Textile Product Design and Development
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Lecture - 04
Specification Development

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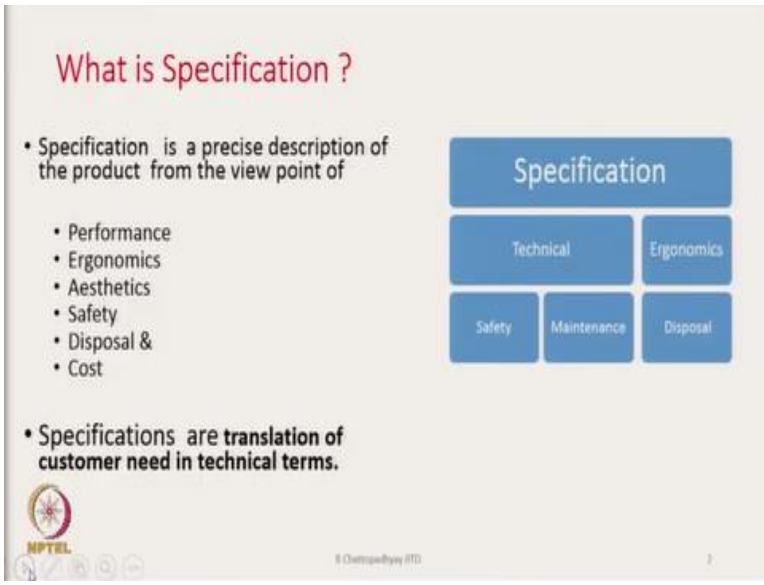

We are going to discuss specification development. What is specification? The specification precisely describes the product from the viewpoint of performance, ergonomics, aesthetics, safety, disposal, cost, etc. We have discussed the customer needs, and specifications are translations of customer needs in terms of technical needs. A set of specifications is needed to translate or transform into technical terms. These specifications can include aspects like ergonomics, safety, maintenance, and disposal, all of which are part of the specifications of the product.

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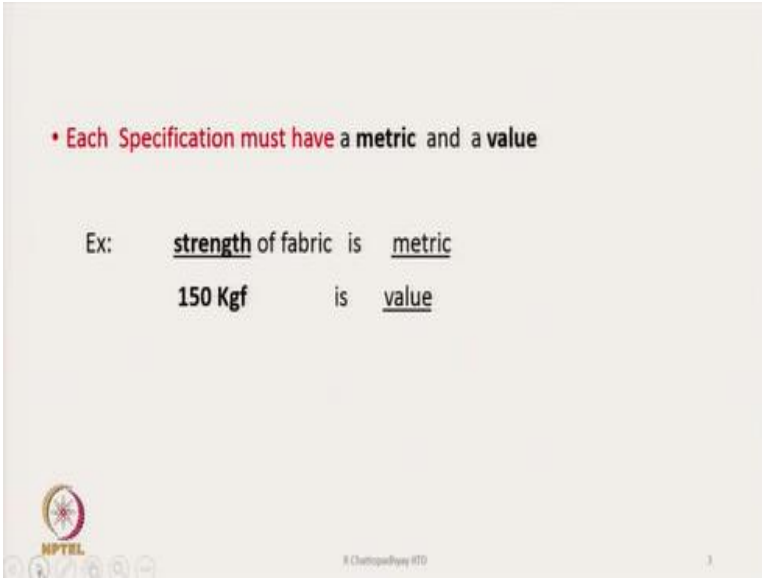

Each specification needs to have a metric and its value. For example, consider the strength of a fabric: "strength" is the metric, and if the fabric can withstand 150 kgf, then 150 kg is the value. The unit can also be in ‘N’. So, "strength" is the metric, and 150 kgf is the value.

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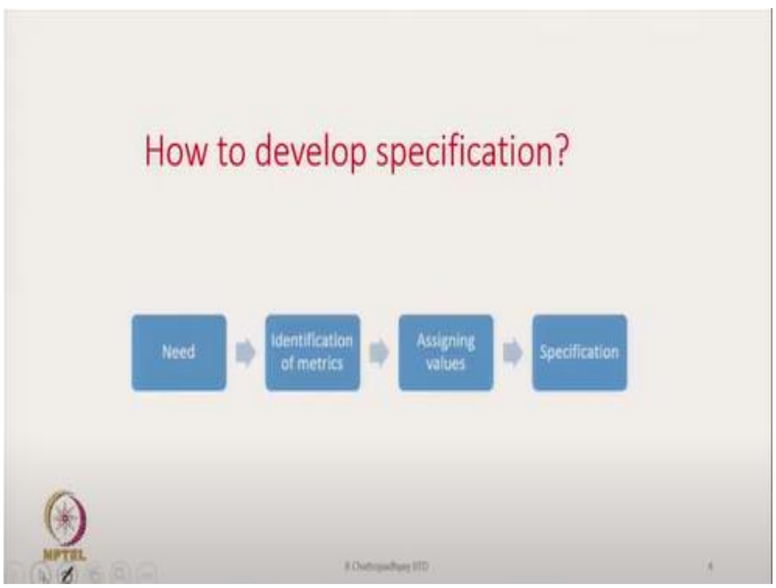

How do you develop specifications? The process starts with identifying the need, which is the starting point. Then, you identify the metrics for these needs and assign values to them. Without these values, designing is not possible. Once the values are assigned to the different needs, they become the specifications. For each need, there must be a corresponding metric and value.

Different needs will have different metrics and values, and these make up the complete set of specifications.

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The most important aspect is translating the needs into specifications. Customer needs are usually expressed in layman's terms, which offer little guidance for designing and engineering a product. On the other hand, specifications provide precise, measurable details about the product. This set of specifications is essential before starting the actual design process and is expected to meet the customer's needs. So, keeping the customer's needs in mind, the specifications must be established to ensure they satisfy all the customer's needs.

For example, if a customer says their winter jacket isn't warm enough, that's the customer statement. The need is that a jacket must provide adequate warmth. The corresponding specification for warmth is insulation. The insulation unit is either in ‘tog’ or ‘clo’. While the metric and unit are clear, the specific value needs to be assigned. For this, we need to determine the insulation value of the existing jacket in ‘tog’ or ‘clo’ units. Then, we assess how much insulation is required to ensure the jacket meets the customer's need for warmth.

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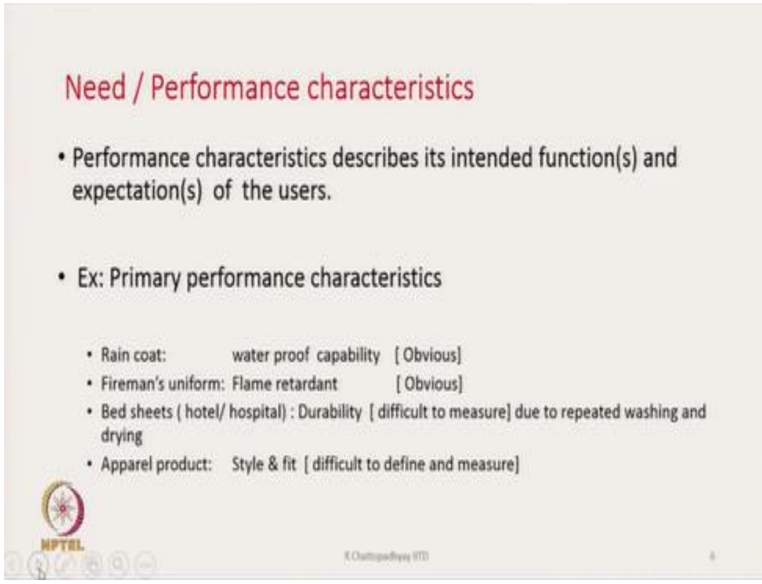

The required insulation value depends on the climate in which the customer is using the jacket. A higher insulation value is necessary for someone in a mountainous area with lower temperatures. In contrast, the insulation requirement is less for persons in milder temperatures. The "need" can also be referred to as "performance characteristics". These characteristics describe the intended functions of the product and the user's expectations. Sometimes, the designer can identify or assign the various characteristics that should be present in a product. For example, the primary performance characteristic of a raincoat.

The primary performance characteristic of a raincoat is waterproof capability. Because from the product's name, a raincoat must protect the wearer from rain. Therefore, the product must be waterproof, the first and foremost performance criterion or characteristic. The other performance characteristics may be important for different products. For example, the performance characteristic of a fireman's uniform is flame retardancy, which should resist fire when a fireman is exposed to fire. Durability is crucial for bedsheets used in hotels or hospitals because they need to withstand frequent laundering and heavy use. In contrast, for domestic use, the focus might be more on comfort and aesthetic qualities rather than extreme durability.

Why did it need to be more durable? Durability is important for bed sheets used in hospitals and hotels because they are washed frequently. Durability is a performance characteristic which is difficult to measure and depends on several factors. So, what parameters are going to affect the durability of a product? For apparel products, style and fit are highly desirable characteristics, but they are challenging to define and measure. These are the certain performance characteristics that customers expect in a product, and they are difficult to measure. Similarly, style is also difficult to measure. The pride in owning something is indeed difficult to measure. Fit, on the other hand, can be measured to some extent. These are some examples of performance characteristics of the most important needs of some products.

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When developing target specifications, we first define the ideal requirements without worrying about current technological limitations. Some specifications may not be achieved, and some exceed depending upon the product concept. It is also possible that some specifications may be achievable, and some may not be achieved. Even so, we should start with what we call target specifications. Since some of these may not be achievable, the target specifications might need to be refined after the product concept is developed. So, once the concept is developed, some of the specifications are difficult to achieve with the existing product concept.

In that case, there are two options: either change the concept to meet the target specifications or adjust the specifications themselves. The choice depends on various factors that need to be considered. The key point is that target specifications may need to be modified or refined based on the product concept.

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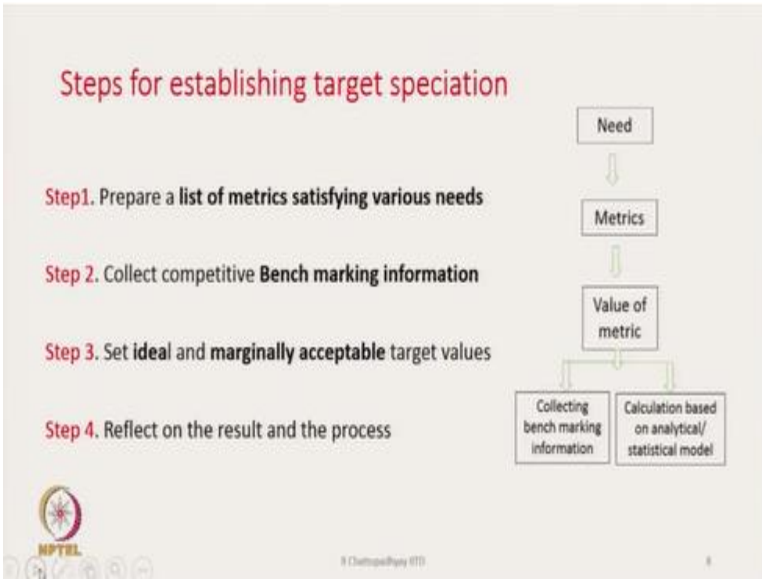

To establish target specifications, the first step is to prepare a list of metrics that address various needs. Start by identifying the customer's needs and then translate these into the technical needs of the product. For each of these technical needs, determine the corresponding metric that satisfies them. Next, benchmarking information is gathered by collecting data on the metrics used by competitors to satisfy similar needs. Then, both ideal and marginally acceptable target values for each metric are set, establishing a range: an ideal value that is preferable to achieve and a marginally acceptable value, even if it falls.

After setting the values, it is important to reflect on the results and the process to finalize the target specifications. Marginal access values are the minimum that should be achieved and should be less than that. Otherwise, the product is not going to function, or it is not going to sell. Ideal values may be slightly higher than this value. We must have ideal values and marginally acceptable values for different needs. Steps for establishing target specifications include the need to use metrics and metrics to value the metric, the collection of benchmark information for finding the value of the metric, and calculation, which may be based on analytical and statistical models. What are the values of this metric? The real challenge lies in collecting benchmarking information. Analyzing the take competitor's products by testing them to find their values. Alternatively, a mathematical model or any other available analytical model can be used.

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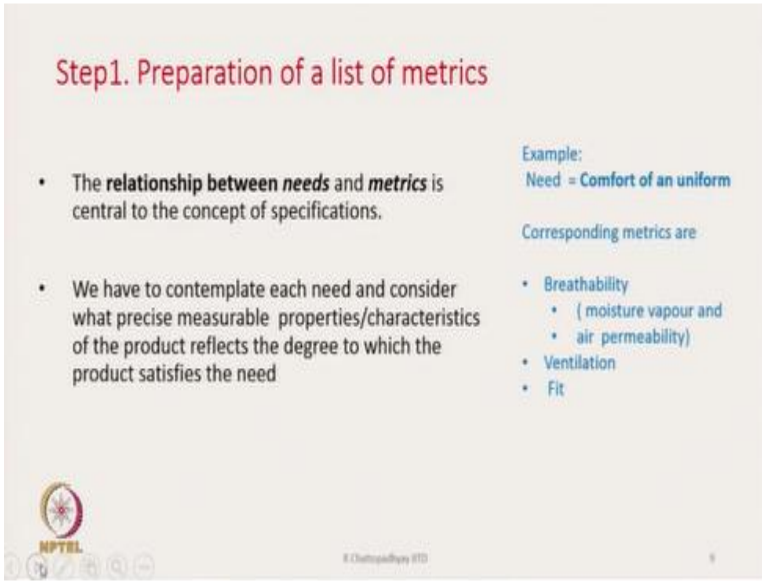

The first step is to prepare a list of metrics. This requires a deep understanding of how needs relate to corresponding metrics. The relationship between need and the metrics is central to the concept of specifications. The person with the domain knowledge can determine which metrics are needed to satisfy each specific need. What are the corresponding metrics for it? For each need, consider the precise measurable properties or characteristics of the product that reflect how well it satisfies that need. For example, consider the need for comfort in a uniform. Comfort is a general term and can be subjective, making it difficult to measure or quantify. Why is it important? Because comfort is a function of breathability.

Breathability refers to how well moisture vapour, and air can pass through the fabric. So, comfort depends upon breathability, which is a very general term. In scientific terms, this is moisture vapour transmission and air permeability through the fabric or through the garment. Comfort in a garment can also be affected by ventilation. In garment design, ventilation plays a key role in comfort by allowing moisture-laden air near the skin to escape through vents. Additionally, the fit of the garment is important in the case of a uniform; if it is a tight fit or loose fit, it also affects comfort.

Several factors influence comfort. It is a function of breathability, which in turn is a function of moisture vapour and air permeability, ventilation, and fit. This illustrates that a single need, like comfort, can be assessed through multiple metrics. For comfort, these metrics include breathability, ventilation, fit, and stretchability properties.

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Following are the guidelines for developing a list of metrics. First, the metric should be complete. Each need should ideally have at least one corresponding metric. The value of this metric should ideally correlate perfectly with the need. However, for some needs, like comfort, multiple metrics may be required, while for others, there may be a single metric. Metrics should be dependent and not independent variables. Since a metric reflects the product's overall performance, it depends on various other properties or construction parameters of a fabric or garment. By using a dependent variable for the specification, designers have the freedom to achieve the specification using the best possible approach.

The designer has the flexibility to meet a specific metric through various combinations of factors. For example, if the goal is to achieve a certain strength in a yarn, such as 300 grams of force, this strength can be attained by adjusting the strength of the fibres used. So, there are many variables that can be used to achieve the target strength of the yarn. For instance, the strength can be varied by changing the fibre strength, twist or yarn counts. Using these different combinations will produce the yarn to satisfy the requirement of a certain strength. Next, some needs may not be translated into quantifiable metrics. For example, the pride someone feels in owning a suit, a car, or a wristwatch. So, how do we quantify pride? This is very difficult.

What could be the metrics related to pride? This is a challenge because while the pride in owning a suit, car, or wristwatch is important, it is difficult to quantify. However, this feeling can still be a crucial part of the design. A design engineer must create products that evoke a sense of pride in the owner or user. In such cases, the metric for pride would be subjective and might be assessed by a panel of judges. Here, there are the things which may affect the pride. This type of attribute, like pride in owning something, is not easily measurable. To assess it, we would typically ask people directly about how much pride they feel in owning the product. Since this is highly subjective, it would often require evaluation by a panel of experts who are familiar with the area.

In some cases, the cost of the product could be a metric, as a higher price might contribute to a sense of pride, making the owner feel unique because others might not be able to afford it. Therefore, a person may feel a sense of pride in owning something expensive because it sets them apart, knowing that others cannot easily afford it.

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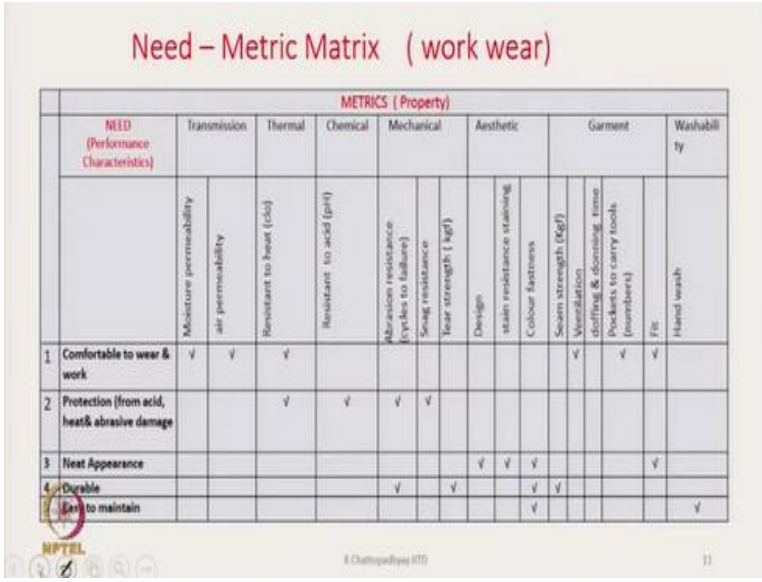

Need – Metric Matrix (work wear)

	METRICS (Property)																
	NEED (Performance Characteristics)	Transmission		Thermal	Chemical	Mechanical			Aesthetic			Garment					Washability
		Moisture permeability	air permeability	Resistant to heat (clo)	Resistant to acid (pH)	Abrasion resistance (cycles to failure)	Snag resistance	Tear strength (kgf)	Design	stain resistance staining	Colour fastness	Seam strength (Kgf)	Ventilation	doffing & donning time	Pockets to carry tools (numbers)	Fit	Hand wash
1	Comfortable to wear & work	√	√	√									√		√	√	
2	Protection (from acid, heat& abrasive damage			√	√	√	√										
3	Neat Appearance								√	√	√					√	
4	Durable					√		√			√	√					
5	Easy to maintain										√						√

People often feel proud when they own an apple computer, and apple has successfully used this for their marketing. The next thing is a need-metric matrix of work wear. This is the first thing that the designer must develop. This matrix lists the needs in the first column. Different metrics or properties of the product are listed in the remaining columns of the matrix. The idea is to connect each need with the relevant properties. These properties are classified as transmission properties, thermal properties, chemical properties, mechanical properties, and aesthetic properties. Garment-specific characteristics are also included if the product is a garment, like workwear. Additionally, maintenance aspects, such as washability, are also considered.

The different metrics have been classified, and the first need is comfortable to wear and work. This is a key requirement for the persons using workwear. Certain properties are essential to meet this need. For example, moisture permeability, air permeability, and resistance to heat are all important factors that contribute to making the workwear comfortable for the user. Additionally, ventilation is important from the garment's perspective, as it allows for proper air circulation. The number of pockets is also important, as they need to be sufficient for carrying tools. The fit of the garment is another key factor. On the right-hand side, we list these properties, and whenever a property is relevant to the need, we mark it. Thus, we can see that the comfort of wearing and working depends on these specific aspects, which are the relevant metrics for achieving this need.

We focus on the relevant properties for the second need, which is protection from acid, heat, and abrasive damage. Resistance to heat is important, so we mark that. Resistance to acid is also crucial, so we tick that as well. Abrasion resistance, which is a mechanical property, is necessary, so it gets a tick too. Snag resistance is another key factor, so it is marked as well. If the remaining properties are not relevant, we simply leave them unmarked. These properties are crucial for ensuring protection from acid, heat, and abrasive damage. Another important need is durability. When we purchase something, we generally expect it to be durable. Some people might expect a product to last for one year, while others might hope for three or even five years. Because of this, durability cannot be measured.

The corresponding metric that helps us make a product durable is abrasion resistance. abrasion resistance, which can be measured, so it gets a tick. Another important metric is the tear strength of the fabric, which is also a mechanical property. However, air permeability and moisture permeability do not influence durability. Thus, you cannot mark a tick under the transmission properties of the fabric for durability. Durability also depends on colour fastness because if the colour fades, we often reject the product, even if it is still mechanically strong. If the product no longer looks good due to colour fading, we tend to discard it.

Therefore, colour fastness can also affect durability. If the colour fades too quickly, the product is considered less durable. Seam strength is another important factor. We can understand which metrics satisfy each need by examining these aspects and marking them in a chart. This task requires domain knowledge, so someone with expertise in the field is essential for identifying and evaluating the relevant metrics.

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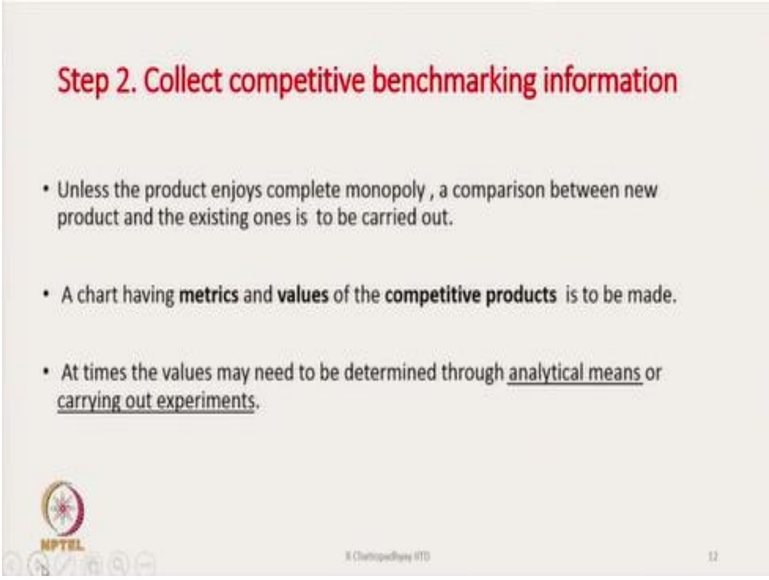

The next step is the collection of competitive benchmarking information, which means assigning specific values to the metrics. For example, if air permeability of a fabric is required, first, we must find out the desired value that helps design a fabric that meets the required air permeability. To assign specific values, competitive benchmarking information must be collected. So, unless the product enjoys complete monopoly, a comparison between the new and existing products is to be carried out.

This involves buying the products made by different manufacturers and testing the relevant properties. So, a chart with metrics and values of the competitive product needs to be made. Sometimes, the values must be determined analytically or by carrying out experiments. This could involve using instruments for direct measurements or conducting specially designed experiments to obtain the necessary values.

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The next step involves setting ideal and marginally acceptable target values. The ideal value represents the best possible result the team hopes to achieve, while the marginally acceptable value is the minimum standard needed for the product to be commercially viable. Falling below this marginal value might render the product unsellable or commercially unfeasible.

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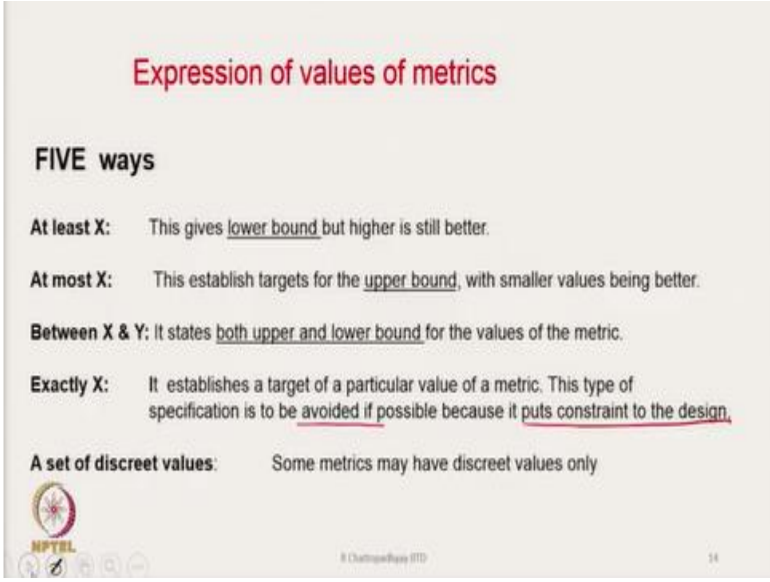

There are five different ways of expressing the values of the metric. One way is "At least X", which sets a lower bound for the metric, meaning that values higher than 'X' are also acceptable and better. For example, if the strength of a fabric is specified as "at least 3.5 kgf", it is acceptable to have any fabric with a strength greater than 3.5 kgf. So, “At least X” becomes a lower bound, and “At most X” is the upper bound. The "At most X" type of value sets an upper limit for a metric, whereas lower values are also better. For example, faults in the fabric. If this many faults become acceptable, if less than that, it is also better. So, if it comes to the level of faults, then this is “At most X” which indicates the upper bound.

The "between X and Y" type of value sets both an upper and a lower limit for a metric. This may also happen in some situations where there is an upper bound and a lower bound, which means the value of the metric must lie between these two limits; neither should it exceed nor should it fall below the lower bound. “Exactly X” establishes a target of a particular value of a metric. This type of specification is important to avoid because it puts constraints on the design. When a precise value is set, it restricts the designer, who must then meet that exact value. The exact value is almost difficult to achieve.

All textile products are basically variable in nature. Properties always vary slightly, so we measure coefficient of variation (CV) values. This is because the properties of fibres and filaments are not identical and go through many processes. Finally, whatever is produced out of it, whether a garment, fabric or another textile product, always has some variability. Setting a fixed value as a target is nearly impossible to achieve. So, in such a metric, the value of the metric should give a range for some flexibility. Some metrics have discrete values rather than continuous values. For example, the number of faults is discrete, while strength, extension, and modulus are continuous values.

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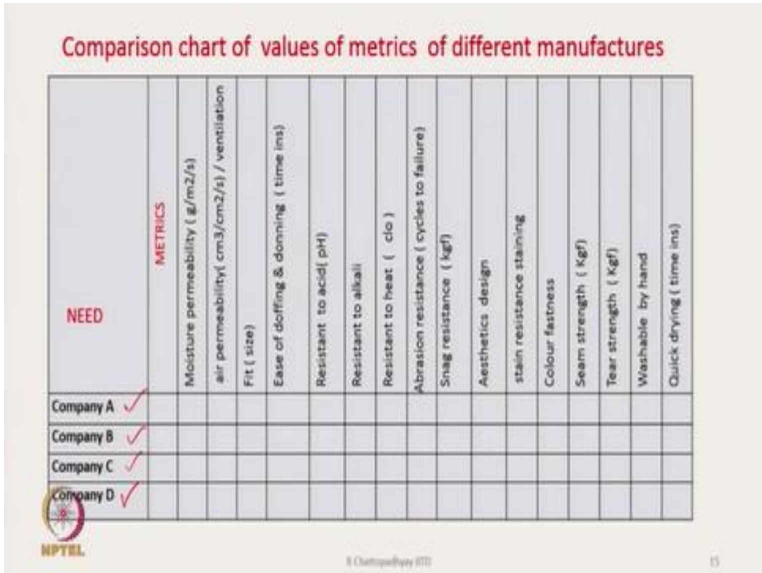

To compare metrics from different manufacturers, collect data from products made by companies like ‘A’, ‘B’, ‘C’, and ‘D’. Create a chart with the metrics for each company, as shown here. This will allow you to compare the values effectively. The comparison gives which company provides the best and lowest values for each metric. By examining the range of values, we can use this data to set specifications for the product we want to design.

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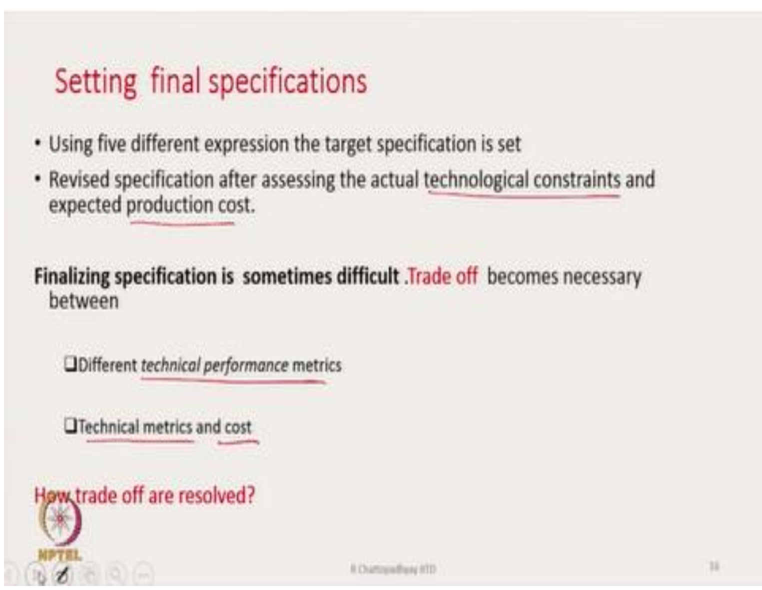

To set final specifications, use five expressions: ‘greater than X’, ‘less than X’, ‘between X and Y’, and so on. After setting these target specifications, consider the technological constraints and expected production costs. What are the technological constraints that we must achieve those specifications? First, we develop a set of specifications. Then, we analyse if there are technological constraints, such as a lack of necessary machines. Similarly, another aspect will be the cost to ensure that the product can be sold to customers.

Considering these factors, the specifications are revised. Finalizing specifications can be challenging and often requires iteration. Trade-offs between technical performance, metrics, and cost become necessary since achieving the best of all metrics may be difficult. We need to make trade-offs between technical performance metrics and cost. It's important to consider both technical aspects and cost. How is the trade-off resolved?

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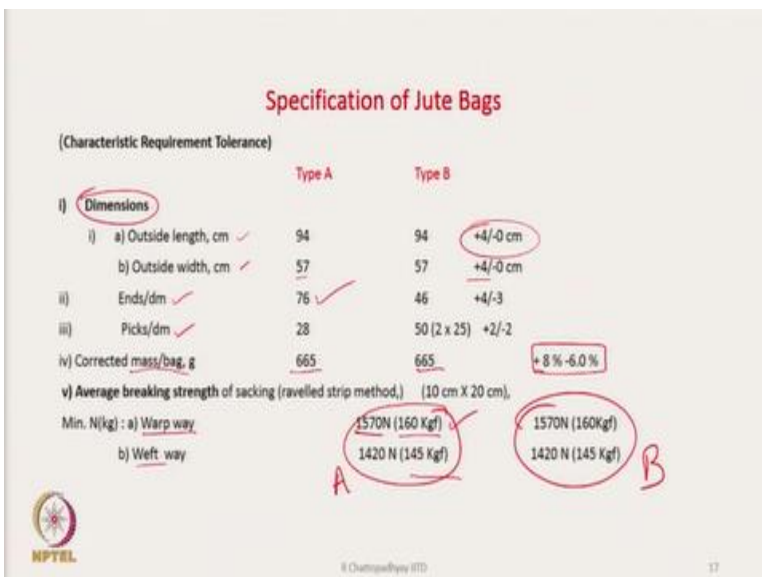

We understand the specifications for jute bags, which are technical products used for transporting grains, sugars, and similar items. Real value specification is stated in this slide. One specification relates to the dimensions of the bag, such as length and width. These dimensions determine the volume, which in turn affects how much grain the bag can hold, whether it is 30 or 40 kg of sugar, rice, or other grains. Therefore, the size is specified in terms of these dimensions. Specifications include tolerances for sizes like ‘Type A’ and ‘Type B’. For example, a length of 94 cm is not fixed; it can vary by plus or minus 4 cm, meaning it could be slightly longer or shorter but not less than a certain minimum.

Similarly, an outside width of 57 cm has a tolerance of plus 4 cm, so it can be up to 61 cm. Any width between 57 and 61 cm is acceptable, but it must not be less than 57 cm, which sets a lower bound. They also specify the ends and picks per dm, which refers to the density of threads. This is important because the thread density affects how tightly the fabric is woven and whether grains can escape through any gaps. The gap between the threads needs to be adjusted based on the size of the grains to prevent them from escaping, which is related to the cover factor of the fabric. Additionally, the weight of the bag is specified with a range of plus 8% and minus 6%, allowing for some variability. The mass of the bag is given because it indicates how much fibre is used, which affects the expected strength.

The specifications also include strength values: warp strength is 1570 N (160 kgf), and weft strength is also specified. Different values are provided for Type A and Type B bags. In this case, the customer has directly provided the specifications. There is no process of translating customer needs into product needs and then into specifications. Instead, the manufacturer simply follows the specifications given by the customer to produce the product. Designing and manufacturing are different aspects. A designer sets specifications, such as warp strength and ends per density. The designer must then determine the appropriate fibre strength needed to meet these specifications. The designer must select the fibre strength to achieve the required warp and weft strength. They will then instruct the manufacturer to use this fibre, process it into yarns of the specified count, produce a fabric with the stated end and pick densities.

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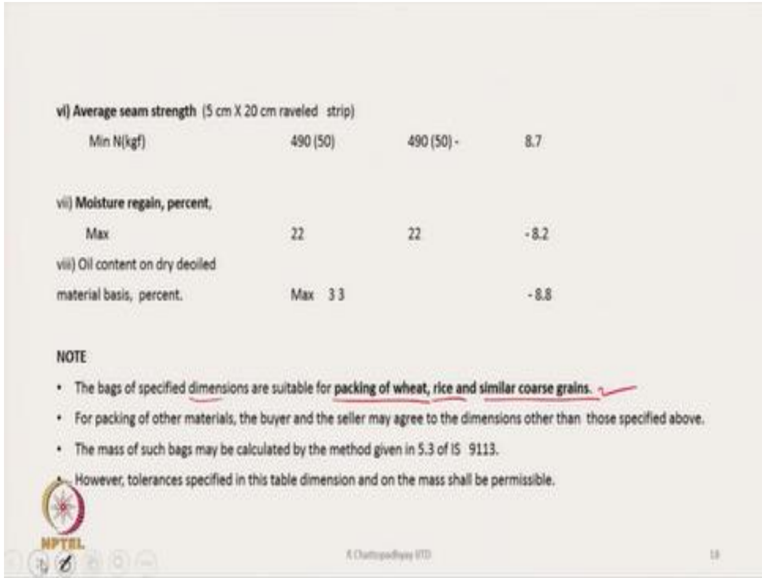

The specified dimensions of the bag are suitable for packing coarse grains like wheat and rice. For finer grains, you would need a higher end density or pick density to prevent grains from escaping through the gaps between the threads. This is just one example of how specifications can vary based on the type of grain.

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Even with specifications, we must consider technological constraints and cost. To finalize the specifications, we must develop a technical model and a cost model for the product. We refine the specifications later and make necessary trade-offs. We need to build two models: a technical model of the product and a cost model.

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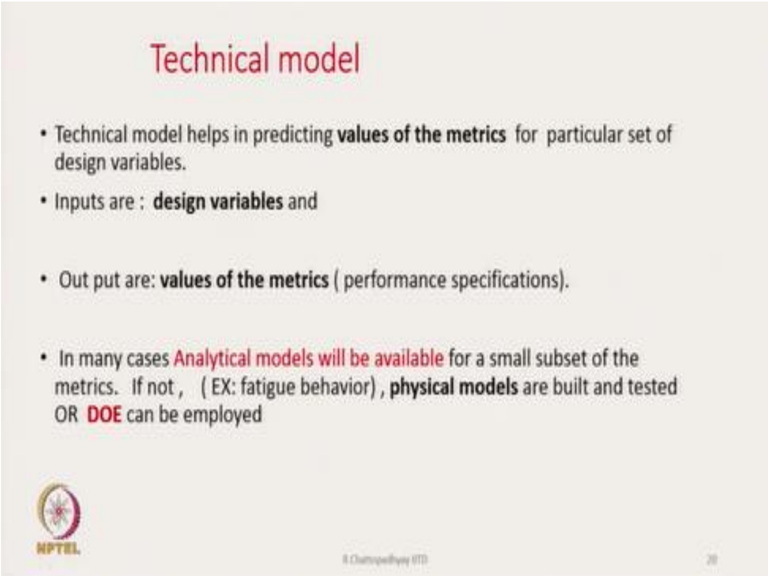

The technical model predicts metric values based on design variables. Inputs are the design variables, and outputs are the metrics values. Analytical models might be available for some metrics; if not, physical models are built and tested. An example is fatigue behaviour. There may not be an analytical model for predicting the fatigue behaviour of textile products. For example, fatigue behaviour is crucial for products like tyre cords, which experience repeated stretching in a running tyre, and textile ropes, which also undergo repeated stress. When analytical models are not available, physical models are used and tested to ensure the durability of designs. Fatigue causes continuous degradation, eventually leading to failure. In such cases, the Design of Experiments (DOE) can also be employed to evaluate performance.

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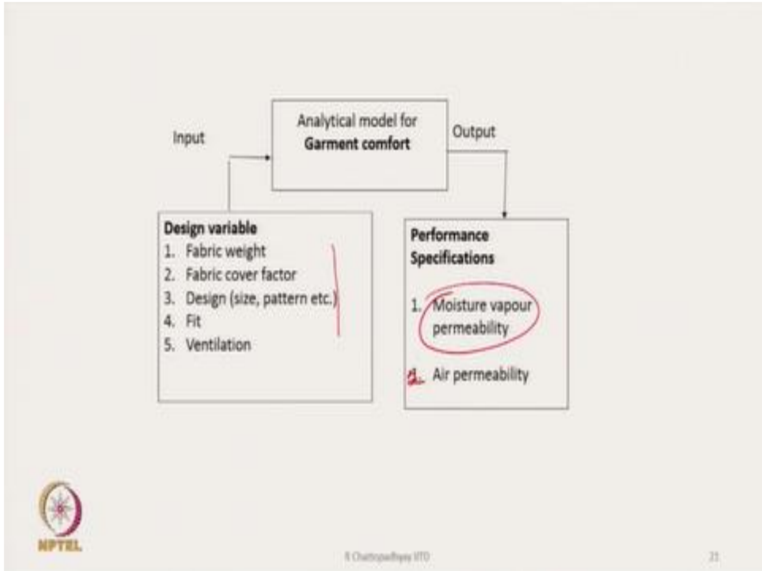

If the analytical model of garment comfort is available, the input is the design variable, and the output is performance specifications. It uses design variables (like fabric weight, cover factor, and size pattern) to predict performance specifications. The output variables are in terms of garment behaviour, such as fit, ventilation, moisture vapour permeability and air permeability. With a model that relates design parameters to moisture vapour permeability, we can adjust the input values to see how they affect the output. We can find the combination that meets the target output value by changing these variables. We use the model to find the right design variables for different performance needs.

By adjusting these variables and observing how the output changes, we can determine the combination that meets the performance specifications. This process helps in optimizing the design based on the model

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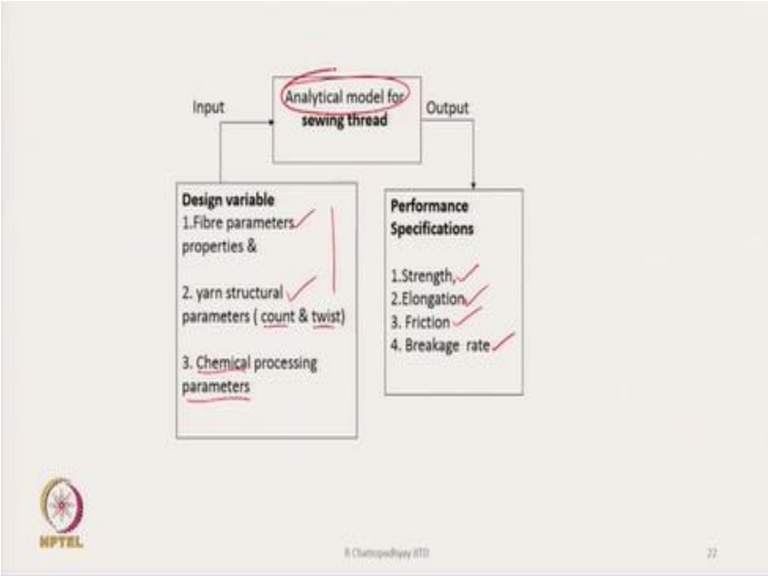

For sewing thread, specifications might include strength, elongation, friction value, or breakage rate. Design variables affecting strength could include fibre strength and yarn structural parameters like count and twist. Chemical processing parameters may not be relevant for strength. For strength, we can use parameters like fibre fineness, strength and yarn structural factors such as count, twist, and number of plies. By using a model that relates these variables to strength, we can determine the combination of design variables needed to achieve the desired strength.

Similarly, for elongation and friction, different design variables come into play. Friction, for instance, depends on chemical processing parameters like the amount of wax used and whether the thread is made from filaments or spun yarns. These variables help predict performance specifications based on the design inputs. To predict these performance specifications, one either needs to build an analytical model or use existing models found in research, textbooks, or literature.

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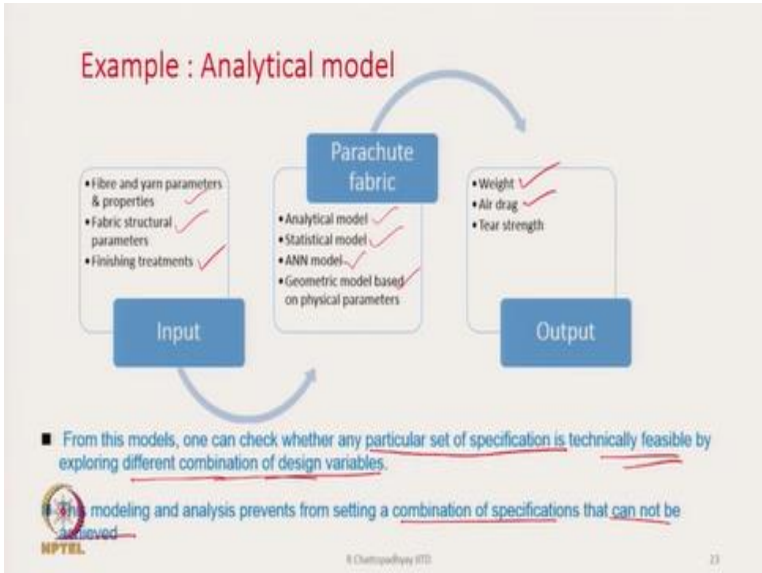

For example, in parachute fabric, design variables include fibre and yarn parameters, fabric structure, and finishing treatments. If available, analytical, statistical, neural network-based, or geometric models can be used to determine how these variables affect the weight of the fabric. Using these models, one can check if the fabric weight and air drag meet the specified values. By exploring different combinations of design variables, you can determine if a particular set of specifications is technically feasible. If none of the combinations of design variables meets the specified values, the specifications might be impossible to achieve. For example, if you require a yarn with extremely high strength, such as 30 or 40 g/tex, none of the design variable combinations can achieve this. If you specify a yarn that needs to be both highly irregular and extremely strong, this may not be feasible.

Combining such requirements, like high irregularity and high strength, often makes the specifications unfeasible, even with a model. There is no combination of design variables that achieves both high strength and high irregularity; the specification is technically not feasible. For example, if you expect a cotton yarn to have a strength beyond what cotton can naturally provide, it is not achievable given the material strength limitations. This modelling and analysis help ensure that specifications are feasible. If the analysis shows that certain specifications cannot be achieved, it indicates that those specifications are not feasible and should be revised.

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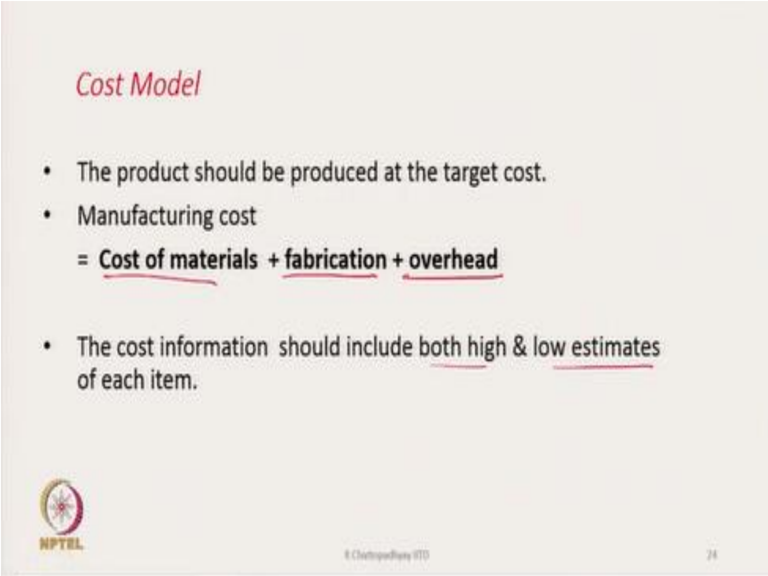

The cost model helps determine the cost of the product. It includes three components: material cost, manufacturing cost, and overhead cost. The cost information should include both high and low estimates for each component.

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With the cost model, refine the specifications by making necessary trade-offs. Feasible combinations of numerical values of design parameters are to be determined using a technical model and its cost implications. Assess the cost implications for these feasible combinations. A competitive and trade-off map is to be developed. we should use the cost model and then find a competitive map. In an iterative fashion, the specification that most favourably positions the product relative to the competitors satisfies customer needs and ensures adequate profit is finally chosen. So, when choosing specifications for a new product, consider these three aspects, i.e., satisfying the customer's need and how the product is going to be placed relative to the competitor's product. Will it ensure adequate profit from manufacturing and selling? All these three questions need to be answered before a company is going to venture out for a new design.

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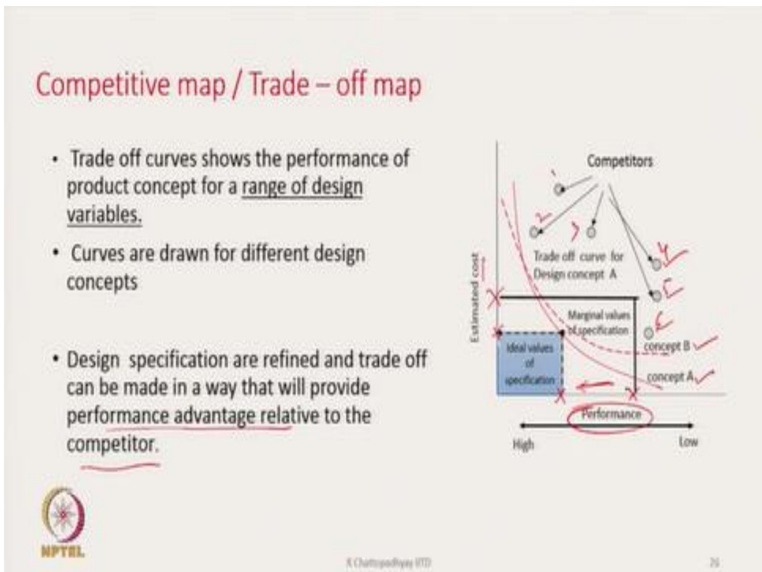

In a competitive or trade-off map, the x-axis represents performance (low to high), and the y-axis represents cost (low to high). Performance vs cost has been plotted, and small circles on the map show the positions of competitors. Each circle indicates where a competitor's product falls in terms of performance and cost. For example, we have found out the performance level of six competitors. and the corresponding cost. For example, competitor 1 has high performance and high cost; competitor 2 has high performance and slightly lower cost than competitor 1. Charts like this can be created, and curves can be drawn for the design. For our design concepts, Concept A and Concept B, we plot their performance versus cost curves on the chart.

Concept A is represented by a dotted line, while Concept B is shown with a solid line. Alongside this, we include the performance and cost values for different competitors. The curves drawn are for different design concepts, design specifications are refined, and trade-offs can be made to provide a performance advantage relative to the competitor. The other one is ideal values or specifications. Ideal value shows the level of performance and, at this level of performance, what the cost is going to be. If the marginal values are chosen, then the performance level and the corresponding cost are mentioned here. Increasing the performance by choosing a certain combination of specifications and determining the cost increase depends on whether concept A design or concept B design. So, the curves indicate the performance level, whether it is above or below the competitor's performance, and the cost at that level. So, an analysis of this competitive map helps in finalising the specifications.

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Sometimes, the overall specification is divided into sub-system specifications, where there is design complexity. For example, designing an aircraft is very complex. There are varieties of components present. There are many designers involved in designing such a complex machine. So, there is an overall system, and there are sub-systems. So, in some complex changing products, such as smart battlefield uniforms. The total design is divided into several sub-system designs, and specifications define each subsystem's development objectives and the product. This is required in a very complex design process.

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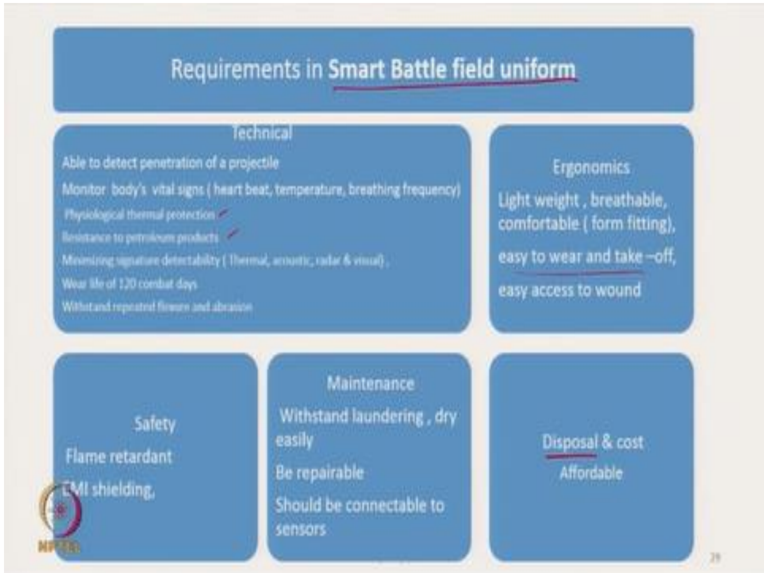

Examples of such a design include a smart battlefield uniform. The required technical specifications are given in the slide, and the values are not stated. The technical aspects are the ability to detect penetration of a projectile and monitor the body's vital signs, heartbeat, temperature, breathing frequency, physiological thermal protections, and resistance to petroleum products, minimizing the signature detectability. From the ergonomics point of view, the uniform should be lightweight, breathable, comfortable, easy to wear and take off and easy access to wounds. In case of a wound or injury, the person should be able to access that wounded region. Safety aspects can include flame retardancy, EMI shielding, maintenance, disposal, and cost. Disposability should be nature-friendly and affordable.

We must find the corresponding design objectives and specifications for each aspect. Monitoring body vital signs and then minimizing signature detectability are sub-system designs. So, the entire design must be split into sub-system designs. For this sub-system, the objectives, requirements, metrics, and values of metrics must be written, and then designing begins.

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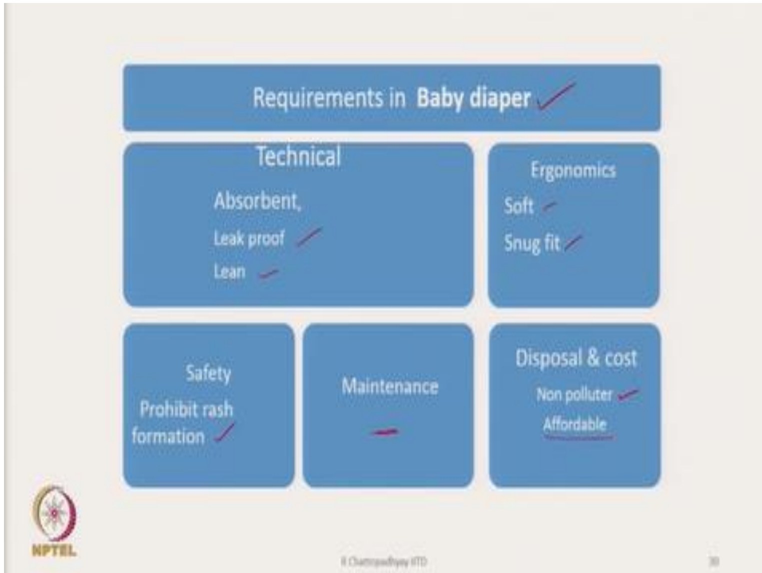

Another simple design is the baby diaper. Technical aspects could be absorbency, leak-proof and lean, i.e., not very voluminous. Ergonomics point of view could be a soft, snug fit. The safety point of view is to prohibit rash formations. Maintenance is not much because these are basically one-use products. Disposal and cost should be non-polluted, and cost-wise, it should be affordable. So, these are the requirements or needs of a baby diaper.

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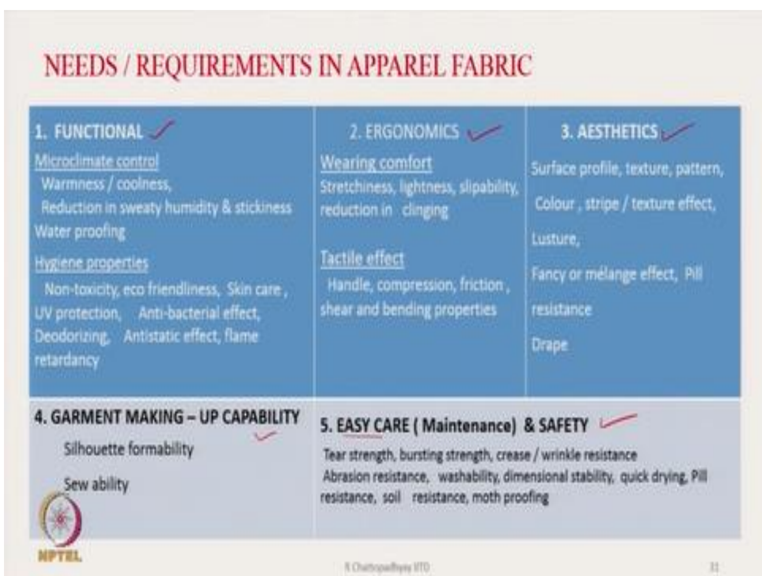

Similarly, the functional, ergonomic, and aesthetic needs of apparel fabrics are given in the slide. In apparel fabrics, needs are also very important. We end this session on specification development. Thank you.