SESSION A - ASPECTS OF DESIGN

LECTURE A.1 - ROUTE DETERMINATION **Presenter : CD SCOTT**

1 INTRODUCTION

It may be said that the most durable aspect of a road is its location. Think of the Via Appia, some of which is still in use although the design vehicle is no longer the two horsepower war-chariot. Since a route will generally serve for a very long time, it is very important its route determination be sound. All possible factors that may influence the route choice must be considered. From this it follows that the systems analysis procedure, including goals, major and minor objectives and restraints, should be the basis of route determination.

The “paperwork” preceding the construction of a road generally covers three phases of planning and design. These are the Route Determination, to establish the road centre-line approximately (possibly within a margin of 200 metres), then the Preliminary Design which would fix the alignment and road reserve requirements precisely on the basis of interpolation from contour plans, and finally the Detail Design and working drawings based on the accurate staking and survey of the planned alignment. Thus in practice, Route Determination is concerned with the location of the corridor in which the road is to be designed and ultimately built.

2 APPLICATION

The outcome of route determination is a statement, usually in the form of a plan and longitudinal section showing the proposed alignment of one or more alternative routes. A lengthy process is generally involved in reaching that point, because much data have to be collected and analysed. Alternative answers to the problem have to be developed and compared, prior to the formulation of a recommendation concerning the route to be selected. If there is a real lack of alternative options this may reduce the level of detail to which the designer must investigate the problem for purposes of comparison, and it may become a feasibility investigation rather than route selection.

If the terminals of the route are, say, only one kilometre apart there doesn't seem to be much reason for an elaborate comparative study. In urban areas, the number of restraints that abound (principally in the form of the cost of land acquisition) may substantially reduce the number of options available. In urban cases, however, alternative solutions have to be developed to establish the cost consequences of acquiring the road reserve along various corridors. (As a rough rule of thumb, urban property acquisition can be anything up to 80 % of the total cost of the road with construction accounting for the other 20 %. In rural areas, the percentages reverse).

To summarise, route determination typically applies to routes of extended length and, in the urban environment, the emphasis is often on factors other than purely geometric design considerations although, obviously, the requirements of the latter must be satisfied.

3 BACKGROUND CONSIDERATIONS IN ROAD PROVISION

The process of route determination typically commences with the thought that a road should be provided between points A and B. It generally follows an initial sequence of network planning for the wider area or region of the road authority concerned. A decision on the basic cross-section of the road (two-lane or multi-lane) and its class would stem from the network planning. Alternatively, perhaps in a more remote area or developing territory, the need for the route would appear from other considerations such as a plain need

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The designer would apply the geometric standards used by the road authority concerned, provided that these are consistent with those of other roads of the same class and in the same area. (If not, there would be some negotiation to decide on the standards to apply

The designer should establish early on, what the functional goals of the road are to be. Generally a road is proposed as an answer to a problem or a need, and its location is a separate problem whose solution must take account of the specific needs or goals.

Note that especially in developing territory, the goal may be to enhance the quality of life of people living in a certain area. Various options could then be considered and transportation may be only one of several. For example, it may be more important to provide a guaranteed supply of potable water, or a decent system of sanitation, public health services or schools. Such competing needs could influence profoundly the funds available for a road, and thus also the design standards and route choice. Economic analysis (for the prioritisation process at the end of the route determination exercise) and the resulting demonstration of the economic benefits arising from providing the road could be very useful in arguing for more road-building funds in such a scenario.

For our purpose here, assume that the objective related to quality of life is specifically economic. Reference could be made to the creation of wealth in terms of job opportunities. Once again, transportation and the provision of a new road may be only one of various possible options.
For example:

- ❑ providing a convenient link to another area in which job opportunities already exist
- ❑ providing job opportunities in close proximity to where the people live

are both options, and they are not mutually exclusive. If the first option is exercised, it may be that a rail link is a more desirable option than a road. Alternatively, a fairly modest improvement to existing infrastructure in combination with a reliable bus service may be adequate.

As an unfortunate side effect, provision of the road or rail link may also have the effect of opening a new market to industrialists already located in the cities. A thriving cottage industry may be totally wiped out by a flood of cheap factory-made goods, so that the chances of an under-developed area actually developing could be hindered rather than helped by providing a road. It is not inconceivable that the rigorous definition of goals and objectives may reveal that the last thing the community requires is a road. However, for the purpose of this exposition, we presume that a road has been found necessary.

4 TRIP PURPOSE AND COMPONENTS

The previous process would have given valuable input as to the broad function the road is intended to serve. Basically, a road is just a conduit along which trips can take place. The intentions or needs of the people undertaking the majority of these trips play a cardinal role in determining the function of the road. Most roads have a very general and mixed purpose, but a recent development is the occasional designation of specialised conduits as rapid bus or freight routes although the latter has yet to be applied in southern Africa. Passenger transport is too often relegated to a subsidiary status.

With regard to people trips ("person trips"), function has two elements. The first is <u>trip purpose</u> and the second is <u>trip component</u>.

Regarding <u>purpose</u>, person trips are typically described as home-based work, home-based school or home-based recreation. The perceptions of the person undertaking a trip are going to vary according the purpose of the trip. Home-based work trips happen under conditions of heavy traffic flow under more or less severe time constraints. The idea that "It is better to travel hopefully than to arrive" does not apply at all to this trip and each driver just wants to reach his destination a.s.a.p. A recreational trip can either be over a relatively short distance to the local gym or squash court, or perhaps a long distance trip as part of the annual holiday. Time is of less consequence and the trip can be a pleasurable experience in its own right. A purely recreational route can or, perhaps even should, have fairly low design standards but should focus the driver's attention on ever-changing natural vistas and should also, of itself, be an application of the principles of aesthetics.

<u>Trip component</u> refers to the fact that a trip invariably involves departing from a terminal, say the home, moving up the hierarchy of roads from a residential street to a collector and then to an arterial for the major length of the trip; this followed by the reverse sequence, working down through a distributor system to the far terminal, say a parking garage in the business area. A driver will have varying expectations according to the segment or component of the trip being undertaken. Low speeds for a short distance are anticipated on a residential network and on the distribution network. High speeds and reasonable freedom from interruption over an extended distance are expected for the major portion of the trip. The underlying network plan should see to it that the "local street" component has only a short length, and that an arterial road is available nearby for the longer-distance and hopefully faster component of the trip.

It virtually never happens that a road serves only one trip purpose. The designer is thus required to have a clear idea of what the predominant type of trip on the road is. He must then establish what characteristics the road requires, in order to best serve that type of trip. Very often the characteristics most affected by trip purpose are the cross-section, gradients and intersection design. These matters are dealt with elsewhere in the course. As an illustration, it is not advisable to include a median island in the cross-section of a road that principally provides access to adjacent properties if a steady stream of traffic crossing the median at random is to be avoided.

5 THE PROCESS OF ROUTE DETERMINATION

5.1 Starting up

It is presumed that the stages of

- ❑ deciding that a road should be provided;
- ❑ determination of trip purpose and trip component;
- ❑ selection of design hourly flow;
- ❑ selection of design vehicle;

have been completed.

The designer thus has a preliminary feel for the type of cross-section that he should be aiming at and also the order of design speed appropriate to the facility to be provided. These may both be prescribed by the road authority, but circumstances in special cases may demand that the designer should recommend to his client that the standards be changed, and this would need agreement at an early stage. The designer must also acquire all the information he needs on the location of services that may be affected by his design, the land use, existing development and committed plans for land use that may either impinge on or be affected by the route. One might imagine that it is now possible to consider the actual route of the facility. Not yet unfortunately, because more tools are required.

In rural areas, preliminary route determination may possibly be done on plans with a scale of 1:50 000. The level of detail required in urban areas will necessitate a larger scale. Orthophoto plans are generally available at a scale of 1:10 000. In some cases of final route location, it is sometimes necessary to commission a survey at 1:5 000. The designer must thus select the scale of plan appropriate to the intended exercise and acquire the plans defining the area of interest. They should show contours, surface detail, cadastral and co-ordinate information. From these, a base plan is produced for further work.

The base plan is then marked up with all the information that has been acquired regarding services and land use. One feature of rural land use is that a single farming unit actually may comprise more than one registered property. Such agricultural business units must be respected just as much as cadastral boundaries may be. Simply following a cadastral boundary to minimise the problem of alienation and fragmentation of property may actually result in a swathe of destruction across a farmer's prize maize land, with all the consequences that his political connections can rain down on the head of the unsuspecting designer.

Contact with the Extension Officers of the Department of Agriculture is thus essential to establish the true consequences of selection of a specific location. They can provide useful information on what is actually happening in terms of farming operations that are current or planned and also provide a very shrewd estimate of what a road located on any particular part of a farming unit will mean to that unit. They should also be consulted on drainage planning. As a small aside, farmers have fertile imaginations, matched only by the asserted fertility of their farms, when it comes to describing the total chaos that will ensue if the road is built anywhere other than immediately on the other side of their fence. They are also very knowledgeable about deposits of road building materials on farms other than their own.

5.2 Tie points and No-Go areas

In designing vertical alignment, reference is also made to tie points, but the meaning attached to the word in that context is totally different. There, the tie point is a level that cannot be exceeded. For example, crossing a watercourse generates a need for a certain minimum height above ground level to ensure that water passes through a culvert rather than the alternative over the road. Similarly, an existing structure or power line may suggest that, to ensure an adequate clearance, a certain maximum height cannot be exceeded. In the case of route determination, a <u>tie point</u> can either be a point through which the route must pass, for example a nek (in English, a cwm or coomb!) or an area towards which the road is attracted somewhere between its terminals. As an example of the latter, there may be silos alongside the railway line that require to be served or a recreational area such as a lake.

Another road may also attract the proposed new route towards itself, if this results in an effective shortening of the overall network and total travel distances without loss of accessibility.

The availability of construction material may also serve as a tie point of sorts in the sense that overhaul of material can be a costly exercise and, by judicious location of the road, it may be possible to reduce construction costs without imposing any penalty in terms of road user cost or other damage to the environment.

<u>No-go areas</u> are simply areas where road location is impossible or prohibitively costly in comparison to the alternatives. Mountaintops and swamps or developed areas are cases in point. The in-situ material may be an expansive clay or collapsing sand - either of which can have dramatic consequences if ignored. In-situ materials and their qualities must be taken into account. A pure design example is the case of a corridor where the longitudinal ground slope is greater than the maximum gradient selected for the route for a substantial distance. This has an economic consequence in that cut or fill quantities would become excessive. The aesthetic result

would also be questionable, suggesting that the route location did not properly consider the topography.

No-go areas also include all areas that it is best to avoid if possible. Areas with complicated drainage patterns can also create problems in terms of protecting the road against flooding. It is more than likely that an area containing a heavily meandering stream, with islets and connecting tributaries, would also have fine grained to silty material which is waterlogged and has a bearing capacity of about zero. Staying away from a wetland is always sound engineering, and these days generally seen as essential for environmental reasons. If a wetland cannot be avoided, it will need special drainage treatment with wide waterway opening and consequent low velocity of flow.

Anyone who has ever tried to shift a cemetery will be able to confirm that it is far more convenient to go around it than across, regardless of what the best principles of geometric design may dictate.

All information concerning tie points and no-goes is marked on the base plan. The information provided by the Agricultural Extension Officers may also suggest areas that should be considered as either tie points or no-go areas and these would also be marked on the plan.

As more and more information is added to the base map, certain corridors should start to reveal themselves as being worthy of consideration.

5.3 Corridor and alignment determination

This is a process of iteration, with successive trials and adjustments to develop a short-list of feasible routes from which a final selection is made. Obviously, the shortest route is the one that will offer the lowest construction cost and also the lowest road user cost, if all else is equal. Unfortunately all else is seldom equal and reductions in overall length invariably pick up penalties in terms of gradient. However, the straight line between the two end points, i.e. the directional route, is a useful point of departure. The terminals are thus plotted and connected by a straight line. If this is being done on paper rather than a screen, it may be helpful to do this on an overlay.

The straight-line route will almost certainly traverse marked up no-go areas, and need adjustment. It must then be investigated whether to shift to one side or the other, where to deviate from the shortest route. .how to get around obstacles. After that, the shortest route has served its purpose and is abandoned. The new routes would then be drawn with a series of straights, points of intersection and circular curves fitted between the straights, to produce better lines that also skirt the no-go area and proceed as directly as possible to the far terminal. Of course, new no-go areas will almost certainly reveal themselves and the process is then repeated. Ultimately, a number of alignments in a generally directional corridor will have been identified. So far this has perhaps been an essentially negative approach, starting with the potentially ideal straight line, and then reacting purely to avoid no-go areas, perhaps without yet taking cognisance of tie points. It has however established corridors along which the road CAN be built from terminal A to terminal B.

If the designer were now to start the process all over again, but starting this time from Terminal B and heading back towards A, a further set of different routes might be found by virtue of the different sequence in which no-go areas present themselves (particularly if the first set of routes were not thought through comprehensively).

The next step in the process is to consider which of all these possible candidates should become probable candidates. The tie points must now come into play if that has not yet been done. One or other of the routes may serve a particular tie point better than do all the others and this would create an obvious bias towards the selection of that particular route.

There is of course no compelling reason to follow the above sequence, which simply provides a systematic approach to a problem with too many variables for the average mind to deal with other than step by step.

It can often happen that an important tie point is remote from the directional route, suggesting a new set of candidate routes. The same procedure as before is then followed with the starting point being two straight lines from terminal A to the tie point and from there to terminal B.

The existence of several tie points complicates the issue. One route may serve one or more tie points and another route another combination of tie points. The designer thus needs a technique to evaluate all the various possible options to each other, ie to prioritise them.

It is generally possible and necessary to eliminate a number of the alternative corridors on the somewhat subjective basis of “engineering judgment”. This obviously reduces the computational burden required by exhaustive analysis of several alternatives. In the end, it will still be necessary to make a motivated recommendation on the route choice. A process of prioritisation is used.

6 ROUTE PRIORITISATION

This is a major field of study in its own right and can only be briefly introduced here.

If the designer, in his capacity as systems analyst, properly defined the objectives for the road and also set criteria and standards for these objectives, he could conduct a meaningful comparison of the various possible routes and hence make a recommendation.

There are two possible procedures for this comparison. They are utility analysis and economic analysis.

Economic analysis is a rigorous procedure which gives a ranking of the alternatives according to their capital and operating costs. The result may or may not be decisive in selecting an option. (Perhaps two alternatives score equally well and the choice will depend on other considerations). Utility analysis is a systematic method of assessing the properties of the alternatives that are less easily measured and quantified than the economic inputs. Economic analysis may be preferred because of the more subjective basis of utility analysis but the latter often covers issues that demand consideration.

6.1 Utility analysis

Utility analysis has been variously defined as an attempt to quantify the unquantifiable and also as lending a mathematical aura of respectability to what is nothing more than (possibly) informed opinion. The main features of utility analysis are outlined below.

Greatly simplified, the process of utility analysis will select some set of characteristics of whatever objects or alternatives are to be compared. A panel of experts is then convened to deliberate on the extent to which the various alternatives or objects possess the desired characteristics – each expert scoring on a numbered scale from low to high. Calculation of the average and standard deviation of the ratings given by the panellists is a straight arithmetic manipulation.

In practice, it will almost certainly be decided that the selected characteristics are not of equal importance. The panel will then have to go through a process of attaching weights to each characteristic, if this has not already been done on their behalf by the designer. This process may also be carried out broadly as outlined above, and it ends up with an agreed mean weighting for each characteristic. The sum of the products of rating and weight is a single number which is intended to describe the relative value of the various objects in all their complexity. The object or alternative with the highest (or lowest, depending on the system followed) score then qualifies as that selected for recommendation.

Utility analysis is a useful tool in that it it provides a disciplined method of looking at parameters which are not readily quantifiable and also has the benefit of being relatively quick to perform.

6.2 Economic analysis

Economic analysis is dealt with in some depth in Lecture T7 and is touched on only briefly here.

Some form of economic analysis is generally required by engineers. As in the case of utility analysis, the final answer of the comparison is a single number according to which the objects - roads in our case - are compared. The derivation of that number can be a matter of some complexity and, once again, only the broadest of outlines is offered.

Three basic methods of analysis can be followed:

- Benefit/Cost Ratio

- Rate of return
- Nett present worth

The construction cost of each alternative design can be estimated with a certain amount of effort.

Benefits are more difficult to estimate because these principally concern road user savings arising from using one route in preference to another. To quantify the expected savings requires projections of future traffic volumes, which may be problematic. The savings take various forms including reduction in the running costs of vehicles, time savings and reductions in collisions. They also apply over a substantial period of time, specifically the design life of the road - typically taken as being twenty years or more - and accrue to an ever-increasing population of road users, the magnitude of which also has to be estimated. The savings occurring in each year of the road's life are estimated in the currency of the base year. Because of the presence of interest, they have to be discounted back to the present if the comparison is to be meaningful. Because calculations are always in the base year currency, inflation does not feature in the economic analysis of competing projects.

Time savings and the value attached thereto have been the matter of heated dispute for an extended period. There can be no perfect answer for the value of people’s time, and a conservative approach is required. Research data is available. It is also virtually impossible to attribute reductions in collision rates to specific geometric features. In fact, the paradoxical nature of collisions is such that, if a road is obviously dangerous, it may have a good safety record. Drivers are more alert and more cautious, driving slower perhaps than is strictly necessary and not taking any chances whatsoever. For example, the fatalities on du Toit's Kloof in its first year of operation after construction of the tunnel route surpassed those on the parallel Bain's Kloof from its inception until the opening of du Toits Kloof.

An important feature of economic analysis is that competing alternatives for a new project are often not compared just between themselves, but rather compared to a base value described as the Null (or Do-nothing) Alternative. This implies that travel between point A and B is by whatever means exists in the present network, so that there is no construction cost at all. Road user costs could however be very high, either because the route is circuitous in the extreme or possessed of a singularly poor surface and geometry or both. The reduction in road user cost thus constitutes the benefit achieved by providing the link.

The ratio between the accrued benefits and the cost involved in achieving it is the Benefit/Cost Ratio. For a road to be economically justified at all, the B/C Ratio has to greater than unity. This Benefit/Cost ratio makes it possible to say that Alternative A or B or whatever is to be preferred on economic grounds because it reflects the highest ratio of all the alternatives tested. The other forms of economic analysis are broadly similar. A feature of the various systems is that they will all produce the same outcome in terms of a prioritised list.

7 CONCLUSION

It would seem, (quite rightly), that route determination is the most difficult task that the designer can be asked to undertake. It may also be the most laborious. The fact of the matter is that it provides a true test of the designer's capabilities. Because of the wide range of factors which require sound answers, it is done most quickly and effectively by one with considerable experience.

Numerous traps lie in wait for the unsuspecting purely because of the sheer volume of competing elements that the designer has to evaluate. The road must serve its intended purpose; it must do so economically; it must be safe and convenient to use; it should also be a work of art in its own right in addition to serving as an enhancement of the landscape. Furthermore it must do all these things better than any competing alternative that may have presented itself. The ability to successfully achieve all these objectives is the hallmark of the competent designer.