Politecnico di Torino

Master Degree in Engineering Management
A.a. 2023/2024

Quality Engineering
Project Work Report Group D

Construction of the HoQ and FMECA

Thermal running shirt

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Sommario

Introduction

For our analysis we selected as product the thermal running shirt, its main purpose is providing effective insulation and temperature regulation for the wearer. The primary function is to keep the body warm in cold conditions by trapping and retaining heat close to the body.

Amidst an era marked by the pursuit of excellence in athletic apparel, our product emerges as a testament to innovation and precision engineering. Designed with meticulous attention to detail, the Thermal Running Shirt embodies the essence of high-quality craftsmanship and performance-oriented design.

Key Emphasis on Superiority

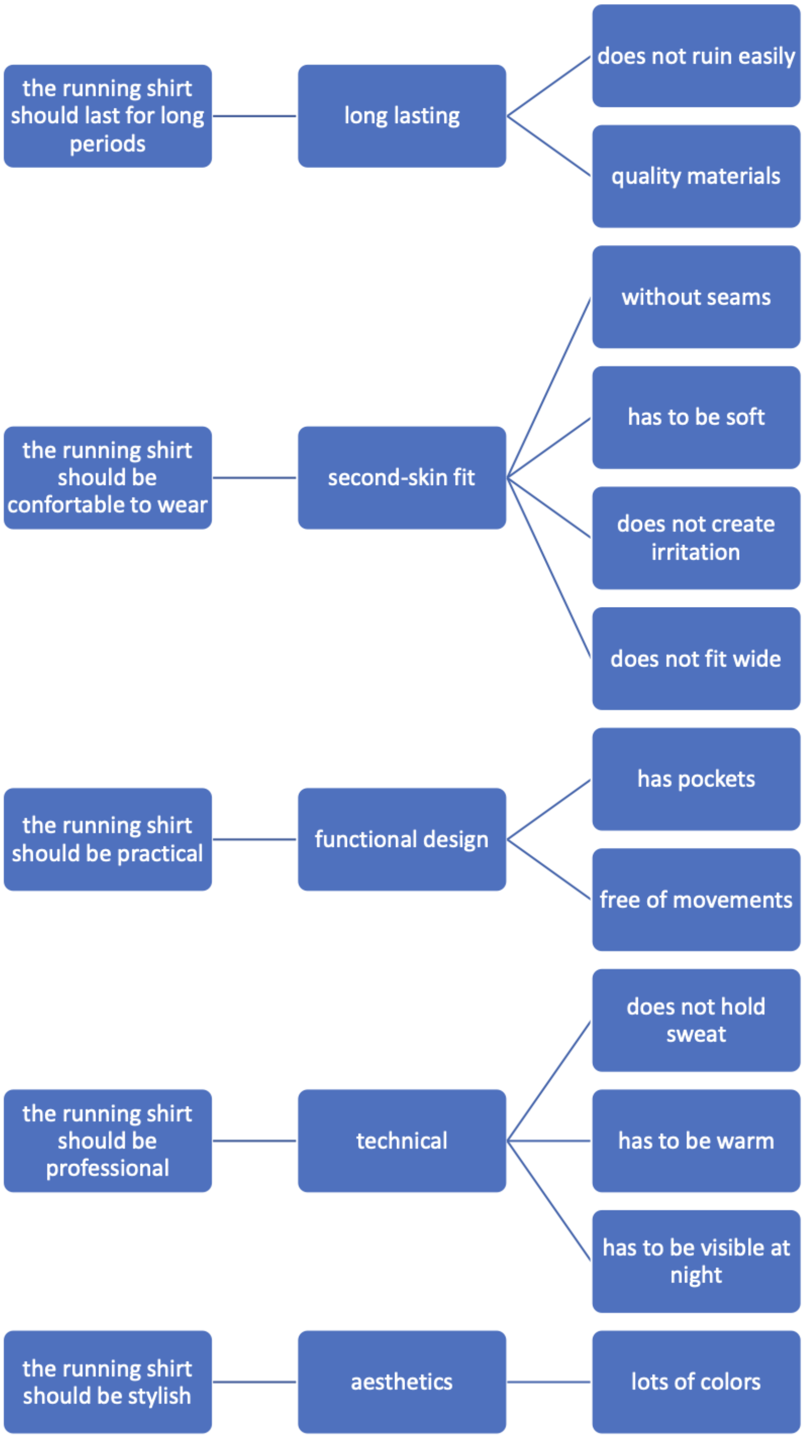
In this analysis, we aim to dissect and understand the foundational pillars of the Thermal Running Shirt—tensile strength, breathability, and water-vapour resistance. These key attributes have been the cornerstone of our endeavour to create a product that not only meets but exceeds the benchmarks set in the industry.

In this technical report, we assessed the strengths and limitations of our existing thermal running shirt by considering customer preferences and comparing it to other available products in the market. Following this evaluation, we conducted an in-depth analysis to identify and examine the crucial aspects and vulnerabilities present in our product.

Customer requirements

In the preliminary stage of formulating the House of Quality for the examination of a unisex thermic shirt, specifically designed for individuals engaged in sporting activities within a delineated market segment, the attention was directed towards the consumer expectations, needs, and requisites. This integral procedure involved interviews and surveys with a specified number of people, undertaken with the objective of comprehensively understanding their perspectives on the product. Considering the thermic shirt's intended usage by individuals actively participating in sports, a strategic decision was to include as participants the team members. This approach sought to immerse the research team in the experiential understanding of the product's usage. The team acted with dynamism to encourage diverse viewpoints, engender rigorous debates, and ultimately arrive at a conclusion of the customer requirements. The ultimate objective was to build a comprehensive set of primary customer requirements through a rigorous and collaborative approach, laying a solid foundation for the subsequent development of the House of Quality.

In the following table there is the final Customer Requirement tree:



Once we decided the basic customer requirements, we have established their degrees of importance trying to find a medium value between all the different evaluations.

Quality Degree of Importance		
5	Extremely important	Our customers prioritize a thermic shirt that **does not hold sweat** due to its direct impact on the user's comfort during the physical activities. This characteristic prevents discomfort from sweat accumulation and is crucial for a thermic shirt intended for active use. The emphasis on **unrestricted movement** reflects the customers' desire for a running t-shirt that facilitates agility and flexibility. Another primary function is to **provide warmth**, ensuring effective thermal insulation in varying conditions.
4	Very important	A key concern for our customers is **durability**. This quality is vital for ensuring the longevity and cost-effectiveness of the garment. They place high importance on the fit of the thermic shirt, expressing a preference for a **tailored fit** rather than a loose or wide one. This choice suggests a focus on both aesthetics and functionality. The emphasis on **quality materials** underscores the customers' interest for fabrics that not only contribute to durability but also enhance the overall comfort and performance of the thermic t-shirt. The customers prioritize a thermic shirt that **minimizes irritations**, using skin-friendly materials and construction techniques that prevent discomfort.
3	Important	Our customers value aesthetic choices and personalization in their thermic shirts, through the desire of a **variety of colors**. **Softness** is an important tactile aspect, indicating a preference for a thermic shirt that feels gentle and pleasant against the skin. The importance placed on a **seamless** design suggests that customers seek a thermic shirt with a smooth, streamlined appearance.
2	Not very important	The lower importance assigned to **pockets** indicates that customers prioritize other aspects over additional functionalities. In sportswear, especially thermic shirts, pockets may be perceived as less critical, given the focus on streamlined design and minimalism.
1	Not at all important	The classification of **visibility at night** as not at all important suggests that customers prioritize daytime functionality over nighttime visibility. This decision aligns with the specific use case of thermic shirts, which may be worn predominantly during daytime activities.

Competitors benchmarking

During our project we made comparisons between our product and other two competitors in order to improve the quality of our product in specific characteristics. We compared our **UYN sports** running shirt with the competing products of **Under Armour** and **X-Bionic**. We decided to select these specific competitors because they have different points of strength, and we can improve our running shirt qualities in many fields. The choice of Under Armour and X-Bionic as benchmarking competitors is driven by their established brand recognition, mid-high- range positioning, and the expectation that they share a target market with our company.

Under Armour - competitor x

Under Armour is known for integrating cutting-edge performance technologies into its sportswear, potentially offering superior thermic features. The brand's most strategic leverage is endorsements from professional athletes, contributing to its credibility and authenticity in the sports apparel market. Under Armour's widespread availability enhances its accessibility to a diverse customer base. The brand's extensive distribution network and retail partnerships contribute to its market penetration. The brand incorporates innovative materials and fabric constructions in its sportswear, contributing to enhanced athletic performance and comfort.

X-Bionic - competitor y

Bionic's Swiss engineering background might translate into precision in design and manufacturing, contributing to the overall quality of thermic shirts. X-Bionic is at the forefront of technological innovation in sportswear. The brand continuously introduces innovative features and technologies aimed at enhancing performance, comfort, and overall functionality. The brand prioritizes sustainability, appealing to environmentally conscious consumers through eco-friendly practices. X-Bionic uses high-quality materials in its sportswear, ensuring durability, functionality, and comfort. The choice of premium fabrics contributes to the overall performance and longevity of their products. X-Bionic pays attention to design aesthetics, creating sportswear that is not only functional but also visually appealing. The combination of innovative technologies with thoughtful design contributes to the overall attractiveness of their products.

Technical characteristics

At this point, we translated the customer requirements, which are expressed in subjective terms, into 12 objective technical characteristics:

Breathability

Breathability refers to the ability of the thermal shirt to allow the passage of moisture vapor (such as sweat) away from the body while retaining insulation. This is crucial for thermal wear, as it helps in maintaining comfort by preventing the buildup of moisture next to the skin. The technical measurement of breathability is often expressed in terms of grams per square meter per die (g/m^2 die). This measurement quantifies the amount of moisture vapor that can pass through a square meter of fabric over a 24-hour period. The higher the breathability rating, the more effective the fabric is in allowing moisture to escape. Manufacturers may use various testing standards to determine the breathability of thermal shirts, and these standards often involve controlled conditions to simulate real-world usage.

Tensile strength

Tensile strength is a key mechanical property used to describe the resistance of a material to a force that attempts to pull it apart. The tensile strength of a thermal shirt's fabric is an important factor in determining its durability and ability to withstand stretching or pulling. When specifying the tensile strength, you might see it represented as a force per unit width or thickness. It could be given in Newtons per millimeter (N/mm). For instance, a thermal shirt might have a tensile strength of, says, 45 N/mm. This means that for every millimeter of width, the fabric can withstand a force of 45 Newtons before breaking. High tensile strength is generally desirable for clothing, as it indicates that the fabric is less likely to tear or stretch out of shape during use.

Heat resistance

Heat resistance is a measure of how well a material can resist the flow of heat. It's often represented by the thermal resistance R and is measured in units of Kelvin square meters per watt ($K*m^2/W$). This value indicates how effective a material is at impeding the transfer of heat through it. In the context of a thermal shirt, heat resistance is a crucial factor in its ability to provide insulation and keep wearer warm. A higher heat resistance value means that the material is better at insulating against heat flow, which is particularly important in thermal clothing designed to trap and retain body heat. The formula for thermal resistance is:

R=Thickness of the material (m)/ Thermal conductivity of the material (W/m*K)

A thermal shirt with a higher resistance would generally be more effective in maintaining a comfortable temperature for the wearer in cold conditions.

Bending rigidity

Bending rigidity is a mechanical property that describes the stiffness or resistance of a material to bending. It's often measured in units of 10^{-6}Newton-meters (10^{-6}Nm) or micro Newton-meters (µNm). Bending rigidity is particularly relevant when considering the flexibility and drape of thermal shirts. A lower bending rigidity indicates a fabric that is more flexible and easier to bed, providing greater freedom of movement and comfort. On the other hand, a higher bending rigidity suggests a stiffer fabric that may have less drape and flexibility.

Antibacterial

The technical characteristic "antibacterial" refers to a material's ability to inhibit or kill the growth of bacteria. The measurement is often expressed as the percentage of positive results in ISO (International Organization for Standardization) tests. ISO tests are standardized methods to evaluate various properties of materials, including antibacterial performance. When a thermal shirt is described as "antibacterial" with a specified percentage of positive ISO tests, it means that the fabric has been tested according to specific ISO standards for antibacterial activity, and the given percentage represents the effectiveness of the material in inhibiting bacterial growth. For instance, a thermal shirt might be labeled as having an antibacterial characteristic with a percentage like "97% positive in ISO tests". This would indicate that, in the conducted ISO tests, the fabric exhibited antibacterial properties in 97% of cases. Consumers often value antibacterial properties in clothing, for hygiene reasons, especially during prolonged use or in situations where washing the garment frequently may not be practical. It's essential to check the specific ISO standard referenced in the product information to understand the testing methods and criteria used to determine the antibacterial performance of the fabric in the thermal shirt. Different standards may evaluate antibacterial properties in various ways.

Stretchability

It refers to the fabric's ability of the thermal shirt to stretch and move with the body during physical activities such as running. This is a very important technical characteristic for athletic wear as it enhances the overall comfort and performance of the cloth. A good stretchability is obtained through an accurate material selection for fabric composition of the shirt. Materials like spandex, elastane are commonly used to enhance the shirt's elasticity. To evaluate stretchability into our analysis we have compared the percentage of maximum stretch. A common range for the maximum stretch percentage of performance-oriented thermal shirts is around 20% to 40% of the original fabric length. The speed at which the fabric returns to its original shape after being stretched is also to take into account. A thermal shirt with good stretchability will have a quick recovery time, ensuring that the fabric maintains its shape and fit during and after movement.

Abrasion resistance

Abrasion resistance refers to the fabric's ability to withstand wear, rubbing, and friction without significant damage. For what concerns thermal shirts abrasion resistance is crucial for ensuring longevity and durability of the garment, this is particularly important for activities that involve frequent movement and potential friction. We have used cycle abrasion to compare abrasion resistance of thermal shirts. The testing process involves subjecting the fabric to a predetermined number of cycles. A thermal shirt may undergo thousands of cycles to simulate the abrasion it would experience over an extended period of use. After completing the specified number of cycles, the product is evaluated for any signs of damage. These results are compared with industry standards to determine if the thermal shirt meets the desired level of abrasion resistance. The range to ensure that the fabric of a thermal shirt withstand repetitive movements and frictions without showing signs of wear is between 10000 and 20000 cycles.

Evenness of weave pattern

The evenness of the weave pattern in a thermal shirt refers to the consistency and uniformity of the interlacement of yarns in the fabric. This technical characteristic is related to the visual appearance and tactile feel of the textile. To evaluate this technical characteristic, we have considered the number of snags. With the word snags we refer to skipped wires, crossed wires or twisted wires. The maximum acceptable number of errors in the thread pattern of a thermal shirt varies depending on the quality standard and the manufacturer's specifications. This number can vary depending on laws or quality standards for the specific product. In our case we have assumed as acceptable number for a thermal shirt a number of snags below 4.

Pilling resistance

Pilling resistance in a thermal shirt refers to the fabric's ability to resist the formation of small, fuzzy balls (known as pills) on its surface after extended use or washing. A thermal shirt with good pilling resistance will maintain a smoother appearance over time, with fewer or no noticeable pills, contributing to the garment's overall longevity and aesthetic appeal. The pilling resistance of a thermal shirt may vary depending on the material used to make it. Pilling resistance values are generally measured using the standard pilling resistance assessment method (ASTM D4970). The result obtained is expressed in terms of pilling class, which can range from 1 to 5. A higher pilling class indicates greater pilling resistance.

Water-vapour resistance

The water-vapor resistance of a thermal shirt is a technical characteristic that describes the fabric's ability to inhibit or allow the passage of water vapor. Water-vapor resistance is inversely related to breathability. A thermal shirt with good water-vapor resistance allows water vapor to escape from the body, preventing moisture buildup and maintaining comfort during physical activities. the unit of measurement commonly used to express the water-vapour resistance of fabrics is Ret(m2Pa/W). In terms of numerical values, the water vapour resistance of a thermal shirt can vary from approximately 0.05 to 0.3. Some textile materials known to have good vapour resistance properties are: Gore-Tex, Nylon, polyester microfibre, waxed canvas and polypropylene.

Number of pockets

We decided to include the requirement for pockets among the technical characteristics. In particular, our survey showed that the customer would consider it useful to have a pocket in the thermal jersey. This feature would be useful for carrying electronic devices such as phones or headphones while running. The inclusion of more pockets appears to be irrelevant to the consumer or even annoying. Many companies that deal with sportswear such as thermal jerseys choose to insert this pocket on the lower back. This turns out to be the most comfortable position during sporting activity. For this technical feature, the chosen unit of measurement is the count of the number of pockets.

Number of colors

The characteristic "number of colors" for a thermal shirt refers to the specific count of distinct colors that will be used in the design and production of the garment. This characteristic is an important aspect of the manufacturing process, influencing various elements from design complexity to production costs. The number of colors directly impact the visual appeal of the thermal shirt. A higher number of colors allows for more intricate designs, patterns, and graphics. This technical requirement impacts the amount of ink and dye used in the printing process, influencing material costs. More colors generally result in increased material consumption, and so higher production costs. This includes expenses related to materials, labor, and setup. For branded thermal shirts, adherence to specific color guidelines is crucial to maintaining brand consistency. The number of colors should align with the established brand identity. Consumer preferences play a role in determining the ideal number of colors. Some markets may prefer bold and colorful designs, while others may lean towards more minimalist or monochromatic styles. Summary this technical requirement is a multifaceted consideration that influences design aesthetics, production processes, costs and brand identity.

Analysis of Data

Examining the HoQ table reveals the key attributes that clients prioritize in a thermal running shirt, as indicated by the degree of importance. Customers place high value on a thermal running shirt that provides warmth and free movement, with less emphasis on secondary features like visibility at night or number of pockets.

Following this, an analysis of the technical characteristics required to meet customer expectations is conducted. The data highlights specific Technical Characteristics (TCs) that demand attention. By considering the parameters of technical importance and absolute weight, it becomes evident that features such as tensile strength and water-vapor resistance hold significant importance.

The second parameter, absolute weight, reinforces the significance of TCs based on customer requirements. Consistent findings with technical importance underscore the critical nature of factors tensile strength and water-vapor resistance.

To craft a thermal running shirt that meets customer satisfaction, the focus should be on particular customer requirements with the highest degree of importance and absolute weight, in our analysis tensile strength and water-vapor resistance. Developing specific technical requirements becomes essential, concentrating on factors associated with the high technical importance and absolute weight, such as tensile strength and water-vapor resistance.

FMECA comment

FMECA is a process oriented to identify, prioritize and eliminate potential failures of products, systems, designs or processes before they reach the customer. It is true that, the later the failures and defects are identified, the greater the harm to the business in terms of reputation, customers' perceptions and costs.

The FMECA process is normally synthetized in a table containing 10 columns, namely: unique reference, function, operational mode, failure mode, severity, failure causes, occurrence, detection system, undetectability and rank priority number.

Each of these columns describe an aspect of failure. In the first one we indicated a unique reference number associated with a function, listed in the second column. These represents the main aim of our product. In the following column, operational mode, we indicated how our product can be used by the customer. In the fourth column we listed some failure modes directly linked to the main goal of our product, such as insufficient wicking capacity, fabric piling, … followed by the effects produced by each failure. Then, the severity for each failure is found and represented by a number in the range 1 to 10, where the higher the number, the higher the level of severity. Thus, attention should be paid to the risks of insufficient breathability and seam failure (severity 9) and so on. This because the former brings high discomfort to the customer and imply the substantial failure of the product, which must be warm but breathable. The latter makes the product useless because it is no more wearable. They both have a quite high chance to happen, so they both need further attention.

In the following column we listed some of the possible failure causes. For each type of failure, more than one cause has been found because there could always be several reasons behind a consequence. Each of this causes is associated with a number ranging from 1 to 10 (where 10 is the highest) showing the occurrence of the cause identified. Here we identified the seam failure and the residual chemicals from manufacturing to be the most frequent and thus need particular attention.

Then, in the ninth column we listed the detection mode used for each type of failure. This is followed by a numerical value ranging from 1 to 10 (where 10 is the highest) indicating the undetectability of the failure cause. This number gives us an idea of how easily a failure can be detected when it verifies.

The last column shows the RPN, namely Risk Priority Number, which aggregates the previous identified numerical values by means of a multiplication between them. It gives us a global idea of where to concentrate efforts and resources to solve the main issues.

According to our study, the company needs to focus on effective quality controls for allergens and the adequate ventilation design, followed by an adequate labelling of allergens and the avoidance of fabric fraying.

We can moreover notice how important failure causes such as “insufficient breathability” or “insufficient wicking capacity” are not addressed as failure causes in need of particular attention. This because it is sufficient that one out of the three indicators rank sensibly lower to exclude it.

This is the principal aspect of this model, which allows the user to have corrective actions taken only on a consistent base rather than on his solely perception based on subjective considerations.

Conclusion and corrective actions

The above analysis of a thermal running t-shirt provided some perspectives on our product, that is a t-shirt designed to meet a high-end customer, who is seeking for comfort and performance features.

The main technical characteristics expected by this analysis are: a warm, breathable, allergen-free product, with a comfort fit. This study allowed us to build the House of Quality, which showed which were the features expected by customers. As a result, we found that the most important features were the “warmth”, “breathability” and “free of movements”.

Considering these results, our company decided to implement these same characteristics.

The FMECA analysis allowed us to position the company in terms of consumer requirements. Thus, we detected the main potential failure modes of the t-shirt that highlighted how, despite our main purpose is to build a product with high performances, we have to take into consideration also the allergen-free aspects, such as the performance of adequate tests and a correct labelling.

These failures, if present, can seriously damage our brand reputation because our company claims to use natural, allergen-free materials.

Therefore, our research and development center needs to focus both on the above mentioned technical characteristic as well as the maintenance of the high levels of performance in terms of warmth, breathability and comfort.

To ensure quality of our brand we have decided to perform a monthly test on a collected random sample of few shirts. This procedure is intended to help our company maintain the high quality of the goods sold and at the same time has a function of keeping track of problems or errors faced over time (Lesson learning).

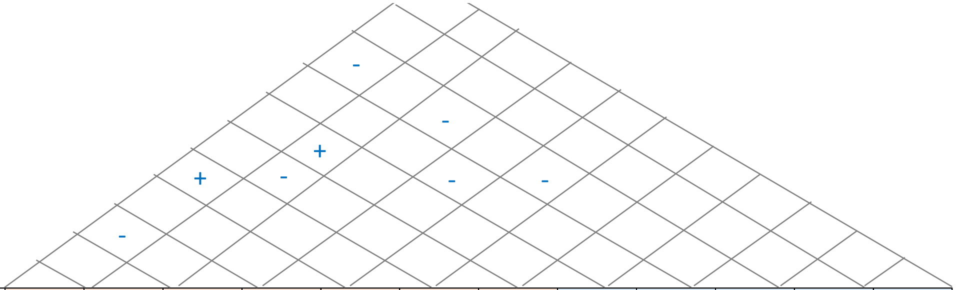
HoQ

Roof:

Positive Correlations	+
No Correlations	◌
Negative Correlations	-

Relationship matrix:

Strong Relationship	●
Medium Relationship	○
Weak relationship	△



	Customer Requirements / Technical Characteristics	**Degree of importance**	**Relative importance**	**Breathability**	**Tensile strenght**	**Heat resistance**	**Bending rigidity**	**Antibacterical**	**Stretchability**	**Abrasion resistence**	**Evenness of weave pattern**	**Piling resistance**	**Water-vapour resistance**	**Number of colours**	**Number of pockets**
				A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
1	Does not hold sweat	5	**11,6%**	●		○							●		
2	Free of movements	5	**11,6%**		●		●		●				●		
3	Does not ruin easily	4	**9,3%**		●				○	●	●	●			
4	Does not fit wide	4	**9,3%**		●										
5	Has to be warm	5	**11,6%**	○		●							●		
6	Quality materials	4	**9,3%**	●	○	●	○	●	●	●		●	○		
7	Lots of colours	3	**7,0%**											●	
8	Has to be visible at night	1	**2,3%**											○	
9	Has pockets	2	**4,7%**												●
10	Does not create irritation	4	**9,3%**	○	△			●				△			
11	Has to be soft	3	**7,0%**				●								
12	Without seams	3	**7,0%**		○						●				
	Total	**43**		↑	↑	↑	↓	↑	↑	↑	↓	↑	↓	↑	
	Absolute weight			2,73	3,13	0,89	1,90	1,74	2,27	1,80	1,36	1,90	3,92	0,48	0,58
	Relative weight			12,0%	13,8%	3,9%	8,4%	7,7%	10,0%	7,9%	6,0%	8,4%	17,3%	2,1%	2,6%
	Unit of measurement			g/m^2 die	N/mm	$K*m^2/W$	10^{-6}Nm	Percentag	% max stretch	abrasion cycles	number o	scale from	Ret(m^2Pa/	Number	Number
	Our existing model			20000	45	120	25	97%	20%	16000	2	3	0.07	4	0
	Competitor 1's model			15000	51,8	110	27	90%	25%	14000	3	2	0.25	6	0
	Competitor 2's model			25000	45	120	27	95%	35%	17000	1	3	0.07	3	0
	Target (new model)			**25000**	**45**	**120**	**25**	**97%**	**35%**	**20000**	**1**	**4**	**0.05**	**4**	**1**

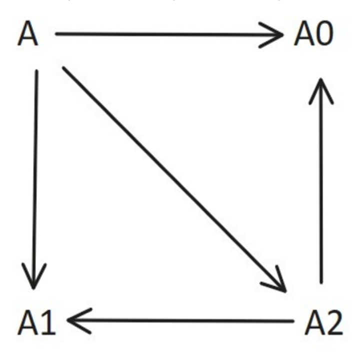
Our existing model	**Competitor 1's model**	**Competitor 2's model**	**Target (new model)**	**Improvement ratio**	**Strength**	**Absolute weight**	**Relative weight**
5	4	5	5	1,00	1,5	7,5	12,1%
4	4	5	5	1,25	1,2	7,5	12,1%
3	2	4	4	1,33	1,2	6,4	10,3%
4	5	5	4	1,00	1	4,0	6,5%
3	5	5	4	1,33	1,5	10,0	16,1%
5	2	4	5	1,00	1,5	6,0	9,7%
2	3	2	2	1,00	1	3,0	4,8%
1	1	1	1	1,00	1	1,0	1,6%
1	1	1	2	2,00	1	4,0	6,5%
5	3	4	5	1,00	1,5	6,0	9,7%
4	3	4	4	1,00	1,2	3,6	5,8%
4	3	4	4	1,00	1	3,0	4,8%
						62,0	

Q bench

Q-bench	Breathability	Tensile strenght	Heat resistance	Bending rigidity	Antibacterical	Stretchability	Abrasion resistence	Evenness of weave pattern	Piling resistance	Water-vapour resistance	Number of colours	Number of pockets
	A	B	C	D	E	F	G	H	I	L	M	N
Nominator	250,8	330	222,9	195,3	167,4	216	167,4	146,7	176,7	341,1	69,9	42,3
Denominator	2326,5	2326,5	2326,5	2326,5	2326,5	2326,5	2326,5	2326,5	2326,5	2326,5	2326,5	2326,5
Relative Importance	0,107801418	0,14184397	0,095809155	0,083946	0,071954	0,092843327	0,071953578	0,063056093	0,075951	0,146615	0,030045	0,018182
Percentage	10,78%	14,18%	9,58%	8,39%	7,20%	9,28%	7,20%	6,31%	7,60%	14,66%	3,00%	1,82%
	↑	↑	↑	↓	↑	↑	↑	↓	↑	↓	↑	-
our model	20000	45	120	25	97%	20%	16000	2	3	0.07	4	0
competitor 1	15000	51,8	110	27	90%	25%	14000	3	2	0.25	6	0
competitor 2	25000	45	120	27	95%	35%	17000	1	3	0.07	3	0
domain contraction	10000-30000	40-55	100-130	20-30	85-100	15-40	10000-20000	1–4	1–4	0.05-0.30	2–7	0-1
target new model	**25000**	**45**	**120**	**25**	**97%**	**35%**	**20000**	**1**	**4**	**0.05**	**4**	**1**

VERIFICATION TEST

	J+	J=	J-	W+	W=	W-	(W+ + W=) / W >= 2/3	W+ / W- >= 1	aOa'
(a,a_0)	A,F,G,H,I,L	B,C,D,E,M,N		55,82%	44,18%	0	100,00%		yes
(a,a_1)	A,C,D,E,F,G,H,I,L	N	B,M	80,99%	1,82%	17,19%	82,81%	471,19%	yes
(a,a_2)	D,E,G,I,L,M	A,B,C,F,H,N		48,05%	51,95%	0	100,00%		yes
(a_0,a)		B,C,D,E,M,N	A, F,G,I,H,L	0	44,18%	55,82%	44,18%	0,00%	no
(a_0,a_1)	A,C,D,E,G,H,I,L	N	B,F,M	71,71%	1,82%	26,47%	73,53%	270,87%	yes
(a_0,a_2)	D,E,M	B,C,I,L,N	A,F,G,H	18,59%	47,84%	33,57%	66,43%	55,40%	no
(a_1,a)	B,M	N	A,C,D,E,F,G,H,I	17,19%	1,82%	80,99%	19,01%	21,22%	no
(a_1,a_0)	B,F,M	N	A,C,D,E,G,H,I,L	26,47%	1,82%	64,51%	28,29%	41,04%	no
(a_1,a_2)	B,M	D,N	A,C,E,F,G,H,I,L	17,19%	10,21%	72,60%	27,40%	23,68%	no
(a_2,a)		A,B,C,F,H,N	D,E,G,I,L,M	0	51,95%	48,05%	51,95%	0	no
(a_2,a_0)	A,F,G,H	B,C,I,L,N	D,E,M	33,57%	47,84%	18,59%	81,41%	180,51%	yes
(a_2,a_1)	A,C,E,F,G,H,I,L	D,N	B,M	72,60%	10,21%	17,19%	82,81%	422,36%	yes



Lyman's Normalization

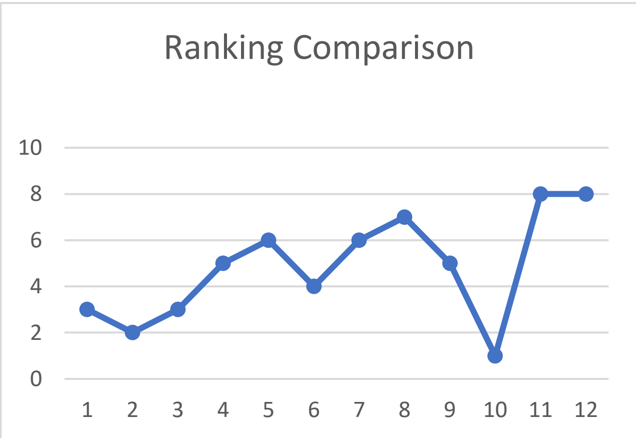
Coefficients											
9,00	0,00	3,00	0,00	0,00	0,00	0,00	0,00	0,00	9,00	0,00	0,00
0,00	9,00	0,00	9,00	0,00	9,00	0,00	0,00	0,00	9,00	0,00	0,00
0,00	9,00	0,00	0,00	0,00	3,00	9,00	9,00	9,00	0,00	0,00	0,00
0,00	9,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3,00	0,00	9,00	0,00	0,00	0,00	0,00	0,00	0,00	9,00	0,00	0,00
9,00	3,00	9,00	3,00	9,00	9,00	9,00	0,00	9,00	3,00	0,00	0,00
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	9,00	0,00
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	3,00	0,00
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	9,00
3,00	1,00	0,00	0,00	9,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00
0,00	0,00	0,00	9,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
0,00	3,00	0,00	0,00	0,00	0,00	0,00	9,00	0,00	0,00	0,00	0,00

Sum	ISM without applying the Lymans Normalization											
21	67,50	0,00	22,50	0,00	0,00	0,00	0,00	0,00	0,00	67,50	0,00	0,00
36	0,00	67,50	0,00	67,50	0,00	67,50	0,00	0,00	0,00	67,50	0,00	0,00
39	0,00	57,60	0,00	0,00	0,00	19,20	57,60	57,60	57,60	0,00	0,00	0,00
9	0,00	36,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
21	30,00	0,00	90,00	0,00	0,00	0,00	0,00	0,00	0,00	90,00	0,00	0,00
63	54,00	18,00	54,00	18,00	54,00	54,00	54,00	0,00	54,00	18,00	0,00	0,00
9	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	27,00	0,00
3	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	3,00	0,00
9	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	36,00
14	18,00	6,00	0,00	0,00	54,00	0,00	0,00	0,00	6,00	0,00	0,00	0,00
9	0,00	0,00	0,00	32,40	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
12	0,00	9,00	0,00	0,00	0,00	0,00	0,00	27,00	0,00	0,00	0,00	0,00

Coefficients corrected by the Lyman's Normalization											
0,43	0,00	0,14	0,00	0,00	0,00	0,00	0,00	0,00	0,43	0,00	0,00
0,00	0,25	0,00	0,25	0,00	0,25	0,00	0,00	0,00	0,25	0,00	0,00
0,00	0,23	0,00	0,00	0,00	0,08	0,23	0,23	0,23	0,00	0,00	0,00
0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
0,14	0,00	0,43	0,00	0,00	0,00	0,00	0,00	0,00	0,43	0,00	0,00
0,14	0,05	0,14	0,05	0,14	0,14	0,14	0,00	0,14	0,05	0,00	0,00
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00
0,21	0,07	0,00	0,00	0,64	0,00	0,00	0,00	0,07	0,00	0,00	0,00
0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
0,00	0,25	0,00	0,00	0,00	0,00	0,00	0,75	0,00	0,00	0,00	0,00

Sum	ISM using the coefficients "corrected" by Lyman's Normalization											
1,00	3,21	0,00	1,07	0,00	0,00	0,00	0,00	0,00	0,00	3,21	0,00	0,00
1,00	0,00	1,88	0,00	1,88	0,00	1,88	0,00	0,00	0,00	1,88	0,00	0,00
1,00	0,00	1,48	0,00	0,00	0,00	0,49	1,48	1,48	1,48	0,00	0,00	0,00
1,00	0,00	4,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1,00	1,43	0,00	4,29	0,00	0,00	0,00	0,00	0,00	0,00	4,29	0,00	0,00
1,00	0,86	0,29	0,86	0,29	0,86	0,86	0,86	0,00	0,86	0,29	0,00	0,00
1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	3,00	0,00
1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00
1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	4,00
1,00	1,29	0,43	0,00	0,00	3,86	0,00	0,00	0,00	0,43	0,00	0,00	0,00
1,00	0,00	0,00	0,00	3,60	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1,00	0,00	0,75	0,00	0,00	0,00	0,00	0,00	2,25	0,00	0,00	0,00	0,00

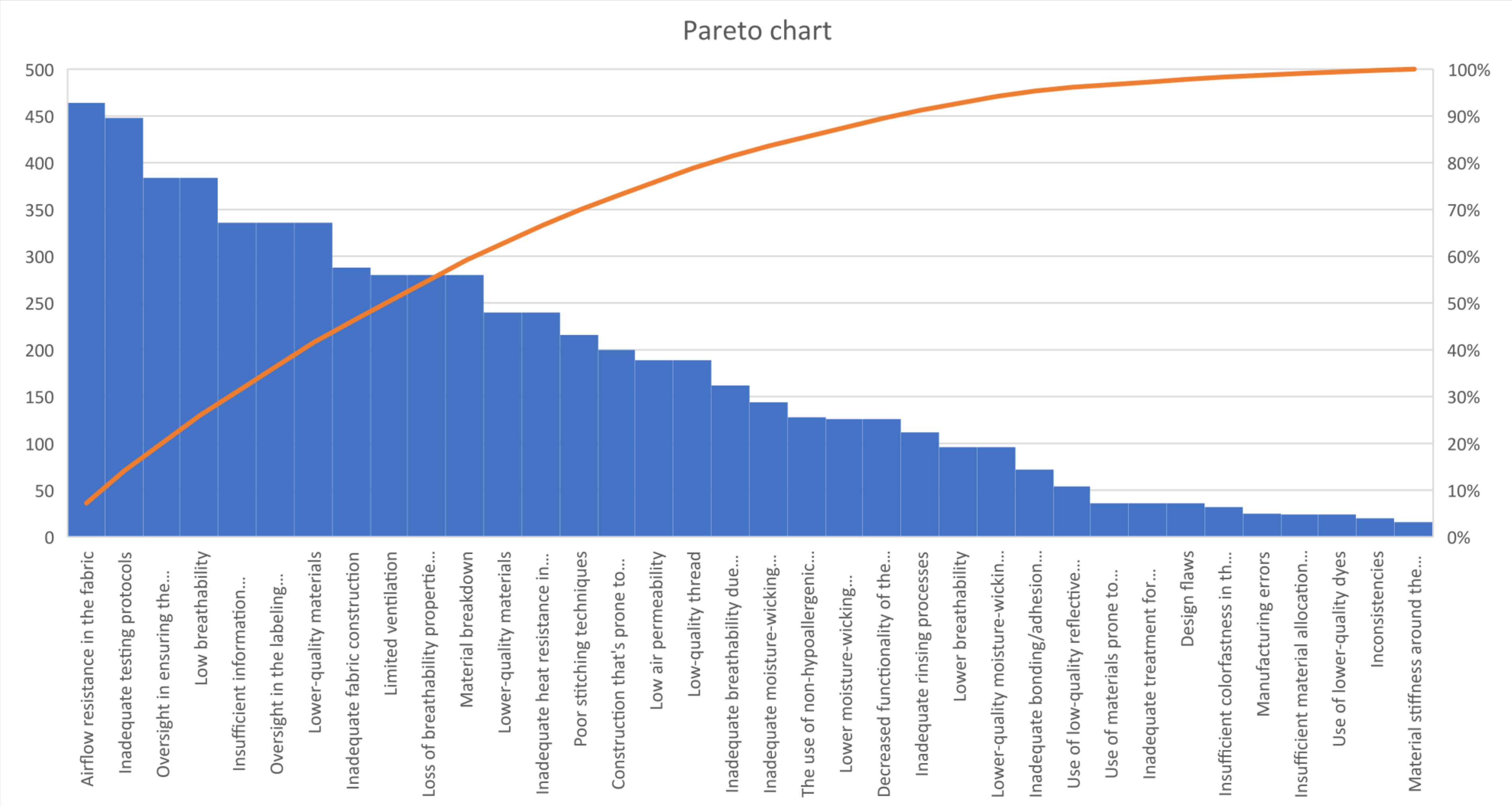
(Technical) Absolute weight (no LYMAN)	169,50	194,10	166,50	117,90	108,00	140,70	111,60	84,60	117,60	243,00	30,00	36,00
(Technical) Relative weight (no LYMAN)	11%	13%	11%	8%	7%	9%	7%	6%	8%	16%	2%	2%
ranking	3	2	3	5	6	4	6	7	5	1	8	8



FMECA

Unique reference	Function	Operational Mode	Failure Mode	Effects	S	Failure cause(s)	O	Detection system	D	RPN(=SxDxO)
N.1	Moisture Wicking	Regular running, intense exercise	Insufficient wicking capacity	Inability to keep the wearer dry, discomfort during physical activity	8	Inadequate moisture-wicking treatment application	6	Stain test	3	144
						Lower-quality moisture-wicking materials	4		3	96
			Fabric pilling	Reduced effectiveness in moisture wicking, aesthetics affected	8	Lower-quality materials	6	Visual inspection	5	240
						Construction that's prone to piling	5		5	200
N.2	Temperature Regulation	Regular running, intense exercise	Insufficient breathability	Reduced air circulation, potential discomfort, overheating	9	Inadequate breathability due to the fabric's inability to manage moisture effectively	6	Thermal resistance test	3	162
						Low air permeability	7		3	189
			Limited ventilation	Reduced air exchange, potential overheating	8	Lower breathability	4	Air permeability test	3	96
						Airflow resistance in the fabric	6		3	144
			Overheating	Discomfort, increased risk of heat-related issues	8	Limited ventilation	7	Thermal sensors	5	280
						Inadequate heat resistance in the fabric	6		5	240
N.3	Comfortable Fit	Regular running, intense exercise, everyday wear	Size labelling inaccurancy	Discomfort, restricted movement	5	Manufacturing errors	5	Image recognition technology	1	25
						Inconsistencies	4		1	20
			Uncomfortable neckline	Discomfort around the neck	4	Design flaws	3	Image recognition technology	1	12
						Material stiffness around the neck area	4		1	16
N.4	Durability	Washing and Maintenance	Fabric fraying	Reduced structural integrity, potential discomfort, compromised aesthetics	8	Lower-quality materials	7	Visual inspection	6	336
						Inadequate fabric construction	6		6	288
			Seam failure	Loss of garment structure, reduced functionality	9	Poor stitching techniques	8	Tensile test	3	216
						Low-quality thread	7		3	189
			Color fading	Aesthetic degradation	2	Use of lower-quality dyes	3	Spectrophotometer	4	24
						Insufficient colorfastness in the fabric	4		4	32
N.5	Visibility Enhancement	Light running	Reflective material peeling	Reduced visibility in low lights conditions, compromised safety	3	Use of low-quality reflective material	3	Visual inspection	6	54
						Inadequate bonding/adhesion during manufacturing	4		6	72
			Inadequate size of reflective elements	Reduced visibility from certain angles, compromised safety	2	Design flaws	3		4	24
						Insufficient material allocation for effective visibility enhancement	3		4	24
			Fabric deterioration affecting reflectivity	Diminished reflectivity overtime, compromised safety	2	Use of materials prone to degradation	3		6	36
						Inadequate treatment for maintaining reflectivity	3		6	36
N.6	Ventilation	Intense exercise	Inadequate ventilation design	Reduced overall airflow, potential overheating	8	Low breathability	6	None	8	384
						Airflow resistance in the fabric	5		8	320
			Deterioration of ventilation material	Decreased effectiveness of ventilation overtime	8	Material breakdown	7	Sensor placement	5	280
						Loss of breathability properties over time	7		5	280
			Ineffective moisture wicking	Reduced evaporation, discomfort, potential overheating	7	Lower moisture-wicking material properties	6	Stain test	3	126
						Decreased functionality of the moisture-wicking treatment	6		3	126
N.7	Allergen-Free Design	Regular running, intense exercise, everyday wear, light running	Residual chemicals from manufacturing	Skin irritation, allergic reactions, potential health risks	8	Inadequate rinsing processes	7	FTIR	2	112
						The use of non-hypoallergenic materials during production	8		2	128
			Inadequate labelling of allergens	Users unaware of potential allergens, increased risk of reactions	7	Oversight in the labeling process	6	None	8	336
						Insufficient information provided to users	6		8	336
			Ineffective quality control for allergens	Potential health risks	8	Inadequate testing protocols	7		8	448
						Oversight in ensuring the absence of allergens in materials used	6		8	384

Pareto Chart



Criticality Matrix

9,10			B1	B2 D3 D4	
7,8		A2 B3	A1 A4 B4 B6 D2 F1 F2 F5 F6 G3 G4 G6	B5 D1 F3 F4 G1 G2 G5	
5,6		C2	C1		
3,4		C3 C4 E1 E2			
1,2		D5 D6 E3 E4 E5 E6			
↑S O →	1,2	3,4	5,6	7,8	9,10

- Acceptable
- Critical
- Non Acceptable