Introduction to Aircraft Design
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Lecture – 12
Illustration of HOQ-GA Aircraft

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Okay let us have a look at the illustration of the House of Quality chart for the conceptual design of a general aviation aircraft. So this is just a typical example of general aviation aircraft, which is very popular.

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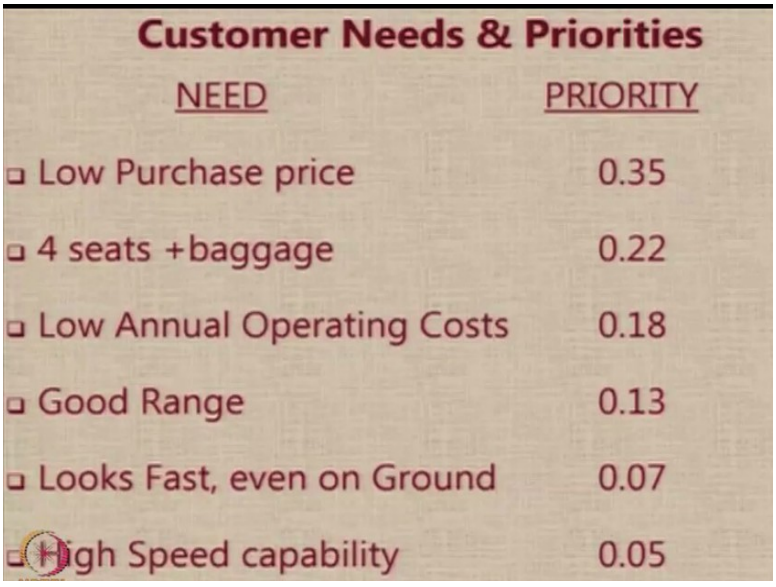

Let us assume that we have carried out a detailed market survey and we have obtained from a

bunch of customers their needs and we have also been able to list them down in the order of their priority. So, we will look at the need and the priority. So low purchase price in this case happens to be the top most priority and the weightage given by the bunch of customers is 35%. Next requirement or next priority is the ability of the aircraft to be able to carry 4 passengers and adequate baggage.

For this there is a 22% priority. Low annual operating costs is the next in the order of preference, 18%. Good range is of the order of 13%. Looks fast, even on the ground, this is a requirement which seems a little bit peculiar, but this is a requirement of looks okay and actually being able to fly high speed capability that is 5%. Interestingly, the customer is more keen to make the aircraft appear fast looking, whereas it may not necessarily actually have the capacity to fly fast.

Notice that if you add up these priorities, they will come to 1.00 or 100%. Now, these are the 6 needs which have been identified and prioritized. We are now going to look at some features which are going to be utilized or we will use the house of quality chart to see what these features can do.

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So we have chosen some features. These are only proposed because how they affect we will come to know very soon by the house of quality chart. The first feature that is proposed is advanced construction technology, large passenger cabin, high aspect ratio for the wing, swept surfaces because the customer wants the aircraft to look faster on the ground and also to fly fast to some extent so swept surfaces, efficient engines okay. These are the 5 proposed

design features.

Now, this example is just an example and please note that it is not always possible for novice aircraft designers to be able to fill up this house of quality chart, but I will just try and give you an idea about how it works.

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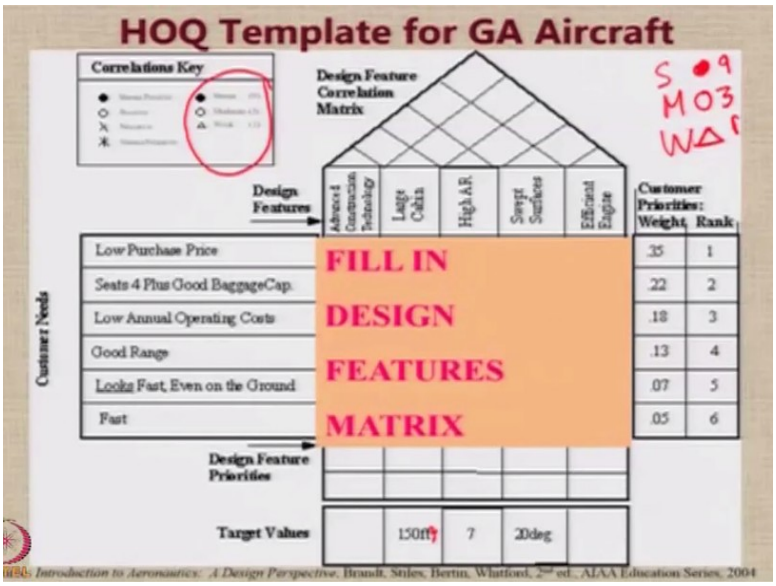

So this is the template which I showed earlier is now filled in. We have the customer needs listed here. We have the proposed features listed here and the priority for each need in the order of rank is also listed here. For some of the design features okay, for example large cabin we have 150 cubic feet. You know we have 150 cubic feet as a proposed target value. For swept surfaces, we have 20 degrees sweep.

For high aspect ratio, we have a target value of 7. So this information has come from past data or from the competition. Now let us see how this matrix is filled. So once again, we are going to use some kind of a symbology, but here this is going to be a low level house of quality, so we are going to use 3 symbols as are listed here okay. The 3 symbols are a strong correlation, a moderate correlation and a weak correlation.

Strong correlation is shown as filled in circle, moderate correlation is shown as an open circle and the weak correlation is shown as a triangle. And if you have a strong correlation, we give 9 points, if we have a moderate correlation we give 3 points and if we have a weak correlation we give 1 point. And also remember we are only looking at positive correlations. In the design feature correlation matrix, we look at positive and negative correlation.

If you remember, I mentioned that you use this darkened circle for strong positive correlation, open circle for positive correlation, a cross for negative correlation and asterisk mark for a very strong negative correlation, but in this particular area in the center we are not going to put any negative correlations. We are going to put only positive correlations between the proposed feature and the customer need.

Now, this is an area where an experienced aircraft designer or experienced designer is required because it is not possible for just anyone to fill this matrix. To do this, you need some kind of prior experience or in some cases you may have to do a little bit of analysis. So let us see we are going to now fill in the design features matrix.

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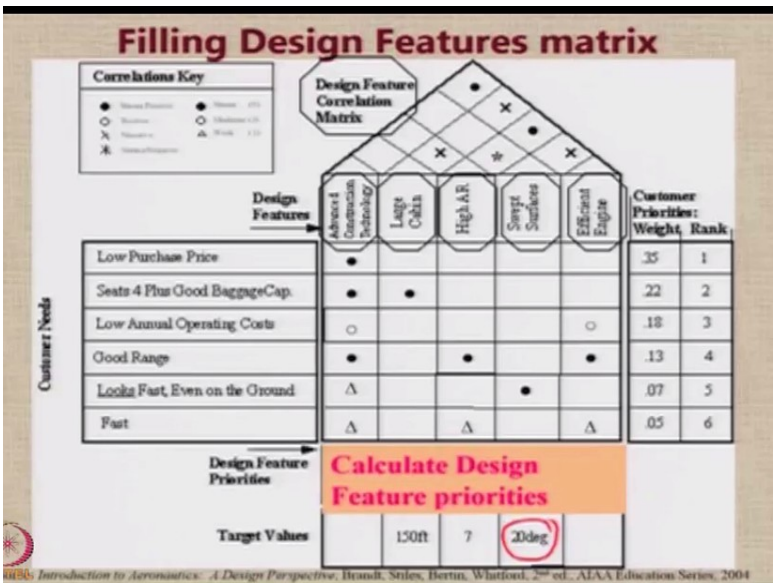

Let us assume that after filling in, so let us start one by one. We look at advanced construction technology and we correlate that with low purchase price and there is apparently a very strong positive correlation. Then if you have advanced technology of construction, you can also provide good capacity for baggage and operating. Operating cost will also be a little bit low.

Range will be very high or I would say that if you use advanced construction technology, you might be able to provide features that give you good range and also you will allow it moderately to look fast on the ground as well as make it fast. So the designers have decided based on their experience and their past knowledge that advanced construction technology is going to have a very far reaching influence on all these aspects.

Now, we are not here to question them. Let us look at the next design feature which is the large cabin. Now, large cabin and purchase price may not really have any correlation, but large cabin will definitely ensure that you have the ability to carry 4 passengers and baggage capacity, others are not going to be of any great importance. High aspect ratio provision will help in providing a good range capability because it will lead to much lower induced drag.

So that is a very strong correlation and high aspect ratio will also allow the aircraft to actually fly fast. Swept surfaces I think they will only affect the looks and that too in a very, very strong way. They may also moderately allow it to fly fast, but you know the designers do not feel because the target value is only 20 degrees, and therefore they feel that with 20 degrees sweep you actually may not get very high speed, but at least it will look like a high speed aircraft.

The efficient engines are going to affect the operating costs because they are going to consume less fuel and definitely they are going to give you more range and also allow you to travel fast. Now, as I mentioned earlier and I want to reiterate it is not expected that any novice student who has no experience in design can fill this chart correctly. It is also possible that two different design teams may fill this chart differently okay.

It depends on what kind of facilities are available to the design team or to the company. The advanced construction technology here seems to correlate positively with many of the design requirements, but in some other country or for some other company, it might so happen that advanced construction technology may not be available and then the designers there may not like to provide it and they may not feel that there is a correlation with these things.

So the house of quality chart is filled differently by different design teams. Nevertheless, if it is filled by a particular team, let us see how we proceed further. So right now, we assume that this filling is sacrosanct and we do not have any reason to question or counter these arguments. Let us now see how we fill the design feature correlation matrix on the top. So advanced construction technology and efficient engines they go very well together.

They both support each other. If you have an efficient engine and also advanced construction technology, then it is best of both, so there is a very strong positive correlation. Between

large cabin and high aspect ratio the designers have put across mark because they are not very sure, they feel that these two are going to contradict little bit each other. Similarly, large cabin and efficient engine is also going to be contradictory.

And high aspect ratio and swept surfaces are going to have a very, very negative correlation because this is a recipe for aeroelastic problems okay. So we know that high aspect ratio wings are more slender and if you also sweep them, then we are entering a regime of aeroelastic problems. So therefore as a mark of caution, there is a star mark between these two factors. High aspect ratio and efficient engine yes.

High aspect ratio will give you lower fuel consumption and lower fuel consumption will also be supported by efficient engines, so they are going to be positively correlated to a large extent. Swept surfaces and efficient engines are going to be a little bit counter because swept surfaces are actually going to create a little bit more drag. We are not going to fly at very high speeds and you know such surfaces are not going to be working positively with the efficient engines.

This is how this particular works has been filled. The next step in our house of quality chart calculation is to fill in the design to calculate the design future priorities okay.

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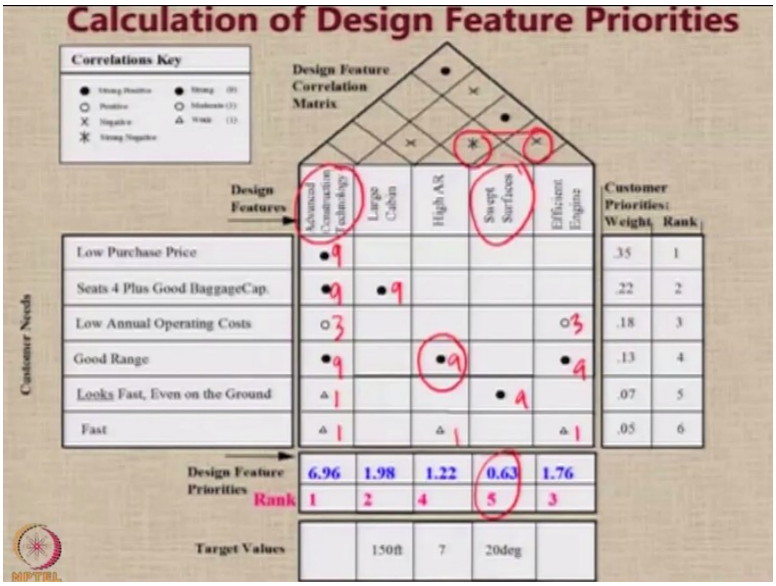

So this is done by simple calculation. So what we do is for every dark circle that you see here you are giving 9 marks. For every open circle, we are going to give 3 marks and for every triangle we are going to you 1 mark. So this will be 9, 9, 9. Let us see how these design

feature priorities calculated. So what we do here is to get this number we have to do this 9 into 0.35 + 9 into 0.22 + 3 into 0.18 + 9 into point 0.13 + 1 into 0.07 + 1 into 0.05 that will add up to 6.96.

Similarly, to get the next number you just do 9 into 0.22 okay and you will get this particular number. For the next one you have to do 9 into 0.13 + 1 into 0.05 and that if you do it will come to 1.22. The next one will be 9 into 0.07 that is 0.63 and the last one can be obtained by doing 3 into 0.18 + 9 into 0.13 + 1 into 0.05 if you add them. So when you do this, you will be able to get the values of the design feature.

And what we do now is we look at these numbers and we start ranking them. So, yeah 6.96 is the highest rank that is the first rank. The next rank is for the large cabin which is 1.98. The third one will be 1.76. The fourth will be 1.22 and the last will be the swept surface. So with this particular calculation, we summarize that the highest priority is actually available for this particular feature and the lowest priority is for the swept surfaces.

So the designers may say okay we might drop this feature because we have found that we thought providing sweep is going to be beneficial, but you know there are lot of these negative things associated with sweep. There is also one positive, but you know there are many which are negative and you also notice that the design feature rank is very low. So we might decide to you know avoid it in the next analysis or we might say no, let us use it.

So what you do is you sum all of this and then you say okay 6.96 upon the total that is the priority for the feature of advanced construction technology and you just rank it here and now you repeat the calculation by identifying what are the features we will provide to address these requirements.

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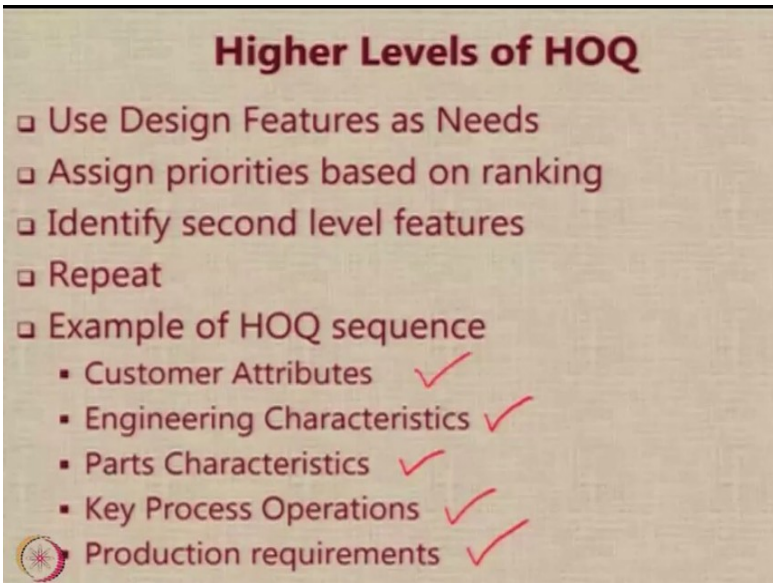

So similarly, you can go to the higher level. In the higher level of HOQ, you use design features as needs. You assign the priorities based on the ranking. Then you identify second level features and then you repeat okay. This is an example of some sequence of house of quality. You might start with the customer attributes as the first level of priorities. Then you might use engineering characteristics as the second level.

From there, you can go to the part characteristics. From there, you can go to the process operations and from that you can go to the production requirements. Like that, you can have many, many levels of house of quality. Thanks for your attention. We will now move to the next section.