Functional and Conceptual Design
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Department of Engineering Design
Lecture 12
Need - Metric Matrix

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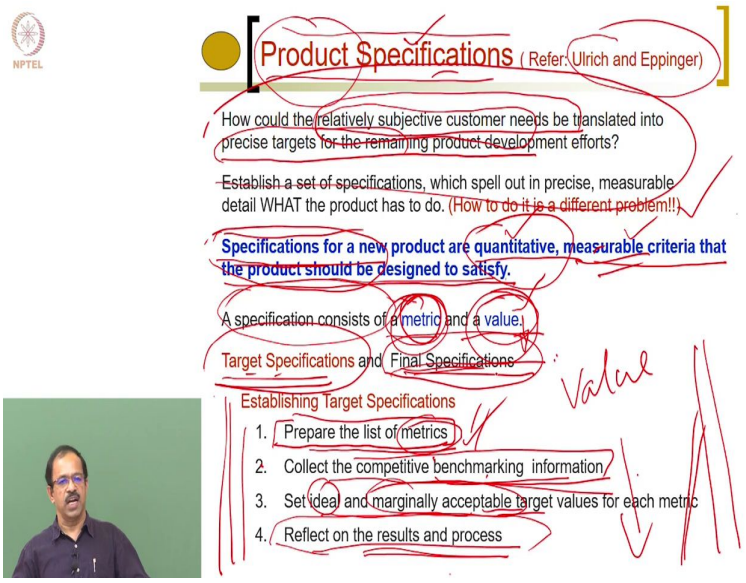

And then we saw in the previous class how to actually do this, by affecting these into specifications. So, you develop the metric for converting the customer needs to product specifications, this was what my discussion in the last class. How do you develop a specification for products, different specifications for products by converting the subjective customer needs, we saw that the relatively subjective customer needs can be converted to objective design specifications? The first step in the design is to convert the customer needs, subjective customer needs into objective design distribution.

And when we do that, the specifications should be a quantitative, you should be able to quantify, whatever you say as the specifications, you should be able to quantify, you should be able to measure it and then you should be able to satisfy this in the design, so that is basically known as the specifications.

The specification has got two components; one is known as the metric, the other one is the value, so every specification you should be able to identify a metric and a value and the understanding is that if you can convert the customer needs into a metric and values, then it

can give a design to meet the metrics. That is why if you convert all the customer needs into specification in the corresponding metric and a value.

So how do I, how do we identify the metric for every need is the challenge or that is the task to be done by the designer. So, you have a customer need like it should be lightweight or it should be easy to use, easy to assemble, less time to operate, so all these things are customer needs. So, we are going to see how we actually convert value to design metric or design specifications. So, when we do that, when we do the specification what we get is the target specifications, that is what is our target, what is that you want to achieve. You say it is easy to use, you will say okay, the number of components should be less than two that is your target.

But then you can have finally after all of these things, because that can be from conflicting design requirements. At the end of all this you will find out what is the final thing that you can achieve while there should be multiple requirements, each requirement you can give the target specifications. And by looking at all those requirements, you will be coming here to final specifications, this is what is the design and diagramming the specifications.

So, the steps involved in developing the specifications that is, actually they are mentioned in the last class, first thing is to do, see how to prepare the list of metrics. What are the metrics that we can identify corresponding to each need is the first step? And once you do this, then we find out how to get the value of that metric and the value comes from benchmarking information. So, what is being done in other areas, other products, what values they are using, that will be used to identify the, what value to be used in your products

And when we set the ideal and marginal value, ideal is something which we get but actually there is some marginally acceptable value that is also there so we have marginally acceptable values. And then analyse these results and then see which one is going against each other and when we have a requirement that it should be low-cost and a requirement then it should be durable also.

So, there are two requirements; one is it should be low-cost, the other one is it should be durable which is actually not a problem. To make it more durable, the cost will go up because of the material used, and the production method is used. So how do we actually overcome

those issues are basically reflecting the results. So first we looked at the preparation of metrics and how do we start the metric conversion.

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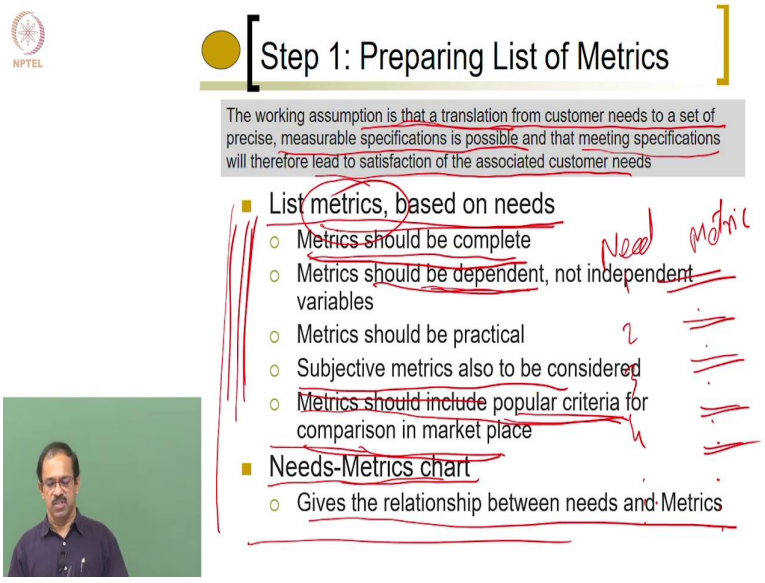

So why we are actually doing this is basically because of assumption that a translation from customer needs to set a precise, measurable specifications is possible and meeting the specifications will therefore lead to satisfaction of the customer needs, that is the fundamental assumption we make, that if you can convert the customer needs into specifications, and if you can meet all the specifications then customer needs can be satisfied. So indirectly you are trying to satisfy customer needs by measuring the, by making specifications and then trying to achieve the specifications.

And if you do that, all the needs to be identified and we need to list the metrics corresponding to each need. So the first step is for every need that you identify, identify a metric which can quantify that need, whatever maybe the need, you need to identify some metric which will quantify the need of the customer that is the first step to be done in developing a specification. As we read in the last class, we discussed a few of these in product specifications.

Somebody says in cycle design, comfortable ride, so when the customer requires it, and the customer says that it should be comfortable to ride the cycle. If you have to satisfy this requirement of customers that it should be comfortable, what metric can you find out or how

can we actually say that it can be quantified? Comfort, how can we quantify comfort? Any idea? So if you are saying that it should be comfortable, what are you actually trying to tell when you say comforts?

Student: Less vibration.

Professor: Less vibration, yeah that maybe one-point right, it should not vibrate in a height. So vibration should be a metric, so the amplitude of vibration or the frequency of vibration can be made as a metric. What else can you think of?

Student: Seat.

Professor: Seat, okay so seat means what?

Student: Seat height.

Professor: The seat height or the seat profile or the seat cushion? Seat cushion yeah, so how to convert that into a metric? Okay so, these are the things we need to understand, how we actually convert such needs into metric, then it should be measurable also, you should be able to quantify, you can say that the thickness of the cushion or the amount of compression it can take, the amount of folding it can take, whatever way you want to quantify, you should be able to quantify, so this is basically what we say based on metrics.

But when we do these metrics, there are a few things which you need to understand. What is that? The metrics should be complete. When I say metrics should be complete, what I mean is that every need, suppose we have needs 1, 2, 3, etc., I should have one metric, minimum one metric associated with each need. I cannot have a need which has raw metrics. Every need should have at least one metric directly, but we can have more than one metric but you need to have at least one metric associated with each need.

If there is a need without the metric, so basically we are telling that we do not know how to design for that. If somebody says that there is no metric for associating that design then basically we are telling, as a designer I have no idea how to meet that requirement because it is not coming from the design, it is coming from somewhere else so that need I cannot provide in the design. Got it?

So every need should have at least one metric associated to that need, this is the requirement that first thing the metric should be complete, every need should have a metric associated with that. Next one is, it should be dependent, not an independent variable. So when I say that, it says that it should not be a variable which cannot be connected to something else. For example, somebody said it should be strong, the product should be strong, what could be a metric? Pardon.

Student: Load bearing capacity

Professor: Load-bearing capacity, yeah. Load-bearing capacity depends on many other things; the material, the thickness, and the way you assembled, how those is made, so it is dependent variable right, but somebody says we need strong, it is a material, so can you use the steel, you can use plastic, you can use titanium, you can use some other material to make it strong. But then material is not depending on anything else.

When you say steel, steel is steel only, it is not depending on anything else, so it is an independent parameter. So we should not use independent parameters for metric, we should use dependent parameters, when you say load-bearing capacity, it is dependent on material, dependent on the size, dependent on the way you assembled all the, mathematically, so it is a dependent variable. So every metric should be a dependent one, do not take it as an independent one, independent material is an independent one, so it should be attractive, we will say it should be blue colour, then it will be attractive.

You cannot say blue colour because it is independent of anything else, but it should not be, you cannot say that, colour is the only thing which actually makes it attractive. So we should not use independent variables as metrics. So when you try to do this, it will be more clear to you, best example is material, you cannot say material as a metric, you will not use material as a metric for specifications because it is an independent part. So that metric should be dependent.

It should be practical one, when we say practical, it means that you should be able to measure it practically. Something which you cannot measure or there is no way to measure it easily that is not used as a metric. For example, weight is a practical metric, you can actually measure it very easily. Surface finish can be measured to some extent, that cannot be

something which you cannot measure. So, for example, if you take some products and you cannot say that the electromagnetic interference under zero gravity should be a metric, because these things cannot be practically measured.

So, you should take something which can actually be practically measured under 0 pressure or 20-30 bar pressure. This thing should be so so. These are not practically feasible , so do not take something which is not practically measurable that is basically what do you mean by metrics should be practical. And in very rare cases, you can take subjective metrics. So, something which I mentioned in the previous class, when you buy an Audi car, the prestige of owning a car is metric there, the prestige of owning a car is important for a customer.

So, in very rare cases, you can say subjective metric also can be considered, the ownership value is a subjective metric, but you can still consider it as basically saying that that is a very important point. So, the owner actually feels some pride in having a product so we can actually quantify it in some sense saying that it is very high, very low, very low, high low or very low like that. So, in various special cases, you can consider a few subjective metrics, but we should be able to say how that can actually be utilized in the research. So, these are the points to be considered when you choose a metric for customer needs.

One more thing, the metrics should be popular criteria for comparison in the marketplace. So, you need to look at what is the criteria used by others in the market. So, try to use the same criteria here also that is a popular criterion so that you will be able to compare your product with other products also. So, that is also an important metric that should include popular criteria for comparison in the marketplace. So, these are the things to be decided or things to be understood when you try to choose a metric for a need.

And once you have these needs, what do you need to do is to prepare a need metrics chart. A need metrics chart basically tells how the needs and metrics are related, in a graphical way you try to prepare this chart that is the need metrics chart, use the relationship between the needs and metrics. So, that is what is needed at the end of these metrics you will be getting the, at the end of this analysis you will be getting the needed metrics chart. So we will take a few examples and then try to see how to do this.

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Need-Metric chart

No	Need	Metrics
1	Reduces hand vibration	Attenuation from dropout to handlebar at 10Hz, maximum value from monster, minimum descend time on test track
2	Allows easy traversal of slow, difficult terrain	Spring pre-load
3	Enables high speed descents on bumpy roads	Attenuation from dropout to handlebar at 10Hz, maximum value from monster, minimum descend time on test track
4	Preserves the steering characteristics of bike	Maximum travel (26" wheel), rake offset
5	Is lightweight	Total mass, no. of components
6	Is easy to install	Time to assemble to frame
7	Allows easy replacement of worn out parts	Time to assemble/disassemble, special tools reqd.
8	Easy maintenance with readily available tools	Special tools required.
9	Is safe in crash	JIS test, bending test
10	Lasts long time	Monster cycles to failure
11	Fits a wide variety of bikes	Headset size, steer tube length, tire width
12	Provides stiff mounting points for the brakes	Lateral stiffness at brake pivots

So, take example of these needs, reduce hand vibration. Similarly, allows easy traversal of slow difficult terrain, enables high speed descents on bumpy roads, preserves steering characteristics, lightweight, easy to install, allows easy replacements, easy maintenance with readily available tools, safe in crash, last long time, fits a wide variety of bikes, provides stiff mounting brakes. So, these are the customer needs you identify or we can identify for a cycle suspension cycle for design which we discussed in the previous class. Assume that these are the customer needs you identified with its own priority.

Now, the task is to see what are the metrics that you can identify for these needs. And as I told you, every need should have at least one metric, if there is no metric with one of these needs, then you are in trouble. You need to make sure that there is at least one metric associated with each need. So tell me what are the needs that you can identify? You just strike the simple one, lightweight. Lightweight; what kind of metric can we use? Weight. Okay, kilogram is unit, metric is weight. So, we will say total weight or total mass whatever it is, weight, what else?

Student: Material

Professor: Material, who said material? Yeah. Is material a metric? Yes, or no? No. Why is material not a metric? It is not independent right, because when you say material you cannot do much, you take steel or you take aluminium or whatever it is. So, it is not a dependent variable, but it is an independent variable, it is a parameter. So you need to choose something

dependent because when I say weight, weight depends on material, weight depends on the dimension, weight depends on assembly, procedure, number of parts, many things. So, weight is a dependent parameter so you can use weight as a metric.

Is there any other thing which you can associate with weight? Number of components, yeah, we can actually reduce the number of components you may or may not be able to reduce weight, but that may be a metric that you can use. So, can you actually put all our possible metrics, sorry number of components, anything else? So, it need not be always directly related because the number of components if you increase it there is a possibility of increasing the weight.

But if you that is not always true because depending on the size of the components also. So you can actually say this may not always be a direct metric, but it can be an indirect metric, this can be a direct metric which can be measured. Easy to install, what metrics can be used? Number of components, number of parts I will say, number of parts, tools required, I say special tools required, whatever it is, I say tools required. What else? Method cannot be quantified. You should say it can be quantified or not.

Student: Method

Professor: No, but then we cannot say because then you should say what is the quantification of methods so that is why it cannot be used. Yeah you can say number of parts, number of steps needed, yeah number of steps can be an easy metric, you can say number of steps needed. Time needed for assembly that is also an important metric right, so time. So, the time needed, number of parts, number of tools required and number of steps involved, all these can be a metric for easy to install.

Now, it lasts a long time, so how many days should it last for a very long time? What is the metric? Yeah, maybe life of the product can be a simple one right? Life of product could be a product life or the useful life or whatever you can call, it just can be quantified, it depends on many other things so, product life maybe a metric. Next, strength of material. Is it a dependent or independent?

Strength of a material fixed? I mean for aluminium you have a strength of material; steel you have a strength of material. So, it is all depending on that one only, so you do not have any

variation there. So strength of materials cannot be taken directly as a metric. If you say load carrying capacity then you can say that depends on many things; material, size, etcetera, etcetera. But life need not be always life I mean load carrying capacity. Another thing can be?

Student: Strength

Professor: How can you vary the strength? That is not strength, strength of material is a material property. Yeah, that is right so what I am saying is that when you say strength of material basically you are telling material. So, material is not dependent, it is a dependent one yeah, but then you cannot change it because, no but then you have only options now, you use steel or you take this, you will get different.

So, this life cannot be directly said that okay if you use steel, it will be the highest life or if you use this you cannot get life that way you cannot tell the strength of life. So, one important thing is it is the life in number of years and number of years or whatever, and the thing may be the warranty period may be an option you can say. When you say the warranty period is 10 years, you have a 10 years' life guarantee, or it is 12 years, it is 12 years guaranteed. So it can be a direct indirect period with though it is not a question of design parameter, we can say warranty period could be a metric.

Student: Number of coats of paint

Professor: Number of coats of paint applied. So, what actually do you mean? Why are you applying paint? Yeah, so, you are talking about corrosion resistance. So, why don't you talk about corrosion resistance capability, simply because you can properly paint or you can do something else also. You are saying paint then you are saying that only painting is possible. So, you can say corrosion resistance as a thing that actually depends on many things. It can improve the corrosion resistance by different methods so corrosion resistance can be a metric. Pardon?

Frequency of maintenance. Frequency of maintenance would be a thing that is either coming under warranty or you can say frequency of maintenance, number of maintenance, it gets all those that can be part of the last long time. Yeah. So, like this, you can actually identify a metric corresponding to each need and make sure that for every need you have a metric. So,

this is the requirement in need and metric chart. So, what you are trying to do is, having a need metric chart.

So, this will be what you are doing in the next class, you have identified the needs, now you need to see, how do you convert these needs into metrics that is the first step. So, can you tell any metric for any of this? Yeah, some of them may not be very familiar to you that is why I am not asking you. Can you identify metrics for any other needs here? Okay, the first one has come, reduces hand vibration.

So, we can say that the particular condition is the attenuation that you are getting in the vibration that you are in, this is basically a measurement of vibration and maximum value from the monster. Monster is basically a test, standard test, practical test available. So, we can do the test and then, where is the, what is the value from that. And minimum descent time on the test track, how much time it takes to descend on a test track. So, these are the metrics that can be used to see whether it reduces the hand vibration.

And if you identify some values for this, then you can say that if the descent time is less than a particular value, you can say the hand vibration is reduced or attenuation is this much then the hand vibration is reduced. This is the way how you convert each of these subjective needs into the design specification or the metrics. So, easy traversal of slow, difficult terrain. So, there are some standard tests for spring pre-loaded test or the spring preload, so depending on the preload of the spring, you can actually get an easy traversal.

Then, again enables high speed descents on bumpy roads, very high subject you want, but then now we are telling what does it mean if you have the handlebar dropouts, the attenuation, then we can say it is easy to do the descents, maximum value from the test and minimum descent time. So, this metric can also be used, so you can repeat the metric, nothing wrong, you can identify these metrics, so the same metrics can be used for this also.

Preserves the steering characteristics of a bike. Maximum travel with the 26, basically specifying what is the steering that you can make with that 26-inch wheel and the rake offsets, that is offset from the wheel and the rake that is basically known as rake off-set. So be specific to that particular design, so you may not be understanding the thing here, but

whatever you can identify from here from these needs you need to convert into the specification.

So total mass, then time to assemble to frame, time to assemble-disassemble special tools required, special tools required. So safely in a crash, there are standard tests for crash testing, so you have to use those tests and then see what is the value to be used for that. Cycles to failure, that is the testing there are some standard tests available for checking the strength of the cycle or the capability of cycle so that can be a metric, then fits a wide variety of bikes headset size, steer tube length, tire width, these are the things which will affect that one, and lateral stiffness at brake pivots.

So now you can see, all these needs have been converted to metrics. Some of them may be very important, some of them may not, the metrics need not be of very same importance, each one will be having different importance. We will see how to handle it later. But the most important point is, for all these needs you need to have a metric associated with it. Any questions? Yeah, that we do not call this as a strength of material. No, no, when I say strength of material, it is basically you might have studied in your engineering mechanics. The yield strength, these are the things which we call as strength of material.

This is the strength of the component, basically the load bearing capacity of the component is what you are talking about, not the strength of material per se, this is the strength of the component that you are talking about. Yeah load bearing capacity can be a metric that depends on the size and the material, you can change the material or you can change the size to get a different load carrying capacity. Any other questions?

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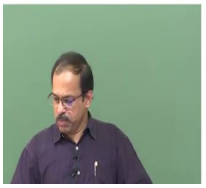

Metric No.	Need Nos.	Metric	Imp.	Units
1	1,3	Attenuation from dropout to handlebar at 10 Hz	3	dB
2	2,6	Spring preload	3	N
3	1,3	Maximum value from the Monster test	5	g
4	1,3	Minimum descent time on test track	5	s
5	4	Damping coefficient adjustment range	3	Ns/m
6	5	Maximum travel (26 in. wheel)	3	mm
7	5	Rake offset	3	mm
8	6	Lateral stiffness at the tip	3	kN/m
9	7	Total mass	4	kg
10	8	Lateral stiffness at brake pivots	2	kN/m
11	9	Headset sizes	5	in
12	9	Steertube length	5	mm
13	9	Wheel sizes	5	list
14	9	Maximum tyre width	5	in
15	10	Time to assemble to frame	1	s
16	11	Mudguard compatibility	1	list
17	12	Instils pride	5	subj.
18	13	Unit manufacturing cost	5	US$
19	14	Time in spray chamber without water entry	5	s

So, finally, we will try to map these metrics to the needs, so you have first metric So here you here you identify many metrics, and then you write down these metrics as here 1, 2, 3 So, you identified 19 metrics, and some of the metrics are related to more than one needs and the importance of the need is also given here. So, sorry, this is the importance of needs, yeah, attenuation from dropout, 1, 3. Now the units for each metric can be identified because you identified the metric, and therefore it will be having a need. It will be having a unit, sorry. Any questions? So this is the metric and these are the needs associated with the metric.

So actually, we put it in a different way. Initially, we identified the needs and tried to identify the metrics corresponding to it, we are identifying all the metrics here and telling that these are the metrics of importance to us and these are the units of these metrics. Now, the question is, what should be the value of these metrics, each metric, attenuation from drop out to handle a 10 hertz, what should be the value to make it satisfy the needs of 1 and 3 so that is the next question how do we get the value.

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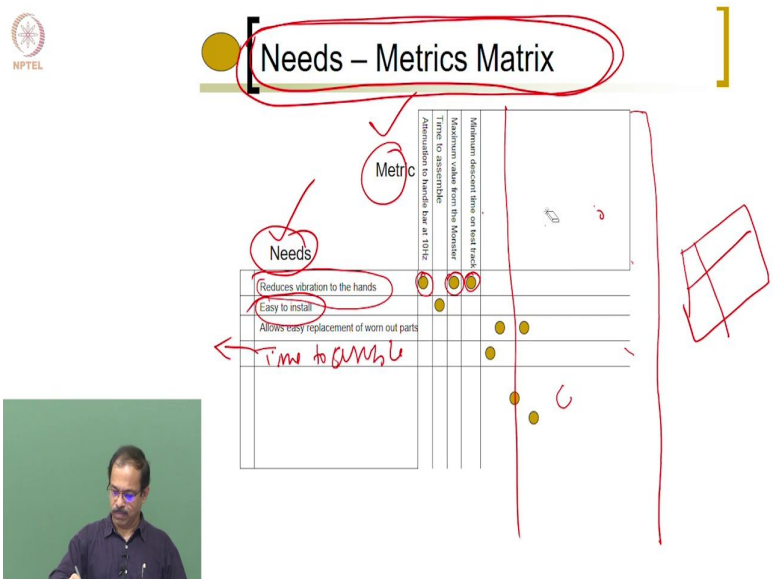

So, before going to that, we will prepare a need metrics matrix. This is known as the Need Metrics Matrix. So, what we do, we write down all the needs here and all the needs metrics here and then try to identify how they are related. So, for example you have reduced vibration to the hands as needed, and you identified three metrics which correspond to this. So, we will make this and suppose you know that one metric is much more important than the other metric. For example, time to assemble. Time to assemble you have many metrics so one of the metrics is time so I will write it as time, then the number of parts, then somebody said number of steps.

So now, if you know the importance you can say that okay this one is most important or this is not that important and this may be important so, you can actually use different forms of representation saying that this is the most important metric for this and this may be not that important or this may be very least important. So, like this you can actually prepare a matrix where you can identify the needs, the metrics and how these needs and metrics are related in terms of its influence on the need. So, which metric has got the highest influence on the need can be represented using different notations.

So, you can use a dark circle or a light circle or some other way to say that, okay, this is the most important one, if I change this, this will be easily controlled. If I change this number of parts, it may or may not, but there is less influence compared to this. So, I give it importance

like this. And similarly, this one also has a number of parts, number of steps, it may or may not so it may be less influenced. So I can actually identify this and then create a metric.

Finally, I will be creating a need metrics matrix like this. So, this need metrics matrix involves the needs, the matrix and the importance of the metrics to the needs. So this way, by looking at this chart, you get a clear idea, if I want to make it easy to install, what are the things I need to change and which one will actually make the change much more easier, which one has got the largest influence, least influence, can be easily identified somewhere. So this is basically the purpose of having a needed metrics matrix.

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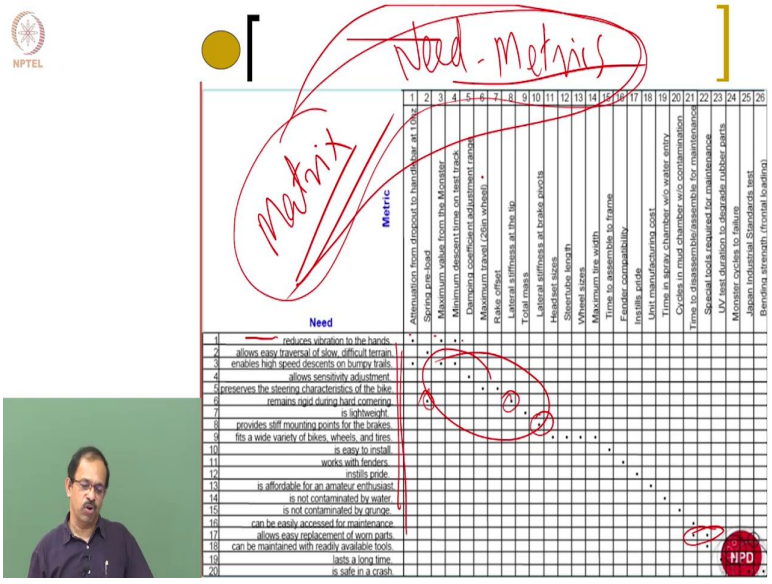

So this is an example for the previous one for the cycle, no need to worry, you do not need to remember this, just for example I have shown. So, you can see that for each need you will see at least one metric associated with it, some of them will be having more than one, some of them will be having only one. For example, this has got only a metric associated with each. Similarly, here there are more than one and you can actually give the different colours or different representations to show which one is more important. So this is the matrix which represents the relation between needs and metrics.

So, the first step in identifying the specification is to get the needed metrics matrix. Any questions? So, let us look at this from what we actually learned so far. So, when we start the design process, we first try to understand customer requirements and using a process we identify the customer requirements. We go through the raw data, from the raw data we

convert to interpreter needs, from interpreter needs, we prepare a list of needs which we call it as needs list, so you prepare a needs list. And we give the importance of each need also.

And once we identify the needs, then we go to the next step where we try to convert the needs into design specification. And design specification consists of two parts; one is known as the metric, other one is known as the, what is other one, metric and value. So, every specification consists of a metric and a value. The question is how do we get the metric. So, what actually is a metric, what is a metric? So, basically the conversion of a subjective requirement of a customer to objective value. So that objective value should have something to measure and that is what we called as the metric.

So, what are the conditions to choose a metric? Metric should be quantifiable, metric should be independent, metric should be complete, what else? Anything else? Yeah, it should be popular criteria which can be compared in the markets. So, you should always choose a metric, which is satisfying all these conditions. And subjective metrics also can be used. So, choose a metric which satisfies these conditions, and then try to prepare the mapping of need and metric and make sure that every need has got at least how many metrics? At least one metric, there should be at least one metric for every customer's needs.

And finally, we prepare a chart, need metrics matrix to list all the needs and metrics in a proper format and then show which metric is most important for that particular need, which metric is the least important for that need, so that we know which one to change, which parameter to be changed to get the desired customer requirement, so that is known as the need metrics matrix.

So, once you have this matrix, the next target is our next thing is to get the value. So, how do we get the value for this? Each metric because we know the metric and we know the unit, we need to say some value for that. How do we get the value? Or is it a time to assemble? You said it is a metric and you know the unit is seconds. How do we say that it is 20, 30, 50 or 60? Pardon? Measure, what to measure? Where do we measure? You do not have the cycle now; we are going to design the cycle right now. So where do you measure it? So you measure from others.

Suppose there is a similar cycle, you say how much time it takes to assemble, or there is another there are two three manufacturers, they have different designs for the cycle you try to measure how much time it takes to assemble. So you will get a comparison okay, they are taking 20, one company is taking 25 seconds, one is taking 20, one is taking 45, so you have an idea okay these are time taken by different one.

So, if the customer is still telling it should be easy to assemble or time to assemble should be less. So, what will you do? You try to either meet the current one or try to reduce the time from that. So, this is known as benchmarking in identifying the value, so, you benchmark your design or your metric, is known as benchmarking.

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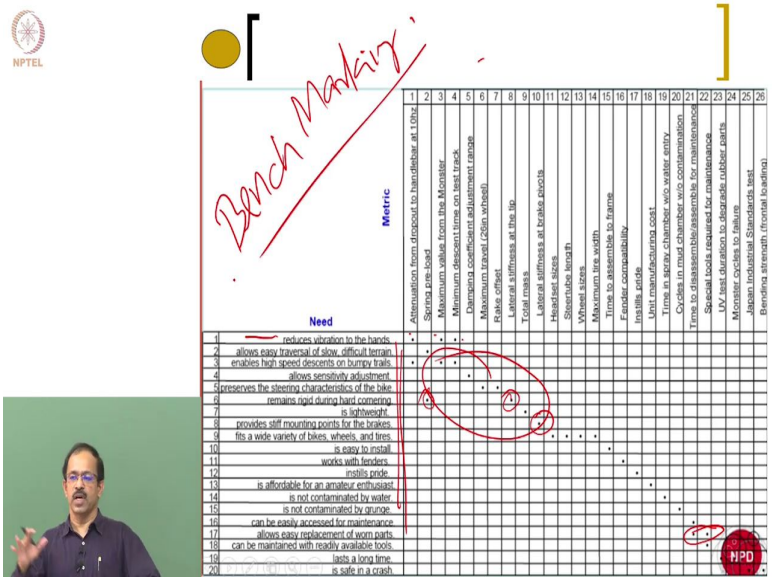

So, benchmarking is when you compare your metrics. So, these are the metrics now, you compare these metrics with other products and then see how these companies are performing, how these products are performing, and then see whether you can use their values or better values for your metric that is known as the benchmarking to identify the metrics or the values for the specification. So we will discuss these in the next class, how can you use the benchmarking information in order to get the values for your metrics? Thank you.