
Fashion by Formula: How Mathematics Helps Innovation and Sustainability in the Fashion Industry

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Abstract

Fashion is usually seen as a creative field based on colour, style, fabric, and imagination. Mathematics, on the other hand, is often seen as a subject of numbers, formulas, shapes, and calculations. At first, these two subjects may seem very different. However, in reality, mathematics plays a very important role in fashion. From measuring the body to cutting fabric, making patterns, creating prints, predicting sizes, designing pleats, making digital clothes, and reducing waste, mathematics is present at almost every stage of the fashion process.

This research paper explores how mathematics supports product innovation and sustainability in the fashion industry. It explains the use of geometry, algebra, trigonometry, statistics, probability, measurement, computer-aided design, 3D modelling, tessellations, fabric simulation, and smart textiles. These concepts help designers create clothes that fit better, use less fabric, and can be tested digitally before being produced physically.

The paper also discusses how mathematical ideas are used in fabric patterns such as herringbone, houndstooth, argyle, tartan, and paisley. It explains how designers like Issey Miyake used mathematical folding, geometry, and pleating to create innovative fashion. It also looks at digital manufacturing, virtual try-ons, 3D printing, smart textiles, and blockchain-based supply chains as examples of how mathematics can help fashion become more efficient and sustainable.

The main finding of this research is that mathematics is not only a technical tool in fashion. It is also a creative tool. It helps designers imagine new shapes, reduce material waste, improve garment fit, and make clothing more responsive to human needs. As the fashion industry faces problems such as overproduction, waste, pollution, and poor sizing, mathematics can help create a smarter and more responsible future for fashion.

Keywords

Mathematics, fashion design, geometry, sustainability, textile design, CAD, smart textiles, digital fashion, garment patterns, tessellation, innovation

1. Introduction

Fashion is everywhere. Every day, people choose clothes for school, work, parties, sports, festivals, and daily life. Clothes help people express their personality, mood, culture, and identity. When we think of fashion, we usually think of designers sketching outfits, choosing fabrics, matching colours, and creating beautiful garments. However, behind the beauty of fashion, there is also a lot of mathematics.

Mathematics helps fashion in many simple and complex ways. A designer cannot make a garment without measurements. A tailor cannot cut fabric without understanding length, width, angles, and shapes. A brand cannot produce clothes for thousands of people without using size charts and statistics. A factory cannot reduce fabric waste without calculating how pattern pieces should be placed on fabric. A digital fashion designer cannot create a 3D garment without using geometry and computer algorithms.

The uploaded source explains that mathematics supports fashion design, production, pricing, cutting, stitching, sizing, pattern making, digital design, smart textiles, and sustainability. It also explains that geometry, measurement, trigonometry, algebra, statistics, probability, and computer simulations are all used in different parts of fashion.

This means fashion is not only art. It is also science and mathematics.

In the past, fashion was mostly made by hand. Tailors measured people, drew patterns on paper, cut fabric, and stitched garments. Today, fashion has changed. Designers use computer-aided design, digital pattern-making, body scanning, virtual try-on tools, 3D printing, and smart materials. These technologies depend heavily on mathematics.

Mathematics is also becoming important because the fashion industry has a sustainability problem. A lot of fabric is wasted during cutting. Many clothes are produced but never sold. Many online orders are returned because of poor fit. Many garments are thrown away after only a few uses. These problems create waste and pollution. If fashion wants to become more sustainable, it needs better planning, better sizing, better production, and better use of materials. Mathematics can help with all of these.

For example, geometry can help place pattern pieces in a way that wastes less fabric. Statistics can help brands understand the body measurements of their customers. Probability can help predict which sizes will sell more. Digital simulations can test a garment before it is produced. Smart textiles can react to heat, moisture, or movement. Blockchain can help track materials in the supply chain.

This research paper studies the connection between mathematics, innovation, and sustainability in fashion. It explains how math helps fashion become more creative, accurate, efficient, and environmentally responsible.

2. Research Question and Aim

Research Question

How does mathematics help fashion designers create better, smarter, and more sustainable clothing?

Aim of the Study

The aim of this research paper is to understand the role of mathematics in the fashion industry. It focuses on how mathematical ideas are used in fashion design, textile production, pattern making, digital manufacturing, smart textiles, and sustainability.

The paper aims to explain:

1. How geometry and measurement help in garment design.
2. How algebra, trigonometry, statistics, and probability are used in fashion.
3. How mathematical patterns appear in textiles and prints.
4. How computer simulations help designers test clothes digitally.
5. How mathematics supports smart textiles and wearable technology.
6. How math can reduce waste and support sustainable fashion.
7. How mathematical thinking can make fashion more innovative.

3. Methodology

This research paper uses a review-based method. This means it studies existing information, examples, and research ideas instead of conducting a new survey or experiment.

The paper uses information from the provided text on mathematics in fashion, along with general knowledge of fashion design, sustainability, digital manufacturing, and textile innovation. The paper explains the topic in simple language for high school students.

The research focuses on the following areas:

- Mathematics in garment measurement and pattern making
- Geometry in textile and print design
- Statistics and probability in sizing and fit
- Computer-aided design and digital manufacturing
- Fabric movement and cloth simulation

- Tessellations and mathematical art in fashion
- Smart textiles and wearable technology
- Sustainability and waste reduction in fashion

The goal is to show that mathematics is not separate from creativity. Instead, it supports creativity by giving designers tools to plan, test, and improve their ideas.

4. Background: Why Mathematics Matters in Fashion

Fashion design begins with the human body. The body is not a flat object. It has curves, angles, measurements, and movement. Clothes must fit around shoulders, arms, chest, waist, hips, legs, and neck. This means designers must understand shape and space.

A piece of fabric is usually flat. But the body is three-dimensional. The challenge of fashion design is to turn flat fabric into a garment that fits a curved body. This is a mathematical problem as much as a design problem.

For example, a sleeve is not just a tube. It must fit the armhole, allow movement, and fall correctly. A skirt must fit the waist and hips but may flare out toward the bottom. A saree, gown, jacket, or trouser all require careful measurements and calculations.

Mathematics helps designers answer questions such as:

- How much fabric is needed?
- What size should each pattern piece be?
- What angle should a seam have?
- How much extra fabric is needed for seam allowance?
- How will the cloth fall on the body?
- How many sizes should a brand produce?
- How can fabric waste be reduced?
- How can a garment be tested digitally?

Without mathematics, fashion would involve much more guesswork. With mathematics, designers can be more accurate and efficient.

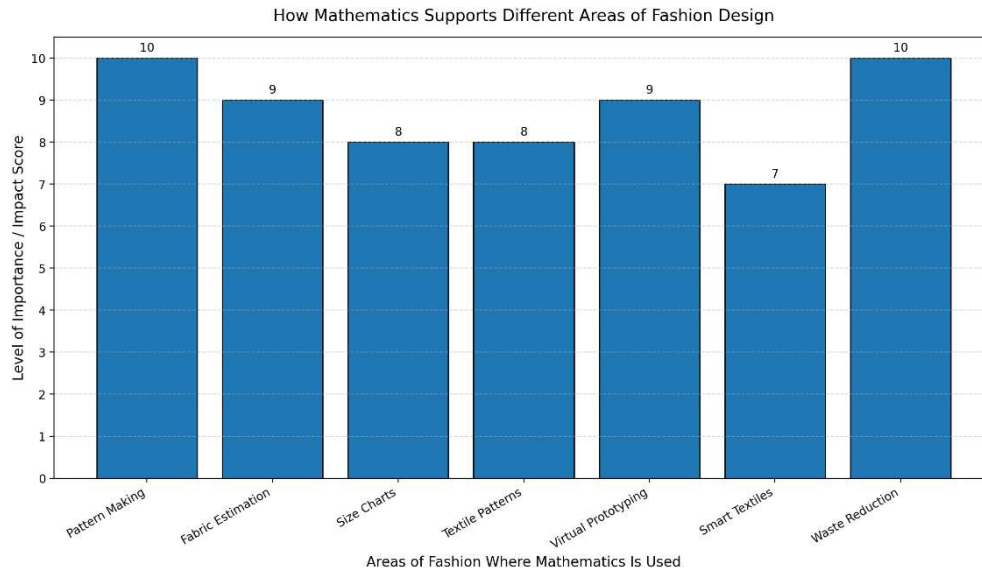


Figure 1. Role of Mathematics in Different Areas of Fashion Design.

5. Basic Mathematical Concepts Used in Fashion

5.1 Measurement

Measurement is the most basic use of mathematics in fashion. A designer or tailor needs body measurements such as height, shoulder width, chest, waist, hips, sleeve length, inseam, and neck size.

If the measurements are wrong, the garment will not fit properly. Even a small mistake can change the look and comfort of a garment.

Measurement is also needed for:

- Fabric length
- Fabric width
- Hem length
- Seam allowance
- Button spacing
- Pleat size
- Collar size
- Pocket placement

A good garment is often the result of accurate measuring.

5.2 Geometry

Geometry is the study of shapes, lines, angles, and space. It is one of the most important branches of mathematics in fashion.

Designers use geometry to create patterns. Pattern pieces may include rectangles, triangles, curves, circles, cones, cylinders, and irregular shapes. A designer must understand how these shapes join together to form clothing.

Geometry is also used in:

- Necklines
- Sleeves
- Pleats
- Drapes
- Skirt flares
- Collars
- Textile prints
- Embroidery layouts
- Repeating patterns

For example, a circular skirt uses the geometry of a circle. A pleated skirt uses repeated folds of equal width. A kimono sleeve uses rectangular and curved shapes. A princess-cut dress uses curved seams to shape the body.

5.3 Trigonometry

Trigonometry studies angles and the relationships between sides of triangles. It may sound advanced, but it appears in fashion whenever designers work with angled lines.

Trigonometry can help with:

- Diagonal seams
- Bias-cut garments
- Pleats
- Draped designs
- Neckline angles
- Flared garments

- Folded structures

A bias-cut dress, for example, is cut diagonally across the fabric grain. This gives the garment a softer fall and more stretch. Understanding angles helps the designer control how the fabric behaves.

5.4 Algebra

Algebra is useful when designers need to adjust patterns. If a pattern is made for one size but needs to be changed into another size, algebra helps increase or decrease measurements proportionally.

For example, if a skirt pattern must be enlarged by 10%, every part of the pattern must be adjusted carefully. If only one section is enlarged and another is not, the pieces may not fit together.

Algebra is also used in cost calculation. A fashion brand must calculate:

- Cost of fabric
- Cost of labour
- Cost of buttons, zips, and thread
- Transport cost
- Profit margin
- Selling price

These calculations are important because a design must not only look good. It must also be possible to produce and sell.

5.5 Statistics

Statistics helps fashion companies understand groups of people. Not every customer has the same body shape. Brands use body measurement data to create size charts.

For example, a company may collect waist, hip, and height measurements from many people. It can then use statistics to decide what small, medium, large, and extra-large should mean.

Statistics also helps companies predict:

- Which sizes will sell most
- Which colours are popular
- Which styles are trending
- How much stock to produce

- Which regions need which products

Good statistical planning can reduce waste because brands do not overproduce unpopular sizes or styles.

5.6 Probability

Probability is the study of chance. In fashion, probability can help predict whether a garment will fit a certain body type within a size range.

For example, if a brand knows that most customers in a group have waist sizes between 28 and 32 inches, it can estimate how many medium-size trousers to produce.

Probability is also used in demand forecasting. A fashion brand may estimate the chance that a certain jacket will sell well in winter or the chance that a colour will become popular.



Figure 2. From Formula to Fashion: How Mathematics Supports Sustainable Clothing Design.

6. Mathematics in Pattern Making

Pattern making is one of the clearest examples of mathematics in fashion. A pattern is a flat template used to cut fabric before stitching.

A garment pattern must be accurate because all pieces must join together correctly. If the front panel, back panel, sleeve, collar, or waistband are not measured properly, the garment may not fit.

Pattern making uses:

- Length and width
- Angles
- Curves
- Fractions
- Symmetry
- Proportion
- Scaling
- Surface development

One important challenge in pattern making is turning a 3D body shape into flat fabric pieces. Since fabric starts as a flat surface, designers must cut and shape it so it can cover the curved body.

This is similar to wrapping paper around a ball. A flat sheet cannot smoothly cover every curved surface without folding, cutting, or stretching. Fashion designers solve this by using darts, seams, pleats, gathers, and panels.

Computer-aided design software now helps designers create and adjust patterns digitally. These tools use mathematical algorithms to make pattern making faster and more accurate. Digital patterns can also be resized more easily for different body types.

7. Mathematics of Fabric Behaviour

Fabric is not like paper, wood, or metal. It bends, folds, stretches, twists, and drapes. Different fabrics behave differently. Cotton, silk, denim, wool, jersey, chiffon, and leather all move in different ways.

Mathematics helps designers and engineers understand fabric behaviour.

7.1 Stretch and Flexibility

Some fabrics stretch easily, while others do not. Knitted fabrics usually stretch more because of the looped structure of the yarn. Woven fabrics stretch less, but they can still change shape when the angle between threads changes.

This is important because a tight sportswear fabric needs stretch, but a formal blazer may need structure. A designer must choose fabric based on both appearance and mathematical behaviour.

7.2 Chebyshev Net

The uploaded source discusses the Chebyshev net, a mathematical idea used to understand how woven fabric can fit over curved surfaces. Chebyshev imagined fabric as a network of straight threads that do not stretch. By changing the angles between the threads, the fabric can cover curved shapes.

This idea helps explain why fabric can wrap around the body even though the threads themselves may not stretch much.

7.3 Shear and Wrinkling

When fabric is pulled or twisted, it can change shape. At first, it may move easily. But after a point, it resists movement. If pushed too far, it may wrinkle or lock. This is called shear-locking.

This is important in garment design because wrinkles are not always bad. Some wrinkles are unwanted, but others create style. Draped dresses, pleated skirts, and folded garments use fabric movement creatively.

8. Virtual Simulation and 3D Fashion Design

Digital fashion is growing quickly. Designers can now make garments on computers before cutting real fabric. This saves time and reduces waste.

Virtual garment simulation uses mathematical models to show how fabric will move on a digital body. The computer must calculate gravity, fabric weight, stretch, friction, tension, and collision with the body.

A common model used in cloth simulation is the mass-spring model. In simple words, the fabric is imagined as many small points connected by tiny springs. These springs stretch, pull, and move, helping the computer show how fabric falls and folds.

Virtual simulation helps designers:

- Test fit before production
- Try different fabrics digitally
- Reduce physical samples
- Save time
- Reduce fabric waste
- Create online virtual try-ons

- Improve garment comfort

This is especially useful for online shopping. Many clothes are returned because they do not fit properly. Virtual try-on tools can help customers choose better sizes, which can reduce returns and waste.

9. Geometry in Textile and Print Design

Textile design uses many mathematical patterns. Some patterns are repeated shapes. Others are based on symmetry, rotation, reflection, and tessellation.

A tessellation is a pattern where shapes fit together without gaps or overlaps. Tiles on a floor are a common example. In fashion, tessellations appear in prints, weaves, embroidery, and knit designs.

9.1 Woven Patterns

Many woven fabrics naturally create geometric patterns. Some examples include:

- Checkerboard
- Herringbone
- Diamond twill
- Houndstooth
- Tartan
- Basket weave

These patterns are created by the crossing of warp and weft threads. The arrangement of threads creates the design.

9.2 Famous Fashion Patterns

Some fashion patterns have become iconic. Argyle uses diamond shapes. Paisley uses a repeated curved teardrop-like shape. Burberry is famous for its tartan pattern. Prada has used triangle-inspired patterning.

These designs are not random. They depend on repetition, balance, proportion, and rhythm. Mathematics helps make them visually pleasing.

9.3 Fractals and Complex Patterns

Fractals are patterns that repeat at different scales. They appear in nature in things like leaves, snowflakes, shells, and trees. Designers can use computer-generated fractals to create unique textile prints.

Fractal designs are useful because they look complex but are built from mathematical rules.

10. Mathematical Art in Fashion

Fashion can also use mathematics as a source of artistic inspiration. This is called mathematical art.

Mathematical art uses ideas from geometry, topology, symmetry, folding, and patterns to create beautiful designs. Designers do not only use math for measurement. They also use it to imagine new forms.

One famous example is Issey Miyake. Miyake is known for pleating, folding, and creating garments that can change shape. His work often looks like origami. The uploaded source discusses Miyake's collaboration with mathematician William Thurston and explains how geometry influenced a fashion collection inspired by mathematical shapes.

Miyake's "Pleats Please" line is a strong example of how mathematics and fashion can work together. Pleats are repeated folds. To make pleats work, designers must calculate spacing, fabric behaviour, folding direction, and movement.

This shows that mathematics can help fashion become more experimental and artistic.

11. Digital Manufacturing and 3D Printing

Digital manufacturing means using computers, software, and machines to design and make products. In fashion, this includes digital pattern making, 3D body scanning, automated cutting, 3D knitting, and 3D printing.

Mathematics is at the centre of digital manufacturing because machines need exact instructions. A machine cannot guess like a human designer. It needs coordinates, measurements, paths, and algorithms.

11.1 3D Printing in Fashion

3D printing allows designers to create shapes that may be difficult to make using normal stitching. It can be used for shoes, accessories, jewellery, experimental dresses, and structural garments.

3D printing uses mathematical models to build objects layer by layer. It allows designers to create complex forms with less material waste compared to some traditional methods.

11.2 On-Demand Production

Mathematics also supports on-demand production. Instead of producing thousands of garments before knowing whether people will buy them, brands can use data to produce closer to actual demand.

This can reduce unsold stock and waste. It can also make fashion supply chains shorter and more efficient.

12. Smart Textiles and Wearable Technology

Smart textiles are fabrics that can respond to the environment or collect information. They may react to heat, light, moisture, pressure, or movement.

Some smart textiles can:

- Change colour
- Change shape
- Regulate temperature
- Track body movement
- Monitor health signals
- Clean themselves
- Respond to humidity

The uploaded source explains that smart textiles can use materials such as shape-memory alloys and shape-memory polymers. These materials can return to a certain shape when triggered by conditions such as temperature.

Mathematics is important in smart textiles because designers must calculate how the fabric responds. They may need to model heat transfer, movement, pressure, stretch, and electrical signals.

Smart textiles connect fashion with science, engineering, healthcare, and sports. For example, a smart sports shirt may track heart rate or movement. A jacket may adjust to temperature. A medical textile may monitor a patient's condition.

This shows that future fashion may not only be about appearance. It may also be about function.

13. Mathematics and Sustainability in Fashion

Sustainability means using resources in a responsible way so that the environment is protected for the future. The fashion industry faces many sustainability problems. These include fabric waste, water use, chemical pollution, overproduction, returns, and discarded clothing.

Mathematics can help reduce these problems.

13.1 Reducing Fabric Waste

When garments are cut, leftover fabric pieces are often wasted. Designers can use mathematical planning to arrange pattern pieces more efficiently on fabric. This is called marker making.

If pattern pieces are arranged carefully, less fabric is wasted. Even a small reduction in waste can become important when a factory produces thousands of garments.

13.2 Better Sizing

Poor sizing causes returns and waste. If customers buy clothes that do not fit, they may return them. Returns use extra packaging, transport, and labour. Some returned clothes may never be resold.

Statistics can help brands create better size charts. Body data can help companies understand real customer shapes instead of using outdated standard sizes.

13.3 Virtual Sampling

Traditionally, designers create many physical samples before final production. Some samples are changed, rejected, or thrown away. Digital simulation allows designers to test garments on computers first.

This reduces the need for physical samples and saves fabric, time, and money.

13.4 Demand Forecasting

Fashion brands often overproduce because they are unsure what customers will buy.

Mathematical forecasting can help predict demand more accurately.

Brands can study sales data, weather, trends, location, and customer behaviour. This helps them produce the right amount of stock.

13.5 Recycling and Circular Fashion

Mathematics can also support circular fashion, where products are reused, repaired, recycled, or resold instead of thrown away. Data systems can track materials and help brands understand where garments go after use.

The uploaded source also mentions that blockchain technology can help fashion supply chains become more transparent by tracking raw materials and product journeys. This can help customers know where their clothes come from and whether they are authentic.

14. Results and Findings

This research paper finds that mathematics is deeply connected to fashion in many ways.

First, mathematics helps with the basic construction of clothing. Measurement, geometry, algebra, and trigonometry are used in pattern making, cutting, stitching, pleating, draping, and fitting.

Second, mathematics helps fashion become more accurate. Designers can use statistics and probability to create better size charts and reduce fitting problems.

Third, mathematics supports creativity. Tessellations, fractals, symmetry, geometry, and folding inspire textile prints and garment forms.

Fourth, mathematics supports digital fashion. CAD software, 3D modelling, virtual simulations, and digital manufacturing all depend on algorithms and mathematical calculations.

Fifth, mathematics supports smart textiles. It helps designers understand how materials react to heat, moisture, pressure, movement, and shape changes.

Sixth, mathematics helps sustainability. It can reduce fabric waste, improve production planning, lower returns, support on-demand manufacturing, and make supply chains more transparent.

The main finding is that mathematics is not only useful in fashion. It is necessary for the future of fashion.

15. Discussion

The fashion industry is often divided into two sides: creativity and production. Creativity includes design, colour, shape, mood, and identity. Production includes measurement, cutting, sewing, costing, and manufacturing. Mathematics connects these two sides.

Without mathematics, a designer's idea may remain only a sketch. Mathematics helps turn the sketch into a real garment. It tells the designer how much fabric is needed, how pieces should be shaped, and how the garment will fit the body.

Mathematics also helps solve modern problems in fashion. One major problem is waste. The fashion industry produces too many clothes, and many are discarded. Mathematical tools can make production smarter.

Another problem is poor fit. Different people have different bodies, but many brands use limited sizing systems. Statistics and body data can help create better fit for more people.

A third problem is the cost and waste of sampling. Digital simulations can reduce physical samples. This makes fashion faster and more sustainable.

A fourth issue is innovation. Customers today want clothes that are not only beautiful but also functional. Smart textiles and wearable technology can create clothing that responds to the body and environment.

However, mathematics cannot replace creativity. It supports creativity. A formula alone cannot create fashion. But a designer who understands math has more control over shape, material, structure, fit, and sustainability.

This is why students interested in fashion should not ignore mathematics. Math can help them become better designers, pattern makers, textile artists, product developers, or fashion technologists.

16. Limitations

This paper has some limitations.

First, it is based on secondary research and does not include a new survey or experiment.

Second, the topic is very broad. Mathematics is used in many parts of fashion, and this paper cannot explain every area in detail.

Third, some advanced mathematical ideas, such as differential geometry, Chebyshev nets, and complex fabric simulations, have been explained in simple language. A deeper technical paper would need more formulas and advanced modelling.

Fourth, the paper focuses more on design, textiles, and sustainability. It does not deeply study fashion marketing, pricing analytics, or e-commerce algorithms.

Fifth, some technologies such as smart textiles, blockchain, and 3D printing are still developing. Their future role in fashion may become larger over time.

17. Conclusion

Mathematics plays a powerful role in fashion. It helps designers measure, cut, shape, fold, stitch, simulate, print, and produce clothing. It also helps brands make better size charts, reduce fabric waste, predict demand, and design smart textiles.

Fashion may look like a world of colours and creativity, but behind every garment there are numbers, angles, shapes, patterns, and calculations. A dress, shirt, jacket, shoe, scarf, or saree is not only a design object. It is also a mathematical object.

This paper has shown that geometry helps with patterns and shapes. Trigonometry helps with angles and diagonal designs. Algebra helps resize patterns and calculate costs. Statistics helps create size charts and forecast demand. Probability helps predict fit and sales. Computer algorithms help with CAD, 3D design, virtual try-ons, and digital manufacturing.

Mathematics also helps fashion become more sustainable. It can reduce waste, improve production, lower returns, support recycling, and help customers make better choices. As the fashion industry faces environmental challenges, mathematical thinking will become even more important.

The future of fashion will not only depend on beautiful designs. It will also depend on smart systems, accurate data, responsible production, and sustainable innovation. Mathematics can help make this future possible.

In simple words, fashion is not only stitched with thread. It is also stitched with numbers.

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