SESSION T - THEORETICAL CONSIDERATIONS

LECTURE T1 - INTRODUCTION **PRESENTER: CD SCOTT**

1 HISTORY

The Geometric Design Course has been presented by the South African Road Federation since 1976. It was initiated by Mr David Giddy, previously of the Johannesburg City Council. He relied on the assistance of other lecturers on an ad hoc basis because, apart from the risk of flat feet, standing on the hind legs for eight hours a day and spouting forth endless volumes of material can be, at best, exhausting and, at worst, downright impossible. The notes were in the nature of headlines with skeletal comments and students were expected to take copious notes.

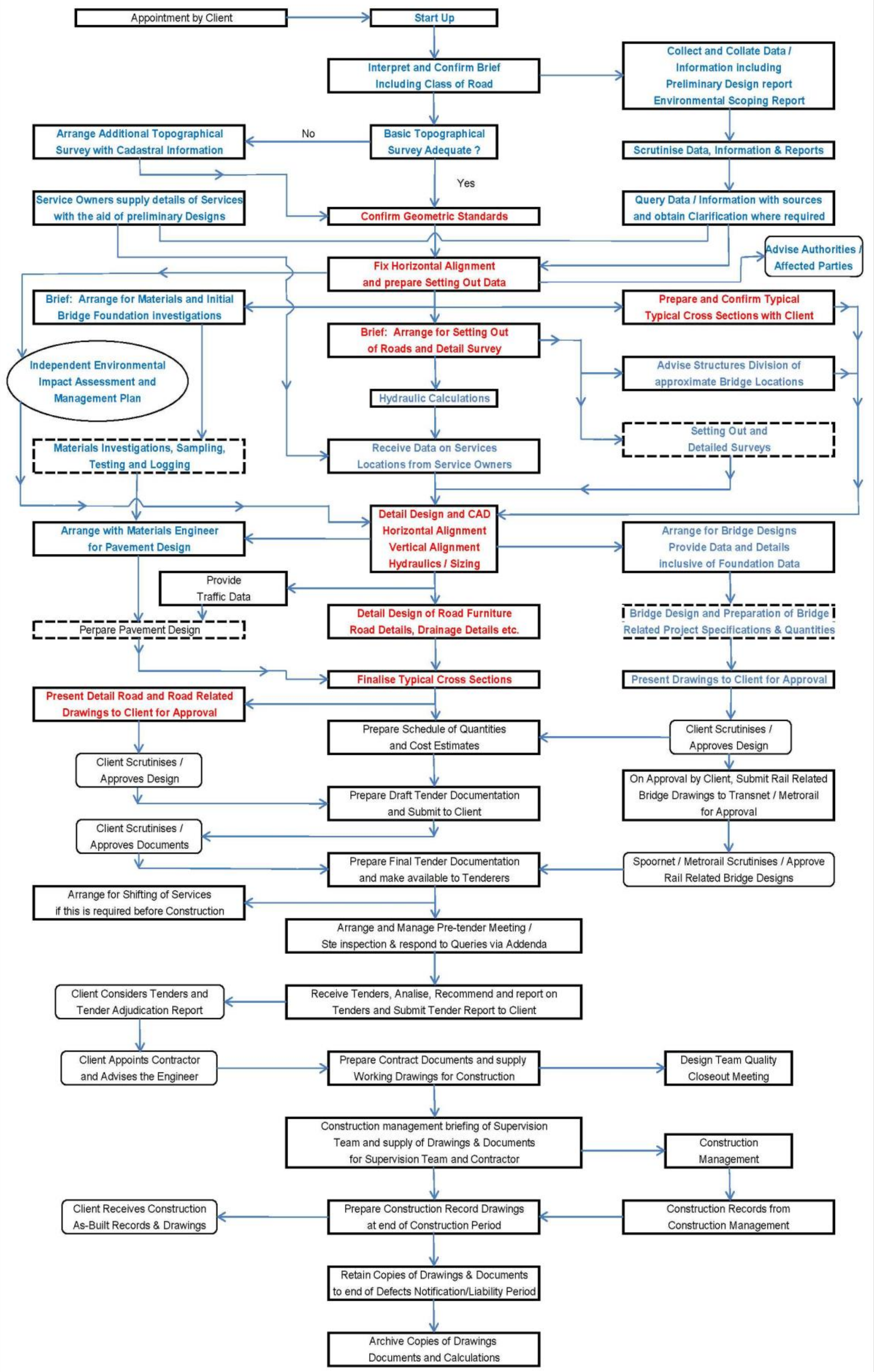
In 1988, Mr Keith Wolhuter of CSIR was brought into the course as a permanent assistant to Mr. Giddy. He was of the opinion that the need to take notes represented an unnecessary intrusion on students' sleep habits and decided that comprehensive lecture notes were to be preferred to outlines. A relatively slim volume thus became a bulky tome.

In 1996, Mr. Giddy felt that twenty years was enough for anybody and stood down, his place being taken by Mr. Mike Smithson, also of Johannesburg City Council. Not being possessed of that much stamina, Mr. Wolhuter felt that ten years was enough and stood down in 1998. Mr. Louis Roodt of the University of Pretoria took over from him. After the 2001 Course, Mr. Smithson decided to return to the home of his fathers, specifically the UK, and Mr. Wolhuter was told that he had had enough of a holiday.

The course content grew over time to include traffic engineering, statistical analysis and drainage components that whilst necessary as part of the overall picture, were not actually Geometric Design. With the advent of modern computing power, and the proliferation of computer aided design tools and programmes, the SARF considered the need to re-evaluate the course content and to focus back onto the Geometric Design component only. The course historically was held over 5 days, but with the focus now being on the Geometric Design component, the revised course is to be held over a 2 or 3 day period, depending on virtual or physical presentations.

The course is aimed at graduate engineers, technologists, and technicians with the intention of sensitizing and advising designers as to the whole cycle of a road design, and how other considerations such as drainage, signage, pedestrians, pavement layers, and roadside furniture interact with, and influence final geometric design parameters. The flow chart presented over page gives a broad overview of how the various activities interact in achieving the final product.

ROADS PROJECT TYPICAL DETAILED DESIGN FLOW CHART



2 COURSE STRUCTURE

The course is split into three sessions, being:

- ❑ Theoretical considerations;
- ❑ Alignment – Horizontal, Vertical and Cross;
- ❑ Intersections and Interchanges

The theoretical session introduces the fundamental principles underpinning geometric design and, in this session, we also discuss some of the topics that you should be aware of and have some sort of understanding of how they impact on geometric design.

The alignment session deals with the three major components that the designer is concerned with, those being horizontal alignment, vertical alignment and cross section parameters.

The last session deals with intersecting alignments both at grade (intersections) and grade separated (interchanges).

3 WHAT THE COMPLEAT GEOMETRICIAN NEEDS TO KNOW

Way, way back a gentleman by the name of Isaac Walton wrote a book which he proudly entitled "The Compleat Angler". This did not mean that, back in 1653, PCs were short in the spell checker department. It actually means that, back then, people spelled things differently. The word "compleat" is, in a way, still around. My dictionary offers:

Compleat (kom-plêt[1]) ***adjective***

1. Of or characterised by a highly developed **or wide ranging** skill or proficiency: *"The compleat speechwriter come to anonymity from Harvard Law"* (Israel Shenker).

2. Being an outstanding example of a kind; quintessential: *"Here was the compleat modern misfit: the very air appeared to poison him; his every step looked treacherous and hard won:* (Stephen Schiff)

[Variant of COMPLETE[1]]

The American Heritage Dictionary of the English Language, Third Edition © Houghton Mifflin Company

The question thus is "What should the compleat geometrician know?" This course attempts to answer the question and also point attendees in roughly the right direction to acquire this knowledge.

We could start off by suggesting that a comprehensive knowledge of geometric design would be necessary. This is certainly necessary but is it sufficient? The answer, unfortunately is a resounding "No".

Many more questions spring to mind. After all, we are starting off with High School and ending up out the other side of a Master's degree. And we are going to do all this in two or three days ………..

It must be realised that what the geometric designer is really trying to do is to find the solution to a problem. The first step, thus, is to define the problem. It is remarkable how often a design is produced without much thought being given to the underlying problem. Problem definition is at the heart of systems analysis and so the compleat geometrician needs to know something about this.

It is a fact of engineering life that problems that have only one solution do not exist outside the classroom. There may be many solutions which are plainly unimplementable but, equally, there could also be many which, to some greater or lesser extent address the problem. However many adequate solutions are found, only one can be implemented. Which one should it be? Economic analysis offers one way of comparing competing solutions and utility analysis another. Without some knowledge of these techniques, the geometric designer is whistling in the dark.

The world the geometric designer lives in revolves around the movement of people and freight in a manner that is convenient, affordable, safe and with minimum side effects. The word "affordable" is addressed through economic analysis but what about the rest?

Convenience simply means that people can move between origin and destination without having to suffer inordinate levels of congestion and correspondingly long travel times which includes having to fight their way through over-saturated intersections. Questions that have to be answered include"
"How many people want to move from A to B, C to D, etc?"
"Where are A, B, C and D relative to each other?"
"What is the preferred mode of travel – car, bus, train etc?"
"What is the average occupancy of each vehicle on the network?"

Techniques to find answers to these questions lie n the field of Transportation Engineering about which the geometric designer cannot be totally ignorant.

Assuming that these answers have in fact been found, the next step is to determine how much infrastructure must be provided to address this demand for movement. The compleat geometrician must be able to carry out Capacity and Level of Service analyses so that he or she can say with confidence, "Here we need a six-lane freeway. Over there, a two-lane two-way road will be fine and back there a piece, we could get by with a gravel road."

The gravel road is, of course, not something to be dismissed lightly. What is its skid resistance?

At what sort of gradient is it likely to scour into total self-destruction in a matter of weeks? Do we have adequate reserves of material to maintain it for the next twenty years or so? Is it going to present an intolerable nuisance in terms of dust seeing that it is traversing orchards where fruit is grown for export? Sight should not be lost of the fact that the bulk of the South African road network is, in fact, gravelled. Don't think that gravel roads are easy to design – they're not.

Minimum side effects suggest that, for preference, the environment should not be wrecked in the process of creating the ultimate in freeways. The environment is more than just a pretty picture. It includes people not necessarily being enthused by large vehicles pouring out clouds of noxious gases and several decibels of noise. The compleat geometrician requires more than just a little environmental sensitivity.

Everyone will no doubt feel comfortable with the word "safe". We know what we have to do to design a safe road. Design to the standards and you've got safety – right? Wrong. You can design to every last standard in the book and still produce a total disaster. Those standards that we religiously live by – where do they come from? Do they actually mean anything at all? What do we do if, for some reason or another, it is not possible to achieve the magic number (which may be gradient, radius of horizontal curve, K-value of vertical curvature or any other) that is enshrined in the literature? Moaning piteously is not a solution.

We need to know something about the limitations of the vehicle we are designing for. More importantly, we need to have an understanding of the limitations of the people we're designing for. In the last about five to eight years, geometric design has undergone a paradigm shift of note. In the good old days, we designed for what vehicles CAN do. We now believe it to be more important to design for what people WANT to do. Research on human factors in road design is now big business.

People may be in vehicles, in which case their performance as drivers is of interest, or outside them. When outside vehicles, people may be pedestrians going some place or standing around browsing at the second-hand books in a street side flea market. Either way, inside or outside vehicles, the compleat geometrician must be able to model their behaviour to provide a solution that does not require the reactions of a Superman (or Superwoman ere we be considered to be sexist) simply to stay alive. Modelling is part of systems analysis and the types of models we construct fall in the realms of traffic flow theory, about which the compleat geometrician should be reasonably informed.

Traffic flow theory, in turn, is based on probability. For example, what is the probability that a gap of sufficient length will appear in a reasonable period of time to allow a vehicle to turn into or cross an opposing stream of traffic? What is "sufficient length", i.e. a gap that a driver will accept, and what is "a reasonable period of time"? Thirty seconds or thirty minutes? In order to understand traffic flow theory at all, the compleat geometrician should have some understanding of statistics and statistical distributions.

Having acquired all this supporting knowledge and bringing a strongly developed sense of aesthetics to bear on the design, a dream is converted into lines on paper. The compleat geometrician then applies his or her knowledge of coordinate calculation to bear on the problem of converting lines on paper to lines on the earth's surface. Some long-suffering contractor thereupon, usually with load cries of "Delay!" or dark mutterings about being forced into bankruptcy by some theoretical idiot who has never built a road in his or her life, goes out and builds the masterpiece. Disaster! The project is about eighty per cent complete when it disappears under water, with the prospect apparently of being there for all time. Pity – we should have told the compleat geometrician about storm water and its management.

To be able to manage storm water, it is necessary to know how much has to be managed and where it is supposed to be taken. This requires some knowledge of hydrology if drainage structures are to be properly sized. The size of required structures is going to have a definite impact on the vertical alignment.

The road is built. It is a visual work of art. It is economic. It is safe. It addresses every possible need of the community in the most convenient possible way. Can the compleat geometrician walk away saying, "This is a job well done"? Unfortunately, not. The road, once commissioned, has to be managed as part of the entire network. It is necessary to have some knowledge of the processes and limitations of Traffic Systems management in order to design a system that can, in fact, be managed.

Given all the things that the compleat geometrician must know, the final question is "What can we do about it, seeing this course is only a few days long?" The short answer is "Not very much". But what we can do is to provide a framework that will serve as the basis on which students can build their own store of expertise over time. We will even offer some indication of the basics of the various disciplines. Anybody who expects any one topic to be dealt with in great depth is doomed to disappointment.

4 URBAN VERSUS RURAL GEOMETRY

The main focus of the course is obviously geometric design and, quite rightly, that is where we are going to be spending the majority of our time. It is, however, necessary to point out that while "A rose is a rose is a rose" geometric isn't the same regardless of where you are. In fact, "Horses for courses" is more appropriate. The person who tells you that a car travelling at x km/h needs y metres to stop regardless of where it is, is telling the perfect truth but is also missing the point completely.

What one typically finds in the rural environment is relatively low volumes of vehicles moving at high speeds for considerable distances whereas the urban environment is characterised by high traffic flows moving at low speeds. High speeds require high values of horizontal and vertical curvature. In consequence, cuts and fills several metres high can occur in the rural environment. The lower speeds prevailing in urban areas mean that it is possible to get the vertical alignment closer to ground level. Ideally, the urban vertical alignment is just slightly below ground level to enable draining the surrounding properties towards the road reserve. Any significant departure from ground level creates problems with regard to access between the properties and the road network.

Intersections in the rural environment are spaced at anything up to kilometres apart and their effect on the smooth flow of traffic is minimal. Urban intersections are closely spaced and can be as little as 100 metres apart. Their effect on traffic flow is significant and it is the intersection that controls the efficiency of the urban network.

Rural intersections are typically no more than priority-controlled bell mouths between opposing two-lane two-way roads. Their urban counterparts can be multilane layouts with dedicated turning lanes, median and other islands, pedestrian crosswalks and a high level of sophistication brought to bear on their signalisation.

Competing activities, i.e. activities other than vehicle movement that also require a share of the road space are just about zero in the rural areas. Whether in a vehicle or walking, everybody on the road is going somewhere. In urban areas, on the other hand, there is a high proportion of competing activities. People window shopping, browsing through the offerings in a flea market, drinking coffee in a pavement café, children playing in residential streets all demand a share of the available space. And they are entitled to it. It is this diversity of activity that gives the urban environment its rich character. Ignoring it in the name of Mobility will almost certainly result in the production of an environment that is dull, uninteresting, and sterile.

In the rural environment, differences between the various vehicles found on the roads are, generally, not critical. In the absence of steep gradients, cars, inter-city buses and trucks are all moving at about the same pace and there is relatively little impedance to overtaking. The only time that this doesn't apply is during holiday seasons, specifically Easter, when, on certain rural roads, volumes become so high that traffic is brought to a complete standstill. In the urban environment physical dimensions of vehicles start to play a role simply because they are that much closer to each other. An articulated vehicle takes about as much space as three passenger cars. Its ability to accelerate from a stop is significantly slower than that of a passenger car. A right turning bus or truck, often requires the active assistance of opposing vehicles to complete the manoeuvre.

The urban designer must be aware of the operational differences between vehicles. In addition, modes of travel become a serious consideration in the urban environment. Congestion simply means that there are more vehicles on the road than it can comfortably accommodate. Historically, this problem was addressed by providing more infrastructure. If we were to continue in this mode, all buildings ultimately would be destroyed, and cities converted into endless seas of bitumen. In terms of the demand/supply equation, we focussed on supply.

It is necessary to consider demand. For an unaltered number of person trips, vehicle trips could be slashed by their taking place through the medium of buses. One bus could take the place of a queue of passenger cars that is three-quarters of a kilometre long. It has often been said at high political levels (where cheap emotionalism is usually considered to be an adequate substitute for thought) that eighty per cent of passenger trips should be by bus and that this goal should be achieved in the near future. And then the Minister gets into his black Mercedes with five blue light escort cars in front and similar following and roars off to harass small babies and other vote getting activities.

Both the percentage and the time frame could be queried but the geometric designer must produce street networks supportive of public transport. This does not only mean the provision of bus lanes and careful consideration of the location of bus stops. It also means that pedestrians should not have to walk too far to get to the nearest bus stop. Obviously, this is going to impact on the layout of both the residential and the destination area.

Public transport requires high population densities to be viable. The alternative is to wind a bus for several kilometres through a low-density residential area to acquire its full load of passengers. This is another consideration that has to be brought to bear on the design of residential townships.

Using the bus as the design vehicle for a road or street also suggests that maximum gradients and minimum curve radii are going to be a critical feature of its location. The location and layout of termini will also require careful attention. The rural designer is not beset by this problem.

Storm water drainage in the rural area simply means getting excess water off the road as soon as possible and providing culverts or bridges to accommodate cross-flows that are already concentrated in water courses. In the urban are, the road reserve is, in fact the conduit for storm water being transported from surrounding areas. However, because of the higher traffic speeds found in the rural areas, water on the road surface is potentially more hazardous than in urban areas where water on the road surface tends more just to be a nuisance. Wet urban roads produce a large number of tail end accidents or shunts. This is, however, attributed to drivers bringing a suicidal exuberance not matched by their skills to bear on the driving task. The approach to storm water drainage differs totally between the rural and the urban environment.

A further complication in the life of the urban designer is that provision must also be made for numerous other facilities not normally encountered in the rural areas. Sewerage, water and power reticulation, street lighting, telephone lines and, in older city areas, gas lines are usually located in the road reserve. Sewerage and storm water drainage operate on gravity and they can have a serious impact on the location of the road reserve in which they are to be accommodated.

What has been described so far is the operational difference between the urban and rural environments. As can be seen, the differences are legion. This does not mean that urban design is necessarily more complex than rural design. The fact of the matter is that the two have different sets of problems and. correspondingly, call for different approaches.

A further difference is the disciplinary approach brought to bear on urban versus rural design. Rural design requires the skills of the geometric designer, and the materials engineer with the latter being concerned with the in situ materials being traversed as well as the availability of suitable construction materials. Inputs from the various environmental disciplines not to mention the agricultural extension officers are also required. Urban design requires ongoing contact with the planning disciplines as well as with the engineers concerned with the provision of the other utilities in the road reserve. Public participation is a major feature of urban design but think that the local farmers are not going to have their say about where the designer should put his road.

Land acquisition costs are typically of the order of twenty per cent of the total cost of provision of a rural road with construction accounting for the other eighty per cent. In the urban environment, the proportions are reversed. To make matters worse, construction is more expensive in urban than in rural areas. This is because material that has to be dumped to spoil or imported for the design layers has to be carted for longer distances than in the rural situation. Even if the haulage distances were similar, travel times are longer in the urban area. Construction sites are more constricted in the urban areas and provision for suitable bypasses can be a major headache. Unit prices thus tend to be higher for urban than for rural construction.

By now it should be clear that urban and rural geometric designs are two totally different animals. The reason for drawing this distinction even before the course has properly started is that, as the course progresses, we are not going to be dwelling on these differences in any great detail but will rather be focussing on the principles that govern design.