Introduction to Transportation Engineering
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Lecture - 23
Highway Alignment

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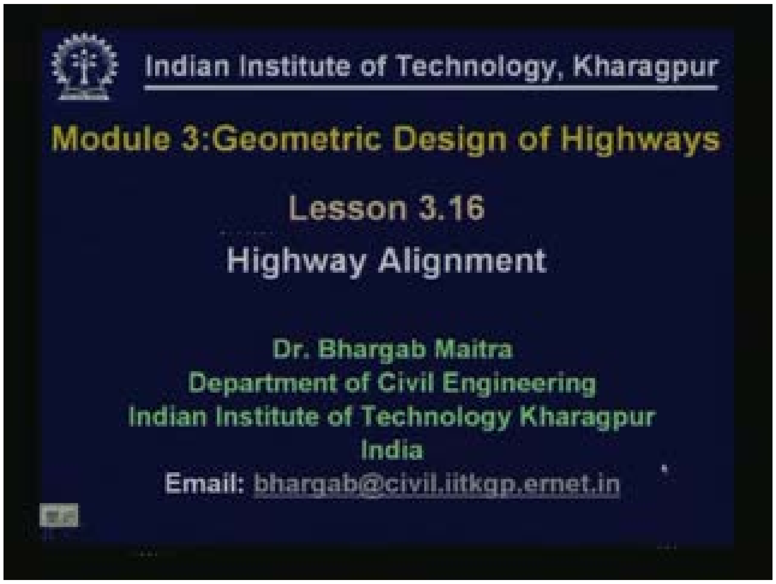

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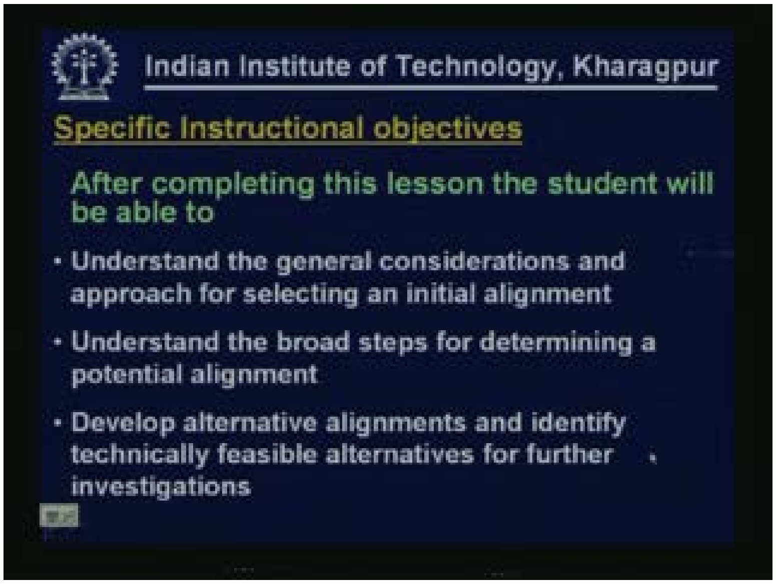

After completing this lesson the student will be able to understand the general considerations and approach for selecting an initial alignment. The student will be able to understand the broad steps for determining a potential alignment. Basically how a potential alignment can be identified. Then student will be also able to develop alternative alignments and identify technically feasible alternatives for further investigations.

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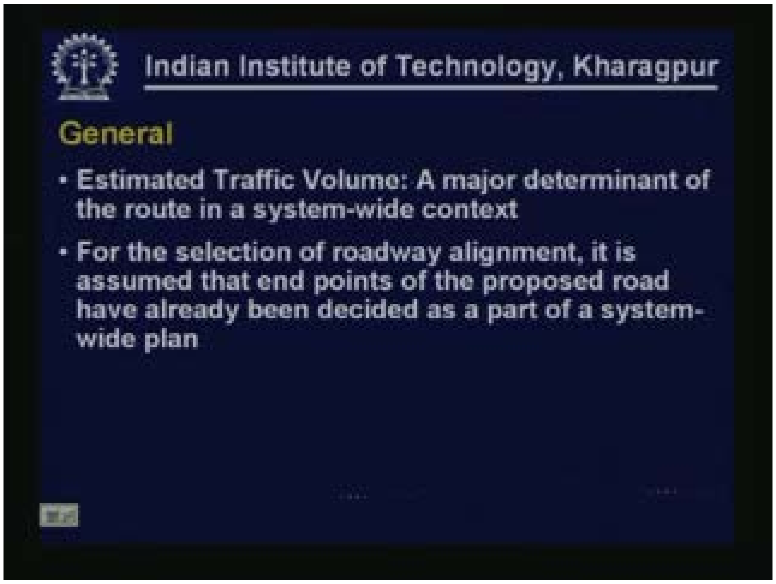

Understanding the estimated traffic volume is a major determinant of the route in a system-wide context. That means, when we are talking about roadway alignment from the demand point of view it has already been established that these two points are to be connected. That means there is a significant demand between the two points and the need for connecting these two points has already been established based on the traffic viability study.

We have already determined that point a and point b to be connected and it is necessary to connect them because there are significant demands. So at this stage we are only trying to fix up the alignment while connecting these two points by a route. For the selection of roadway alignment, it is assumed that end points of the proposed road have already been decided as a part of the system-wide plan as I have explained just now. We have already decided that point a and point b to be connected. We are only deciding at this stage, but how do we connect these two points with the route?

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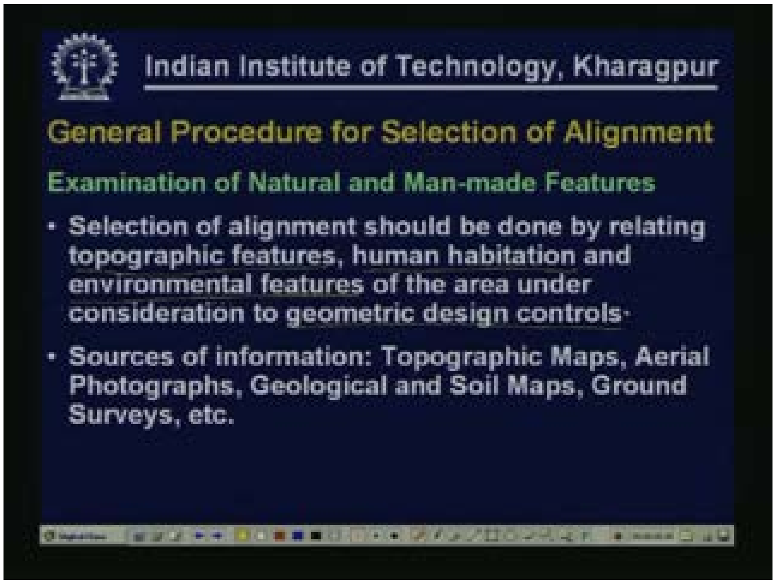

Let us look at the general procedure for selection of alignment. The very first thing we should do is, try to examine the natural as well as manmade features. While doing that, selection of alignment should be done by relating topographical features, human habitations and environmental features of the area under consideration to geometric design controls. That means we have topographic features, we have human habitation and we also have environmental features which are the three major aspects. And we have to relate them to the geometric design control. We have geometric design controls in one hand and in the other side we have topographic features, human habitation and environmental features, so we have to relate them.

In the process, we use various sources of information namely topographic maps, aerial photographs, and geological soil maps and sometimes we carry out ground surveys. These are all the different sources of information.

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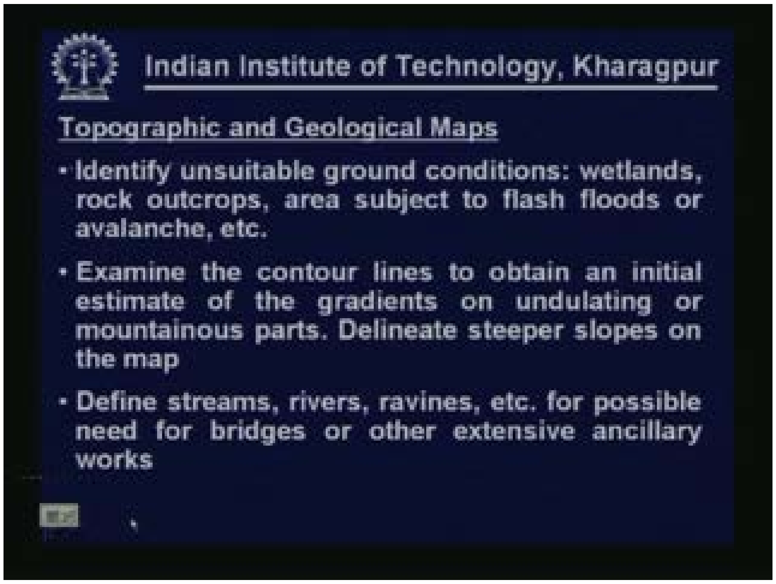

Let us see how we use that information.
First, topographic and geological maps: We study topographic and geological maps and we identify unsuitable ground conditions for example may be wet land, rock outcrops areas, subjected to flash floods or avalanche etc. Then we examine the contour lines to obtain an initial estimate of the gradient on undulating or mountainous parts and we delineate steeper slopes on the map. Remember that at this stage we do not intend to calculate the exact slope, but we calculate or we try to develop a feel about the slope conditions. Like, if we know that we have the contour lines and within a very short distance we are crossing so many lines, which obviously indicate that slope is going to change at a much faster rate. So like that it is a broad estimate to develop a feel about the slope and the general ground conditions.

We also then define streams, rivers, ravines etc, because these are the places where we have to provide bridges or other types of extensive ancillary structures or rocks. So we try to identify the places like for example, if we take a road, then we may have to construct a major bridge or major tunnels. Hence we try to identify those areas also.

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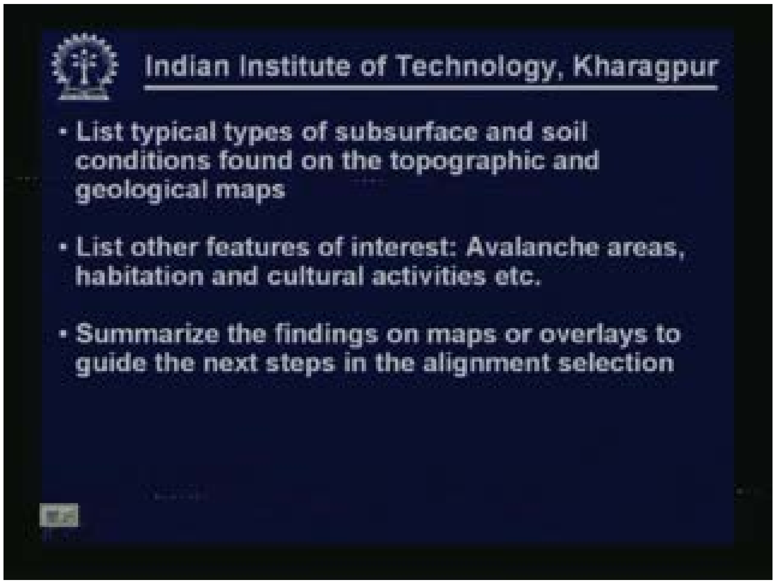

Once we have identified those things, we list all the typical features of subsurface and soil conditions that are found on the topographic and geological maps. We also list all other features of interest for example avalanche areas, habitation and cultural activities, because all these places tell us that probably we should not run the road through an area which is avalanche areas or where there are cultural activities. Because we want to protect them or we want to avoid such places while taking a new road.

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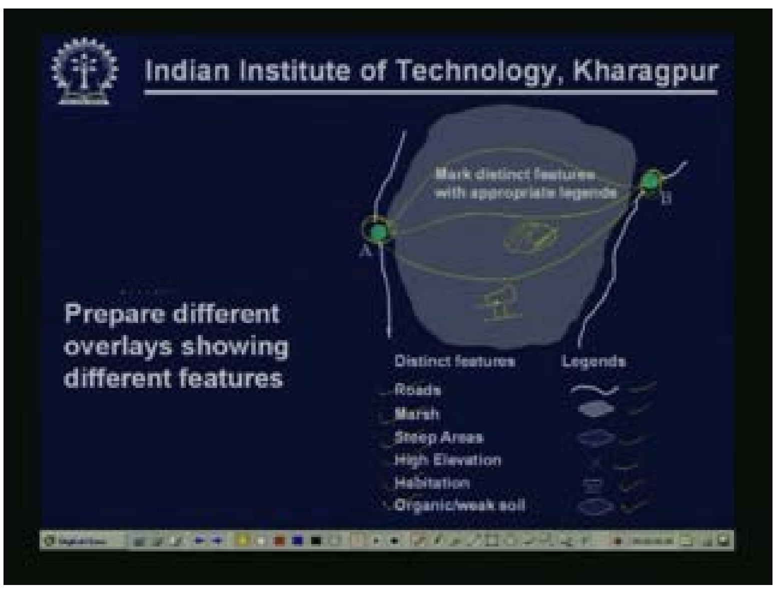

Then with all these we would try to summarize the findings on maps or overlays to guide the next step in the alignment selection.

Let us try to explain these features what we have discussed till now. Say these are the two existing roads and say we have already identified that point A and point B to be connected by a new route. So obviously we have to take these roads somewhere like this (Drawing 3 different routes in the slide – Refer Slide Time: 8:01).

We have to take this road through this area to connect point A and point B. What are we trying to say from all these maps? We try to identify distinct features such as roads, marsh areas, steep areas, high elevation, habitation, and organic or weak soils. That means positions or features which are generally unsuitable for taking the roads. At least we do not prefer to run the alignment through those areas and we represent all these items with proper legend which I have indicated in the slide. So that, the area which is having some kind of special structure can be identified using the legends, which would help us to understand the area we should try to avoid.

As there may be a number of features which are coming or which exist in that area, it may be necessary that we prepare a number of overlays instead of trying to show all the features on one map. So, we can prepare different overlays and may be four features shown in one map, next four features are shown in another map etc, so that all the areas and all the items or features which are to be protected or which we try to avoid while you know taking the road. We do not want the road to run through all those areas or do not want to destroy some of these existing features, so accordingly we identify what are the unsuitable things and we prepare different over lays.

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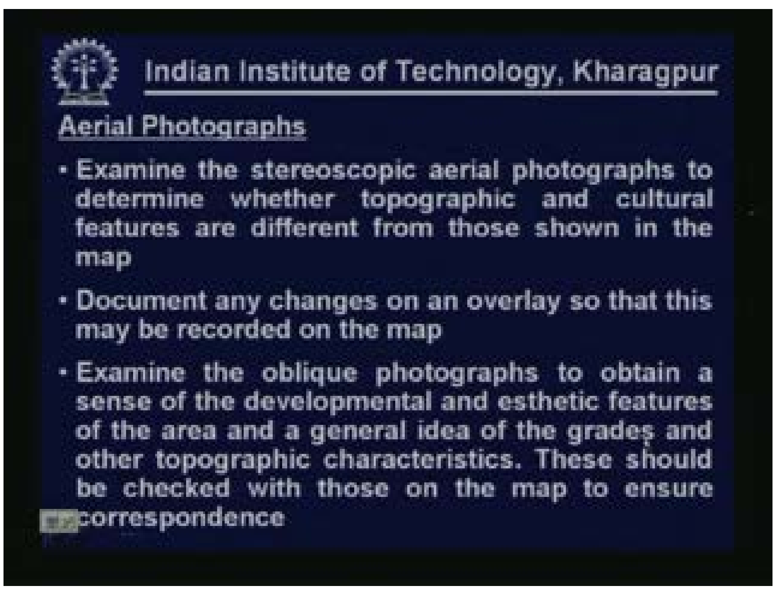

Next one is aerial photographs.
Often it happens that whatever information you obtain from topographic maps might be old maps. Existing or the present ground reality might have changed a lot. In that case if we have photographs which have been taken very recently can be used to update the information, basically what we have extracted so far from the topographic maps. So we use aerial photographs

wherever and whenever they are available. And we try to update information that we have already plotted in terms of different overlays using the topographic information.

In aerial photographs we examine the stereoscopic aerial photographs. Two types of aerial photographs normally are used; stereoscopic aerial photographs and oblique photographs. From stereoscopic photographs we determine whether the topographic and cultural features which are found or which are captured in the photographs are different from those shown in the map and in case you find any change, all those changes are to be appropriately incorporated in the overlays. That means whatever we have already done earlier we just update them and we make them or try to provide as far as realistic and present scenario.

We also examine the oblique photographs to obtain a sense of the development and esthetic features of the area and try to develop a general idea of the grades and other topographic characteristics. And obviously all these should be checked with those on the map to ensure correspondence, because we have already developed the overlays using topographic features/topographic maps. So at this stage from stereoscopic photographs and oblique photographs, we just try to update the information. But the most recent condition in the ground or the features is what we try to take into consideration in terms of developing or updating the overlays.

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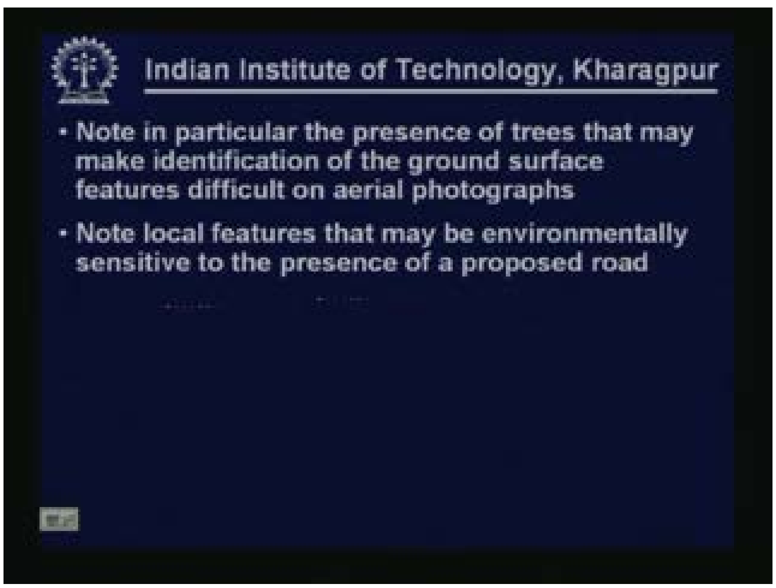

It is worthwhile to mention that one should note in particular the presence of trees, especially the big trees because such trees may make identification of the ground features difficult on aerial photographs. The big trees may obstruct the view of the ground reality in aerial photographs. Finally note all local features that may be environmentally sensitive to the presence of the proposed road. So we should note all such features.

We use topographic maps, we also use the aerial photographs whenever and wherever they are available and we try to update all the information in terms of overlays, so that overlays clearly show us where or which are the areas we should try to avoid while we are trying to take the road while connecting these two points A and B.

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Now let us try to understand the process for identification of technically feasible alternative alignments. When we say we want to connect road, we want to develop a road all our idea is basically to develop or to improve the condition. So at this stage it is worthwhile to look at this term 'improvement' or when we say 'improve it' what we really mean by that.

Let us take a look. Improvement means make less expensive and safer for public in general. Obviously this part is well understood; we want to make it less expensive and safer, safer means more safe for public in general as well as for the road users. So this part is well understood and most of us will only concentrate on this part (Refer Slide Time: 14:55). But remember that this is an incomplete definition of improvement.

We must consider this part also; 'while at the same time maintaining or contributing to the improvement of environmental quality'. We cannot really make it safer for public or less it less expensive for public at the cost of environment. If we are doing it at the cost of environment, then we cannot call it improvement. So we can claim it as improvement when we are making it less expensive and safer for public and road user, but at the same time maintaining or contributing to the improvement of environmental quality which is very important.

Now as the title says that, it is identification of technically feasible alternative alignment, it is necessary for us to understand what we mean by technically feasible route. It essentially means that no excessive construction or maintenance problems are envisaged and such that design controls and policy on geometric design standard are adhered to. You are already familiar and you have already studied the geometric design part in details. So with that background, we have to satisfy all the geometric design controls; the curve, or the radius, or the super elevation, or the grade, all the design controls are to be satisfied. And these are to be satisfied without excessive construction or maintenance problem. If we can ensure that with any alignment, then we can call it a technically feasible route. That means we satisfy the design controls without excessive construction or maintenance problem.

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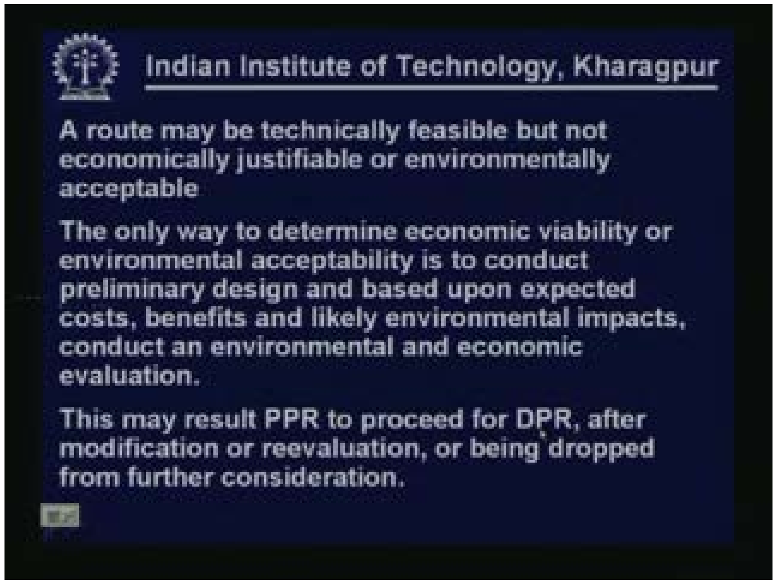

Now remember that a route may be technically feasible but not economically justifiable or environmentally acceptable, because we have already indicated that crossly if you are satisfying the design control and criteria they generally mean a technically feasible route. But remember that even if a route is technically feasible it may not be environmentally acceptable or economically justifiable. Because if it is causing any major environmental degradation or concern then obviously from environmental point of view even the so called technically feasible route may be rejected.

Similarly once we carry out economic evaluation or economic analysis, we see the economic cost and economic benefit from the project or from the development. We may reject a project which is otherwise technically feasible just because of the fact that the project is not economically viable, that means economic benefit is not more than the economic cost. So in that case we have to reject that.

But how do you know whether a route is economically viable or how do you know that a route is not environmentally acceptable? Of course preliminary selection does matter a lot. Suppose we are avoiding environmentally sensitive areas and we know that we are running the alignment through areas where grossly there are no environmental issues or no detrimental impact on environment. So that generally will give a sensible alignment.

But finally we have to carry out detailed environmental analysis or evaluation and also the economic evaluation and the only way to determine economic viability or environmental acceptability is to conduct a preliminary design. Unless we know that this is the preliminary design, this is going to be the block cost or the approximate cost of construction, we cannot go for calculation of expected economic cost, economic benefit and also the likely environmental impact.

Obviously when we carry out all these investigations, this may result the PPR- Preliminary Project Report to proceed to DPR that means Detail Project Report, may be as it is or may be after modification or we may drop it from further considerations.

Let me clarify this point once again: We fix up or we decide an initial alignment which is technically acceptable, and we carry out preliminary engineering what do you call as preparation of preliminary project report, and we estimate the block cost say the approximate cost, and we calculate the benefit, and carry out economic evaluation. If you find it is economically viable project, beneficial project and also it is environmentally acceptable, then we proceed for the detail engineering and we try to go for the DPR preparation.

In some cases obviously you may have to make some minor changes in the overall process to safeguard the environmental aspect or to make sure that it is economically viable project but with minor modification. And then we proceed for the Detail Project Report, which is preparation of DPR or else if we find that is a serious problem at that stage, we drop that alternative for further consideration. We just leave it at that stage and we either try to find out a new alternative or a new possibility.

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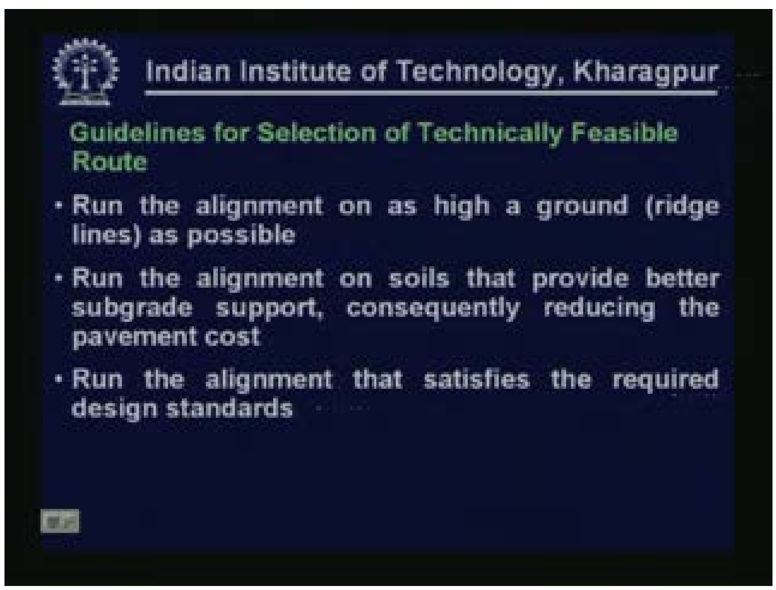

Here some of the guidelines for selection of technically feasible roads. It is very difficult to give you exact items, but you can try to develop a feel and develop a sense that when you are deciding an initial alignment what are the things you should look at. In other way, we can tell you some of the Dos and Don’ts.

Let us try to see that. Run the alignment on as high a ground as possible. Basically try to take the ridge line, it will obviously be beneficial from drainage point of view and there are several other advantages.

Similarly run the alignment on soils that provide better subgrade support, consequently reducing the pavement cost. You all know that pavement takes about 40% of the total construction cost. So obviously if we take a better soil property or run the road through soil which is better or which provides a better subgrade support, may be we will require lesser thickness of the pavement and we can save substantial cost. If you find there are ((marshilious)) marshy lands or areas where the soil condition is not that good, do not try to take the road through that area. Run the alignment that satisfies the required design standards.

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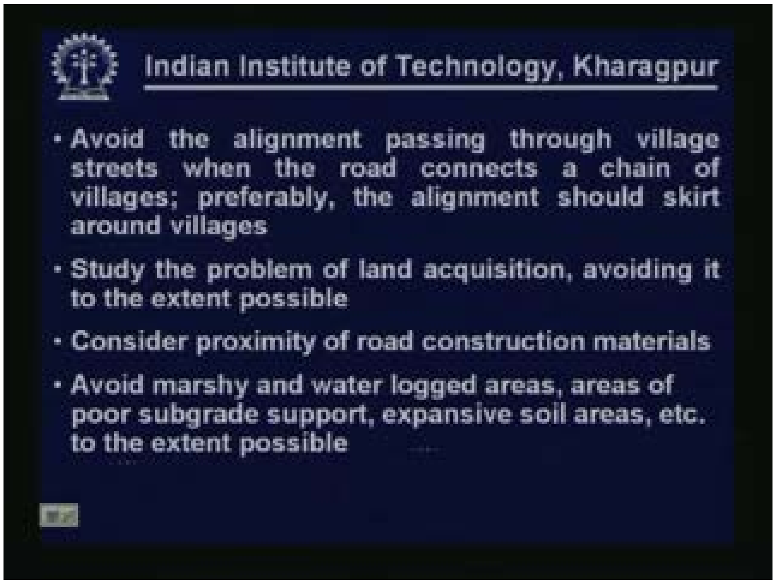

Avoid the alignment passing through village streets when the road connects a chain of villages; preferably the alignment should go around the village. Because there are settlements, there are villages, and habitations etc. So obviously it is very difficult to construct the road within or it is difficult to take the road through that area. So let them be by the side of the road and you take the road may be just by the side of the village. So that the villagers get connectivity but you have least disturbance to existing habitation, population and features.

Also remember and try to study the problem of land acquisition, avoiding it to the extent possible. This is a major bottleneck for development of new roads if we have to acquire a land where there are permanent structures, even in other ways also land acquisition is a major problem. So while taking the road, keep it in mind that as far as possible you should be able to take the road without the need of land acquisition. Wherever it is necessary also that land acquisition to be done, it is much easier to acquire land where there are no permanent structures. So rather than taking or occupying area where you have permanent features, people are living, and there are houses, buildings and all other features, you should consider open land or free area. So, obviously try to keep in mind the possibility requirement and also the problems associated with land acquisition and try to avoid the possibility or the need for acquiring land. Also, consider the proximity of road construction material because materials are to be brought from other areas. So you take the road in such a way that you can get easy access for construction material. Avoid marshy lands, water logged areas, areas of poor subgrade support, expansive soil areas etc. to the extent possible. Basically as far as possible, avoid the problematic areas.

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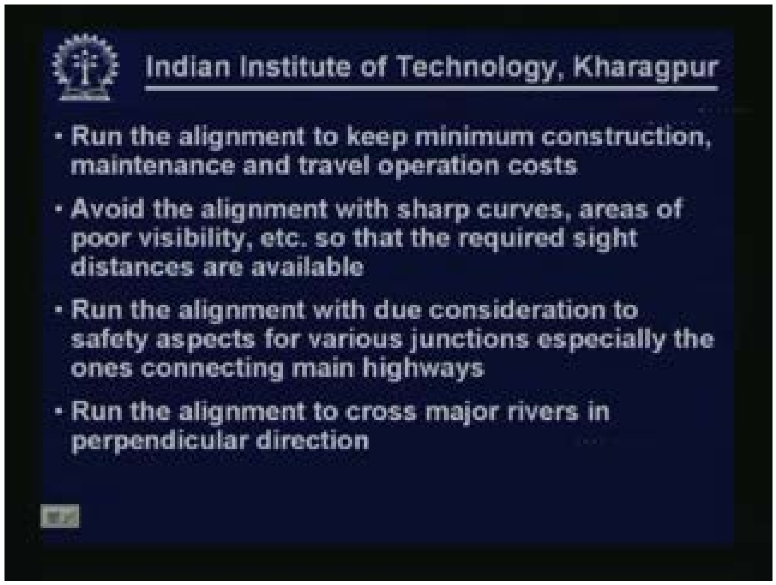

Run the alignment to keep minimum construction maintenance and travel operation cost.

Avoid the alignment with sharp curves, because it will be difficult for you to satisfy the design control and criteria. Avoid areas of poor visibility, because that may invite sight distance problem. You are already aware of this requirement of sight distance.

Run the alignment with due consideration to safety aspects for various junctions especially the ones meant connecting the main highways. So when it is connecting the main highways the grade should be proper, the angle should be proper. So when you are finally connecting it to the main road you must bear in mind all these aspects during the initial alignment selection itself and accordingly select an alignment. Later on, it will be much easier to satisfy all such requirements when you are making the final design.

Run the alignment to cross major rivers in perpendicular direction. Of course for minor streams it may not be a major problem, but when you have big rivers or major rivers, try to cross the rivers as far as possible in perpendicular direction.

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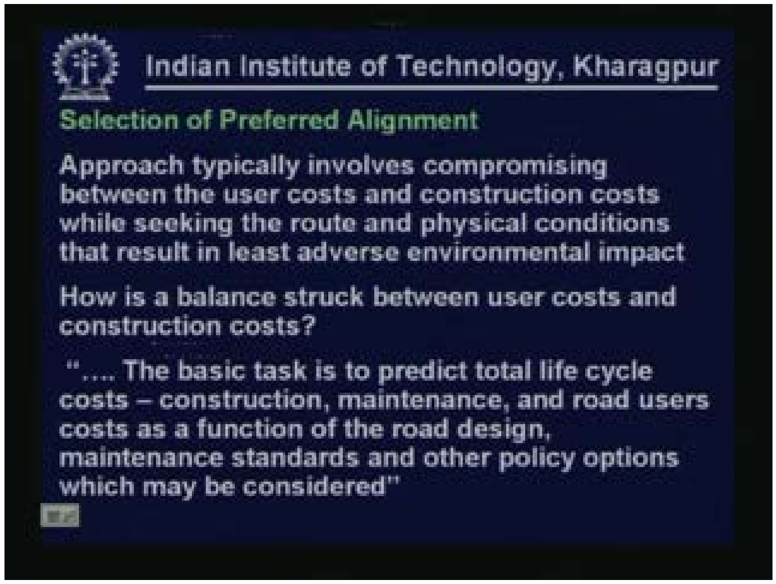

With this background, let us the see the selection of preferred alignment. The approach typically involves compromising between the user cost and the construction cost. Try to understand these two aspects very clearly; one is the user cost, another is the construction cost. What happens if we make a road say perfectly straight road, which is anyhow not desirable, but generally with a good alignment; as far as with shorter length, good geometry and straight or maybe with some very mild curves and taking the shorter distance; obviously the road user cost will be much lesser. Because the road is taking the shorter route, alignment is fine, and geometry is fine, so obviously road user cost will be lesser. But in a case where you may have to construct bridges, you may have to construct tunnels, or you may have to encounter other sorts of problem such as heavy cutting, heavy filling; what will happen? Your construction cost will go up.

On the other hand, if you try to minimize the construction cost that means run the alignment as far as possible, following the contour. Or even if you anywhere crossing the contour you have to cross the contour lines, but over a longer length what will happen? The road length will increase, the user cost will be more, but the construction cost will come down. That means, if we try to minimize the road user cost it is possible that the construction cost will be higher. If we try to minimize the construction cost it is possible that you will encounter or you will come out with a design or alignment where the road user cost will be higher.

So when we are selecting a preferred alignment, this approach typically involves compromising between the user cost and the construction cost while seeking the route and physical conditions that result in least adverse environmental impact. That means, again we have to give due consideration to the environmental aspect. So we are trying to compromise between user cost and construction cost, safe guarding the environmental aspect.

Now, how is a balance struck between user cost and construction cost? This is very interesting. The idea is; the basic task is to predict the total life cycle cost instead of considering only the construction cost or only the user cost. It is judicious or more rational to try to predict total life cycle cost where we consider construction cost, maintenance cost and also the road user cost. Obviously they are all function of the road design and other policy options which may be considered. That means, essentially take the alternative or that is the preferred alignment which is minimizing the life cycle cost. That means we are considering the construction cost, we are considering the maintenance cost, we are considering the road user cost and we are taking the option where the life cycle cost is minimum.

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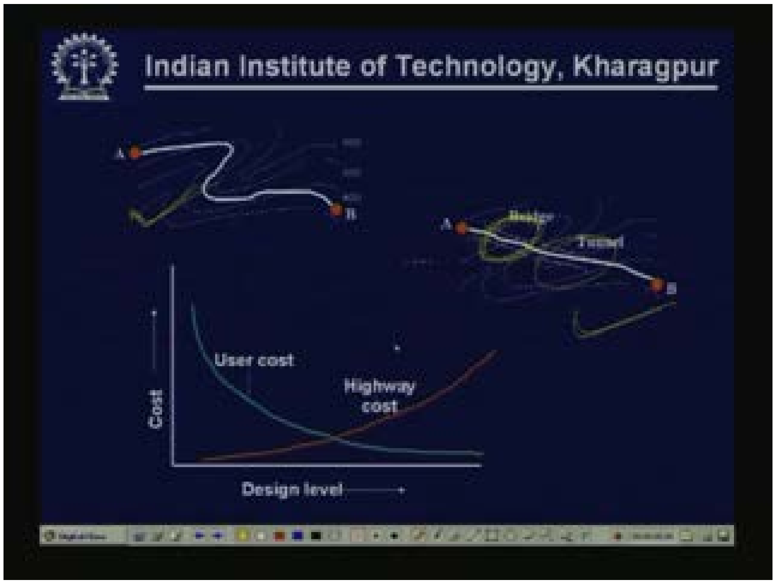

Whatever I have discussed just now, I am trying to explain the same thing once again. Let us consider that point A and point B to be connected. These are the contour lines you can see (Refer Slide Time 31:15). In this case we have taken that alignment following the general contour line. So you need know the list such as earth work or all sorts of other expensive items like bridge or tunnel or other ancillaries to the structure. But here the route length is more, so the user cost you can expect to be more and construction cost is lesser because there is no ancillary to the structure (Fig 1).

In this case, I have tried to indicate generally almost a straight line connecting the two points (Fig 2). But in this case you need probably a bridge because you are crossing the contour lines within a very short distance and you also need the tunnel. So what we find here in this case is, user cost is more and construction cost is less (Fig 1). In this case construction cost is more because of the bridge and tunnel and the user cost is less because it is nearly a straight road, and further generally following the shorter route with good geometry (Fig 2).

What happens if you try to increase or decrease?
If you try to decrease the user cost with a better design like this one (Fig 2), your highway cost or the construction cost will be more. And if you try to minimize the highway cost like in this case (Fig 1), your user cost will be more. So, it normally follows a trend as shown in this gauge or the graph. And what is our attempt? We tried to take that option which is neither minimizing only the user cost nor minimizing only the construction cost, but trying to minimize the life cycle cost;

considering user, cost construction cost as well as the maintenance cost. That is what is explained in this slide.

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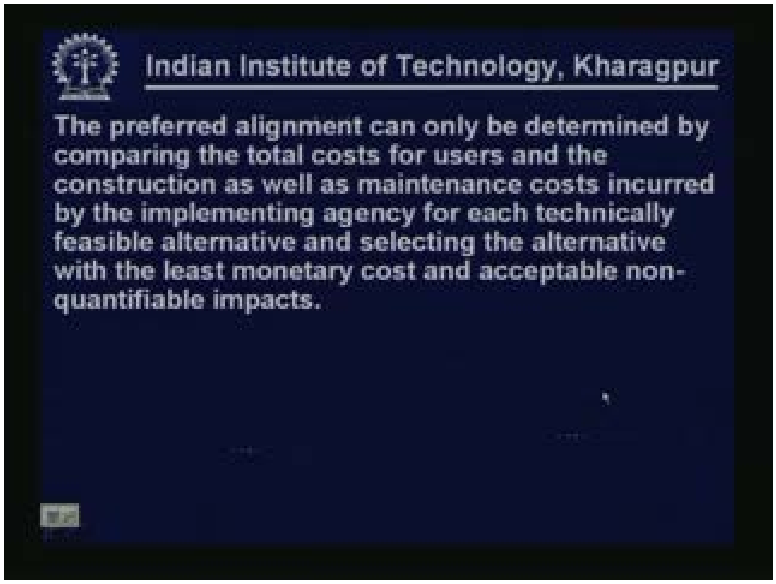

Now the preferred alignment can only be determined by comparing the total cost for user and the construction as well as maintenance cost incurred by the implementing agency at each technically feasible alternative and selecting the alternative with the least monetary cost and acceptable non quantifiable impacts.

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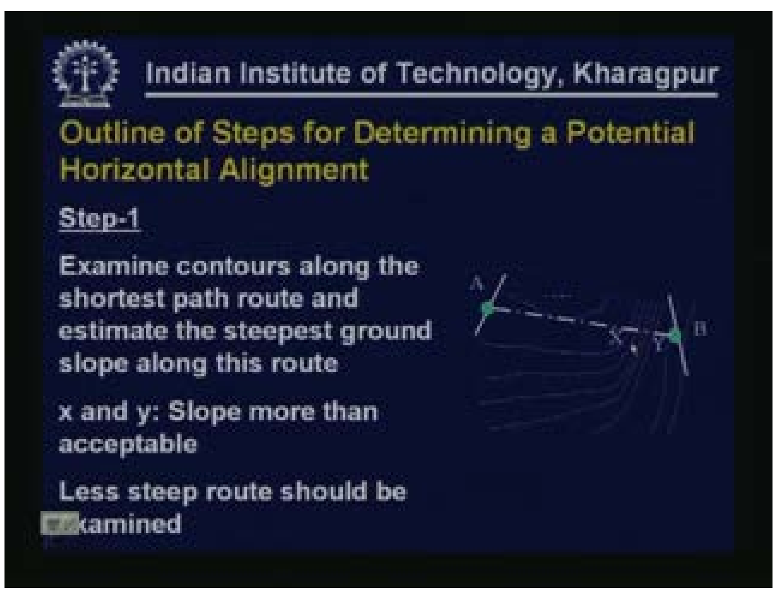

Now, let us try to understand the outline of steps for determining a potential horizontal alignment. Let us consider this point A and point B are to be connected by a new road and you can clearly see here the contour lines which are plotted, which are obtained from the topographic map.

First, let us try to connect it by almost a straight line. So if we connect it like this as the first attempt, then you can observe that between the points X and Y, number of contour lines are crossed within a very short distance (Refer Slide Time: 34:34). If the scale is known, and you know how the contour lines are plotted and you know the approximate distance between point X and point Y, then you can easily calculate the approximate slope. So if you calculate that, you can find out that, connecting the two points as shown in the example, like almost by a straight line, then your slope will definitely be more than the acceptable one and in that case your earth work will be substantial. So what it is indicating is basically we must try to find out alternative roads with less steep slope. Let us go for the next one.

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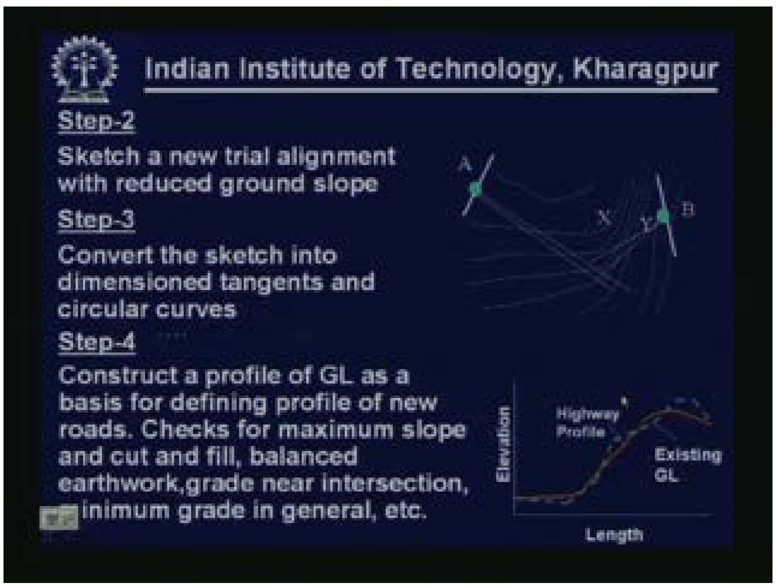

We give a new trial. While giving a new trial what is our aim?
We know that if we try to cross it by almost like a straight line, then we are crossing the contour lines within a very short distance. So if Y is the change in elevation of the Z value and X is the distance, Y by X is becoming much higher. So what we can do here is we can try to cross the contour line over a longer length. We take the alignment in such a way that we cross the contour lines over a longer distance, and so higher will be the X value.

So what we have done here is, we have started with drawing different tangents. Earlier we were connecting the two points like this (Refer Slide Time: 36:20). Now we are drawing tangents like this and hence obviously we are crossing the contour lines over a longer horizontal distance. After we draw it like this, we then try to give a finished shape by making proper curves. So sketch a new trial alignment with reduced ground slope, convert the sketch into dimensioned tangents and circular curves. Wherever these two tangents are meeting you try to insert a curve.

Then step 4, construct a profile of GL as a basis for defining profile of new roads. Check for maximum slope, cut and fill, check for the possibility of balance earth work, grade near the intersection, minimum grade in general etc. Here I have shown it you can see these green lines showing the existing profile and the red line showing the approximate highway profile. So, once we have plotted that, we know what the amount of cut is, what the amount of fill is, whether that cut material can be used as fill, whether the earth work can be balanced with that, and the grade is permissible etc. One can study all these features and it can be studied very easily.

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So, now I will show you the process for developing and checking alterative alignments. It is again a hypothetical example. Let us consider that we have to connect this point A and point B. The topography is known, so the contour lines are known. So here is the preliminary analysis of a road connecting point A and point B. This is an example of design control. You know the design speed, maximum super elevation, minimum radius, maximum grade, horizontal angle at intersection, maximum grade at intersection, minimum grade at all locations from drainage point of view worst case minimum crest curve length, and worst case minimum sag curve length. All detailed design controls are available.

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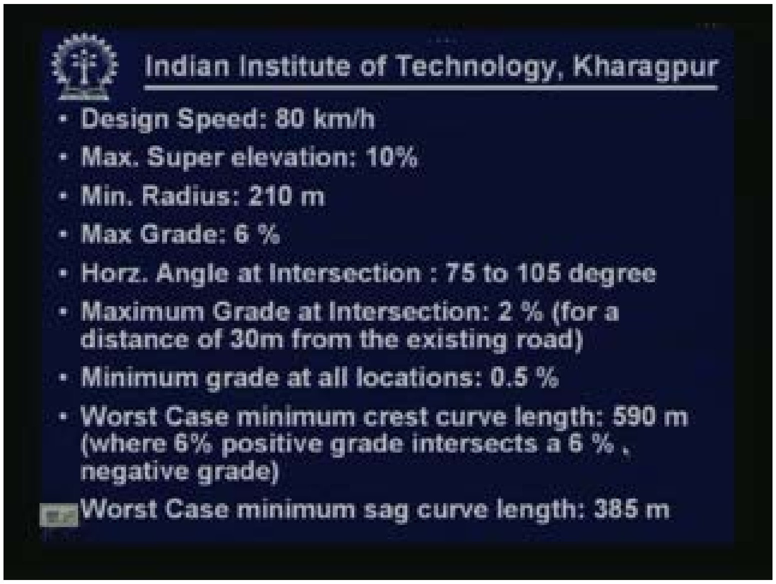

You already know in detail about the geometric design part. Like that, you have the design control.

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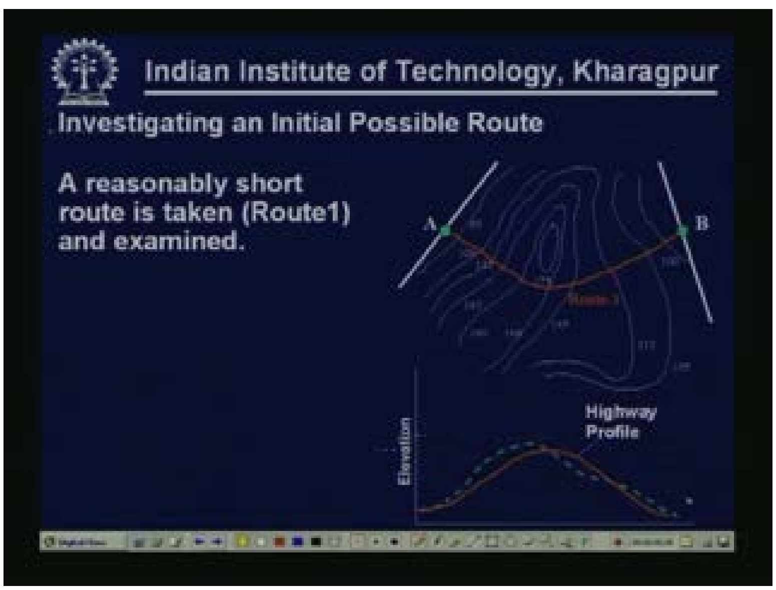

Now keeping those things in mind, we are now trying to investigate an initial possible route. It is clear from our past experience that if we want to connect it by a straight line obviously that will not satisfy the requirement. That means we will have to encounter much steeper slope or we may require some ancillary structure. So we take a reasonably shorter route say Route 1. It is not exactly a straight line connecting these two points but a reasonably shorter length defined as Route 1.

Then as I have explained you earlier we carry out all the steps: Initially we draw tangent, then provide smooth curve, then we take the ground profile, we also take plot the highway profile, we see what are the cuts, what is the maximum amount of cut, what is the maximum amount of fill, and whether the earth work is balanced etc.

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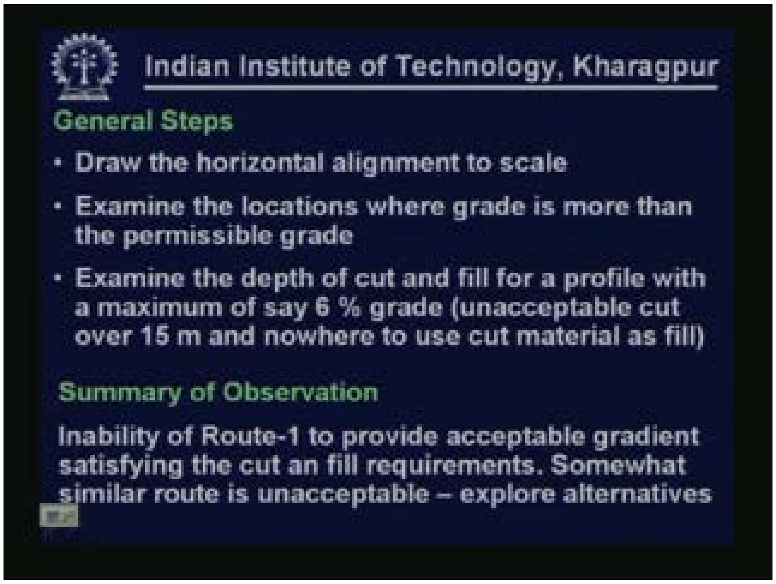

The general steps are:
Draw the horizontal alignment to scale. Examine the location where grade is more than the permissible grade. Examine the depth of cut and fill for a profile with a maximum of say 6% grade as per the design control. And we know that it is unacceptable if the cut is over 15 m and nowhere to use the cut material as fill. Say in this example you have seen that the depth of cut is maximum, it is assumed that it is more than the permissible. If you actually take the values and calculate it, you will find like that and that way only it is plotted.

What we have observed in this case is that, if we try to keep the slope maximum 6%, then we have to go for heavy cutting over more than 15 m and nowhere the cut material can be used as fill. That means cutting and filling is not balanced, earth work is not balanced.

So what we conclude from this exercise is as follows:
Inability of Route-1 to provide acceptable gradient satisfying the cut and fill requirement. And also you can see clearly a somewhat similar route, every designer every planner will probably draw a different line, but any line which is almost similar to this existing one whatever is shown here is Route-1 will also bring out the same observations. No drastic or you know substantial change. So we conclude that Route-1 is unable to satisfy the requirement of grade without violating the maximum cut limit and it is also found that earth work cannot be balanced. So cut and fill cannot be balanced.

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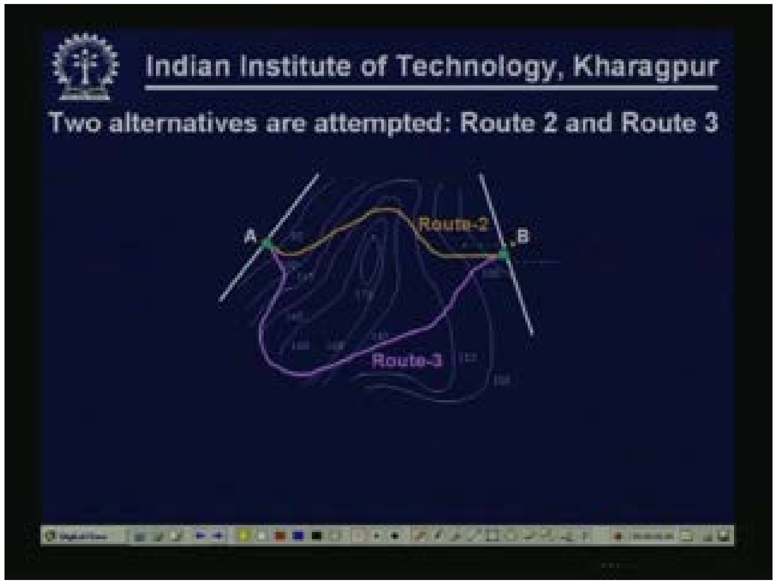

So we explore now two other alternatives called Route-1 and Route-3. I have shown it here. You can see that we have not taken route which is similar to the earlier one. And we know any similar route will also not be acceptable. Hence we take or cross the contour over a longer length. So obviously because of this nature of the contour here, either we can take the route like this as indicated by Route-2 or else we take the route like this taking or going to the other side Route-3. These are the two possible routes that we have identified logically from the experience of the first route and now we try to explore these two routes.

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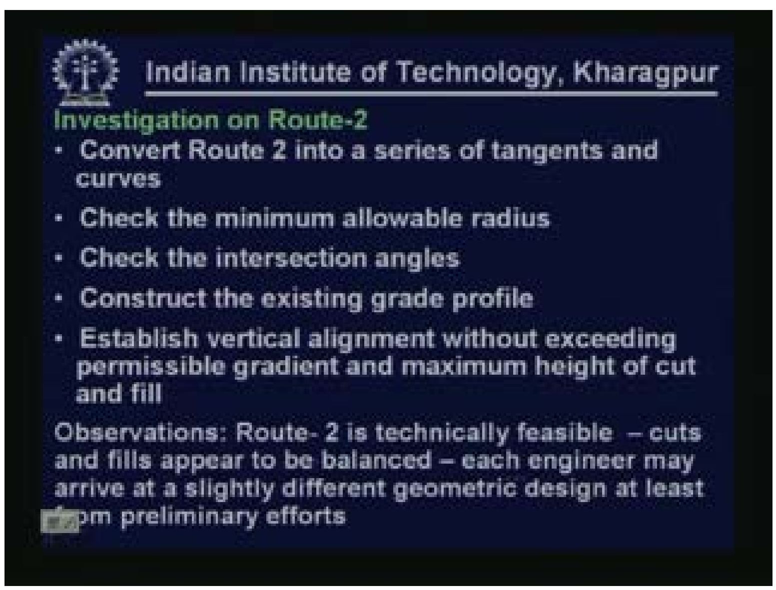

Investigation on Route-2: Convert Route-2 into series of tangents and curves. Check the minimum allowable radius. Check the intersection angle. Construct the existing ground profile. Establish vertical alignment without exceeding permissible limit and maximum height of cut and fill. That means you remember that last example in Route-1, when we try to satisfy the requirement of the acceptable grade, we had to go for heavy cutting more than the permissible limit and also cutting and filling were not balanced. So here in this case we try to achieve that. That means we try to achieve acceptable slope and also at the same time without violating the maximum cut limit and also we try to make sure that as far as possible generally earth work is balanced. That means the amount of cutting and amount of filling are generally balanced. Let us see as I have shown earlier in this case also we have drawn the profile of Route-2.

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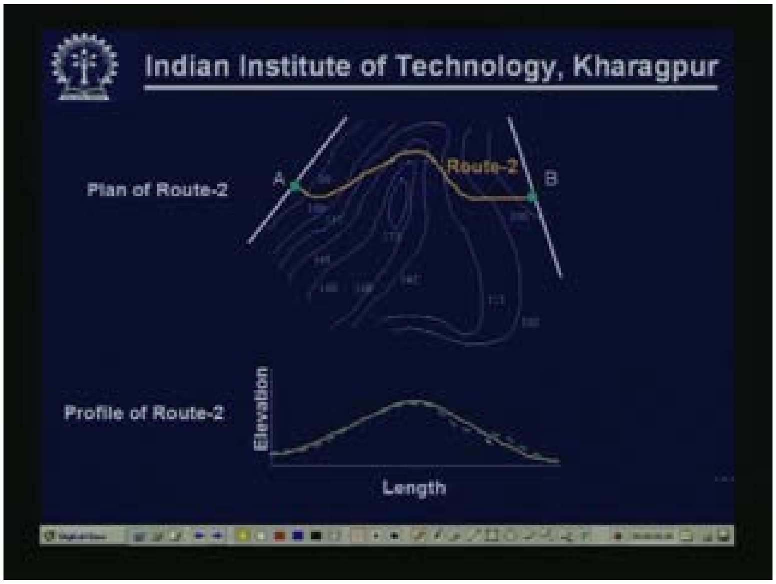

You can clearly see that this gives a much better match with the existing ground profile. You can see the cutting is not substantial filling is also not substantial and you can easily see the cut and fill are generally balanced. You have to cut here, you have to fill here and you have to cut mild amount here again you have to fill (Refer Slide Time: 44:40). So what you can see the cutting and filling are generally balanced and also the other design controls are also satisfied. So what we say as our observations are: Route-2 is technically feasible because we are able to satisfy the general design controls, we able to provide the grade as required without exceeding the permissible value, we do not exceed the permissible value for cutting and earth work is also generally balanced. Hence this is a technically feasible route. But obviously each engineer may arrive at a slightly different geometric design at least from preliminary efforts.

The way I have drawn the line or alignments and if you draw the same, you probably draw in a slightly different manner. But you will also generally reach to the same conclusions. The way I draw, the way you will draw and the way others will draw may be slightly different, but an alignment of that nature or generally following that path, you will find the same observations.

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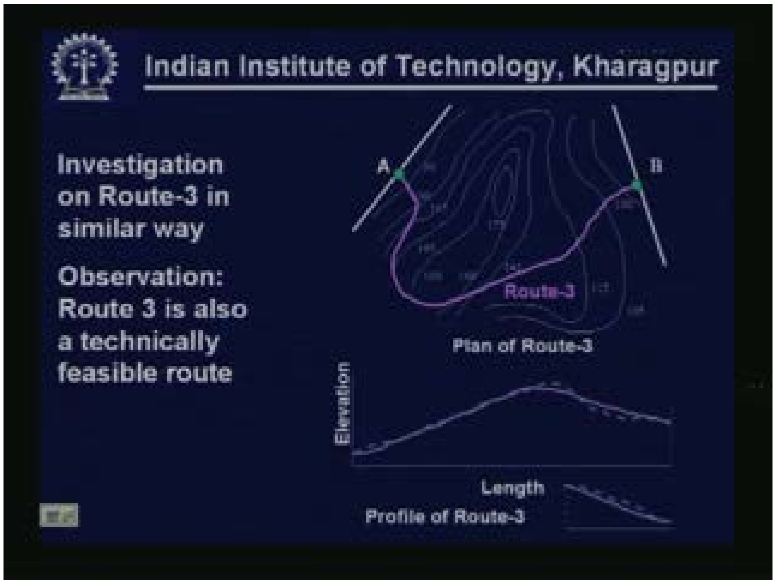

Now similar investigation on Route-3: In this case also you will find it is very well matching with the existing profile and you are able to satisfy all the requirements. Cut and fill are balanced and no excessive cut, slope is also maintained, and other features can also be maintained the way you have taken the line. So observation on Route-3 is also similar and you find that the Route-3 is also a technically feasible route.

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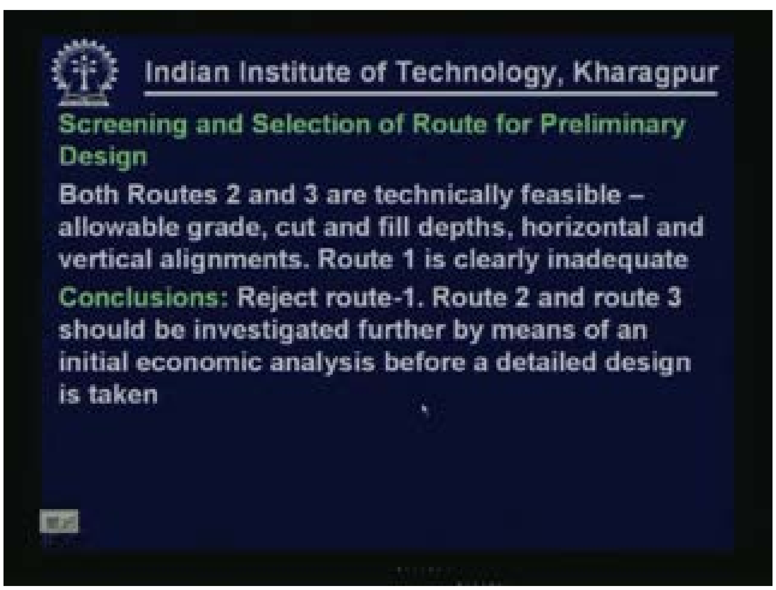

What we find now in terms screening and selection of routes for preliminary design is, we find that both the Routes 2 and 3 are technically feasible in terms of allowable grade, in terms of cut and fill depth, in terms of horizontal and vertical alignment. And Route-1 is clearly inadequate.

So what we conclude from this exercise is, we reject Route-1 where we could not satisfy all the requirements. But we take Route-2 and Route-3 for further investigations as I indicated earlier, that once you have identified technically feasible routes, now we have to go for some kind of further investigation by means of an initial economic analysis and also environmental studies to take the best of out of these two for detailed engineering or preparation of DPR. At this stage we reject Route-1 and take both Route-2 and Route-3 for further investigations.

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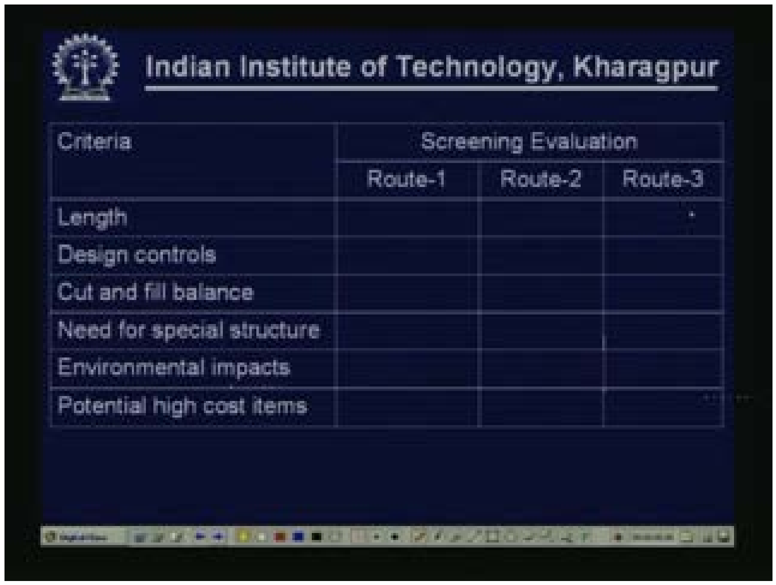

In some cases, you will find that it will be easy when you try to put the information in this format shown here. You can put the criteria in the above format and these are only indicatives. You can make your own criteria like the way I have shown here. Say the length you can see, whether you are able to satisfy all the design controls, whether the cut and fill are balanced, whether you a need any special structure or ancillary structure, whether there are major environmental impacts or possibility of major environmental impacts, whether there are any potential high cost item etc. This is not a comprehensive list; I am just trying to show the way that you can summarize the findings for a better evaluation purpose. So you put all the criteria and then you say Route-1, Route-2 and Route-3. In this case we have explored three routes, if you explore some more routes may be Route-4 and Route-5, then based on all these criteria you write all the items. May be length of Route-1 is 2 km and for Route-2 it is 2.5 km and for Route-3 it is 3.5 km. And for one route, the cut and fill is balanced and for the other it is not balanced etc for example.

Once you have this tabular representation, you can easily see in a summary form, how different routes are, in terms of satisfying your requirements and accordingly you make decision. In this case, as I have already told you, I have rejected Route-1 for certain reasons and both Route-2 and Route-3 are technically feasible alternative. So we carry them forward for further investigation and for carrying out preliminary economic analysis and also environmental impact analysis.

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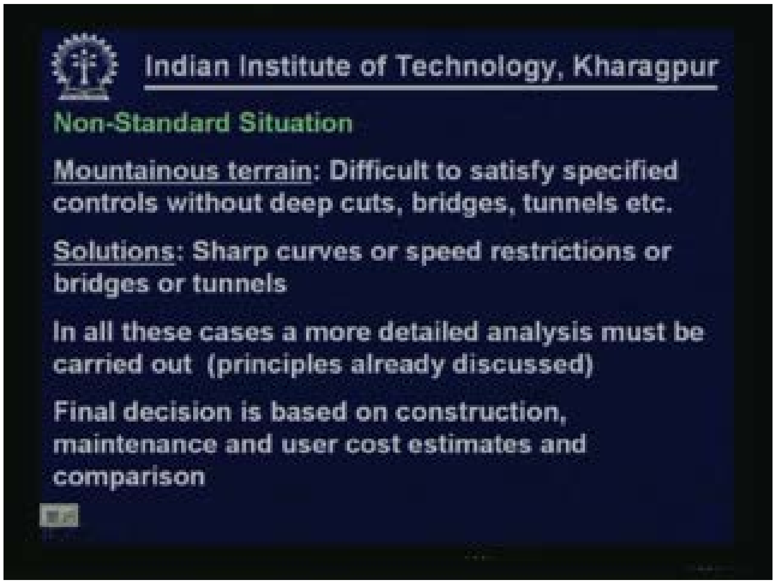

Now, there could be some non-standard situation. In some cases, for example if you are doing it for mountainous terrain, it may be difficult to satisfy specified controls without deep cuts, bridges and tunnels. Because the terrain condition itself is like that. You probably cannot avoid the deep cuts, bridges and tunnels etc.

In such cases what could be the solutions?
Solutions are like this; either you take sharp curves or go for speed restrictions or you construct bridge, tunnel etc. So either you go for an expensive construction or else you compromise in terms of design standard. So go for the speed reduction that may be giving some shaper curves etc. And in all these cases more detailed analysis must be carried out and that procedure I have already discussed. And the final decision is based on construction, maintenance and user cost estimate and comparison. Again the final decision must be made based on life cycle cost analysis and comparison. Take all the cases, for example without bridge and all such possibilities and then make final decision based on life cycle cost analysis considering construction, maintenance and user cost estimates.

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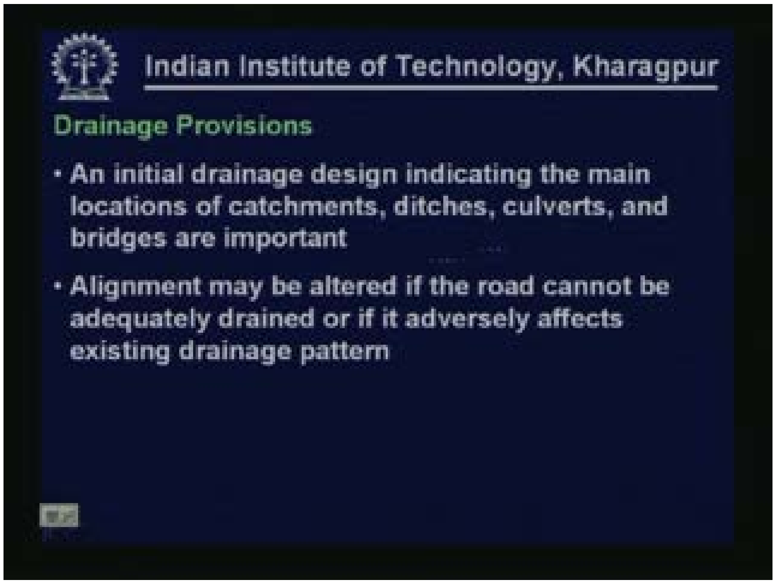

Now drainage provision is also very important, I have indicated it when I talked about Do's and Don'ts. An initial drainage design indicating the main location of catchments, ditches, culverts and bridges are important even in the preliminary stage.

Alignment must be altered if necessary and if you find that the road cannot be adequately drained or if it adversely affects the existing drainage condition. This is a very serious problem you face in many cases. So you have to take care of this part. Do not disturb the natural drainage system and also you have to make sure adequate or required drainage for the newly developed roads or whatever you are going to develop. Now, let me put some of the questions.

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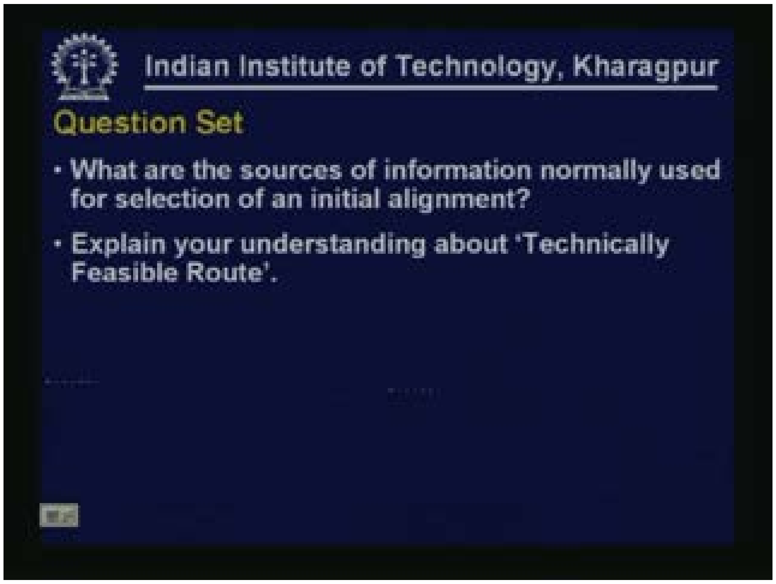

What are the sources of information normally used for selection of an initial alignment? – That is one question.
And the second question is; explain your understanding about 'Technically feasible route'.
Now, quickly I will try to answer to questions of lesson 3.15.
First question was, when the climbing lane is justified on a two lane road?

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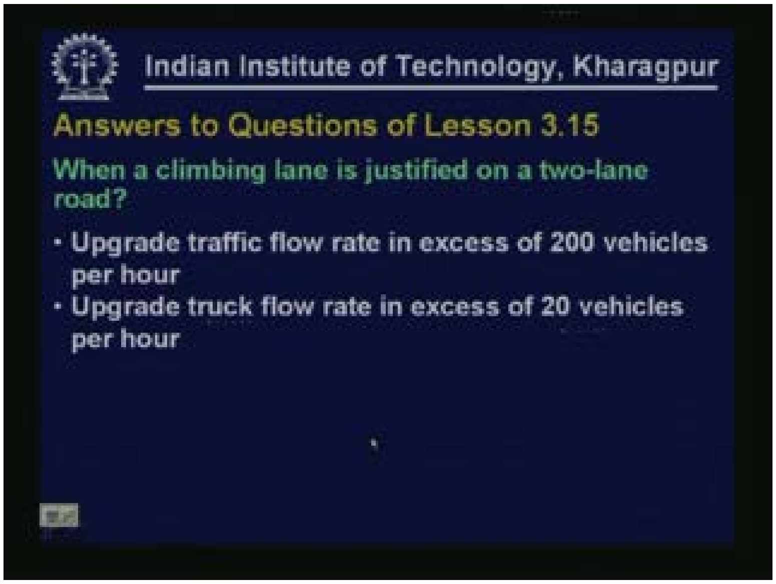

You know there are three possibilities. First is, upgrade traffic flow rate in excess of 200 vehicles per hour and second upgrade truck flow rate in excess of 20 vehicles per hour and one of the following conditions must exist.

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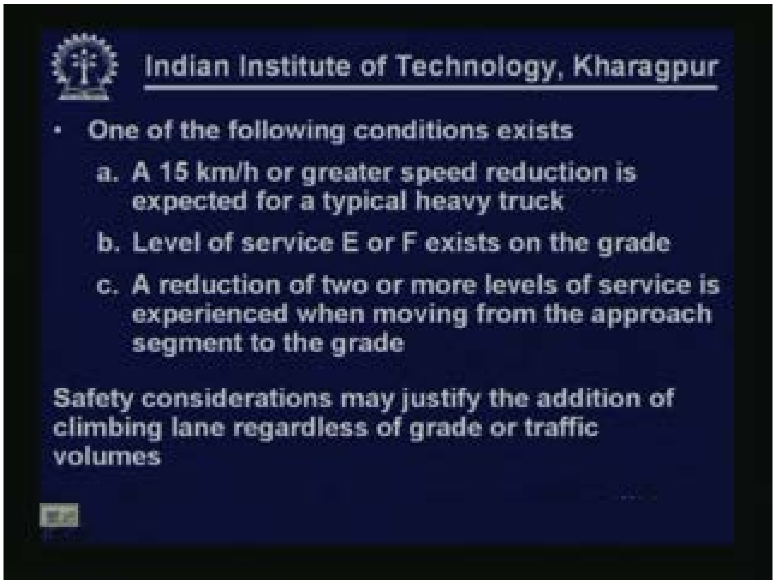

A 15 km or greater speed reduction is expected for a typical heavy truck or the level of service E or F exists on the grade or a reduction of two or more levels of service is experienced when moving from the approach segment to the grade. So one of these conditions should exist and the earlier two, then you can justify a climbing lane. But I must mention that safety consideration may justify the addition of climbing lane regardless of grade or traffic volumes. So if you find major safety problem then that itself may justify the need for climbing lanes.

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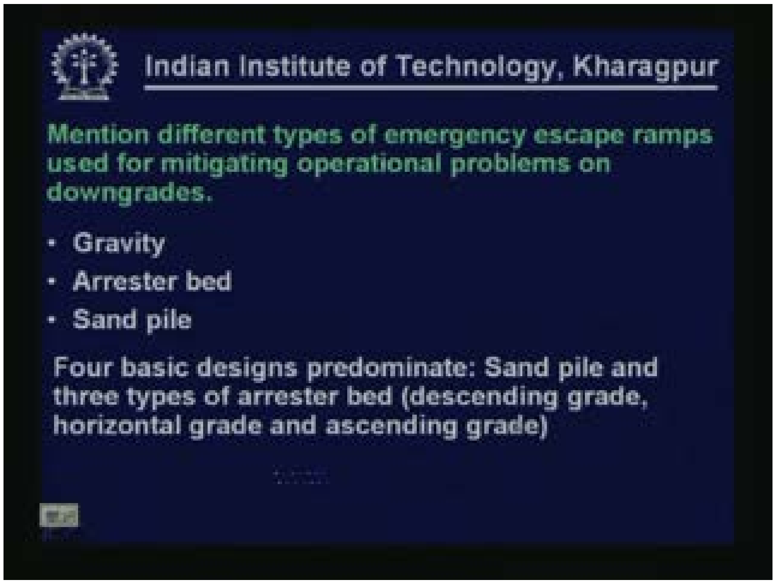

The next question was; mention the different types of emergency escape ramps used for mitigation of operational problems on downgrades. There are gravity type, arrester bed type and sand pile type. But four basic designs are predominant. One is the sand pile type and there are three types of arrestor bed - descending grade, horizontal grade and ascending grade. The next one was; discuss various methods for increasing passing opportunity on two lane roads.

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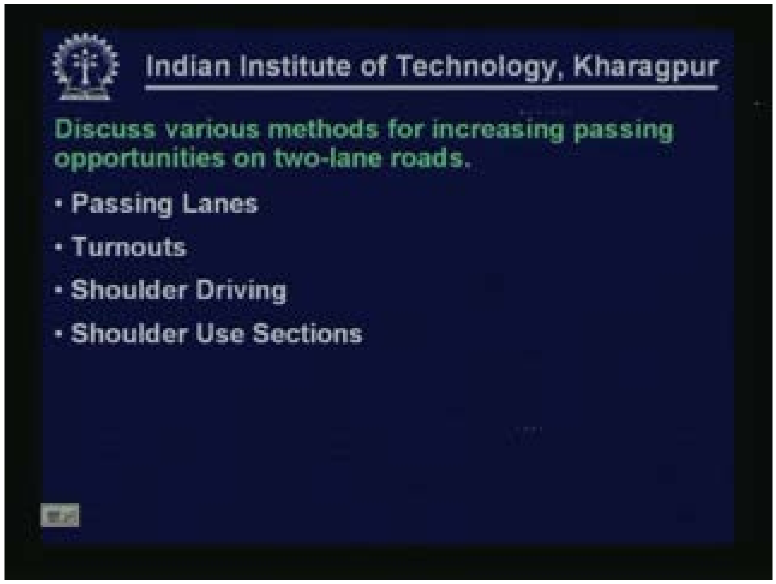

You know that we have discussed this: We can improve the passing opportunities by providing passing lanes, by providing turnouts, by providing shoulder driving and by providing shoulder use sections. So these are the four major methods for increasing passing opportunities on two lane road.

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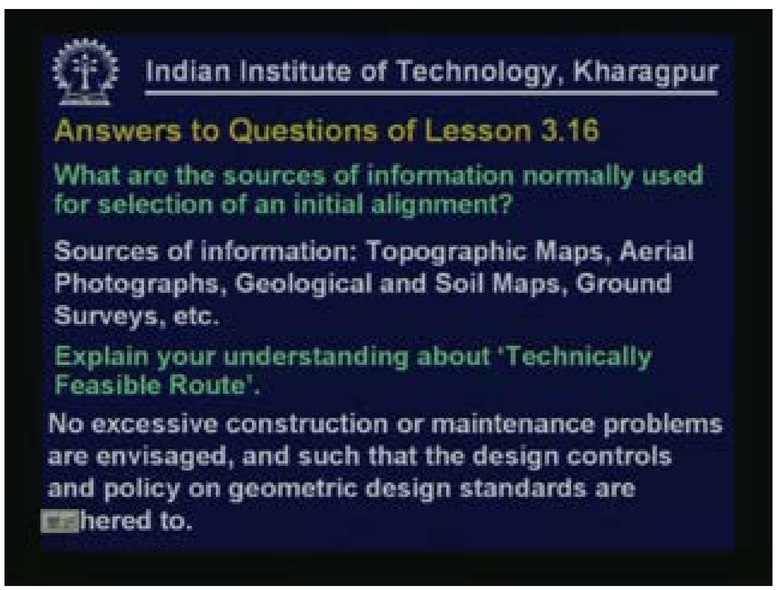

As this is the last lesson for this module, the two questions what I asked based on today's lesson, I will provide the answer now.
What are the sources of information normally used for selection of an initial alignment?

Sources of information are; topographic maps, aerial photographs, geological and soil maps and also ground surveys.

Explain your understanding about technically feasible route:
Remember that, no excessive construction or maintenance problems are envisaged, and such that the design controls and policy on geometric design standard are adhered to. That means we have to satisfy the requirement of design controls, whatever should be the curves, super elevation, angle, grade - all aspects are to be satisfied without major construction and maintenance cost. Then we will consider that alternative as a technically feasible route. That completes our discussion about 3.16 lesson and also with this we close this module.

Alignment normally we do at first and then we carry out the detailed geometric design. But it is better to understand first all the features, so we have first discussed in details about geometric design and with that background today we have learned how the initial alignment can be decided. So teaching wise or learning wise we have first learned the geometric design part in details and then we have learned how to have a better alignment or how to decide a better alignment. But when you go in reality, first you decide an initial alignment and then you go for detailed geometric design. So with this one, we have completed all our discussions about this module ‘geometric design’. Thank you.