

Product Engineering and Design Thinking
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Module - 04
Concept Generation and Testing
Lecture - 20
Morphological Design Concept

Welcome back to our course on Product Engineering and Design Thinking. Today we will be in the module 4 the last lecture of module 4 that is the Morphological Design concept.

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Concepts Covered

- ❖ Morphological Chart (Matrix)
- ❖ Some Salient Points
- ❖ Method
- ❖ Generating alternative concepts
- ❖ "Developing" Generated Concepts
- ❖ Morphological Matrix
- ❖ Morphological Design for Forklift Truck (Example)
- ❖ The Morphological Synthesis followed by Concept Evaluation (e.g., Pugh Method)
- ❖ Conclusions
- ❖ References

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First, I will go to the concept covered slide. We will discuss what is morphological chart briefly that is actually to generate design alternatives. We will discuss some salient points on that about that and the method associated with it. Then the generating of alternative concepts

and developing generated concepts, morphological matrix and then we will discuss with a case example or an example with a forklift truck which perhaps you have seen or you might have seen the video if you have not visited any factory as such.

So, which is used for material handling that the piece of equipment is a very you know effective mobility device for material handling. Then we will talk about the morphological synthesis and there actually we would say that the next logical phase would be the concept evaluation. After generation the next step is evaluation which actually is the input for the embodiment design.




So, next module where we will be discussing embodiment design as an input to embodiment design, we will discuss the concept evaluation method. One of the concept evaluation method other methods are there we will be discussing just one method there which is a very useful method. So, before delving into the detail we will discuss Pugh method which is the concept evaluation that is the initiation I am telling you here and so, we will go to these slides now.

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Morphological Chart (Matrix)

Utility of the method developed by Prof. Fritz Zwicky (1898–1974):

- ❖ It provides a structured framework for systematic process in problem-solving in the context of concept generation that would aid in channeling and guiding ideas, which are new, additional, and often unanticipated as a design solution to a problem.
- ❖ It may be noted that the problem formulation, and the choice of basic elements, actually determines the outcome of a design, and the solution(s), to a product development problem.
- ❖ It is possible that a problem may be solved by developing alternate design solutions involving form/ configuration of a product with different combinations of elements or components obtainable from the morphological method. However, usually, the designer would use judgment and expertise to decide on the optimum solution from a number of acceptable solutions obtained from the Morphological Matrix.
- ❖ This enables the early conception of the product 'architecture' through the generation and evaluation of different combinations of 'sub-solutions' that otherwise could have been missed out.



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And it is first let us understand the utility of this chart. It is a structured approach a structured framework. It was developed by Fritz Zwicky and it provides a structured framework for systematic process in problem solving in the context of concept generation that would aid in channeling and guiding ideas which are new, additional and often unanticipated as a design solution to a problem.

It may be noted that the problem formulation and the choice of basic elements actually determines the outcome of a design that is the most important. The first is the it is channelizing the idea, guiding the idea and the second point is that that in the beginning if we are doing this then actually it determines the outcome of idea how are we selecting the elements in the design process that we will see as we move forward.

It is possible that a problem is solved by developing alternative solutions involving you know a form configuration of a product with different combinations of such elements. Say a transmission can be done by say a gear systems, it can be done by chains sprockets, it can be done by belt pulley and several other methods. Which one for a particular application or particular concept we will take for a function that would determine on various other considerations. So, we go to that.

Usually, the designer would use judgment there that is the most important thing because designer's judgment would be there, but this will give a great help because now design normally when you are when one is getting a chart on a structured framework one is forced to consider the alternatives extensively. I am not using term exhaustively, but actually so, but it is a for a complete range of alternatives are to be explored.

This enables the early conception of the product architecture which actually is the starting point practically for the embodiment design which very soon we will be discussing in our subsequent sessions. Through this generation of such alternatives concept alternatives design concept alternatives and evaluation of different combinations of sub solutions.

So, each sub function will be addressed through certain means like say as I said the rotational movement say out of these three. Suppose it is addressed through the gear box system then that becomes the means for that function of rotational motion and that will be combined in the system say in a car the transmission involves gear ok.



But in some other application in the car that the transmission rotational transmission is them through belt pulley so, depending on the particular use where what kind of transmission would be used. So, there are alternative transmission chain and sprocket for cycle is there it can be done through gear also it can be done through belt pulley also.

But then which is most suitable for a given situation or application that the judiciously the designer has to determine that. If the structure is not there, there is a possibility that some of the elements would be missed out.

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Some Salient Points

- ❖ Morphological charts (Matrix) provide a structured approach of widening the search space for solution concept generation for a defined design problem.
- ❖ It thereby aids in generating, for the design team, an extensive range of alternative design solutions through a systematic analysis of the form or configuration that a product might be built with.
- ❖ A morphological chart helps in the visualization of the necessary product functionalities and for exploring and capturing alternative means and combinations of achieving those functionalities.
- ❖ For each sub-function, there could be a number of possible solutions and the Chart lets these solutions be designated and provides a systematic way for considering alternative combinations.
- ❖ This facilitates early consideration of the product 'architecture' by considering the newly generated concept or options resulting from different combinations of 'sub-solutions' that would perhaps have not been brought into the visualization zone previously.
- ❖ It can be used suitably to create a potential generation of user-centered solutions.



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So, the salient points we will discuss that it is a structured approach the morphological chart, provide a structured approach as I already mentioned of widening the search space. Because we are considering the complete range of the functions or the means for the functions say functions may be say 10, 12 functions that we are studying sub functions we are studying.

When I am say functions here we are breaking the functions into sub functions and each sub functions will be dealt with or addressed through certain means and that will give you the sub solutions in each cell and then some combination of the cells will give the full solution.

Now, possibly the cells etcetera because you are not seeing the diagram, it may be a little difficult for you to visualize, but hold on for a minute I will very soon go to those charts when it will be clearer, but before I go to the chart let us see how what it works and how it works.

So, it is a systematic analysis process for the form or configuration with that a product should be built up.

A morphological chart helps in visualization because the chart helps to see which function which means or whether the means are complete everything and that visualization helps to explore and capture the alternatives or the means and combinations of achieving those functionalities. It might sound here a bit theoretical, but you have to hold on for a moment or two as I said that when we hear that and then we when we go then it would be absolutely clear to you.

Now, for each sub function because if I do not introduce these terms then and what they are it will be difficult for you to grasp there for each sub function there could be a number of possible alternative solution and the chart let us these solutions be designated and provides a systematic way for considering alternative combinations. Because this slide is not only for the understanding of the charts which is which will be coming up just now.

But later on when you would be seeking explanation this will be of great help this write up will be of great help. This capacitates early consideration of product architecture that is very important. The product architecture is early on is being planned or being considered and that architecture ultimately would lead us to the embodiment design.

Concepts or option resulting from different combination of sub solutions that would perhaps have not been brought into the visualization zone had the chart not been there. So, that is the important point. It can be used suitably to create because it is actually the function driven thing. So, it is user centric.

So, for a user centered or user centric design if we intend to see that ok what is comfortable or convince the user and those are the functions accordingly if we move then possibly, we would be able to create a design that is that caters to those functions and thereby it becomes the user center or very user friendly. So, that is possible through proper attention to this.

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Method:

- ❖ Listing of the features (or functions) that are essential to the product:
 - ❑ It may be noted that the functions are to be listed, not the components and each function should be mutually exclusive. For example, the functions for a mobile phone could be like, display, dialling, storage, power supply, signal reception, sound output, etc.
- ❖ Listing of the possible 'means' for each function:
 - ❑ Charting the functions and The 'means' or possible solutions by which a function might be achieved is to be listed. It allows the scope to think out new ideas alongside the existing solutions or components and the idea may be drawn or written for convenience of expression and capturing. Maintenance of generality is preferred for possible solutions - for example, it may be beneficial to consider different power sources or may be different types of batteries in an electronic gadget.
- ❖ Means as well as exploring for good combinations:
 - ❑ To frame-up every possible sub-solution that will lead to identify possible combinations of sub-solutions. If done judiciously, the total number of combinations may be reasonably short. And from this the best option may be selected.

So, now I will just go into the method then I will go to the charts. Method is rather simple method says that listing of the features or functions that are essential to the product as I was just telling you now. So, basically what is that? It is to be listed the functions are to be listed. For example, the function of a mobile phone would be display, storage, power supply, signal reception, sound output etcetera.

Similarly, the listing of means how it can be done like say I talked about transmission so, if I talk about creating pressure then I may talk of mechanical pressure, mechanical regenerated pressure it can be hydraulic pressure, it can be pneumatic pressure so, and so, forth. So, alternatives are there those are means. So, charting down the means will have to be there and there say when we are doing the means we need to have a generality maintain like say if you say that we would be using battery for an electronic gadget.

There could be several different types of batteries. So, when you are saying battery there can be different batteries that we can use as for this purpose as means. Now, the means as well as exploring for good combination so, now to frame up every possible sub solution we will very soon see what the sub solution is that will lead to identify possible combinations of sub solutions if done judiciously the total number of combinations may be reasonably short and from this the best option may be selected. So, this you can say a theoretical preamble.

Now, with this theoretical preamble what do you have understood that there are certain functions of a product because this description is was important because without the description at hand now and also in future when you revise this it would be difficult. So, what have you learned that basically there would be a functions on the rows there would be means on the columns. So, it will form a matrix and each cell will give a sub solution. Now, we will combine the sub solutions to get the best design.

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Generating alternative design concepts

e.g. fasten papers

- a) flexible clamp, paperclip
- b) Gem clip, Butterfly clamp, staple
- c) adhesion, glue, Cello tape, double-sided adhesive tape

| (Sub)Functional requirements | Concept |
|------------------------------|--|
| SF ₁ | {C ₁₁ , C ₁₂ } |
| SF ₂ | {C ₂₁ , C ₂₂ , C ₂₃ } |

Concept Generating = finding or crafting "matches"

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Now, let us see how it goes. Say for example, if we are talking about paper fasteners. So, what are the different types of fasteners possible? Flexible clamp, paper clip with gem clip, butterfly clamp, staple that is the using stapler if we are thinking of adhesion, adhesives, glue, cello tape, double sided adhesive tape, a concept generating actually basically is finding or crafting matches, matches between function and means.


So, this C for this sub function say for example, SF 1 if we express it as SF 1 sub function, the concepts may be C 11 and C 12; that means, for sub function 1 the first and second means are workable or possible or available or can be created. Similarly, for sub function 2 the 21, 22, 23; that means, second or the first second and third column, there is been 3 means are possible or can be utilized.

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“Developing” Generated Concepts

Example: Motorcycle

| | | Alternative Concepts | | |
|---------------|----------|----------------------|---------------|-------------|
| | | 1 | 2 | 3 |
| Sub functions | Transmit | Chain | Belt | Gearbox |
| | Brake | Disc | Drum | |
| | Steer | Handlebar | Control stick | Fly-by-wire |



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It will be clearer from this short brief and simple example. Sub functions say as I said already transmit, brake, steer, suppose these are the sub functions, these are to a motorcycle these are the 3 sub functions. Now, what are the already concepts for transmission? The chain, belt, gearbox as I said just a little while ago, brake it may be disc brake, it may be drum brake, for steering it may be handlebar, it may be control stick, it may be fly by wear.

So, these are the alternatives possible. Alright we will come back to that. So, now what kind of combination basically would help that is the purpose. Now, I have I am presenting a simple example from available literature because this shows a very simple form of how it is done.

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Morphological Matrix

Creating combinations of concepts (means) into alternative product concept designs

| | | Alternative Concepts | | | | | |
|--------------|-----------------|----------------------|-----------------|-----------------|-----|---|-----------------|
| | | 1 | 2 | 3 | ... | n | |
| Subfunctions | SF ₁ | C ₁₁ | C ₁₂ | C ₁₃ | | | C _{1n} |
| | SF ₂ | C ₂₁ | C ₂₂ | C ₂₃ | | | C _{2n} |
| | SF ₃ | C ₃₁ | C ₃₂ | C ₃₃ | | | C _{3n} |
| | ... | | | | | | |
| | SF _m | C _{m1} | C _{m2} | C _{m3} | | | C _{mn} |

Alternative 1 Concept design {C₁₁, C₂₂, C₃₁...C_{m2}}

Alternative 2 Concept design {C₁₂, C₂₃, C₃₃...C_{m3}}



Now, if we put those C₁₁, C₁₂, C₁₃ in that matrix, we see the sub functions on the rows, SF₁, SF₂ and so on to S F_m and already concepts or means as we call 1 2 3 4 up till n. So, it is a m by n matrix that we can see. Now, say already 1, there now there can be multiple already. So, now here the designer would choose ok what combination would be useful or economical or attractive or user friendly or whatever the characteristics are according to product design specification as we had that earlier.

So, these combinations say for from the line which is drawn, you can see the first concept alternatives it is combination of C₁₁, C₂₂ and then it goes to C₃₁ and then it goes to there are I mean I am not placing all these things in the rows or columns just to show you we will actually deal with an example very soon and it goes to C_{m2}. So, that is one alternative.

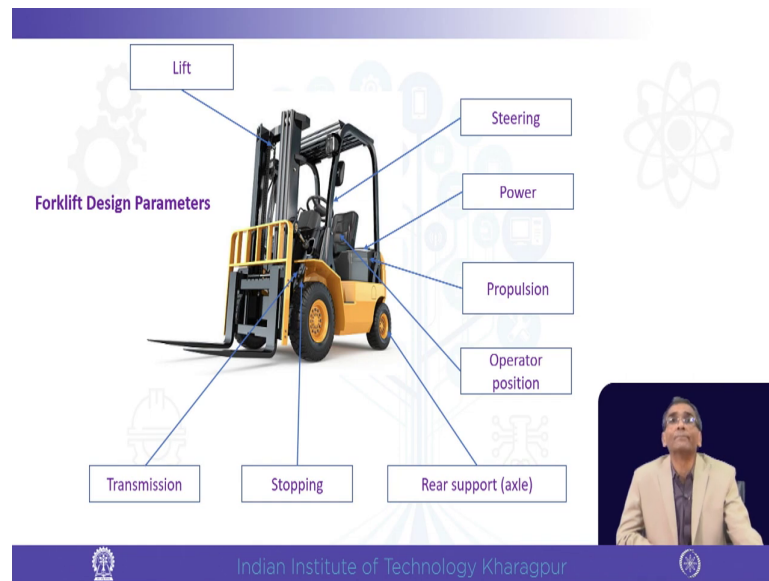
So, here you can see already 1 is bracket is C 11, C 22, C 31 dot dot dot C m2. Similarly, the other alternative is 2 which you can see from the matrix it is C 12, C 23, C 33 and C m3 this is the approach.

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Now, we will take up a case of a forklift truck that we just said that which is used in factory which is a product is a material handling equipment product. And it is used for lifting and shifting of material picking up storing etcetera for all these purposes it is used.


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So, this is a forklift truck if we just see what are the different parameters, I mean this is an example parameters by no means it is exhaustive, but these are the parameters that we have say lift, steering, power, propulsion, operator position, rear support, stopping transmission. Suppose these are 8 such parameters we have chosen for a forklift we will see how this concept design method is built and created.

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| Parameters | Design Options for a Forklift Truck | | | | |
|-------------------|-------------------------------------|------------------|----------------|----------------|-----------------------|
| Rear Support | Tyres | Castor Wheel | Air Cushion | Slides | Omnidirectional Wheel |
| Propulsion | Air thrust | Engine Driven | Moving cable | Elec. Motor | |
| Power | Petrol | Diesel | Elec. Battery | CNG gas | Steam |
| Transmission | Belts-pulley | Gears and Shafts | Chain-sprocket | Hydraulic | Compressed Air |
| Steering | Turning wheels | Joy stick | Handlebar | | |
| Stopping | Ratchet | Drum Brakes | Disc Brakes | Reverse thrust | Solenoid brake |
| Lifting | Hydraulic Ram | Rack and Pinion | Screw | Chain hoist | Rope hoist |
| Operator position | Seated at front | Seated at rear | Standing | Remote Control | |



So, here as we said the parameters 8 parameters, we said look at the chart the 8 parameters are placed on the left hand side column in rows. So, against say rear support how the rear can be supported a tyres it can be castor wheel, air cushion slide ok. It here may be all are not equally suitable or even quite feasible, but then this gives an extensive view before discarding. So, what is not to be taken also is to be judiciously considered from the alternatives.

But initially they may be there in the chart otherwise there is a possibility a good option is left out. Now, like that you can see the power it alternative is petrol, diesel, electric battery, CNG gas even steam. Now, obviously, people would say ok forklift with steam is very difficult because steam generation with coal burning and all these just out of questions. So, then why as steam there? Because it is one of the means of generating power.

Similarly, stopping; stopping can be brakes disc, drum brakes, ratchet, reverse thrust and so on so forth. Lifting can be hydraulic chain hoist screw rope hoist and so on so forth. Operator position can be also be changed one can be seated at the front one can be seated at the back or here even one can stand and make a move or and now there are options to do it remote control that also is possible. So, this is how the say the matrix is formed with an example case as a forklift here.

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| Parameters | Design options for a forklift truck | | | | |
|-------------------|-------------------------------------|------------------|----------------|----------------|-----------------------|
| Rear Support | Tyres | Castor Wheel | Air Cushion | Slides | Omnidirectional Wheel |
| Propulsion | Air thrust | Engine Driven | Moving cable | Elec. Motor | |
| Power | Petrol | Diesel | Elec. Battery | CNG gas | Steam |
| Transmission | Belts-pulley | Gears and Shafts | Chain-sprocket | Hydraulic | Compressed Air |
| Steering | Turning wheels | Joy stick | Handlebar | | |
| Stopping | Ratchet | Drum Brakes | Disc Brakes | Reverse thrust | Solenoid brake |
| Lifting | Hydraulic Ram | Rack and Pinion | Screw | Chain hoist | Rope hoist |
| Operator position | Seated at front | Seated at rear | Standing | Remote Control | |

So, now here if we see multiple options are possible, I have shown it with only two options with two different color lines one is with a black dashed lines and other is the blue dotted lines. So, here one is considering the two order is where it is touching. The circle marks may show indicate that ok there is some preference on that, but be that as it may there can be other

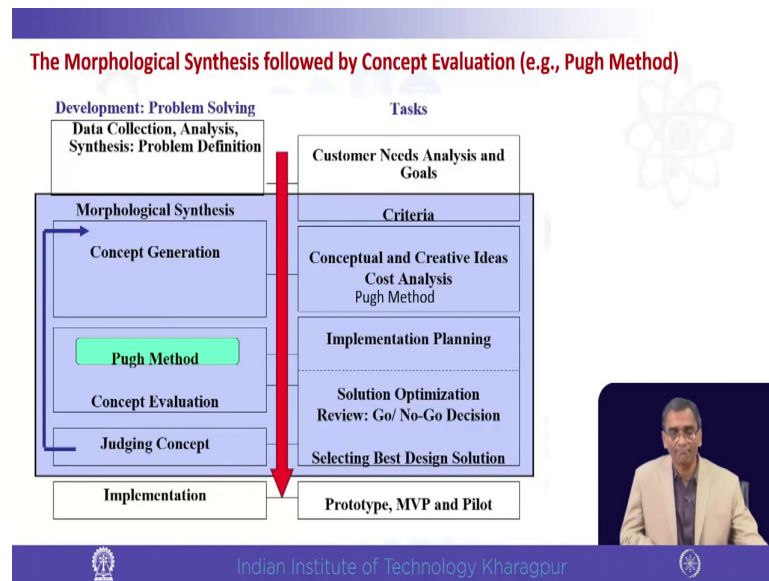
symbols to highlight that, but then idea is to first find out which is connecting to what that is the most important thing.

So, here as we see that one alternative is that rear support is tyre, propulsion is electric motor, power is electric battery, transmission is the gears and shafts, steering is turning wheel that is wheel, then stopping is drum brake, lifting is chain hoist and the operator sits in the rear these are the parameters or sub functions as we call it. So, this is the these are the means and these are the sub functions of parameters.

So, from this what we realize is that the this can create multiple alternatives in the design and when I say multiple alternatives it is shown with two, but for a large system it may be actually more. And now similarly, this can be done for a particular sub part of a system these morphological analysis and then multiple sub parts will then be added together to give the main system.

Say for example, if we brake the car down into say engine, the propulsion, the power train or if we exclude the engine and make a drive train or say we call the chassis system. So, each can be divided into sub functions and then those sub functions can further be grouped together or added together or assimilated together to give the complete configuration.

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Here it is interesting to note that we are discussing here in the first top item in blue zone because rest all are the you know the product development process starting from the you know data collection analysis etcetera. So, we are not going there what we are saying because we have already discussed it, we are showing the different tasks.

Logically it leads us back to the implementation, but we have not discussed that yet, we are we have discussed morphological synthesis or the matrix as we are discussing here for concept generation.

But generation is one part and then from the so many generated output one is the judicious decision and other is some systematic method again which out of say few judiciously selected

when we categorically say judiciously selected are 3 4 5 or whatever and when we want to select further into that to come to a conclusion very analytically logically and quantitatively.

Then the very for the very accurate method we need to have a systematic concept evaluation technique that we will discuss in our subsequent lecture say for example, we will be discussing Pugh method which is actually the entry point of embodiment design that the correct solution is being selected which will be taken forward in embodiment design which we will take up.

Here one thing at the end this morphological design it helps finally, through these steps if it is done correctly to build the right architecture into a good prototype or MVP for pilot. So, prototype or MVP prototype we understand a MVP is minimum viable product that is where some of the features are to be tested prior to building the complete product.

So, minimum viable product where not all the features are included as it would be for a product, but the core features the basic features which we had already discussed in one of our sessions in Kano feature selection. And for that a very good method would be this morphological analysis using that morphological analysis such prototypes or MVP would be prepared or built to give a very good and effective result.

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Conclusion

In this lecture, the Morphological Chart (Matrix), commonly used in Generating alternative concepts, is discussed with elucidation on the matrix development and creating combinations for alternative design choices and illustrating the process with an example.

The slide features a central graphic of a tree with various icons (gears, lightbulbs, etc.) on its branches. To the right is a small video inset showing a man in a beige jacket speaking. The bottom of the slide has a blue bar with the Indian Institute of Technology Kharagpur logo and name.

So, from here we will take up with the next session. Here I would like to conclude this session that the morphological chart commonly used in generating alternative concepts is discussed with elucidation on the matrix development and creating the combinations of alternative design choices and illustrating the process with an example which you did with a forklift truck here.

I am sure you may try simpler or a complex such thing and do a morphological analysis by yourself taking up a vacuum cleaner or washing machine or any other product that you like to have or a mobile phone and that is your choice. But please do it would help. Otherwise, this lecture content is there for you to understand things. And so, for future discussions you can look at the prescribed reference, the lecture notes and that will help you in revising the knowledge that you are learning here.

Thank you very much. Thank you for attending this program.