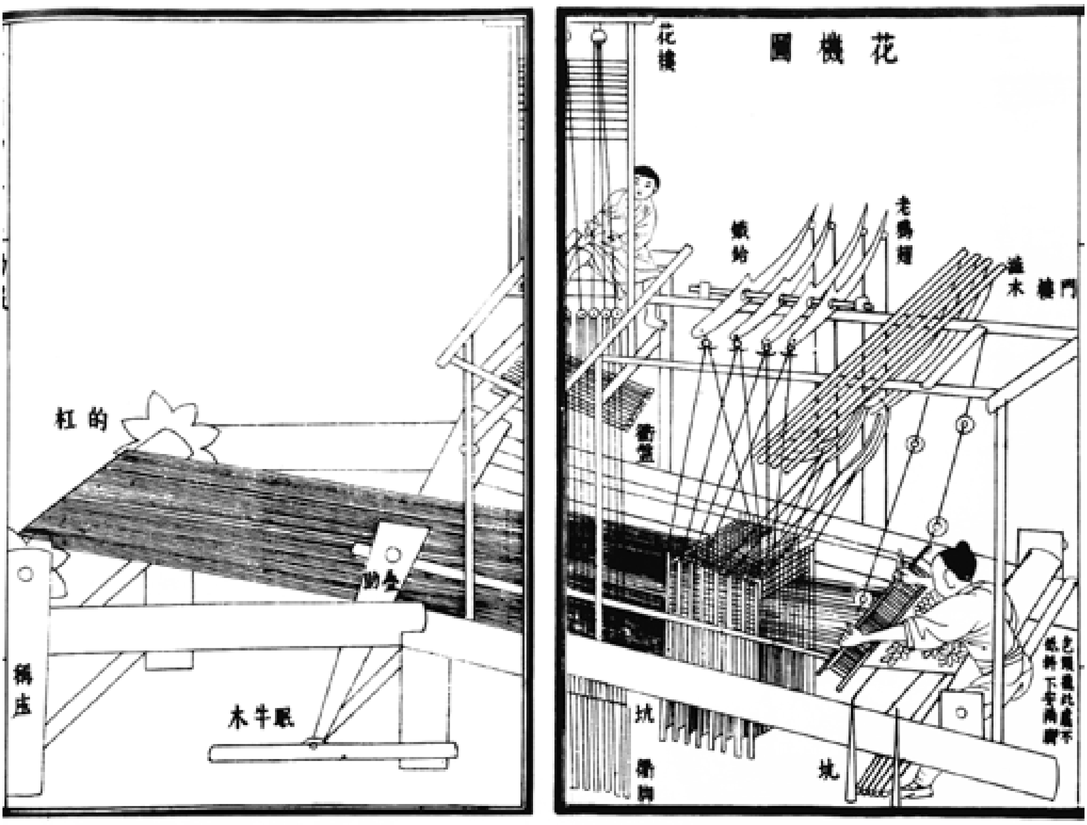


Fig. 21: Chinese drawloom, 1637

in 1804, whose name it retained. Broudy points out that the jaquard device (Fig. 22) was thus not a completely new loom in itself, but 'actually a treadle-operated automatic shedding mechanism that could be mounted on top of any treadle loom with the frame to support it' (Broudy, 1979, p. 134).

The new device made the drawboys and drawgirls superfluous. Another economic advantage of the device was that pattern changes became much easier as compared to the previous drawloom technique, where for each new pattern all the drawstrings had to be rearranged. This process could take several weeks (Broudy, 1979, p. 134). In the case of the jacquard loom, it sufficed to punch new cards to change the pattern, a matter of a few hours. It was so successful that already by 1812, 18,000 treadle looms in Lyon had been equipped with the new device (ibid.).

The industrialisation of garment-making, meanwhile, was marked by the introduction of the sewing machine. Historian Grace Rogers Cooper relates the need for such a machine to the increased productivity of the spinning and weaving sectors (Cooper, 1985/1968, p. 6). Its principle originated in embroidery stitches and a first attempt at mechanising this principle was patented by the English cabinetmaker John Saint in 1790. During the 1830s and 1840s, different inventors in France, England, Austria and especially in the United States realized the potential of such a machine for tailoring purposes (ibid., p. 4f.). By the mid-1850s, all the important components had been patented and the machine began to be commercialised in the United States and Europe. It is interesting that right from the beginning there were models destined for industrial purposes and home use (ibid., p. 45f.; Forty, 2014/1986, p. 94f.). This diversification of the market led to very high production rates for sewing machines, with 74 factories in the United States producing 111,000 sewing machines per year by 1860 (Cooper, 1985/1968, p. 64).

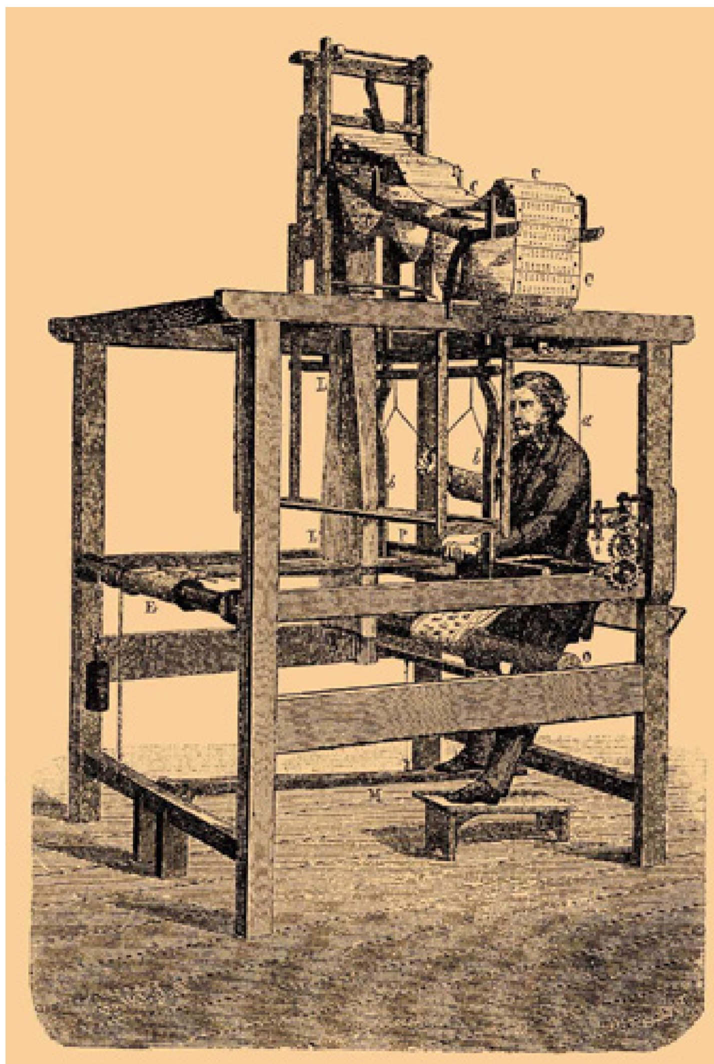


Fig. 22: Jacquard loom with punched cards, c. 1890

One reason for the great success of the sewing machine was that it drastically reduced the time needed to assemble garments and therefore also their cost. According to a study by the manufacturer Wheeler & Wilson, the time needed to stitch a gentlemen's shirt by hand was 14 hours 26 minutes, while a sewing machine could reduce this time to 1 hour and 16 minutes (cited in Cooper, 1985/1968, p. 58). Another factor Cooper points out was the emergence of the ready-made clothing industry in the mid-19th century, which was largely facilitated by the new machines. She explains that while in the early years of the United States many people produced their own garments at home, the growing wealth also increased the demand for ready-made clothes. This lead to the establishment of 4,278 clothing manufacturers in the United States by 1850 (ibid., p. 57f.). However, since many seamstresses were needed to respond to the growing demand, garment production did not only take place in factories but was also 'farmed out to the girls in their homes' (ibid., p. 58).

Design historian Adrian Forty explains that some historians have related the advent of complicated trimmings in women's dresses in the 1860s and 1870s (Fig. 23) to the introduction of the sewing machine, which enabled such complicated dresses to be made more quickly and thus more cost-efficiently. Forty, however, points out that such an explanation only holds true 'because sewing machines had been introduced into a capitalist system of manufacture' (Forty, 2014/1986, p. 54). He further explains:

> One of the main objects of the sweatmasters and clothing wholesalers, who controlled their [i.e. the sewing machines'] use, was to cheapen the price of sewing. In other circumstances, the speed of the machines could have allowed the machinists to earn more or to work only a few hours a day instead of the twelve or more that were customary for hand sewers. To the customer, the cost of the sewing would have continued the same, and all advantages would have been to the worker. [...] Of the money that the sweater or dressmaker saved, part went to pay the cost of the machine, part went to increase profits, but most went to reduce the price of sewing to the customer, so that more sewing could be put into a dress at no additional cost. (Forty, 2014/1986, p. 54f.)

Forty's point makes clear that the innovations during this period were not limited to technological improvements. The whole production process was rationalised to increase productivity even more, a way of thinking that has greatly shaped the way in which goods are produced to the present day.

Fig. 23: Trimmed dresses, c. 1860

Forty further outlines how these changes can be applied to many industries during the period of the industrial revolution by giving the example of the Wedgwood potteries in England. Already in 1759, Josiah Wedgwood had installed showrooms in different cities in which customers could pre-order the potteries, which were then produced according to demand. This was a drastic change compared to earlier times, when 'potters normally sold their goods by sending batches of completed work either direct to markets, or to merchants' (Forty, 2014/1986, p. 30f.). This new way of selling, however, required a constant and uniform quality of the proposed goods since customers were expecting the pieces they bought to be identical to the ones they had seen in the showroom. New mass production techniques like enamel-printed transfers for the decoration of the pots were therefore introduced, which ensured that all of them looked the same (ibid., p.31f.).

Another factor in ensuring uniformity was the division of labour. Forty points out that 'pottery had once been a craft industry, in the sense that a single individual was responsible for all the stages of making a pot' (Forty, 2014/1986, p. 32), but that this form of production had already been diversified before Wedgwood went into business (ibid.). An analogy could be drawn here to the division of tasks in the production of textiles presented previously. By separating the production steps, 'several craftsmen were responsible for the making of a single pot, [so that] no individual was able to make any major changes to it' (ibid., p. 32f.). However, the results of this production method were still not uniform enough for Wedgwood who had the intention 'to make such Machines of the Men as cannot Err [sic]' (Wedgwood cited in Forty, 2014/1986, p. 33). To achieve this, he broke down the production process into even more stages which could then be supervised more closely and which enabled him to 'make do with less skilled labour' (ibid.) While this division further reduced his production costs, it also meant that the tasks to be executed by the single employee became very repetitive.

Forty further relates the profession of the modern designer to the division of labour introduced in eighteenth-century factories. Wedgwood employed so-called modellers whose task it was to make prototypes of every type of pot the company produced and to precisely specify its shape and production process. He further states that '[t]he modeller's value in preparing an exact design increased with the number of pots made from it, because he was, in a sense, taking over a fraction of the work that had once been done by each craftsman every time he made a pot' (Forty, 2014/1986, p. 34). This demonstrates that right from its beginning as a separate profession, the designing of products was intrinsically linked to capitalist industrialised production methods.

In summary, there were thus two important changes that the industrial revolution brought about and that stem from the capitalist organization of society. These are the increased speed of production and the further division of labour. Both points are adressed by Broudy when he remarks that each sophistication of the loom also brought with it a loss of flexibility to a certain extent. As Broudy puts it, '[t]he history of the loom is essentially a history of mechanical improvements that were directed mainly at increasing the quantity and speed of fabric production' (Broudy, 1979, p. 22). However, this did not always mean an improvement of quality since 'the further removed the yarn became from the hands of the craftsman, the less flexibility he had to exercise his inventiveness' (ibid.). Broudy's remark is important since it points out that faster production and mechanisation does not necessarily equal better products. Furthermore, when tasks are divided too much, the individual worker will lose the overview of the whole product and faults in the system of production are thus more difficult for her or him to notice. It should also not be forgotten that machines cannot think for themselves and rather repeat the same task over and over again, which means that innovation in production processes and products still has to come from humans.

These points may be part of the explanation of why there is a gap between garments and the textiles they are made of. In a way, the machines that were invented served to maintain the status quo, which had been that non-rectangular patterns for tight-fitted clothing were cut out from rectangular fabrics. The improved loom and the sewing machine only served to dramatically speed up the production of fabrics and garments, and not to rethink how both could actually be produced at the same time. This way of production has led to a number of environmental problems that we have to face today, some of which will be addressed in chapter 2.

2. The Gap as a Burden for Sustainable Design

The historical analysis in Chapter 1 has pointed out the foundations of the way woven fabrics and garments are produced today. In the Western world, the tight-fitted silhouette has persisted and has also become accepted in female clothing. Meanwhile, the production process has become automatised, globalised and to a large extent highly specialised. It relies on cheap labour, mostly in low-income countries with low environmental standards. Fast fashion and ready-to-wear apparel have become standard terms in an industry that constantly overproduces garments, which are consumed at increasing rates. This chapter aims to show that the gap that has been previously identified between the production of textiles and garments is a key element in the environmental impact that these industries have today.

Lecturer in development and environment Andrew Brooks and his colleagues have pointed out a number of factors that have emerged after World War II and that have importantly shaped the fashion industry as we know it today. The use of synthetic fibres as well as washing machines became widespread in Western Europe and North America, which has lead to a large-scale contamination of the world's oceans with microfibres (Brooks et al., 2017, p. 486; Ellen MacArthur Foundation, 2017, p. 66f; Greenpeace, 2017, p. 29f.). Furthermore, Brooks et al. enumerate several factors that have contributed to the unsustainability of the current system of textile production:

> During this period there were many other transformations in the fashion industry, including the global shift in production away from the West to East Asia, the proliferation of manufactured obsolescence, the declining quality of garment construction, an acceleration in cycles of clothing consumption and a breakdown in the spring-summer and autumn-winter seasons, the spread of branding, and the increasing sexualization of body types. (Brooks et al., 2017, p. 491)

While it would be beyond the scope of this thesis to discuss all these factors in detail, a few of them will be relevant in this chapter to analyse to what extent the gap between textiles and garments is a burden to sustainability.

Today, the consumption of clothing in the Western world is higher than ever before. Julian M. Allwood et al. of the Cambridge Institute of Manufacturing have estimated that an average person in the UK bought 35kg of clothes in 2006, of which only about one eighth was recycled and the rest sent to landfill (Allwood et al., 2006, p. 2). In France, these numbers are lower but still reflect a high level of consumption. 600,000 tons or 9,2 kilograms per person are proposed to consumers annually there, of which about one third is recycled (Eco TLC, 2016, p. 6; Sbai, 2018, p. 36). Recent figures published by the Ellen MacArthur Foundation also indicate that the number of garments produced worldwide doubled between 2000 and 2015 while the number of times a garment is worn decreased by about 20% (Fig. 24) (Ellen MacArthur Foundation, 2017, p. 18). These numbers appear alarming, especially when considering that the textile and clothing industry has one of the highest greenhous gas emission rates at 1.2 billion tonnes annually in 2015, which is 'more than those of all international flights and maritime shipping combined' (ibid., p. 38). Apart from greenhouse gases, its consumption of the earth's water resources is tremendous, at currently 93 billion cubic metres annually, which is 4% of the global freshwater withdrawal and which has grave consequences in water-scarce regions with a high textile production such as India, Pakistan, the southern United States and parts of China (ibid.).

The recognition that human actions have direct and far-reaching consequences on our natural environment is a relatively new phenomenon. The United Nations' Report of the World Commission on Environment and Development, the so-called Brundtland-Report (1987), has been a key step in the realisation of the consequences of our way of living and in the formulation of definitions of terms like sustainability. According to the report, '[s]ustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (World Commission on Environment and Development, 1987, Ch. 2.1).

The concept of sustainability has gained much interest in recent years, notably in the production of garments and in the design field as a whole. However, there are many different standpoints as to what constitues sustainable design (Chapman & Gant, 2007, p. 4; Madge, 1997). This might be due to the fact that it is a highly complex topic as a myriad of factors need to be analysed in order to evaluate the environ-

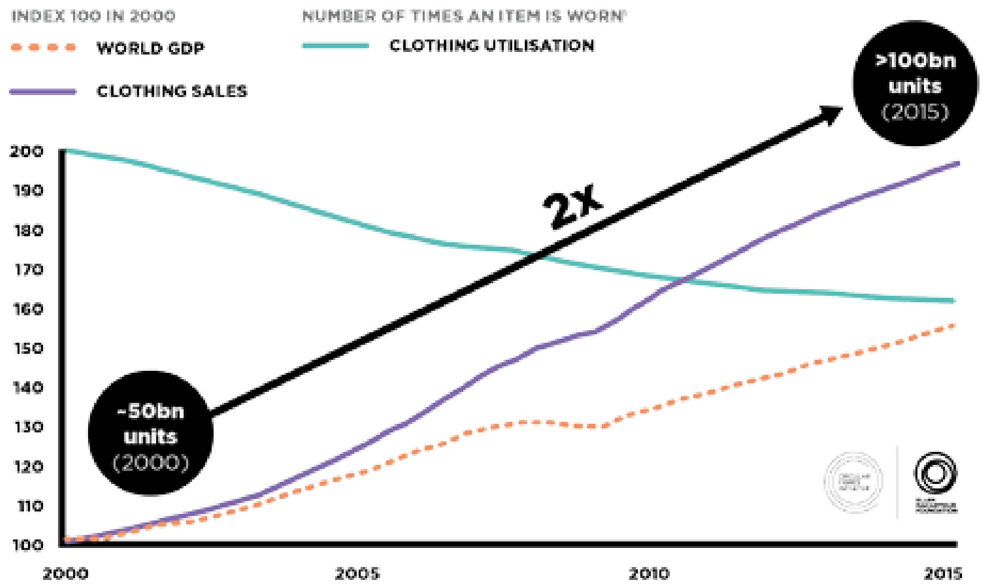


Fig. 24: Growth of clothing sales and decline in clothing utilisation, 2000-2015

mental and social impact of an industry. These include direct and quantifiable factors such as for example the choice of materials and their production processes, the question of recyclability and waste reduction, and the impact of transport in a globalised economy. However, another more complex layer of factors are for example the way the fashion industry is organized today and ethical concerns about the production of our clothes. In this chapter, I will focus on the factors that are directly related to the gap between the textile and fashion sectors, notably waste, transport, and finally the education and role of today's designers within a capitalist system of garment production.

Waste

The current system of garment manufacturing produces enormous quantities of waste. One source for such waste is the tremendous overproduction, which is mainly linked to overconsumption. According to Greenpeace's *Fashion at the Crossroads* report, 'the average person buys 60 percent more items of clothing every year and keeps them for about half as long as 15 years ago' (Greenpeace, 2017, p. 13). Overproduction is an uncomfortable topic for the textile and garment industry and it is therefore difficult to obtain solid data about clothes that are not sold or sold under their value due to overproduction. Nevertheless, it is safe to say that much more clothing is produced under the current system than anybody could ever wear. In 2017, Danish journalists even accused the global retailer H&M of burning 12 tons of overproduced stock per year (Engell, Vegendal & Fredriksen, 2017), a practice which the company denies (H&M, 2017).

British luxury brand Burberry has even acknowledged partly destroying its production to keep prices and the exclusivity of the brand high. In its annual report, the brand states that '[t]he cost of finished goods physically destroyed in the year [2018] was £28.6m (2017: £26.9m)' (Burberry, 2018, p. 165).

Another factor of waste production that is much more closely related to the question of the gap is pre-consumer waste, i. e. waste that occurs during the production process. Industry expert Gerry Cooklin estimates that the average quantity of fabric waste amounts to approximately 15% when the pattern pieces are cut from the fabric (Cooklin, 1997, p. 9). With an estimated 400 billion square meters of fabric produced annually, this leads to the considerable number of 60 billion square meters of fabric that are designed for the landfill every year (cf. Rissanen & McQuillan, 2016, p. 10). However, this number takes into account only the waste that is produced when the patterns are cut out of rectangular pieces of fabric. Allwood et al. go even further with their analysis by also taking into account the waste that is created in the production of the fabric. They have followed an exemplary production cycle for t-shirts and calculated the amount of material lost en route:

> In 2004, the UK imported 460 million T-shirts, valued at around £3.2 billion. To meet this demand 150,000 tonnes of cotton fibres were needed to produce yarn in the USA. In China 126,000 tonnes of fabrics were knitted from USA yarn. This fabric would have been bleached, washed, dyed and finished before being cut and sewn to create 115,000 tonnes of T-shirts (i.e. about 25% cotton waste arises in production). (Allwood et al., 2006, p. 26)

While the fashion industry mostly treats the problem of waste as an economic one, fashion designer and scholar Timo Rissanen also calls back to mind the environmental and ethical aspects of wasting fabrics. He points at the high amounts of water and energy required for the production of textiles and the far-reaching consequences this has for local populations such as water shortages and the excessive use of pesticides (Rissanen, 2013, p. 11f.). If, in consequence, 10-15% of a fabric is lost simply due to cutting out patterns, this means that 10-15% of the water and energy used to produce the garment were wasted due to an inefficient production process. Furthermore, designing for waste according to Rissanen also means devaluing the work of the producers of the fabric:

> It may be easy for a fashion designer to forget that someone, whether a textile designer or a textile engineer, designs every fabric; wasting any is wasting part of the embodied time and effort of textile design. (Rissanen, 2013, p. 13)

It is obvious that the most sustainable fabric is the one that does not have to be produced in the first place. However, the current practice in the fashion industry is very different, since zero-waste initiatives are far from being an industry standard. Nevertheless, sustainability researchers Kate Fletcher and Lynda Grose point out that the use of computer-aided design (CAD) has become widespread in the industry in an effort to reduce pre-consumer textile waste, mostly out of economic interest. Nowadays, computers calculate the most efficient way to place the patterns on a fabric and by this means reduce the waste to a minimum. This way of producing certainly makes a small contribution to waste reduction. However, it does not tackle the underlying problem itself, which is that it is logically impossible to cut non-rectangular pattern pieces from rectangular fabrics without generating waste. According to Fletcher and Grose:

> CAD programs work on efficiencies within the set parameters of an existing industrial pattern-cutting system. They do not have the capacity to accommodate completely new concepts for building clothing and they can therefore stifle the emergence of new innovations around reducing waste and the corresponding new aesthetic that these might reveal. (Fletcher & Grose, p. 48)

This way of thinking recalls Eric Broudy's critique on the mechanisation of the loom as a burden for innovation at the end of the previous chapter. It also points out that CAD technologies are more a reinforcement of a malfunctioning system than a solution, or, to say it in the words of World Bank economist Herman Daly: 'To do more efficiently something that shouldn't be done in the first place is no cause for rejoicing' (cited in Fletcher & Grose, p. 75).

It is only fair to say that sporadic attempts are made to revalue and recycle waste in the garment industry. This is especially the case in the luxury industry where more expensive materials are used. Burberry, for example, states that it has 'recycled 52 tonnes of damaged garments into geotextile materials and 51 tonnes of pre-consumer textile waste into regenerated yarns, fabrics and automotive insulation materials' (Burberry, 2018, p. 46). While it is certainly laudable that Burberry thinks about recycling solutions and is one of very few luxury brands to publish its efforts, its report lacks a critical analysis of why such waste occurs in the first place. In other words: Why is a brand like Burberry not capable of optimising its production in a way that it does not have to transform new high-quality textiles into lower quality yarns or automotive insulation? Because in the end it makes no difference if a car's insulation is made from shredded new Burberry leftovers or from shredded used cleaning rags.

A much more sustainable solution could be to integrate waste elimination directly into the production process. The knitwear industry especially has made significant progress in recent years to produce whole-garment and seamless knitting solutions. For these, a three-dimensional garment is produced directly from the yarn, which means that the intermediary step of producing a textile surface from which pattern pieces have to be cut out is eliminated. As Allwood et al. have explained, '[a] small whole garment can be produced in about 20 minutes by seamless knitting which is 30 to 40% less time than for conventional cut and sew manufacture' (Allwood et al., 2006, p. 33). Furthermore, such solutions could reduce the need for transport and therefore 'would allow production of smaller batches, including made-to-order production of individually designed and sized garments; the cost of stock-holding and the need for end-of-season price reductions would be reduced if production was fast and close to the retail outlet' (ibid., p. 30). Kate Fletcher additionally points out that next to the reduced time needed for production, 'whole-garment technologies reduce labour costs (there are no post-production labour costs) [...] and eliminate fabric waste or cut-loss' (Fletcher, 2014, p. 59).

It is true that seamless whole-garment solutions are currently mostly used in knitted fabrics and for products like sportswear and undergarments and might therefore be less appealing to high-end companies like Burberry. However, the second part of this thesis will present ideas on how to translate this technique into weaving as well and how it could be used to produce seamless garments without wasting resources.

Transport and globalisation

The production of whole garments directly from the yarn could also largely reduce the need for transport. In reality, however, the production chain of garments remains highly globalised and therefore geographically fragmented. The raw materials are grown or produced in one place, spun in another, woven or knitted in a third, and then cut and assembled at a fourth only to be transported to a fifth location for retail. Kate Fletcher has pointed out that 'the average T-shirt travels the equivalent distance of once around the globe during its production' (Fletcher, 2014, p. 166f.).

Several studies suggest that the environmental impact of transport is small when compared to factors like the manufacturing process or the use of water (Allwood et al., 2006, p. 27; Quantis, 2018, p. 22; Muthu, 2014, p. 22). However, given the large scale of the industry, it could still be worthwile to make an effort to reduce the impact of transportation in the supply chain of the textile industry. As textile management expert Rudrajeet Pal has pointed out, 'the increase in energy consumption [of clothing transported by road] is at a faster pace than that consumed by cars and buses, and is expected to surpass it in the next 10 years' (Pal, 2014, p. 250). He further points out that '[c]hanging freight from air or road to rail and water-borne transport can also significantly reduce the retailer's footprint' (ibid., p. 251).

However, it is not only the transport emissions that have to be taken into account. As shown in chapter 1, the introduction of capitalist production methods has led to a division of tasks in the Western textile and garment industry. In today's globalised economy, the tasks are not only separated but often exercised on different continents. This means that the single individuals ensuring their small part of the production of a garment are even more cut off, or, to put it in Marxian terms, alienated, from the product of their work. It is difficult for them to oversee the production process of the whole garment since they can hardly communicate with whoever comes before or after them in the production chain. This disconnection from the product as a whole could also be a factor to reconsider when trying to render textile and garment manufacturing more sustainable. Kate Fletcher relates sustainability to the concept of localism when she points out that 'in small communities people see and sense the effects of their own actions on each other and on the environment and are quicker to enjoy the benefits of change. Localism promotes a field of vision that is 'human' in scale' (Fletcher, 2014, p. 167). It is therefore likely that a concentration of several production steps in the same place can lead to production processes that are more thought through and put some control back into the hands of the individual worker.

The education and role of the designer within a capitalist fashion system

Several studies have indicated that up to 90 percent of a product's economic and environmental impact can be determined during its design phase (Graedel, Comrie & Sekutowski, 1995, p. 17; Hawken, Lovins & Lovins, 1999, p. 111; Lewis et al, 2017/2001, p. 13f.). This is because the role of designers goes far beyond assuring a product's looks. As design researchers Helen Lewis et al. have put it:

> Working alone, the designer's environmental role is limited; in combination with other disciplines, the designer emerges as a critical player in ensuring that a diverse and sometimes conflicting range of issues and considerations are successfully built into a product. It is ultimately the designer who creates the interface between the consumer and the technology underlying the shell or surface of a manufactured product. Thus the designer's ability to play the role of environmental champion is unequalled compared with others. (Lewis et al., 2017/2001, p. 15)

Nevertheless, Fletcher & Grose point out that despite being at the beginning of the production chain, designers often have too little time to overview the whole production process (Fletcher & Grose, 2012, p. 44). This is especially the case when considering the high time pressure under which the textile and apparel industries operate. According to Fletcher & Grose, this fact is aggravated by the hierarchical structure of these industries, since 'suggestions to amend designs [...] are rarely made by the technicians, for that would encroach on the expertise (and ego) of design' (ibid.). With such a lack of feedback culture and actual cooperation between fashion designers and other actors in the production chain, it is no wonder that change is slow in the fashion industry. It is often easier (and faster) to do things the way they have always been done instead of changing them and taking the expertise of all actors involved seriously - not only that of the designer.

The lack of communication between designers and technicians that Fletcher and Grose point at is also apparent in the exchanges between textile and fashion design. A higher degree of cooperation between the disciplines and a culture of asking curious and constructive questions could be beneficial in this context. Asking such questions should not be seen as probing each other's expertise but as a way to find new, innovative solutions with a common goal in mind: improving the production of garments ecologically and therefore also economically.

The foundations for change in the industry have to be laid in the education of young textile and fashion designers. If exchange, interdisciplinarity and communication are encouraged from an early stage onwards, this new culture of talking to and learning from each other will also be brought into the industry.

In her Anti_Fashion Manifesto, however, trend analyst and designer Lidewij Edelkoort draws rather disappointing conclusions for the generation of fashion designers that is currently prepared to enter the industry. Many educational institutions face high budget cuts and therefore focus on a very market-oriented education without critically asking if this market needs profound changes. According to Edelkoort, educational institutions continue to 'train[...] their students to become catwalk designers, highly individual stars and divas, to be discovered by the luxury brands' (Edelkoort, 2014, p. 1). This leads to the fact that 'the fashion world is still working in 20th century mode, celebrating the individual, elevating it-people, developing the exception...in a society hungry for consensus and altruism' (ibid.).

Edelkoort also observes that the exchanges between textile and fashion design are actually discouraged in many educational institutions: 'In the process [of budget cuts], the first to be sacrificed are knitting and weaving ateliers' (p. 2), leading to the fact that today many fashion students are no longer informed about the basic construction of textiles:

> Therefore they speak of chambray-like cottons and moiré-like silks since they have no clue what the constructions are all about. Some students even order their colours and fabrics on-line, further promoting a two dimensional world without the sensuality of texture, weight and drape. This ignorance of textiles is also rampant amongst journalists and recently we have seen prestigious magazines such as Vogue, Elle and Marie-Claire write about the important comeback of printed garments, while these coats, dresses and pants were actually realized in jacquard, which happens to be an intricate woven. Ladies! Do your homework! (Edelkoort, 2014, p. 2)

Apart from the lack of interdisciplinarity in the education of young fashion and textile designers deplored by Edelkoort, there is also a lack of education in terms of sustainability. Aurélie Mosse and Jean-François Bassereau, who are professors at Paris' Ecole Nationale Supérieure des Arts Décoratifs, point out several projects through which they aim to prepare their students for the ecological challenges they will have to face in the future and enable them to find more sustainable design solutions (Mosse & Bassereau, 2019). Nevertheless, they underline that sustainable design 'remains a sporadic approach' (ibid.) in French higher education.

This slow-paced integration of sustainable design into art school curricula may have a tendency to slow down much-needed changes to the system of garment manufacturing. Since the current system has more than proven its negative impacts on a planetary scale, a new and more radical generation of designers is often called for. Ann Thorpe, a sustainable design researcher, has pointed out how intertwined design still is with capitalist methods of production:

> Designers are trained to respond to clients and consumers, and add value to businesses. Governments develop policies that position design as a tool of economic growth. [...] Design is a key cog in the wheel of consumerism, so it is no wonder that most designers have trouble conceiving of their work in any other form than commerce and consumerism. Many designers fall back on the idea of making consumerism 'better'. (Thorpe, 2010, p. 15)

Thorpe therefore invites designers to rethink their role as mere producers of consumer goods and to develop '[d]esign strategies that help us meet needs with fewer purchased solutions [that] could lead to more sustainable consumption' (ibid., p. 16). Brooks et al. go even further by asking designers to question the capitalist background to their profession and by calling for a more radical and progressive and even utopian design:

> Radical visions of the future are required to help launch change, and progressive utopian ideas need to embrace different social futures and a revolutionary transformation of the relationships among fashion, consumption, technology, and the environment. (Brooks et al., 2017, p. 499)

Given the fact that textile and fashion designers often operate within a well-established and complex system of production, these radical visions and utopian ideas that Brooks and his colleagues ask for may appear difficult to implement in real life at first. After all, as shown in chapter 1, design as a separate profession has emerged from the capitalist logic of process rationalisation. However, given the flaws of the capitalist system, a new generation of designers should ask itself how to emancipate itself from this heritage and how a collective effort can be made to develop a more sustainable future. The educational system may have a hard time integrating the topic of sustainability into its curricula, but this does not mean that young designers cannot take action themselves. They can educate themselves on a wide array of subjects and try to re-establish connections between many different disciplines. Further approaches may be to reclaim the time to thoroughly develop their design proposals, and to redefine their sphere of influence by not limiting their profession to the conception of aesthetically pleasing consumer products.

Part II

Bridging the Gap

3. Techniques and Garments that Bridge the Gap

The first part of this thesis has provided an overview of the historical relationships between garments and woven textiles and has presented the way in which the textile and apparel industry work today. It has been argued that a gap has formed between the production of garments and textiles. First and foremost, this is because the weaving loom is still considered a tool to produce rectangular surfaces, while today's clothing construction mainly relies on non-rectangular pattern pieces cut from such surfaces.

This chapter aims to show different historical and current approaches at bringing garments and the textiles they are made of closer together again. It will present weaving techniques and design approaches from different parts of the world that tackle various aspects of constructing garments directly on the loom. These include techniques to shape pattern pieces in a non-rectangular way as well as fictional and existing examples of garments produced directly on the loom by means of inverting warp and weft fibres. Furthermore, three more recent approaches by contemporary fashion designers will be presented that attempt to conceive garments at the same time as their fabric.

This overview of techniques and ideas aims to stimulate a reflection on how these could be used as alternatives to the current system of garment manufacturing. Neither does it claim to be exhaustive, nor does it attempt to provide a chronological historical overview. It rather aims at presenting different aspects whose integration into today's production processes could be worthwile. Furthermore, it should constitute a framework that my practical work can be situated in, which will be discussed in the final chapter of this thesis.

The Turfan trousers

An interesting archaeological find was made in 2014 in Turfan in the Central Asian region of Xinjiang (China) that sheds new light on the historical relationship between textiles and clothing in this region. Fragments of two pairs of woven

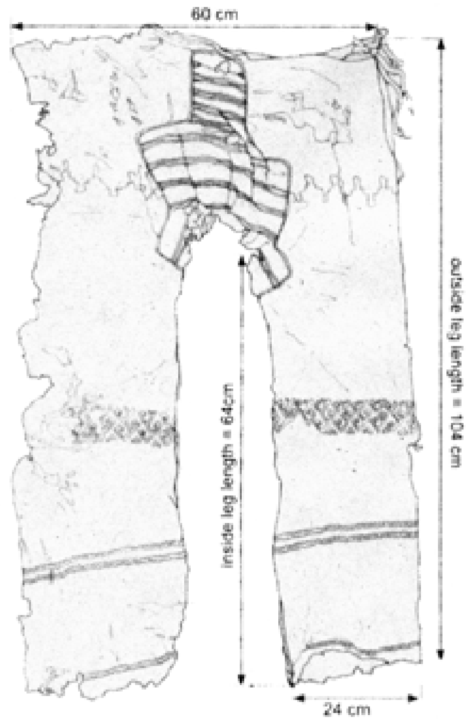


Fig. 25: Drawing of the Turfan trousers, c. 1300-1000 BC

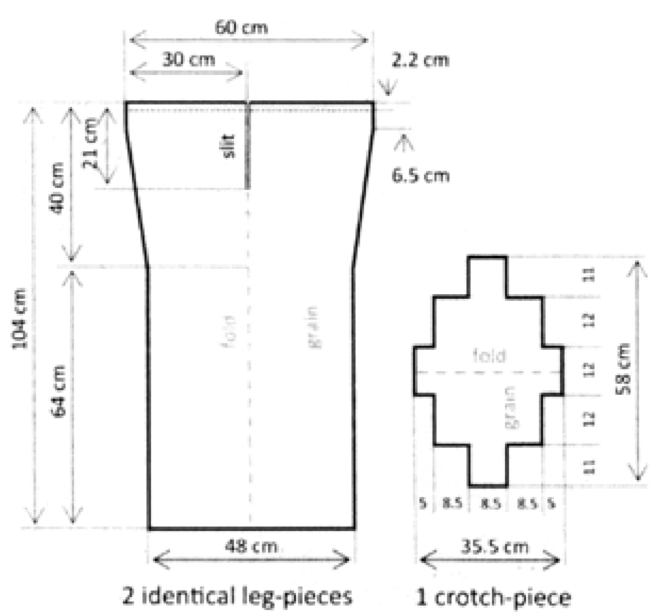


Fig. 26: Pattern pieces of the Turfan trousers

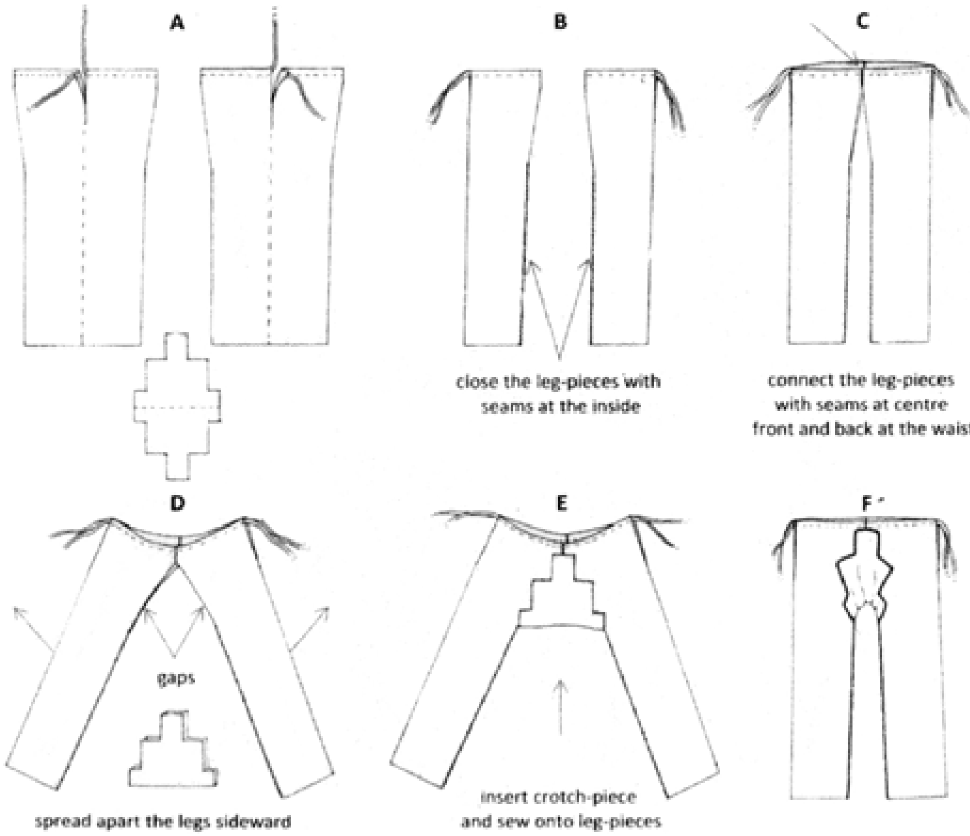


Fig. 27: Assembly of the Turfan trousers

woollen trousers were found in tombs that date from around 1300-1000 BC, a drawing of which is shown in Fig. 25. While the shape of these trousers gave archaeologists Ulrike Beck et al. new insights on horseback riding in this region, it is the peculiar weaving technique that proves interesting to analyse in the context of this thesis. For their report, which will be the basis for the following descriptions, Beck et al. not only analysed these trousers archaeologically, but, '[u]sing methods of fashion design, the cut of both trousers was studied in detail' (Beck et al., 2014, p. 224).

The trousers consist of three pieces of woven cloth, two identical leg pieces and one centre piece to connect them and to cover the wearer's crotch (Fig. 26). The leg pieces were not woven straight but become narrower towards the bottom part of the trousers, thus following the contours of the legs of the wearer. In the middle of each leg piece a slit was woven. The crotch piece is also not woven straight but has the shape of a stepped cross. All three pieces are realized in twill* weave and feature decorative geometric patterns in varying shades of brown. At the waist, the trousers were held in place by twisted strings made from the same material as the trousers and knotted together at the side slits. Fig. 27 illustrates the assembly of the three pieces by means of sewing. Beck et al. point out that the seams were covered with a decorative braid that was 'appliquéd with a woolen thread in the same brown as the basic colour of the trouser legs' (Beck et al., 2014, p. 228). They also remark that the hems did not feature a trimmed edge but that 'loosened threads [were] hanging from both hemlines' (ibid., p. 230).

Beck et al. further give very interesting interpretations of the production process of the trousers:

> The three pieces [...] match in colour and weave, suggesting that they were made from the same wool and woven by the same person or at least in the same workshop. The side slits were already woven into the textiles of the trouser legs during the weaving operation. There is no indication that the cloth was cut. These features prove that the three pieces of fabric were, from the very beginning, planed [sic] and manufactured for their later function as parts of one pair of trousers [...]. Small functional features, such as the slits at the sides and the strings, as well as their ornaments, were woven into the fabrics at the correct positions with regard to their later purpose and aesthetic appearance. This requires that the weaver was familiar with the entire sewing process of the trousers and the size of the intended user. [...] Weaver and tailor either cooperated closely or were one and the same person. (Beck et al., 2014, p. 230)

In the context of the gap between textiles and garments, Beck et al.'s observations are very interesting, especially when comparing them to the way garments are produced today. Instead of cutting the different pieces from a rectangular piece of fabric, they were directly woven into the desired shape and according to the measurements of a specific person. This production technique also implies that no resources were wasted to produce the garment. Furthermore, the different production steps were controlled either by one person alone or a second person whom they cooperated closely with, which is a stark contrast to the fragmented process of clothing production pointed out in the previous chapters. The example therefore shows that a closer cooperation between textile and garment makers can lead to garments that are closely connected to the fabric they are made of. It also allows for a careful and thorough planning of the garment from the beginning to the end.

It would be interesting to learn more about the looms used to produce the components of these trousers. While no looms from this period have been found so far, it is very interesting to see that in both the leg and crotch pieces, the restrictions of rectangular weaving were entirely abandoned. Furthermore, while these trousers are rather different in appearance from the ones worn today, their technique could be adapted to meet modern clients' expectations. If, for example, a production process was developed that would facilitate the creation of finished pattern pieces woven directly on the loom and that would therefore omit the need for a large amount of intermediary production steps, clients could be much more involved in the design process. It would be much easier for them to make individualised demands for colours, shapes or weaving patterns and the resulting garment would therefore be more adapted to their actual demands. This could create a greater attachment to the garment, which could imply that it would be worn more often and treated more carefully than conventional fast-fashion. Combined with the reduction of pre-consumer waste, this would mean a large improvement in terms of sustainability.

Pre-Columbian shirts from Peru and Chile

Another example of garments whose components were woven directly in the desired shape are pre-Columbian shirts found in Peru and Chile (Fig. 28/29). Their appearance is difficult to date since few historical sources from before the Spanish conquest remain. However, they are part of the 'stunning catalogue of [Peruvian] fabric techniques' (Broudy, 1979, p. 81) that was fully developed by the time of the Incas (c. 1100-1532). Eric Broudy explains that the garments shown here circumvented tailoring since they were directly shaped on the loom to fit the contours of the wearer. He mentions several techniques that could have been used to achieve such garments, even though evidence for the actual looms they were produced on is scarce. He explains for example that 'by adding double warps through a looped end of a single warp the weaver could broaden - or by reversing the technique taper - the textile' (Broudy, 1979, p. 81). Other techniques could have been 'angling one or both loom bars, adding extra wefts, or adjusting warp tension' (ibid.).

Analysing these shirts, Bauhaus textile designer Anni Albers also concludes that '[they] are, by adding or dropping warp threads, woven wider at the shoulders than at the waist' (Albers, 1974/1965, p. 57). However, by making a connection to current processes of garment manufacturing, Albers thinks that this technique of shaped weaving is nowadays becoming obsolete:

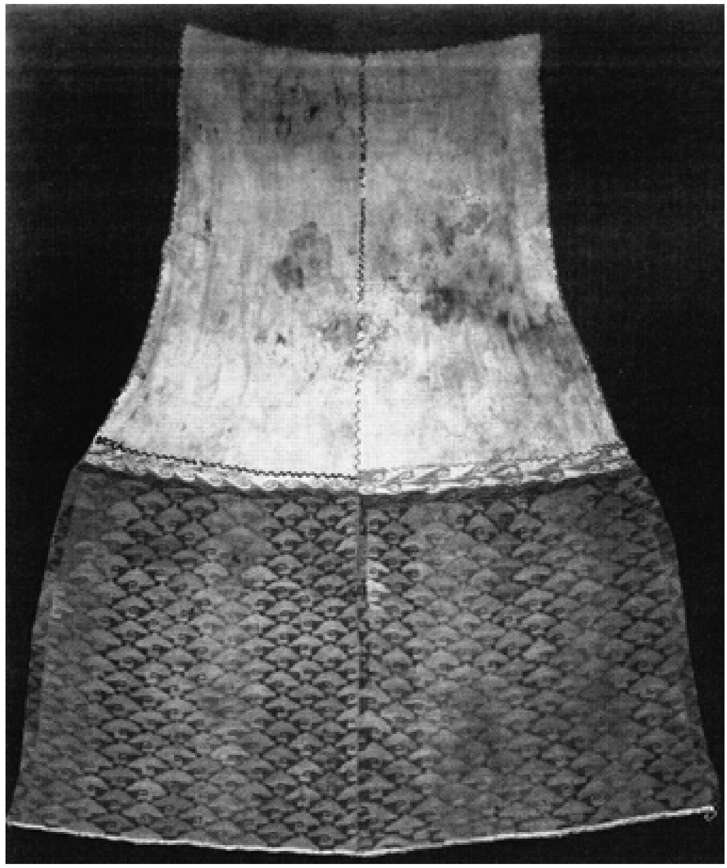


Fig. 28: Pre-Columbian shaped garment from Peru

Fig. 29: Pre-Columbian shaped garment from Northern Chile

> Today this problem of shaping, usually linked to clothing, is effectively solved by the process of knitting, which is moving more and more to the foreground. Our nylons, our underwear [...] are now produced by this process. Besides the advantage of shaping, the time-consuming warp preparation of weaving is here eliminated, and the elasticity of the product suits our present-day needs better in many cases than the stable fabrics resulting from the horizontal-vertical construction of woven materials. These usually demand more laborious tailoring or complicated draping to give them shape. Furthermore, our new synthetic materials can now be molded in some cases and are moving us further toward fabrics shaped in the process of production rather than afterwards. Thus, with a long glance backward we can discern the rise of the technique of weaving, and with a long glance forward we may see it perhaps dimming in its dominance. (Albers, 1974/1965, p. 57f.)

While Albers is a highly skilled weaver and scholar and has drawn a lot of inspiration for her work from Native American weaving techniques, her analysis here clearly reflects the time in which it was written. First and foremost, the high potential Albers sees in synthetic fibres in the 1960s needs to be revised today, especially considering the environmental problems these materials bring with them because they are not biodegradable (Zalasiewicz et al., 2016; Brooks et al., 2017, p. 486; Ellen MacArthur Foundation, 2017, p. 66f.; Greenpeace, 2017, p. 29f.).

Secondly, while knitting surely is a very suitable technique for many purposes, it would be a disadvantage to leave behind the technique of weaving in its favour. This is mainly because knitting and weaving produce very different textile surfaces that are used for different types of garments. Knitted fabrics are stretchable, which means that they are mainly used for garments that are worn close to the body and that require a higher degree of flexibility of movement. Woven fabrics, on the other hand, are stiffer, which is due to the orthogonal alignment of the fibres. They are therefore more suitable for garments that require less movement. Additionally, there is an aesthetic difference between knitted and woven textiles. While knits consist of interlaced loops and therefore often give the impression of a more open and structured surface, many wovens usually have a much denser, less transparent and smoother appearance.

Another point in favour of developing both techniques at an equal pace is that given the complex ecological challenges the world faces today, it is an advantage to have alternatives at hand. The more techniques we have at our disposal, the more flexibility we have in adapting the manufacturing of garments to our environmental and economic needs. Furthermore, as pointed out in the previous chapters, weaving and especially the loom have not yet been developed to their full potential. Just because techniques like shaped weaving have not yet been exploited industrially does not mean that they should not have a valid place in garment manufacturing today. On the contrary, it could be quite fruitful to explore their integration into current production processes in more detail. An approach at merging the two techniques will be discussed in chapter 4.

The Otomí loom and multi-selvedge weaving

Another example of shaped weaving can be found in the *quechquemitls* produced by the Otomí indigenous people in Central Mexico. The quechquemitl (Fig. 30) is a poncho-like garment that has been worn by native people all over Mexico since pre-Cortesian times. Ethnologist Bodil Christensen points out that the garment can have a large variety of shapes (Fig. 31) but that it is 'usually made of two rectangular pieces of cloth sewn together by joining the end piece of one [...] to the long side of the other [...], and vice versa, thus forming a garment with an opening in the middle for introducing the head' (Christensen, 1947, p. 301).

According to Christensen, the Otomí developed a backstrap loom that 'produces the two pieces of the quechquemitl not exactly rectangular but woven into shape, forming a graceful curve which falls over the shoulders' (ibid.). This curved shape is achieved by 'using part of the warp as weft' (ibid.). Fig. 32 shows an illustration of this intricate weaving technique.

Another peculiarity of the Otomí loom shown in Fig. 32 is the way that the warp fibres are attached to the loom bars, which allows additional selvedges* to be woven. Conventional hand-woven fabrics have two selvedges. These are created by the fact that the weft yarns form loops around the very last warp fibres on the left and right side of the fabric. In order to remove the woven piece from the loom, the warp ends are cut and need to be knotted together or sewn at the top and bottom edges to ensure that all the weft fibres are contained in the fabric and will not be loosened and fall out. The selvedges, however, do not need such a treatment since all the warp fibres are securely contained.

The Otomí loom, just like ancient Peruvian backstrap looms (Fig. 33), permits the weaver to not only form selvedges with the weft yarns, but also with the warp fibres. These are

Fig. 30: Modern Mexican
quechquemitl

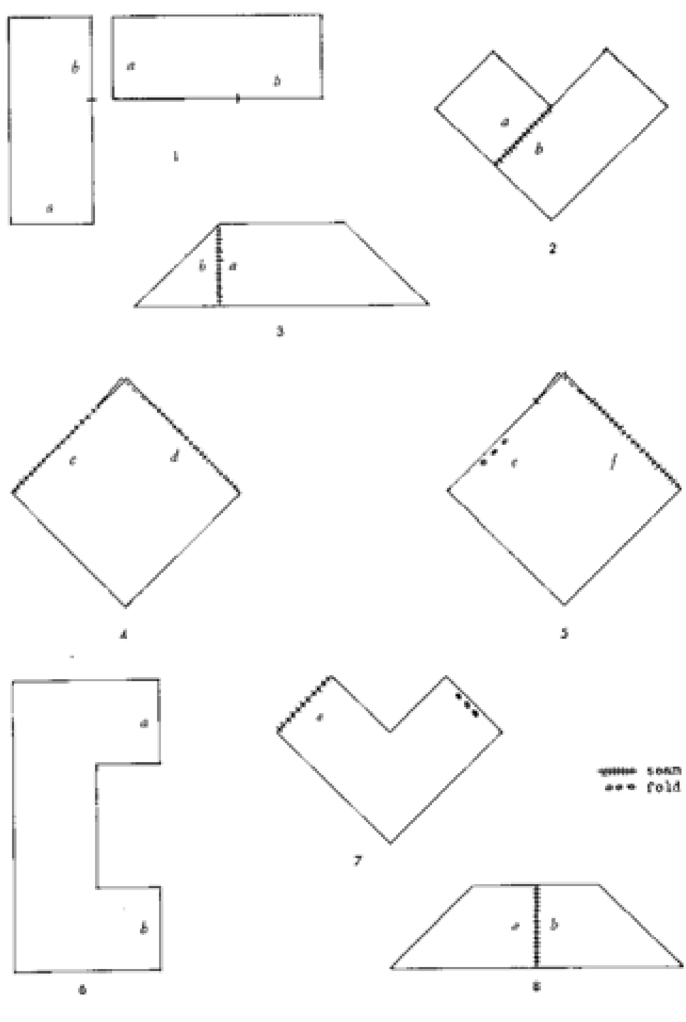


Fig. 31: Different shapes of
quechquemitls

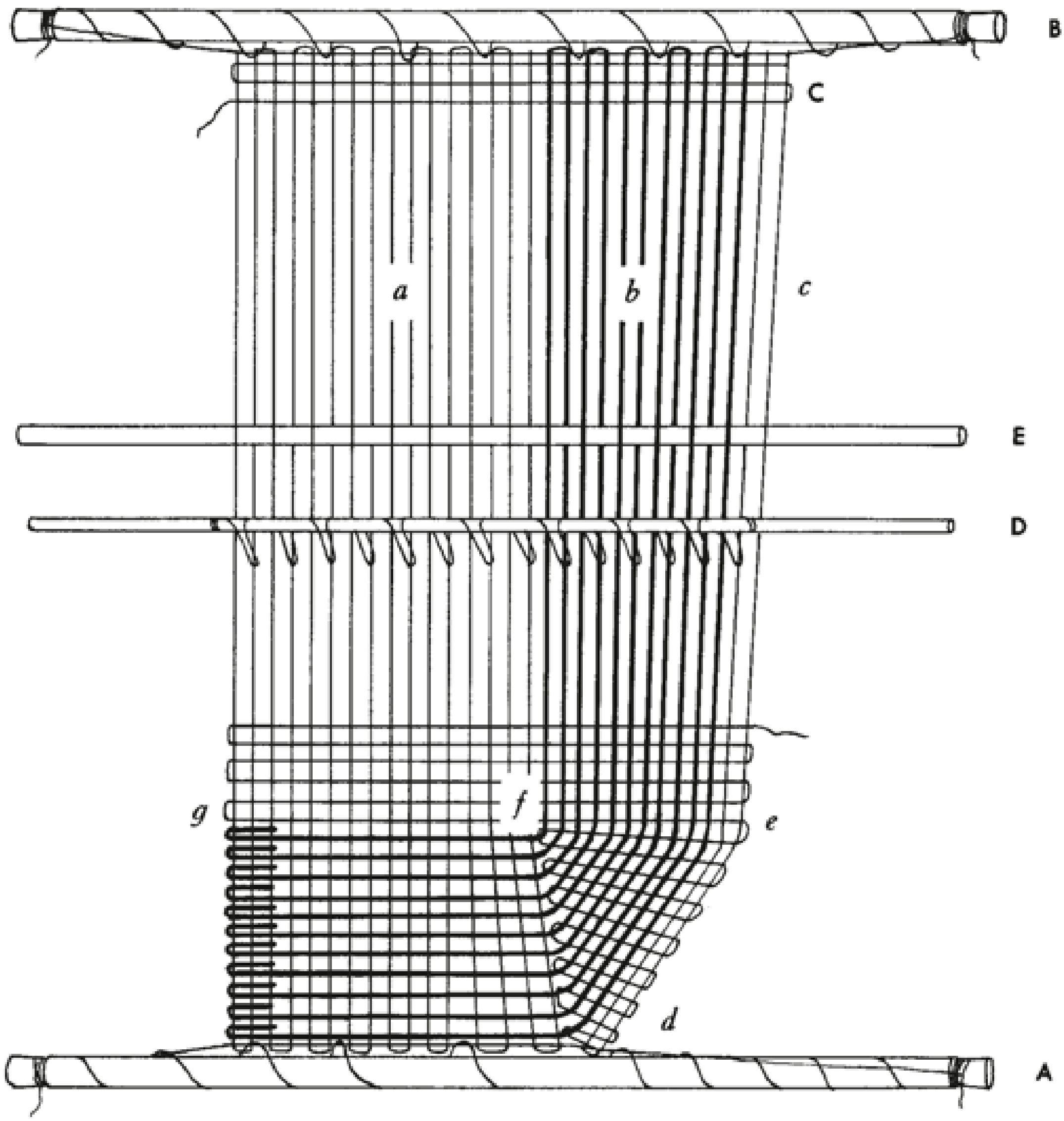
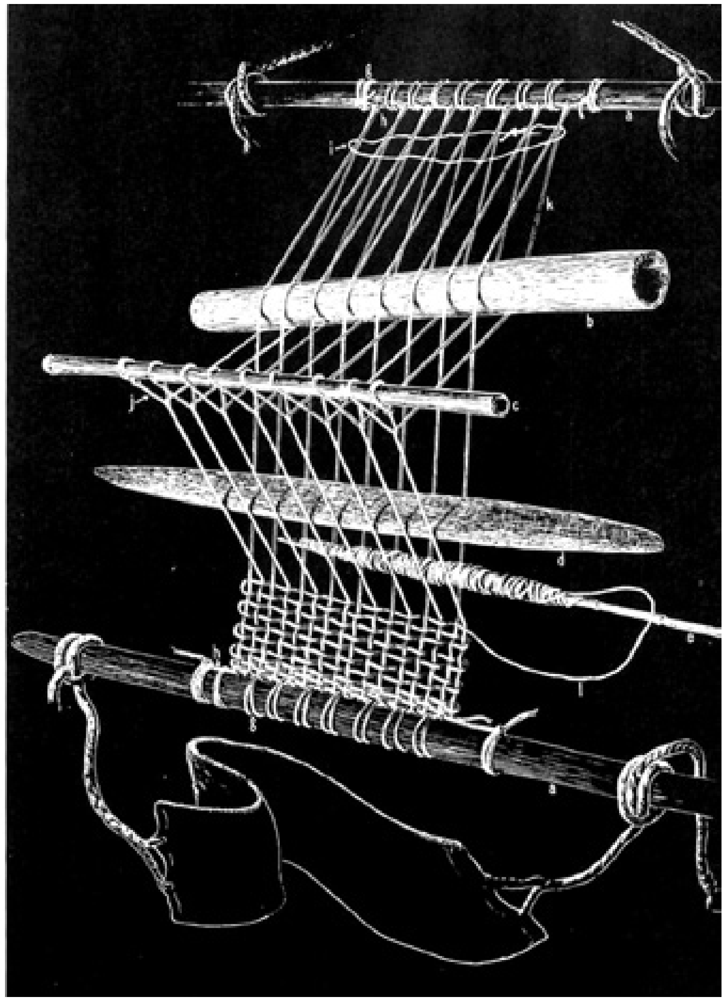


Fig. 32: Drawing of an Otomí loom in which warp fibres become weft and vice versa to form the edges of a *quechquemitl*

looped around heading cords, which in turn are attached to the loom bars. The set-up of this loom allows the weaver to start weaving at the lower end of the loom, right above the lower loom bar, thus turning the loops of the warp yarn into an additional selvedge. Eric Broudy points out that to make a fourth selvedge, 'the weaver had only to turn the loom around after starting one end and to begin again at the other, finishing where she left off, near the original cloth beam' (p. 80f.). This means that these looms can be operated from both sides. As can be seen in Fig. 32 and Fig. 33, a few weft yarns have already been introduced in the upper part of the warp.



5. Back-strap loom (diagram) of the type used in Peru.
- a. Loom bars.
- b. Shed-rod.
- c. Heddle-rod.
- d. Batten or sword.
- e. Bobbin.
- f. Back strap.
- g. Warp lashing.
- h. Heading string.
- i. Lease cord.
- j. Leach cord.
- k. Warp.
- l. Weft.

Fig. 33: Traditional Peruvian backstrap loom allowing to weave four selvedges. Legend by Anni Albers.

Bodil Christensen further elaborates on the problem that when weaving from both sides of the loom, the shed becomes extremely small around the shed roll (E in Fig. 32). She points out that therefore '[t]hinner and thinner sticks are used as shed rolls, and when at last not even the thinnest shed roll can be used, the picks* are put through by means of a long coarse needle' (p. 309f.). After the shed roll has been removed, the small remaining space is then closed by pushing together the weft yarns with a comb (ibid.), meaning that the density of the weft picks is losened up to cover the remaining small bit of unwoven warp.

Another technique to create additional selvedges, observed mostly in Lapland, is to weave a so-called starting border. It is closely linked to the continuing use of the warp-weighted loom in Scandinavia, pointed out in chapter 1. The starting border, which is the top edge of the fabric, is woven separately on a

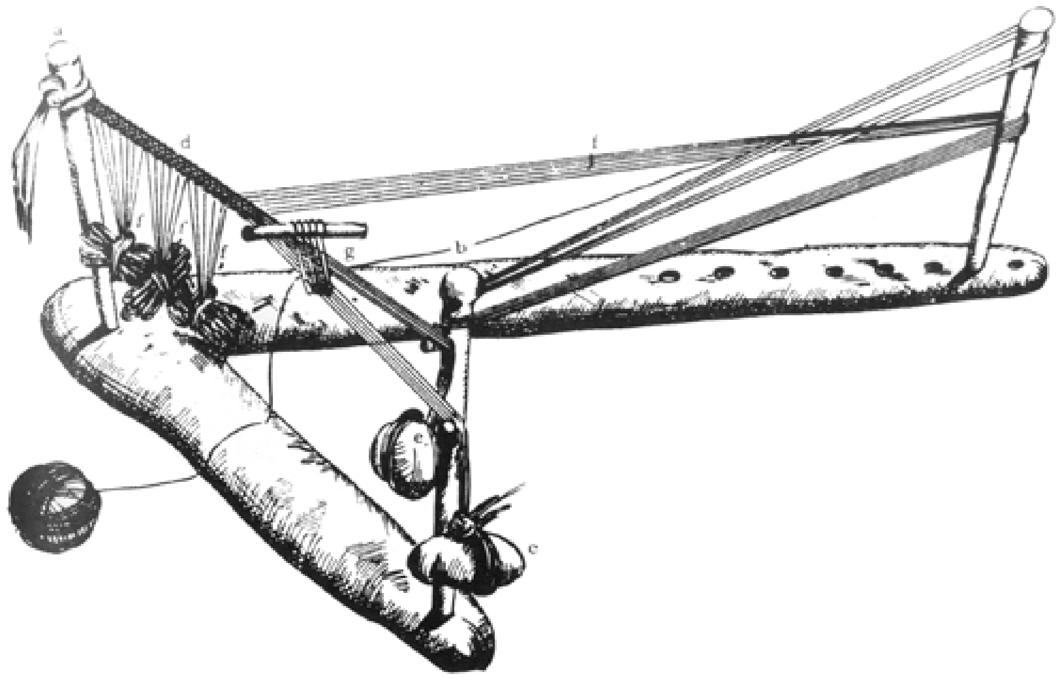


Fig. 34: Starting border device
from Lapland

dedicated device (Fig. 34). A small strip of fabric is woven whose length corresponds to the desired width of the final fabric. During weaving, the weft threads are left long on one side to later form the warp. When completed, the border piece is attached to the top of a vertical warp-weighted loom with the long weft fibers facing to the floor and becoming the warp. Eric Broudy points out that while this technique may seem overly complicated at first, it provides two advantages: 'it spaces the warp evenly and provides a strong third selvage for the fabric' (p. 31).

These techniques of creating additional selvedges do not necessarily aim at producing finished garments on the loom. Nevertheless, they provide an interesting approach toward reducing the post-treatment effort required for the woven piece by creating more than two secure selvedges that no longer need to be hemmed. Furthermore, despite being used for different purposes, the starting border technique shows a level of ingenuity similar to the one of the Otomí looms presented earlier. Turning warp into weft fibres during weaving and vice versa is not at all common in conventional weaving today. This might be because weft and warp are often considered to be such distinct entities that mixing them might seem confusing at first sight. Furthermore, the loom as it is used in the Western world today is simply not designed to support such a way of weaving. Yet the the technique provides an enormous potential for producing finished garments directly on the loom. It will therefore be further explored and reflected on in chapter 4 in respect to my own practice.

Johannes Braunius' loom

Another interesting attempt at producing garments directly on the loom and at reusing long weft fibres as warp can be found in Europe. In 1680, Dutch theologian and scholar Johannes Braunius described a very peculiar loom and weaving technique in his *Vestitus Sacerdotum Hebraeorum* (Clothes of the Hebrew Priests). Braunius had found many ancient and biblical sources that talked about 'tunics which are seamless, round, and closed from all sides' (Braunius, 1680, p. 357). At another point, he explicitly underlines the fact that these garments had sleeves (p. 354). He further explains that he was pondering the question of which tools the ancients could have used to achieve such a seamless garment woven in one piece. He found artisans and weavers who could build such a tool and weave a seamless tunic with sleeves on it. Apparently, this was a difficult task, 'since not every weaver in this town could follow [his] mind' (ibid., p. 358). The drawing he includes of this tool is of extraordinary detail (Fig. 35) and he also gives a precise description of it. This latter has been translated into English by the British historian Henry Ling Roth (1918). A shortened and commented version of this translation will be reproduced in the following, since it is crucial to understand Braunius' intricate loom design. In the first part, Braunius presents the basic set-up of his warp-weighted loom and specifies that the upper part of the tunic woven on it is tubular, while the lower part consists of two separate woven surfaces:

AAAA. — Loom, or ancient weaver's beam. An upright loom. [...]

B. — Shirt, rounded and closed without seam; "seamless" [...] as was the shirt of Christ [...]. Otherwise "tunica recta." [...] This shirt is woven in an upward direction; for the weaving begins from the topmost thread CC and gradually works down to D. [...] The shirt is rounded and closed from B to I; then, however, it is divided to D and E, as men's undergarments usually are to-day.

[Braunius continues by explaining that the sleeves are constructed by leaving the upper weft threads long and subsequently reintroducing them into the loom:]

CC. — Threads, which are part of the weft (trama), but so prolonged beyond the body of the shirt that at last they can be made the warp (stamen) of the shirt-sleeves. When the finished shirt is taken off the loom, the threads CC are cut at the ends; they are afterwards turned in, and finished off in the same way as BD.

[Braunius then explains that the garment is constructed by using two different warps that are separate at the lower and joined at the upper part of the garment. He further points out the weights that assure the warp tension and the tool used to push the weft threads upwards and explains how the upper tubular part of the garment is woven.]

DE. — Two warp-threads, of which D is the anterior, and E the posterior; they are joined by one and the same thread to the weft, and plaited together[...].

FF. — Weights with which the warp threads in this manner of weaving were weighted [...].

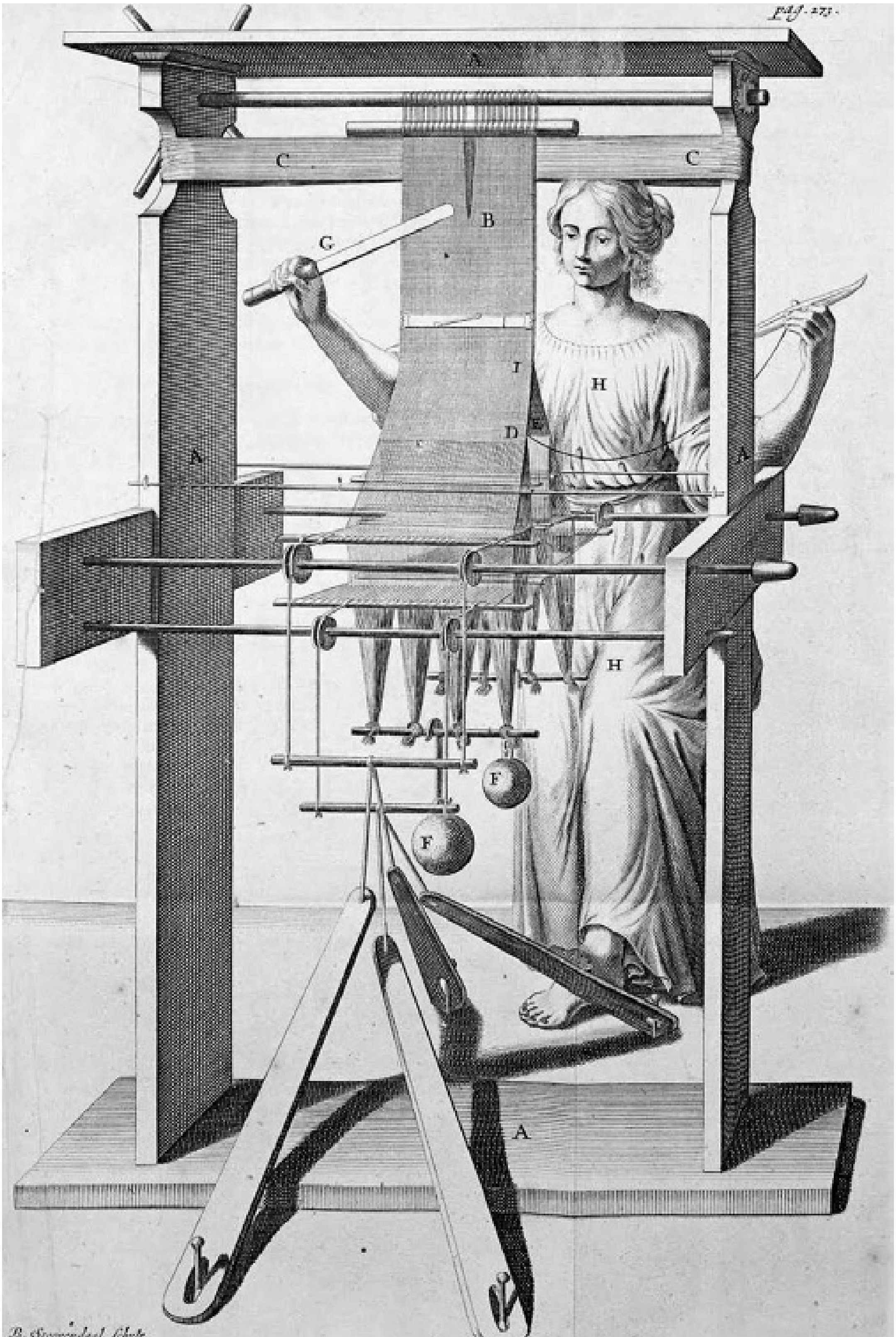
G-. — Spatha, [...] an instrument used for keeping the threads of the weft together [...].

H. — The woman-weaver, holding the spatha in her right hand for the purpose of bringing the weft together, by pushing the threads upward; in the left hand she holds the weaver's shuttle. Moreover, she weaves standing, not sitting [...]. As she weaves she walks round in a circle; for when she has passed the shuttle or weft through the web or threads D, she has to go round the whole loom, so that she may pass the same shuttle and weft through the threads E, in order that the webs D and E may be woven together [...]. (Ling Roth, 1918, pp. 125-126)

In addition to Braunius' explanations, another particularity about his loom should be noted. In Fig. 35, the weaver places her foot on what seems to be a treadle that activates a complicated mechanism to change the shed. Braunius' design therefore seems to be a combination of an ancient warp-weighted loom and a treadle loom that was introduced in Europe in the 11th century. While it is unlikely that such a combination has ever existed in another loom than Braunius', it shows that he has made a very thorough effort at producing a functioning loom that produces seamless tunics, while at the same time inventing new techniques to operate it.

It should be underlined here that Braunius' approach of inventing a tool in his own time that ancient peoples may have used is completely devoid of any historical accuracy when measured by modern standards. There is no evidence that ancient looms looked like this and the sources Braunius uses would need to be studied in much more detail to determine what they meant by seamless garments. This is why historians

Fig. 35 (opposite page): Johannes Braunius' loom weaving seamless tunics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H
D
E
A
A
H
F
F
A
B. Stoopendaal sculp.

such as Joachim Marquardt or Hugo Blümner have discredited Braunius' loom as 'fiction' (Marquardt, 1882, pp. 502-503; Blümner, 1875, p. 138).

However, apart from its limited value for historians, Braunius' loom is of great ingenuity. Not only did he invent a way to weave tubular fabrics on a vertical warp-weighted loom, but he also found a working solution to produce finished garments directly on the loom without sewing. The sleeves consist of weft fibres that are left long in the beginning. Once the middle part of the tunic has been woven, these former weft fibres can be turned into warps and reintroduced into the loom. This reminds of the techniques introduced in the previous section that also exchange warp and weft fibres and it shows the degree of inventiveness that Braunius was capable of.

Ling Roth also underlines that Braunius' loom is fully functional in principle. However, he considers that the fact '[t]hat it has not survived is no doubt due to its complicated nature, coupled with the warp-weight system' (Ling Roth, 1918, p. 126). He is right by pointing out that in practice, operating Braunius' loom would be extremely tedious and time-consuming and its use unimaginable in a capitalist system of garment production. However, this does not mean that the technique of exchanging warp and weft fibres itself is futile. It simply lacks the right tool to be integrated into modern production processes. The example further shows that the loom as we know it today is maybe not yet fully developed and could take different shapes. This idea will be elaborated in more detail in chapter 4 when talking about my design practice.

A-POC (A Piece of Cloth)

A much more recent attempt at producing garments at the same time as their textiles can be seen in Issey Miyake's and Dai Fujiwara's *A-POC (A Piece of Cloth)* collection first presented in 1997. While some garments of the collection were woven, its main part consisted of garments produced in the technique of circular knitting. Nevertheless it will still be discussed here as it can be considered a radically new approach to garment-making that intentionally breaks with the standards of the industry. Miyake describes the idea behind *A-POC* as follows:

> Will fashion be able to afford to keep the same old methodology? I have endeavoured to experiment to make fundamental changes to the system of making clothes. Think: a thread goes into a machine that in turn, generates complete clothing using the latest

> computer technology and eliminates the usual needs for cutting and sewing the fabric. The idea stemmed from my desire to make a contribution to environmental protection and the conservation of resources. [...] With a little imagination, we might even be able to go beyond making clothing to making robots! I believe that technology can function only as long as we have the ability to imagine, a sense of curiosity and a love for our fellow men. (Miyake, 2001, p. 68f.)

This new holistic approach to producing garments directly from the thread is unusual for a number of reasons. It implies that the garment and the material it is made of are planned at the same time, which means that both go together in a more optimal way than is the case in conventional garment-making. Furthermore, it completely omits the production of patterns to be cut out from the fabric by directly producing the finished garments on the knitting machine or loom. Additionally, while embracing the fact that garments are manufactured industrially nowadays, it holds a place for the human imagination. This is because it does not aim to invent one technique that will produce endless amounts of clothing, but rather seeks to provide new tools to the designer to constantly reinvent garments with the help of technology. This is especially the case since Miyake did not limit *A-POC* to one season, but rather sees it as an ongoing process which has developed over a longer period of time.

One of the first garments of the collection to be presented was *Just Before* [Fig. 36], in which an industrial knitting machine produces a continuous strand of tube-knit dresses which could be cut out in different predefined shapes, which, according to Miyake, 'enables every woman to participate in the last stage of the creation of her own dress, using her own criteria' (Miyake & Fujiwara, 2001, p. 62). A similar technique was used in *Le Feu* (Fig. 37). Woven *A-POC* garments include *Pain de Mie* (Fig. 38), which consists of a double-layered woven rectangle that can be cut along predefined lines and thus turned into different seamless garments, and *Frame Work: Woven* (Fig. 39). The latter is a jacquard weave in which simple pattern pieces are predefined in a rectangular 'template that enables the creation of up to 64 varieties in one entire range' (ibid., p. 60). While in this last piece the problem of waste related to the pattern-cutting technique remains, the modular nature of the different pieces means that '[t]he production of one small lot accomodates a wide range of individual demands' (ibid.).

Apart from this focus on a new way of garment production that includes consumer participation and modularity, it

Fig. 36: Issey Miyake & Dai Fujiwara: *Just Before (A-POC)*, 1997

Fig. 37: Issey Miyake & Dai Fujiwara: *Le Feu (A-POC)*, 1997

should not be forgotten that Issey Miyake is a luxury brand that operates within a capitalist fashion system. It is famous for its innovative designs which make bold visual statements that many mainstream consumers may find hard to integrate into their wardrobe. This means that even though *A-POC* tackles the notion of industrial garment production, its target audience could be considered marginal since it must be both fashion-oriented and able to afford designer garments.

These reflections should not discredit Miyake's and Fujiwara's intentions to make fundamental changes to the production of garments, but it should be critically questioned whether such changes can be called sustainable if they only touch a very small target group. Furthermore, this target group is expecting such radical approaches from a brand like Issey Miyake. When recalling Sarah-Grace Heller's statement that '[f]ashion systems constantly reject the immediate past' (Heller, 2010, p. 25), it becomes clear that innovation is intrinsic to fashion culture, and that a brand like Issey Miyake is no exception here. While it is certainly time to introduce new production methods in the luxury sector as well, the question is whether these are long-lasting or subject to change in the next season. While Miyake and Fujiwara have explicitly pointed out that *A-POC* is an ongoing project that is disconnected from the logic of seasons, it will be interesting to see whether the brand will stick to its ideals in the future.

Fig. 38: Issey Miyake & Dai Fujiwara: *Pain de Mie (A-POC)*, 1999

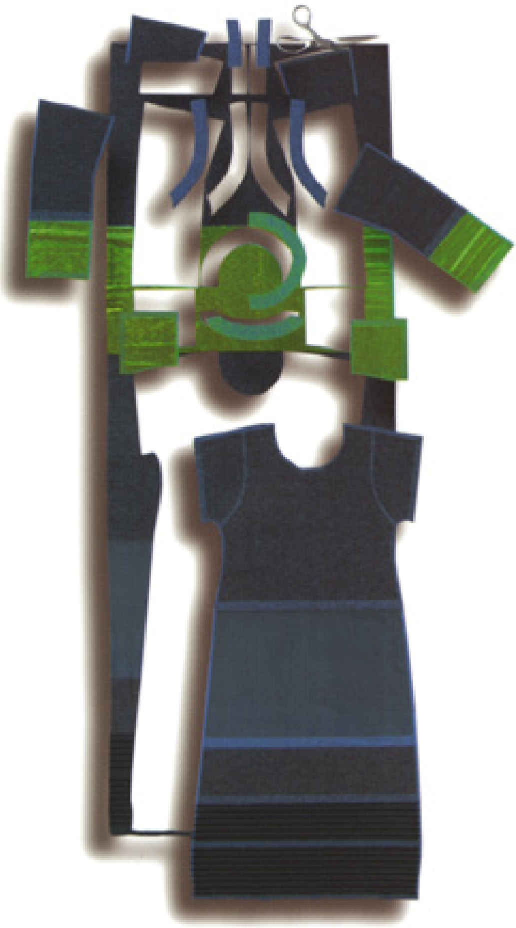

Fig. 39: Issey Miyake & Dai Fujiwara: *Framework: Woven (A-POC)*, 2000

466km/fil

Another proposal for the production of garments from a single thread is the work of fashion designer Jeanne Vicerial who is currently finishing her PhD thesis at École Nationale Supérieure des Arts Décoratifs in Paris. A main conceptual focus of her work is the shift of the fashion industry from bespoke-tailored garments that are adapted to the individual body towards ready-to-wear apparel that requires the adaptation of the body to industry standards. Vicerial therefore aims to reintroduce the notion of custom-made garments into the production of clothes. She finds inspiration for her designs in the human muscular structure and thus readapts her garments to the individual body. Furthermore, she considers herself a surgeon who studies clothing as a product of a "sick" fashion industry:

> Face à ces questionnements et aux différentes problématiques rendant obsolète et malade l'industrie de la mode, je souhaite développer une collection sur la notion du sur-mesure en étudiant le vêtement comme un médecin, un chirurgien afin de répondre de façon alternative à la production vestimentaire contemporaine. Pour toute création vestimentaire, il me semble nécessaire de m'attarder sur la sémantique du vêtement afin de repenser nos modèles de conception et de production. Pour moi l'anthropologie s'impose dès lors comme la discipline du futur. (Vicerial, 2017, p. 4)

For her master's project, Vicerial has therefore developed a collection called *466km/fil*, wherein 466km refers to the total length of recycled thread used in the collection. Every piece was constructed directly on the mannequin by using a technique that Vicerial has developed and that she calls 'tricot-tissage' ('knit-weaving') (Vicerial, 2017, p. 3). She uses one continuous thread to connect different predefined points and thus manages to construct custom-made garments without generating any waste (Fig. 40/41). During her PhD she has successfully translated her approach into a proposal for a new technique of semi-automatised garment production. In cooperation with the École des Mines ParisTech, she has developed a machine in which a robotic arm uses her technique to automatically construct the garment according to the individual measurements of the wearer.

Vicerial's technique is interesting in the context of this thesis as it addresses a number of issues evoked in the previous chapters. Not only does she radically question the way the textile and apparel industries work today, but she has also managed to invent a tool that constructs a garment at the same moment as its textile. Like Miyake and Fujiwara, she

Fig. 40: Jeanne Vicerial: *Robe Épine Dorsale 140km/fil*, 2015

accepts the fact that garments are produced industrially nowadays, but shows a way of reintroducing a notion of individuality into the production process.

Fig. 41: Jeanne Vicerial: *Radiographie portative*, 2015

However, the reflections made on Miyake's and Fujiwara's *A-POC* collection in the previous section are partly also applicable to Vicerial's work. While her garments have a high visual appeal and function well as concept pieces and as illustrations of her technique, many people may find it hard to wear them on a daily basis. For the moment, it might not be Vicerial's primary goal to cater to a mainstream market, but her technique could be promising for this very market if it was extended to include more wearable proposals since this would allow for a more widespread proliferation of her idea. Furthermore, as outlined in relation to the Turfan trousers, individualised garments such as Vicerial's could strengthen the emotional link between a garment and its wearer while drastically reducing fabric waste. Nevertheless, it should be acknowledged that new techniques often bring new aesthetics with them, but it is between these new aesthetics and the expectations of the consumer that a successful balance needs to be found.

Zero-waste fashion design

Yet another approach toward re-evaluating the relationship between a garment and the fabric it is made of can be found in zero-waste fashion design. While several designers have made attempts at reducing waste in the pattern-cutting process, it is the work of Timo Rissanen that will be pointed out in the following. This is mainly because Rissanen has presented a quite comprehensive body of work in this field and because this topic forms the main concept of all his designs.

According to Rissanen, '[a] zero-waste garment [...] refers to a garment that has been designed and pattern cut in such a way that when the garment is cut, all of the fabric is in the garment, and none is left behind as off-cut waste' (Rissanen, 2013, p. 2). His approach at garment-making is therefore based on adapting the patterns that are to be cut from a fabric to its basic rectangular shape. In this way, he uses all of the fabric at hand and not only the pieces needed to construct his garments.

Rissanen identifies one source of pre-consumer waste in the lack of communication between the fashion designer and the pattern cutter. In many cases, these are two distinct professions whose relationship is defined in a hierarchical way since the pattern cutter is often considered a technician who has to translate the designer's sketches into concrete garments. Rissanen, however, points out that '[i]n contrast to this dominant hierarchy of roles, pattern cutting is integral to zero waste fashion design' (Rissanen & McQuillan, 2016, p. 43). He therefore also calls for a closer integration of pattern cutting in the education of young fashion designers, which recalls the problems addressed in chapter 2:

> Historically the focus of fashion design education has been to teach sketching and drawing skills as 'design' and pattern cutting and sewing skills as either somewhat separate from design or subservient to it. There is no doubt about the technical acumen offered in most pattern cutting books aimed at fashion design students. The issue with many of them, however, is that pattern cutting is usually presented as a rigid technical process. As a consequence fashion design students tend to regard and approach pattern cutting as a 'closed' activity rather than an open-ended process of discovery and thinking. (Rissanen & McQuillan, 2016, p. 44)

Fig. 42: Timo Rissanen:
Hoodie, 2008

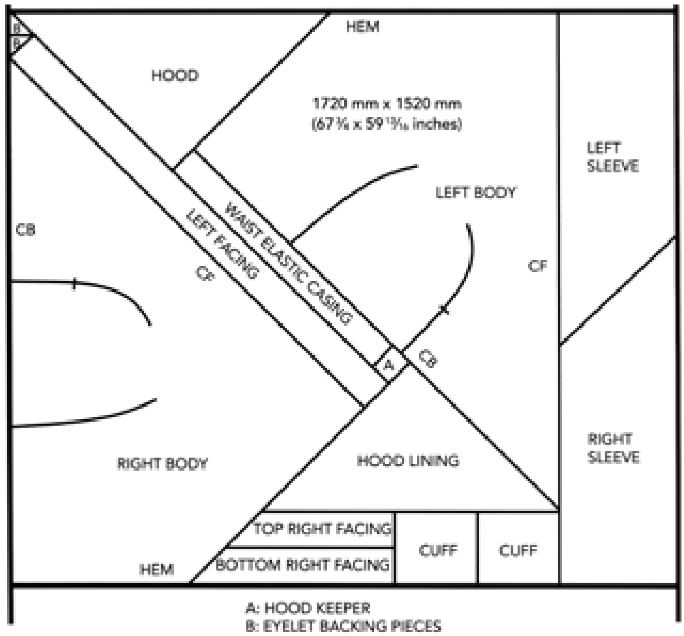

Fig. 43: Timo Rissanen: Hoodie pattern, 2008

Rissanen has thus turned efficient pattern cutting into a design principle and calls for a more profound reflection on the technique and its increased integration into the design process. Furthermore, despite the fact that he uses the conventional technique of pattern-cutting, he actually brings the garment and the fabric it is made from closer together, since he voluntarily imposes on himself to use the entire fabric and not only parts of it, thus revaluing the base material by not wasting any of it. It could be expected that this leads to a form-follows-function way of making clothes since the shape of the garment needs to be adapted to the shape of the fabric. Quite on the contrary, however, Rissanen manages to design garments whose aesthetics are close to that of their conventionally produced counterparts. Examples for this can be seen in items like the hoodie (2008) (Fig. 42/43) or the pajamas (2011) (Fig. 44/45) he designed.

Rissanen's approach is quite different from the two recent examples presented previously. He does not aim at reinventing the whole process of garment production but rather seeks to optimise an existing technique. However, it lacks the notion of individuality that is present in Issey Miyake's and Jeanne Vicerial's approaches and it does not aim at producing a garment at the same time as its fabric. Furthermore, even though he manages to produce garments that are more wearable on a daily basis than those presented previously, this does not mean that Rissanen's technique is the only possible solution and that we should discard the quest for

Fig. 44: Timo Rissanen:
Pajamas, 2008

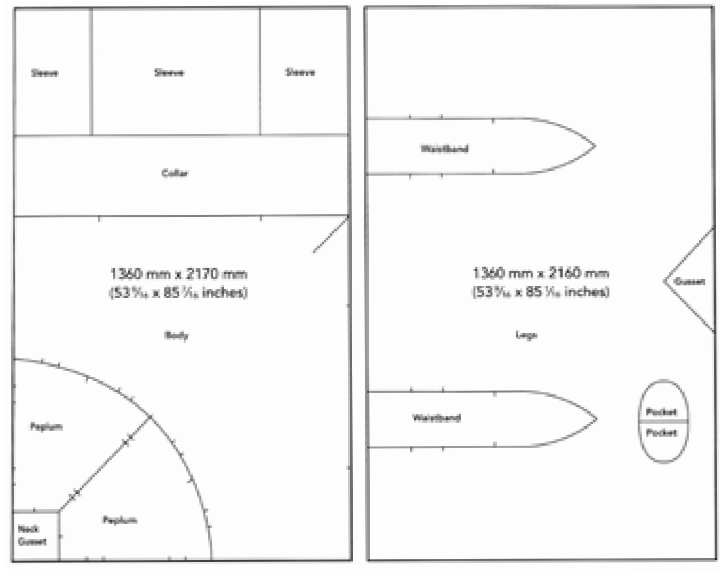

Fig. 45: Timo Rissanen: Pajamas pattern, 2008

alternative production methods. Quite on the contrary, his approach at eliminating cut-losses could also be seen as an important intermediary technique that can reduce the apparel industry's environmental impact and that can build bridges between fashion designers and pattern cutters. In the long run, however, it may be useful to further develop and implement alternative techniques that bring the production of fabrics and garments closer together. The examples presented in this chapter indicate what aspects could be considered when developing such techniques, while the following chapter illustrates my own practical design approaches concerning this topic.

4. No Cuts No Seams

Being a former student of cultural studies, I still find joy in the theoretical analysis of why things are the way they are. However, since my professional focus has changed to textile design, I find it equally important to also relate my theoretical findings to my practical work and vice versa. As a designer, I can have a very direct impact on the way things are produced, so theory and practice have to go hand in hand. In this chapter, I will therefore present my ongoing project *No Cuts No Seams* and reflect how far the theoretical framework I have drawn up in the previous chapters can be related to it.

Connecting theory and practice is not always straightforward. Interaction designers and researchers Bill Gaver and John Bowers have pointed out that in their experience, 'theory plays an unexpected, indirect, and sometimes rather humble role in design practice' (Gaver & Bowers, 2012, p. 42). According to them, a problem with theorizing design is that a designed object can be interpreted and theorized in many different ways, while a theory on the other hand can also be translated into a myriad of different designs. They further point out that theory and design practice do not necessarily follow the same standards, since '[m]ethodological frameworks promise rigor but jeopardize the possibility for designers to invent ad hoc approaches, or draw inspiration from unorthodox sources, or take inexplicable imaginative leaps—all forms of a productive indiscipline that we see as integral to design practice (ibid., p. 42). Gaver & Bowers therefore introduce the notion of the annotated portfolio, which is a way to combine theory and practice. To them, designed objects and their theoretical accounts are mutually dependent and need each other to point out the object's relevance in varying contexts:

> [W]e see textual accounts of artifacts, including any theoretical pronouncements about them, as annotations. The textual account achieves its sense and relevance by virtue of its indexical connection with an artifact. At the same time, aspects of that artifact are highlighted and linked to the concerns of a community by the text. Just as a pointing gesture depends on both the finger and the target, and as a caption makes sense of, and exists because of, its associated figure, so artifacts and their descriptions are mutually reliant on their relationship to produce meaning. This line of reasoning implies that designs need to be annotated if

> they are to make clear and accountable contributions to research. (Gaver & Bowers, 2012, p. 43)

This chapter, then, could be seen as such an annotated portfolio since it tries to relate *No Cuts No Seams* to the theoretical findings in the previous chapters. Even more so since I am writing this thesis at a point when *No Cuts No Seams* already exists. I have indeed discovered most of the theoretical framework presented here only after producing several prototypes for the project, which means that theory here serves rather as an explanation of what I find relevant in the project than as an ideological guideline.

Beginnings: The No-Cut-Dress

No Cuts No Seams was not born from theory, at least not from the one presented in the previous chapters, but rather from practical design experience at the crossroads of textile and fashion design. In Autumn 2017, when we were both studying at weißensee kunsthochschule berlin, fashion design student Abeer Tahir and I decided to collaborate on a semester project. We chose to create a fashion collection on the topic of transorientalism. Our initial division of tasks was rather classic, with Abeer making the clothes and I their fabrics. Of course, I had my word to say on the design of the garments and would also discuss the textile design with her in quite some detail but in the beginning, both of us more or less stuck to our respective disciplines. However, while weaving the fabrics for the collection, I asked myself the question of whether it would be possible to weave an entire garment, and not only a rectangular surface for Abeer to cut patterns from. This question in particular arose because we both found the moment when the fabric had to be cut in pieces a little heartbreaking. I had carefully chosen the colours and materials and had spent hours weaving the fabric, so not seeing all of it used was rather disappointing.

I therefore asked Abeer to drape a dress out of one single rectangular piece of calico. The maximum width of the fabric corresponded to the width I could weave on the loom, while the length of the fabric was hers to choose. She came up with a design that had a hole for the head and was wrapped once around the body. She fixed the calico at different places using pins. My task, then, was to find solutions for transfering this design into weaving. I marked all the spots where she had used pins and came up with the idea of leaving long weft threads hanging from the woven surface at the points where the pins had been. These would ultimately be knotted together and thus hold the drape in place. In the back of the dress, the left selvedge needed to be attached to the fabric's upper edge. I decided to knot these areas together as well

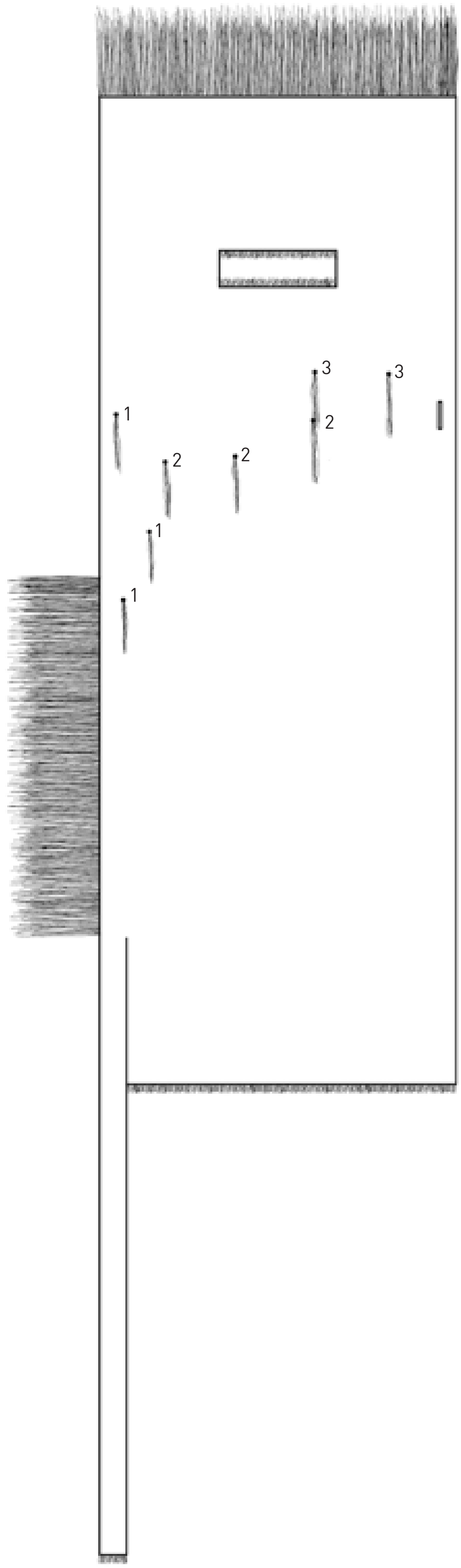

Fig. 46: Drawing of the fabric for the No-Cut-Dress. The long threads with the same numbers are connected, as well as the long threads at the upper and side edges.

Fig. 47: No-Cut-Dress, front view

Fig. 48: No-Cut-Dress, back view

by leaving the warp threads at the top rather long and by further leaving long weft threads at the selvedge at the given position. The design also included a belt that was a partial extension of the rectangular surface as well as a hole to hold it in place (Fig. 46/47/48). Although we had both been rather sceptical that this garment would actually work, we were both quite satisfied with the result since the long weft fibres proved to be very stable attachment points. We had thus come up with a garment that was produced at the same time as its fabric and that was a sort of deviation from our actual project.

A seamless shirt

While Abeer decided to further focus on transorientalism, I was intrigued by the dress we had created and decided to continue on my own and base my bachelor's project in the following semester on further research on the construction of garments directly on the loom. I wanted to go even further with the reuse of weft fibres that were left long in the weaving process and had the idea to reintroduce them into the loom as warp. While I did not know about Johannes Braunius' loom discussed in chapter 3 at the time, the principle I came up with is quite close to his. Even though I did not reinvent a loom but decided to make do with a semi-automatic conventional loom provided by the school, I was able to produce a seamless tunic shirt with sleeves (Fig. 49/50).

I began by weaving a tube to construct the sleeves. In its middle, I did not close the right selvedge but left the weft

Fig. 49: Seamless tunic

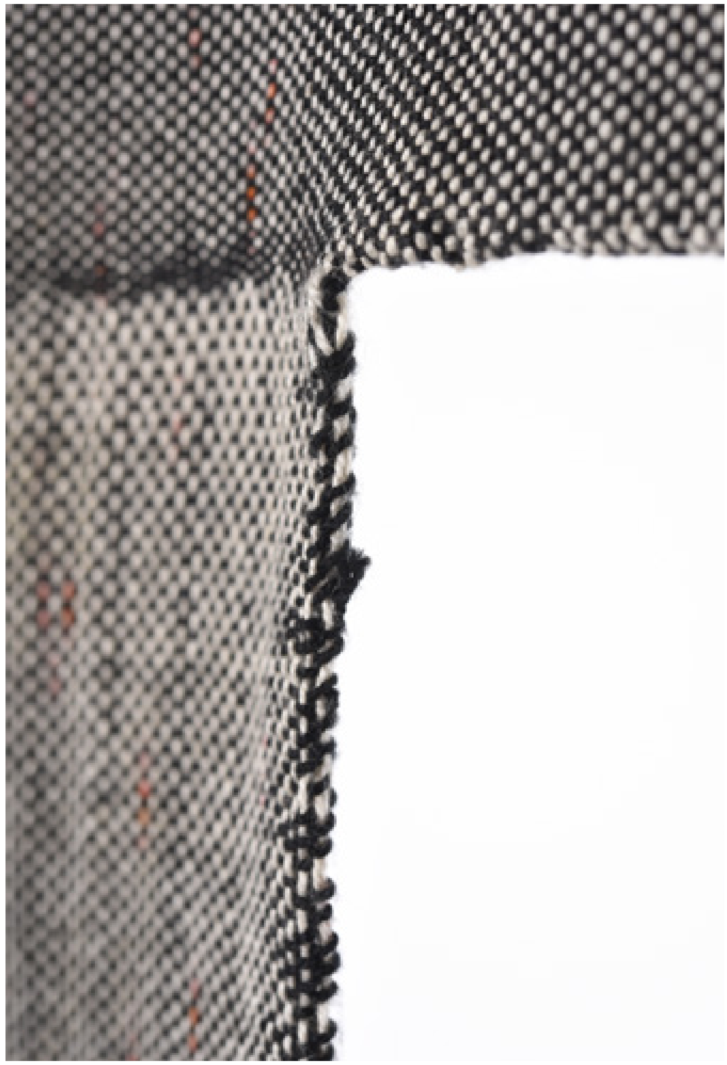

Fig. 50: Close-up of the right angle formed between the torso and the sleeve

fibres about one meter long. The central section of the left selvedge was completed, but without connecting the two layers, which allowed me to leave an opening for the head. The weft fibres that had been left long beforehand were then reintroduced into the loom as warp fibres (Fig. 51). In conventional weaving, the warp is usually wound on the warp beam and then threaded through the heddles and the reed to be ultimately attached to the cloth beam. In my case, I had to work in the opposite direction and attach the finished sleeve tube to the cloth beam, and then put the long former weft fibres first through the reed and then through the heddles to ultimatly attach them to the warp beam in the back. With this construction, I was able to weave another tube that was directly connected to the sleeves and that would form the torso of the garment.

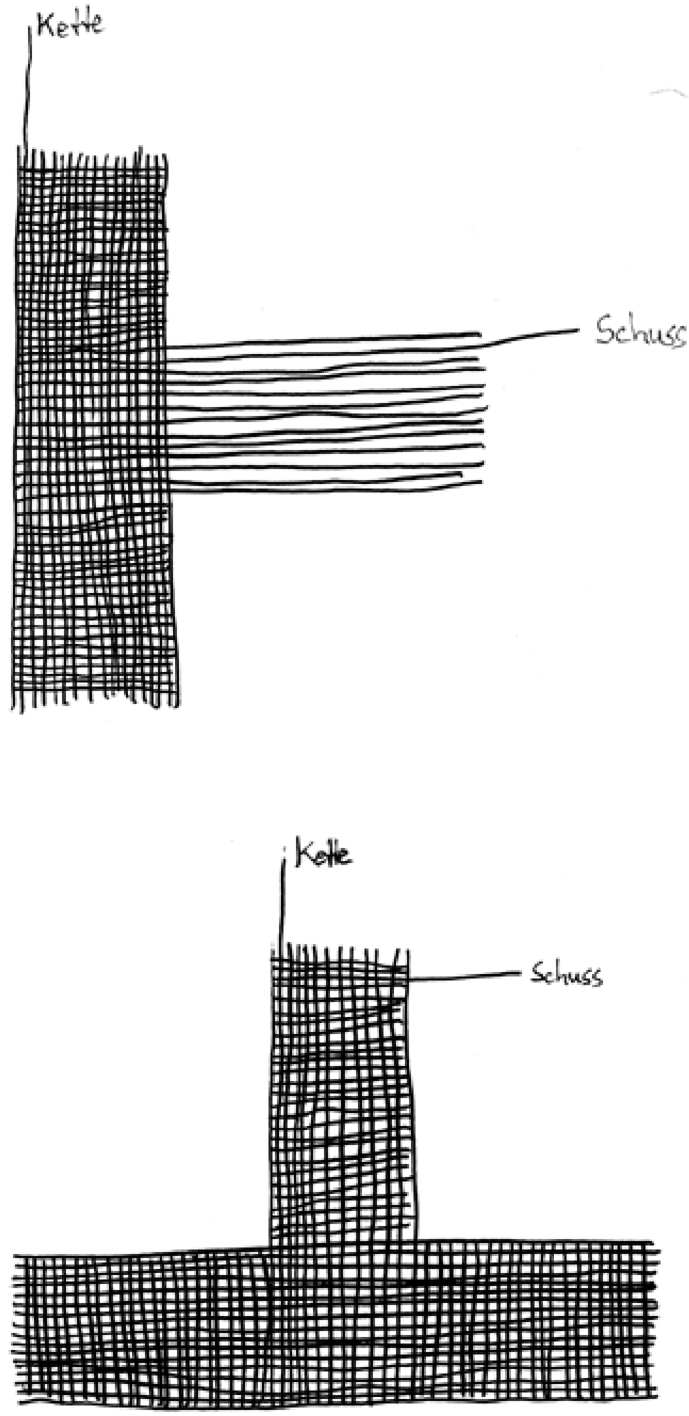

Fig. 51: Sketch describing the construction of the tunic. After weaving a first tube for the slee-ves and leaving long weft fibres (Schuss) on one side, the piece is turned by 90° and the long fibres are reintroduced into the loom as warp fibres (Kette).

Fig. 52: Sample demonstrating 3D- weaving

Three-dimensional weaving

As a next step, I decided to produce a sample that would show the possibilities my technique of reusing weft as warp fibres could have for constructing three-dimensional shapes directly on the loom (Fig. 52/53). Using two shuttles, I wove a

Fig. 53: Close-up of the 3D-weaving sample

rectangular surface. In its middle, I did not weave all the way from selvedge to selvedge but left the weft threads hang out from the surface, one warp thread at a time. This created a line of loose weft threads that were "standing" on the base surface in an angle of 45 degrees. These threads were then reintroduced into the loom as warp, which allowed me to create two connected surfaces that face in different directions (Fig. 54). This sample serves to illustrate that it is possible to connect different woven surfaces in a three-dimensional way directly on the loom, which will be of use when trying to come up with solutions for garment-making that omit pattern-cutting and sewing.

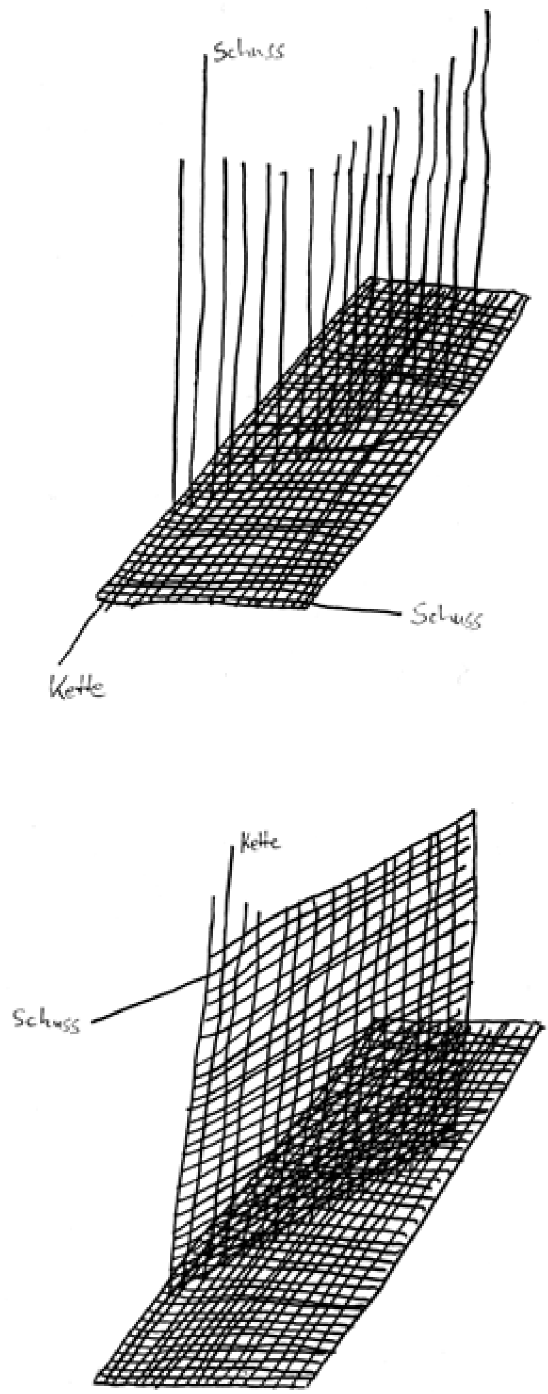

Fig. 54: Sketch describing the construction of the 3D-weaving sample. A surface is woven from which loose weft threads (Schuss) stand out. These are subsequently reused as warp threads (Schuss).

Fig. 55: Sample illustrating the seamless combination of a knitted surface (above) with a woven one (below)

Connecting weaving and knitting

The reuse of weft fibres as warp also gave me the idea of directly connecting woven and knitted surfaces, which is only possible through sewing in conventional garment-making. Combining stretchable knitted surfaces with stiffer woven ones in one piece could provide interesting possibilities to develop garments that have more flexible zones where movement is needed and more rigid ones where this is not the case.

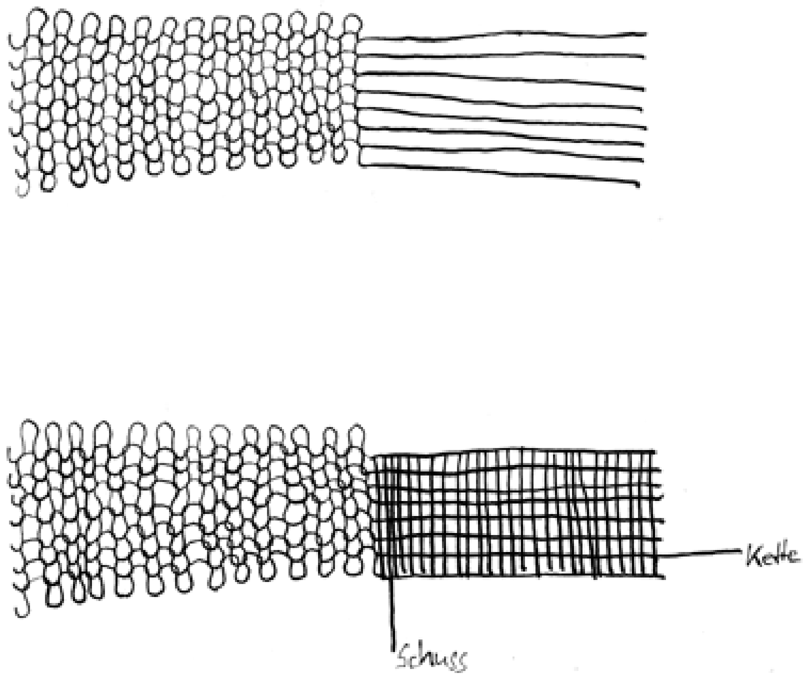

Fig. 56: Sketch describing the combination of knitting and weaving. Long fibres are left on one side of the knit that can subsequently be reused as warp fibres (Kette).

Knitted surfaces can be produced from one single thread that forms consecutive rows of meshed loops. However, it is also possible to use a new thread for each row, which means that a long thread is hanging loose at the fabric's edge. I decided to produce a knitted surface with many such loose threads on one side. These could subsequently be used as warp threads in the loom in the same way shown in the previous examples (Fig. 55/56).

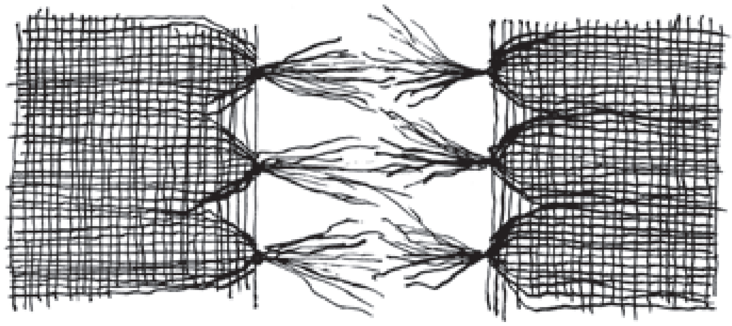

Fig. 57: Attachment of two woven surfaces through knotting

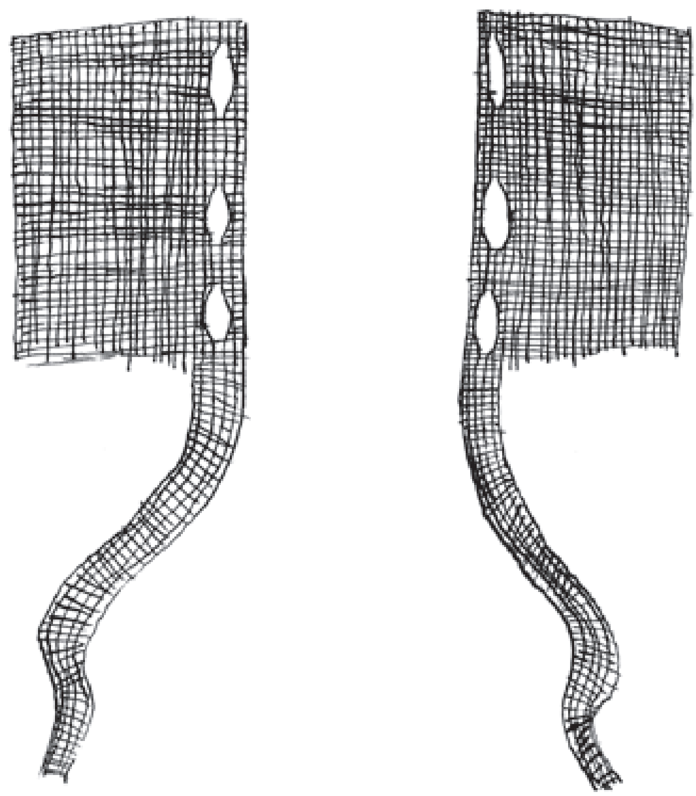

Fig. 58: Woven 'shoelace' attachment system

Attachment systems

Another important question I asked myself during this project was how to temporarily connect different textile surfaces. This is important for example for jackets that can be worn open or closed. The basic idea was to find attachment systems that can be integrated into the textile during weaving and do not need to be sewn onto the finished garment as zippers or buttons do. One basic idea was to bundle different threads of yarn and simply knot them together (Fig. 57),

Fig. 59: Attachment system using magnetic yarns woven into the edge of the fabric

a technique that had already proven its functionality in the dress designed together with Abeer. Another approach was to leave holes in the fabric and to weave an extension of it to permit a system similar to a shoelace (Fig. 58). A third option was to replace parts of the warp yarns with a flexible magnetic thread on one edge and to introduce a magnetic tape into a tube woven on the other edge to connect the edges by means of magnetic attraction (Fig. 59). Following the bachelor's project, I have had other ideas such as crocheting buttons from weft yarns directly while weaving, but I have not yet had the possibility to test them.

Cutting the warp and producing a seamless skirt

I am currently continuing *No Cuts No Seams* in my master's studies at the Ecole nationale supérieure des Arts Décoratifs (EnsAD) in Paris. Having already thrown a good amount of conventional weaving techniques to the wind, I have decided to take a step further and to add another element to my repertoire of unorthodox weaving. This is to cut warp threads in mid-weave to reuse them as weft. During my very first weaving lessons in Berlin, I was told to be extremely careful with the warp as it ensures the right tension of the fabric and since a broken warp thread will cause more trouble than anything else. Nevertheless, deliberately cutting single warp threads proved to be inevitable for the solutions I will present in the following.

The first sample I produced in Paris was a development of my T-shaped shirt described earlier. I wondered whether it would be possible to attach the sleeves not in a rectangular way but slightly inclined so that they would follow the contours of the body more closely. I produced a sample (Fig. 60) in which I first wove the section covering the torso using a white and red warp and a black weft yarn. In its upper part, I did not weave selvedge to selvedge but stopped the weft yarn earlier in order to produce a slanted line of unwoven warp threads. Afterwards, I slightly turned the woven piece to align the unwoven weft fibres with the reed. Starting on the left, I then cut one warp thread at a time and passed it immediately to the right for reutilisation as weft. This technique created

Fig. 60: Sample illustrating my attempt to attach a sleeve in a non-rectangular way

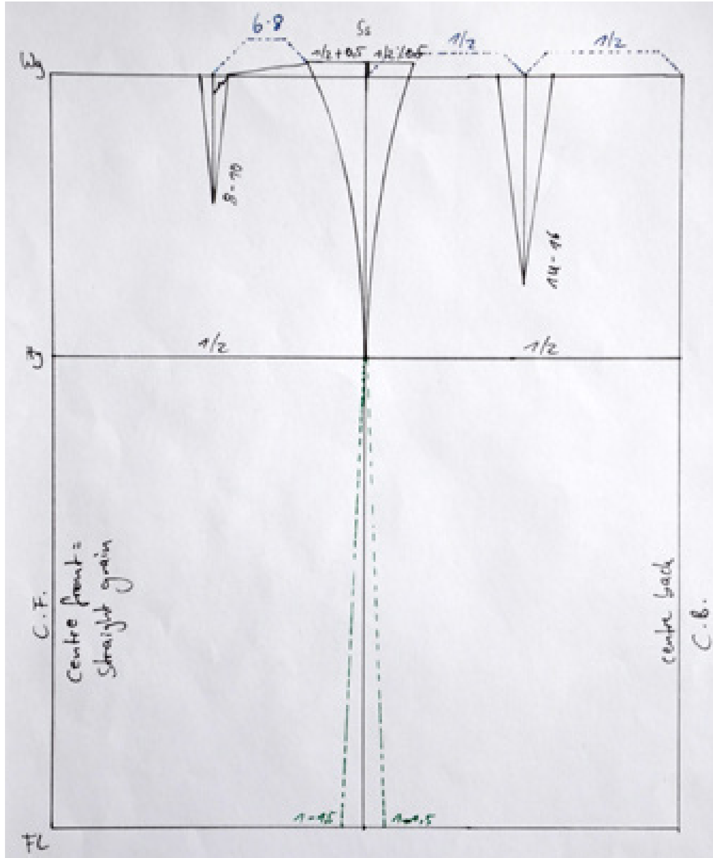

Fig. 61: Basic skirt pattern that was translated into weaving

a triangular shape that was attached to the first part of the sample. The course of the threads can be traced when looking at the red threads in the sample. However, the technique also created a fundamental problem: as the warp fibres are progressively removed and reused as weft, they can no longer ensure the tension of the whole piece, which leads to a rather crooked edge. A device to overcome this problem still needs to be developed and would be of great help. Once all the former white warp fibres were reutilised as weft, they were in turn reintroduced into the loom as warp fibres as previously explained and the sample was finished with a black weft thread.

At EnsAD I was also able to attend a pattern construction course in the department of fashion design which allowed me to understand the principles of this technique in much more detail. I decided to use a basic skirt pattern (Fig. 61) and to translate it into seamless weaving. This skirt is unfinished at the time of writing and can thus unfortunately only be shown in parts.

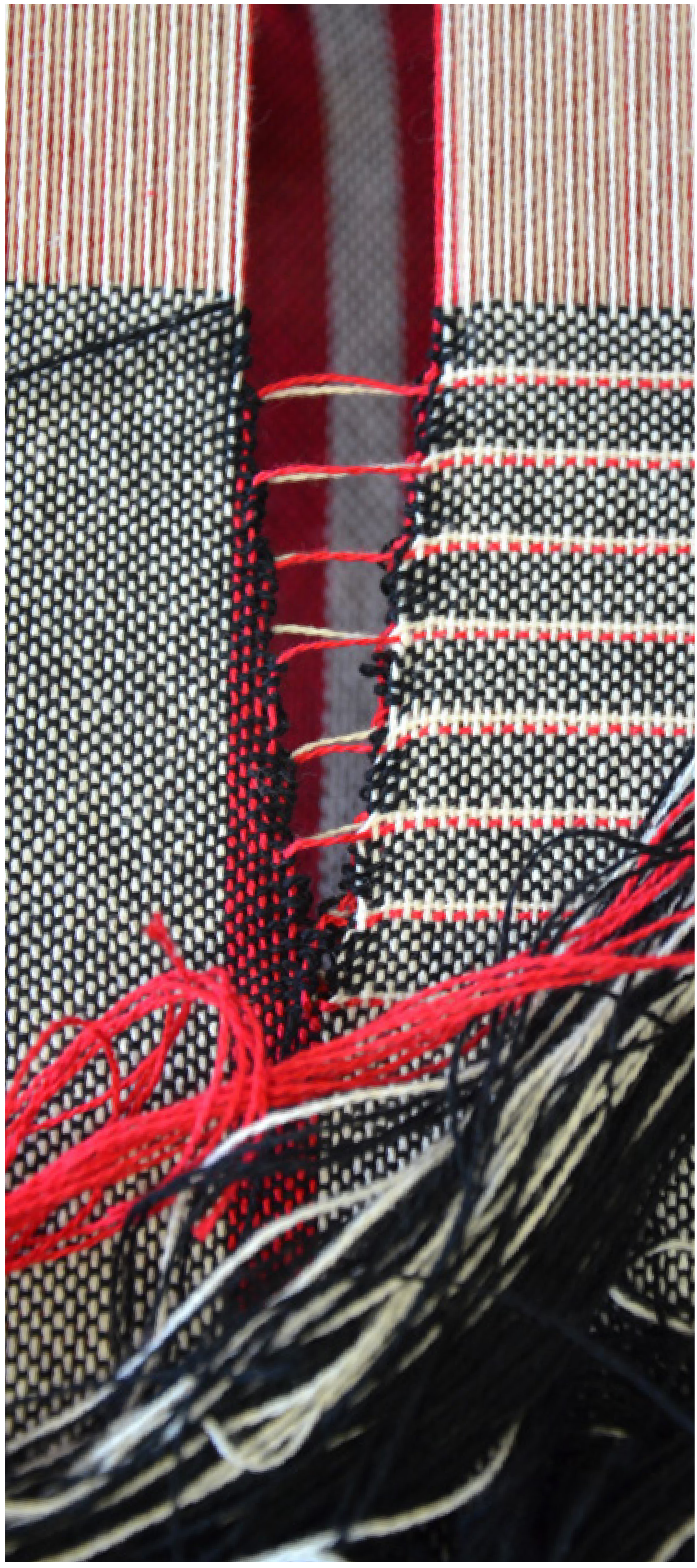

Fig. 62: Detail of one of the woven darts. The red warp yarn is cut and immediately reused as weft.

The lower part of the skirt was rather simple to translate since it only required a tubular double-layered weave. At the lower end of the skirt, I decided to test the technique of the Peruvian and Otomí looms described in chapter 3 that permits to create an additional selvedge and thus removes the need for hemming. The upper part was more complicated. In the human body, the waist girth is usually inferior to the hip girth. Therefore, darts are used in tailoring which allow cropping of the excess fabric at the waist by means of cutting and sewing. Since I did not want to use either of these techniques and wanted to find a way not to waste any of the fabric I had produced, I came up with a different system to construct the darts (Fig. 62). During weaving, I gradually removed warp threads and immediately reused them as weft. This provided triangular blank spaces at the position of the darts. When taken off of the loom, the darts can be closed by pulling on the red fibres that are left long on the sides of the skirt. Not only the red fibres are left long, but also all the regular weft yarns. These will be bundled and can then be knotted together to close the sides of the skirt. This technique also permits the size of the skirt to be adjusted slightly to a larger size.

A disadvantage of this technique is that the warp fibres have to be cut one by one while weaving, since they initially have to be under tension to accomodate the weft fibres. This means that whenever a warp fibre needs to be cut, I had to walk around the whole loom to do so. Since the loom I am working on is about 2 metres long, this can soon become tedious as the weaving process is constantly interrupted. This is especially the case since there are two differently shaped darts in this skirt, which need to form different angles. This means that with nearly every weft pick, removing one single warp yarn becomes necessary. Nevertheless, the technique could have the potential to be translated into industrial weaving processes, but I will need further discussions with weaving loom engineers to find out more about such possibilities and to get an overview of techniques that already exist in the industry.

Outlook

No Cuts No Seams is far from finished. The samples I have presented here can be seen as a repertoire of techniques that are waiting to be turned into a collection of seamless garments.

In my next and final year at EnsAD, I am planning to pursue a double diploma in both the textile and material design and the fashion design departments. This will enable me to obtain a much broader view of the construction of my garments since my education will include both textile and fashion design perspectives. I also intend to continue the pattern-making course in order to understand the conventional construction of even more complicated garments and to translate these into seamless weaving.

The aim of the project is to create a collection of seamless garments produced directly on the loom. The form and colour scheme of this collection is still to be determined, but it is clear that the theoretical framework I have given in the first three chapters of this thesis will be a good base for the further development of *No Cuts No Seams*.

A fundamental question evoked in relation to the three recent examples presented in chapter 3 will concern the shape of the garments in the collection. Should they try to imitate conventional garments as far as possible or should they reinvent forms that may be hard to integrate into the mainstream market but reflect the particularity of the technique? The result will probably be a compromise between the two extremes. The techniques I am using avoid the traditional cut-and-sew approach at garment-making, so it is clear that it will be impossible to come to the exact same results. As stated earlier, new techniques often bring new aesthetics with them, which can be seen as a positive thing since it means that garment-making is evolving and that the visual canon of what a garment can look like is widenend. On the other hand, *No Cuts No Seams* should not become a project that is only directed at a small, wealthy and fashion-forward elite. It could include concept pieces that playfully interpret the techniques I have developed in a more open way. However, it should also try to propose accessible garments that an average consumer can easily include into their daily wardrobe.

One strategy to achieve such more accessible garments could be to continue the approach I had when working on the skirt and to study how exactly a garment is conventionally constructed. The insights gained from this technique could then be translated into seamless weaving. However, it needs to be acknowledged that the skirt I have chosen has a relatively simple tubular shape and that other garments such as trousers or jackets may be much more difficult to translate.

A second point to consider could be the question of how to stimulate an emotional attachment of a wearer to their garment. As shown in the examples of Jeanne Vicerial's work and the Turfan trousers, the introduction of methods from bespoke tailoring could provide an additional dimension to the project that would give the wearer the impression that their garment was conceived with their personal body in mind. Another idea could be to draw inspiration from Miyake's and Fujiwara's approach to provide modular pieces that the consumer can assemble according to their needs or to introduce versatility into the garment designs, meaning that one piece has the potential of turning into several different garments. This would give agency to the wearer and probably also increase the utilisation of the garment since it could be worn in different situations.

Furthermore, the choice of materials is far from simple. For sampling, I have made use of rather thick cotton yarns because in this experimental phase, I had to manipulate the threads a lot and the cotton proved resistant enough to withstand such manipulations. However, since there is also an ecological dimension to this project as it aims to reduce waste, cotton is definitely not be the best choice due to its heavy impact on the environment. Synthetic materials like polyester may be recyclable, but not biodegradable and thus pose unforeseeable threats for the environment. Therefore, linen, hemp, or sustainably sourced wool or camel hair may be much more promising alternatives. Additionally, it should be ensured that the materials used to produce the garments of the collection offer a certain comfort to the wearer. This may be another means of increasing their bond with the garment.

Another factor to consider are colours. The dominant black, white and red used in the technical samples were mostly used to permit a clear distinction between weft and warp fibres. This combination may also work in the garment collection, however, it may be interesting to enlarge this colour palette. Many people still associate sustainable clothing with baggy shapes that come in natural shades of beige and green and therefore find it hard to wear. *No Cuts No Seams* should propose alternatives to this view and deliberately use different colours to underline that the concept of sustainability can be applied to more aspects of a garment and not just to the base material.

In terms of technique, a large focus of *No Cuts No Seams* has been on weaving so far. One reason for this emphasis was that I wanted to find out whether the advancements that have been made in knitting in recent years can also be applied to weaving. However, the technique that I have developed also allows for seamless combinations of wovens and knits, which could be very interesting to explore in more detail when it comes to garment-making. As pointed out in chapter 3, it would be a disadvantage to leave behind the technique of weaving just because knitting is currently a bit further explored. Therefore, a direct combination of both techniques could reconcile them and provide many new possibilities for garment-making.

Another aspect I would like to work on is the further development of the loom. As I have mentioned before, it is my firm belief that the creation of seamless woven garments is not impossible since we simply lack the right tools to exercise it. I would like to start imagining such tools. Based on the experience I have acquired in producing the samples presented in this chapter, I would like to build a simple prototype loom that is more adapted to the techniques I am using. First and foremost, this loom should include features that facilitate the exchange of warp and weft fibres during weaving. Secondly, it could include a special reed that allows for an adjustment of the distance between the warp fibres during weaving as in the case of the ancient Peruvian and Chilean garments presented in chapter 3. A third feature could be the possibility to weave four finished selvedges. To achieve this, the loom would have to be operated from both sides and include heddles and reeds that can easily be removed once the whole fabric has been woven. Such a construction could also further reduce the loss of material, since traditional looms require about 60 to 70 centimetres of warp to remain on the loom when reaching the end of the warp. Meanwhile, the prototype loom should stay flexible and adaptable to future experiments. These could include techniques to produce rounded woven fabrics instead of rectangular ones, for example by using conical instead of cylindrical warp and cloth beams.

Another important factor to consider is that all my samples were produced on semi-automatic hand looms. Furthermore, the traditional weaving techniques presented in chapter 3 mostly aim at producing one garment from one warp at a time on the loom. However, given the fact that the preparation of a warp is a rather tedious and time-consuming process, it may be difficult to introduce this principle into industrial production processes, where kilometres of warp threads are used that do not need to be replaced as often. Therefore, the question must be asked as to how my principles could be applied to the industrial production of garments. In order to gain more experience in this field, I will do an internship at the sampling facility of TESCA France this summer, which is a company that specialises in the conception and production of automobile textiles such as car seats. The connection between car seats and garments may not be obvious at first sight, but TESCA possesses an enormous range of industrial weaving and knitting machines at this site. This will give me the opportunity to gain broad insight into the possibilities that the industrial textile production offers today and may inspire new ideas for producing garments directly on the loom that could be more adaptable to industrial production processes. Furthermore, being a fervent supporter of interdisciplinarity, I am convinced that the fashion and car textile industry face similar problems and can benefit from exchanging ideas.

If we want to come up with alternatives to the conventional production of textiles and garments (and also car seats), we have to cooperate and not divide ourselves into arbitrary categories.

No Cuts No Seams will therefore continue to be developed at many different levels and will be nourished by the theoretical framework provided in this thesis. Its goal is to re-evaluate the multi-faceted relationships between garments and their textiles, between textiles and the tools used to produce them, between weaving and knitting, but also between the designer and the wearer of their garments.

Conclusions

This thesis has endeavoured to summarize different aspects of the gap between the production of woven textiles and garments and has presented a number of techniques that could be employed to bridge this gap. It has asked the question of why it has become rare nowadays to conceive a garment at the same time as its fabric. Furthermore, it has tried to relate my practical work as a textile designer to a larger theoretical framework.

The historical analysis in the first part of this thesis has shown that textile- and garment-making were activities that were initially much more connected to each other than they are today. Sewing was invented in the Stone Age to connect animal skins and therefore to adapt the arbitrary shape of the raw material to the human body. Ancient woven garments merely required rectangular surfaces that were draped around the body or stitched together with a very limited amount of seams. At this time, producing a fabric thus also meant producing a garment.

It is only with the higher complexity of garments from the late Middle Ages onwards that the gap between the production of textiles and that of garments has widened. Due to the advent of fashion and the tight-fitted silhouette, tailoring and pattern making became more widespread. However, the basic set-up of the loom as a tool to produce rectangular textile surfaces remained the same and was not prone to the high speed of innovation that developed in the fashion industry. While the introduction of jacquard looms and mechanical weaving machines certainly increased the complexity of motifs and the speed of production, the rectangular shape of woven fabric has never been questioned.

This has led to a sort of disconnection of garments from the textiles they are made of that persists to the present day. Long panels of fabric are produced in one factory only to be shipped to another part of the planet in order to be cut according to patterns often designed at yet another spot and to be sewn together. The products of this process are highly globalized clothes and well-travelled scraps designed to end in landfills.

At the same time, the first part of this thesis questioned the capitalist logic of dividing tasks, which renders the whole production process highly complex and difficult for its individual actors to oversee. It has further shown that design has emerged as a separate profession out of a capitalist desire for profit maximisation. Even though designers stand at the beginning of the production process and play a key role in the definition of a product's ecological impact, the current system does not allow them to exercise this complex and important task thoroughly.

The second part, then, has provided examples of garments from various times and places that are produced in a different way. It has shown that garments that follow the contours of the human body more closely than draped ones can be produced directly on the loom. Furthermore, it has provided technical solutions to create additional selvedges that reduce the need for hemming and has introduced the idea of using weft and warp yarns more flexibly than is the case in conventional weaving. Additionally, it has introduced the works of three different contemporary fashion designers who are trying to redefine the way garments are produced today and has discussed in what way these proposals could be applied to the production of garments at a larger scale. It has been pointed out that in order to have more sustainable impact, a garment not only needs different techniques of production, but also needs to be desirable to a larger audience. Such desirability could be achieved through individualisation and modular design which could increase the wearer's emotional attachment to their garment and by proposing designs that an average consumer can easily integrate into their wardrobe.

In the final chapter I have introduced my practical project called *No Cuts No Seams*, which is an attempt at finding techniques that permit the construction of zero-waste garments directly on the loom without any need for pattern cutting or sewing. I have included this project to relate my practical work to my theoretical findings and to provide the reader a more profound understanding of my motivation for writing this thesis.

I am convinced that the technique of weaving seamless garments is far from futile and that further research into it will provide a fruitful ground for profound changes in the way garments are produced today. The loom as a tool to produce rectangular woven surfaces has a lot of potential to be reinvented as a tool that produces complete garments. This reinvention has already taken place in knitting to some extent, so weaving should not be left out of this development. The textile and apparel industry may find it hard at first to integrate such changes into its production processes, but especially in a time when resources are becoming scarce, it is my hope that it will turn to more sustainable solutions that bridge the gap.

Bibliography

Albers, A. (1974/1965) *On weaving*. London: Studio Vista.

Allwood, J. M., Laursen, S. E., Malvido de Rodriguez, C. & Bocken, N. M. P. (2006) *Well dressed? The present and future sustainability of clothing and textiles in the United Kingdom* [Internet]. Cambridge: Institute for Manufacturing, University of Cambridge. Available from: IFM, <https://www.ifm.eng.cam.ac.uk/uploads/Resources/Other_Reports/UK_textiles.pdf> [Accessed 24 April 2019].

Barlow, A. (1878) *The history and principles of weaving by hand and by power.* London: Sampson Low, Marston, Searle, & Rivington.

Beck, U., Wagner, M., Li, X., Durkin-Meisterernst, D. & Tarasov, P. (2014) The invention of trousers and its likely affiliation with horseback riding and mobility: A case study of late 2nd millennium BC finds from Turfan in eastern Central Asia. *Quaternary International*. vol. 348, pp. 224-235.

Blümner, H. (1875) *Technologie und Terminologie der Gewerbe und Künste bei Griechen und Römern.* Leipzig: B. G. Teubner.

Braunius, J. (1680) *Vestitus sacerdotum hebraeorum. Liber Primus.* Leiden: Arnoldum Doudium.

Brooks, A., Fletcher, K., Francis, R. A., Rigby, E. D. & Roberts, T. (2017) Fashion, sustainability, and the anthropocene. *Utopian Studies*. vol. 28(3), pp. 482-504.

Broudy, E. (1979) *The book of looms. A history of the handloom from ancient times to the present*. London: Brown University Press.

Burberry (2018) *Annual report 2017/18* [Internet]. London: Burberry. Available from: Burberry, <https://www.burberryplc.com/content/dam/burberry/corporate/Investors/Results_Reports/2018/Burberry_AnnualReport_FY17-18.pdf> [Accessed 24 April 2019].

Chapman, J. & Gant, N. (2007) Introduction. In: Chapman, J. & Gant, N. *Designers, visionaries and other stories. A collection of sustainable design essays*. London: Earthscan.

Christensen, B. (1947) Otomi looms and quechquemitls from San Pablito, State of Puebla, and from Santa Ana Hueytlalpan, State of Hidalgo, Mexico. *Carnegie Institution of Washington, Division of Historical Research, Notes of Middle American Archaeology and Ethnology*. vol. 78, pp. 301-311.

Cooklin, G. (1997) *Cooklin's garment technology for fashion designers.* Chichester: John Wiley & Sons.

Cooper, G. R. (1985/1968) *The sewing machine. Its invention and development.* Washington D. C.: Smithsonian Institution Press.

Eco TLC (2016) *Rapport d'activité 2016. Bilan à mi-parcours de l'agrément 2014-2019* [Internet]. Paris: Eco TLC. Available from: Eco TLC, <https://www.ecotlc.fr/ressources/Documents_site/RA_2016_EcoTLC_web.pdf> [Accessed 11 May 2019].

Edelkoort, L. (2014) *Anti_Fashion. Un manifeste pour la prochaine décennie.* Paris: Trend Union.

Ellen MacArthur Foundation (2017) *A new textiles economy. Redesigning fashion's future* [Internet]. Cowes: Ellen MacArthur Foundation. Available from: Ellen MacArthur Foundation, <https://www.ellenmacarthurfoundation.org/assets/downloads/publications/A-New-Textiles-Economy_Full-Report_Updated_1-12-17.pdf> [Accessed 10 April 2019].

Engell, C., Vegendal, S. & Fredriksen, L. C. U. (2017) *Eksperter undrer sig over H&M's afbrænding af nyt tøj* [Internet]. Odense: TV2. Available from: TV2, <http://nyheder.tv2.dk/samfund/2017-10-15-eksperter-undrer-sig-over-hms-afbraending-af-nyt-toej> [Accessed 24 April 2019].

Fletcher, K. & Grose, L. (2012) *Fashion & sustainability. Design for change.* London: Laurence King Publishing.

Fletcher, K. (2014) *Sustainable fashion and textiles. Design journeys.* Abingdon: Routledge.

Forty, A. (2014/1986) *Objects of desire. Design and society since 1750.* London: Thames & Hudson.

Gaver, B. & Bowers, J. (2012) Annotated Portfolios. *Interactions*. vol 19(4), pp. 40-49.

Gorsline, D. (1953) *A history of fashion. A visual survey of costume from ancient times.* London: B.T. Batsford.

Graedel, T. E., Comrie, P. R. & Sekutowski, J. C. (1995) Green product design. *AT&T Technical Journal*. vol. 74(6), pp. 17-24.

Greenpeace (2017) *Fashion at the cross roads. A review of initiatives to slow and close the loop in the fashion industry* [Internet]. Hamburg: Greenpeace. Available from: Greenpeace, <https://storage.googleapis.com/planet4-international-stateless/2017/09/76e05528-fashion-at-the-crossroads.pdf> [Accessed 10 April 2019].

H&M (2017) *H&M does not burn usable clothes* [Internet]. Stockholm: H&M. Available from: H&M, <https://about.hm.com/en/media/news/general-2017/h-m-does-not-burn-functioning-clothes.html> [Accessed 24 April 2019].

Harris, J. (1998) 'Estroit vestu et menu cosu': evidence for the construction of twelfth-century dress. In: Owen-Crocker, G. R. & Graham, T. *Medieval art. Recent perspectives. A memorial tribute to C. R. Dodwell.* Manchester: Manchester University Press.

Hawken, P., Lovins, A. & Lovins, L. H. (1999) *Natural capitalism. The next industrial revolution.* Abingdon: Earthscan.

Heller, S.-G. (2010) The birth of fashion. In: Riello, G. & McNeil, P. *The fashion history reader. Global perspectives.* Abingdon: Routledge.

Kibler, W. W. & Zinn, G. A. (1995) *Medieval France. An encyclopedia.* New York: Garland Publishing.

Lewis, H., Gertsakis, J., Grant, T., Morelli, N. & Sweatman, A. (2017/2001) *Design + environment. A global guide to designing greener goods.* Abingdon: Routledge.

Ling Roth, H. (1918) *Studies in primitive looms.* Halifax: F. King & Sons.

Madge, P. (1997) Ecological design. A new critique. *Design Issues*. vol. 13(2), pp. 44-54.

Marquardt, J. (1882) *Das Privatleben der Römer.* Leipzig: S. Hirzel.

Miyake, I. (2001) Clothing for the future. Captured by imagination and technology. In: Miyake, I. & Fujiwara, D. *A-POC making.* Weil am Rhein: Vitra Design Museum.

Miyake, I. & Fujiwara, D. (2001) *A-POC making.* Weil am Rhein: Vitra Design Museum.

Mosse, A. & Bassereau, J.-F. (2019) Soft Matters. En quête d'une pratique plus résiliente du design textile et matière. *Sciences du Design*. vol. 9(1), pp. 50-63.

Muthu, S. S. (2014) *Assessing the environmental impact of textiles and the clothing supply chain.* Cambridge: Woodhead Publishing.

Pal, R. (2014) Sustainable business development through designing approaches for fashion value chains. In: Muthu, S. S. *Roadmap to sustainable textiles and clothing. Environmental and social aspects of textiles and clothing supply chain.* Singapore: Springer.

Piponnier, F. & Mane, P. (1995) *Se vêtir au Moyen Âge.* Paris: Adam Biro.

Quantis International (2018) *Measuring fashion. Environmental impact of the global apparel and footwear industries study. Full report and methodological considerations* [Internet]. Lausanne: Quantis International. Available from: Quantis International, <https://quantis-intl.com/wp-content/uploads/2018/03/measuringfashion_globalimpactstudy_full-report_quantis_cwf_2018a.pdf> [Accessed 24 April 2019].

Riello, G. & McNeil, P. (2010) Fashion's 'origins'. The Middle Ages and Renaissance. In: Riello, G. & McNeil, P. *The fashion history reader. Global perspectives.* Abingdon: Routledge.

Rissanen, T. (2013) *Zero-waste fashion design. A study at the intersection of cloth, fashion design and pattern cutting.* Sydney: University of Technology.

Rissanen, T. & McQuillan, H. (2016) *Zero waste fashion design.* London: Bloomsbury.

Sbai, M. (2018) *Une mode éthique est-elle possible?* Paris: Rue de l'échiquier.

Semper, G. (1878) *Der Stil in den technischen und tektonischen Künsten oder Praktische Aesthetik. Ein Handbuch für Techniker, Künstler und Kunstfreunde.* Munich: Friedrich Bruckmann's Verlag.

Thorpe, A. (2010) Design's role in sustainable consumption. *Design Issues*. vol. 26(2), pp. 3-16.

Vicerial, J. (2017) *466km/fil*. Paris: Clinique Vestimentaire.

Vigoureux-Loridon, J.-N. (2006) *Histoire illustrée du costume. Introduction visuelle*. Lyon: Samedi Midi Éditions.

World Commission on Environment and Development (1987) *Report of the World Commission on Environment and Development. Our Common Future* [Internet]. New York: United Nations. Available from: UN Documents, <http://www.un-documents.net/wced-ocf.htm> [Accessed 24 April 2019].

Zalasiewicz, J., Waters, C. N., Ivar do Sul, J. A., Corcoran, P. L., Barnosky, A. D., Cearreta, A., Edgeworth, M., Galuszka, A., Jeandel, C., Leinfelder, R., McNeill, J. R., Steffen, W., Summerhayes, C., Wagreich, M., Williams, M., Wolfe, A. P., Yonan, Y. (2016) The geological cycle of plastics and their use as a stratigraphic indicator of the Anthropocene. *Anthropocene*. vol. 13, pp. 4-17.

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Fig. 40 photo by courtesy of Jeanne Vicerial, 2015

Fig. 41 Vicerial, 2017, p. 21

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*Glossary

backstrap loom — métier à ceinture/Gurtwebgerät: loom attached to the weaver´s body by means of a belt

batten — battoir/Weblade: stick used to push the weft yarn into place

cloth beam — ensouple avant/Warenbaum: roller at the front of a loom to roll up the woven fabric

drawloom — métier à la tire/Zugwebstuhl: loom with a separate figure harness that permits the weaving of complex patterns. Often needed the assistance of a „drawboy" sitting on top of it and activating different parts of the pattern by pulling cords.

heddle — lisse/Weblitze: cord or wire with an eye in the middle for each warp thread to pass through, suspended on a heddle harness

heddle harness — cadre/Litzenschaft: moveable frame to which the heddles are attached

pick — duite/Schuss: insertion of the weft yarn into the shed

reed/reed beater — peigne/Weberblatt: comb-like frame with many vertical slits used to space the warp threads evenly and to push the weft threads into place

sectional warp beam — rateau/Reedekamm: warp beam equipped with metal separators to space the warp evenly

selvedge — lisière/Webkante: closed edges of a woven fabric that are formed by looping the weft yarns around the outmost warp fibre

shed — foule/Fach: situation when the warp yarns are separated to allow the warp yarn to pass through them

shuttle — navette/Schiffchen: tool to pass weft fibres through the warp threads

spool rack — cantre/Spulgestell: tool to stack several rolls of yarn at once for warping

treadle loom — métier à tisser à pédales/Pedalwebstuhl: loom in which the movement of the shafts is controlled by foot pedals

twill weave — sergé/Köperbindung: weaving pattern of diagonal parallel ribs

warp — chaîne/Webkette: parallel threads stretched between the beams of the loom

warp beam — ensouple arrière/Kettbaum: roller at the back of a loom on which warp fibres are rolled in preparation for weaving

warping mill — ourdissoir/Schärgestell: static or revolving frame used for warping

warp-weighted loom — métier à poids/Gewichtswebstuhl: vertical loom in which the warp tension is assured by weights at the lower warp ends

weft — trame/Schuss: threads intersected orthogonally with the warp

This thesis introduces the idea that there is a gap between the production of woven textiles and garments. Nowadays, most garments are composed of pattern pieces that are cut out from rectangular fabrics, which generates large amounts of waste since the shape of the fabric does not correspond to the shape of the pieces to be cut from it. This thesis looks for the origins of this way of producing, questions its environmental impact and shows alternatives to it. It asks why the loom has not been adapted to the requirements of the apparel industry and still mostly produces rectangular surfaces while different shapes would be possible. It also looks for ways to produce finished garments directly on the loom and relates the theoretical framework to the author's practical work.

Keywords: textile design, fashion design, weaving, loom development, alternative weaving techniques, seamless clothing, sustainability, zero-waste design

Ce mémoire introduit l'idée qu'il y a un écart entre la production de textiles tissés et de vêtements. Aujourd'hui, la plupart des vêtements sont composés de pièces découpés suivant des patrons. Cette technique produit beaucoup de déchets puisque la forme rectangulaire du tissu de base ne correspond pas à celle des patrons. Ce mémoire recherche les origines de cette technique de production, questionne son impacte environnemental et montre des alternatives. Il questionne pourquoi le métier à tisser n'a pas été adapté aux besoins de l'industrie vestimentaire et continue à produire des surfaces rectangulaires, malgré le fait que d'autres formes seraient possibles. Il explore également des moyens de produire des vêtements entiers dans le métier à tisser et relie la recherche théorique au travail pratique de l'auteur.

Mots clés: design textile, design vêtement, tissage, développement du métier à tisser, techniques de tissage alternatives, vêtements sans couture, durabilité, design sans chutes