LECTURE A12 – INTERACTION BETWEEN DIMENSIONS

CONTENTS

Introduction

The Need to Consider Interaction between Dimensions

Problems Arising from Interaction

Resolution of Problems Created by Interaction

INTRODUCTION

The designer and the road user see a road from totally different points of view. The designer sees the road as though from a considerable altitude but is nevertheless restricted to two dimensions at a time. He designs the horizontal alignment first, followed by the vertical and determines the cross-section as a separate exercise.

In comparison, the driver sees the road from a very restricted altitude and hence sees very little of it at one time. However, the little that he does see is a dynamic picture in all three dimensions (length, width and height) simultaneously.

INTRODUCTION

A fourth and very important dimension that the designer needs to see and visualise in their mind at all stages in developing the design is the influence and interaction of drainage, road safety audit findings, road signs and markings, safety devices and traffic calming, all as covered in previous lectures.

A further important difference between the two points of view is that the designer sees a static picture. The driver, on the other hand has a dynamic view of the road, constantly changing his vantage point as he travels along it.

INTRODUCTION

The designer must therefore train his eye to look at his drawings and visualise the three dimensions of the road and their changes as an integrated highway picture which corresponds with the driver's experience. Fortunately, the designer is also a driver, and most of this training can come from looking critically at roads while driving along them, consciously evaluating their designs with a view to spotting poor design features and then seeking methods to eliminate such features in his own future design efforts.

THE NEED TO CONSIDER INTERACTION BETWEEN DIMENSIONS

Here, “Dimensions” does not refer to measurements, but rather to the three dimensions in space along the X, Y and Z axes. The four major reasons why the designer has to consider the effect of interaction between the three dimensions of the road are:

1. to ensure a clear message to the driver regarding what is expected of him
2. aspects of safety
3. the fundamental difference in the points of view
4. aesthetic considerations

THE NEED TO CONSIDER INTERACTION BETWEEN DIMENSIONS

Clear Message to Road Users

When a driver has to react to a new road situation, he has a limited choice of courses of action open to him. He can change either the speed or the heading of his vehicle.

The designer must therefore provide signals giving timely warning to the driver regarding what and how much is required. As far as possible this should be done by allowing the driver to see in good time what lies ahead.

THE NEED TO CONSIDER INTERACTION BETWEEN DIMENSIONS

Safety

The most pervasive element of safety is the ability to stop in time to avoid whatever obstruction may present itself. Stopping sight distance is based on the ability of a passenger car to stop while travelling in a straight line on a level road. A steep gradient can just about double the distance required for stopping. A horizontal curve will reduce the drivers' enthusiasm for sharp braking and so increase the stopping distance by a factor of 2 to 3. In terms of each individual “dimension” (related here to curvature or gradient), the road may well be according to the standards, but the interaction of the dimensions in combination results in a significantly under-designed facility.

THE NEED TO CONSIDER INTERACTION BETWEEN DIMENSIONS

The Difference in Point of View

Reference has already been made to the bird's eye view enjoyed by the designer. A driver eye height of 1,05 metres corresponds more closely to a worm's eye view. An interchange can be quite easy to interpret when seen in its totality as a static entity, but the driver is treated to a series of glimpses of less than obvious lane changes, lane drops, off-ramps and on-ramps from which he is supposed to make logical decisions ensuring that he achieves the desired destination as opposed to some other.

THE NEED TO CONSIDER INTERACTION BETWEEN DIMENSIONS

It is necessary to ensure that the driver can see sufficient of his immediate environment in addition to the obvious need for clear and unambiguous signing to make the correct decisions.

For navigational purposes we may legitimately rely on the use of road signs to assist drivers. Note however that signs should never be used to try and rectify or compensate for geometric design shortcomings. Signs are removed too often, and ignored too often, to allow that.

THE NEED TO CONSIDER INTERACTION BETWEEN DIMENSIONS

Aesthetics

The human eye is remarkably sensitive to departures from a smooth line. The designer must therefore train himself to perceive the end-on appearance of his road from the square-on data presented to him by a plan-view, and must not lose sight of the fact that the plan-view data is itself incomplete, representing only two of the three dimensions.

The effect of these apparent discontinuities will be to create an un-aesthetic environment which will not be conducive to a relaxed attitude in the driver. In short, aesthetics means more than just a pretty picture.

THE NEED TO CONSIDER INTERACTION BETWEEN DIMENSIONS

Interactions and Combinations

Besides the effect of interaction between changes along dimensions which bring about a change in the basic parameters (e.g. stopping sight distance on a downhill curve), attention must also be given to combinations of changing dimensions which do not have that interactive effect but which create particular difficulty in complying with all the normal "one-dimensional" standards. An example is an intersection with a stop condition (effectively a change, actually the termination, of the longitudinal dimension) being placed just after a crest vertical curve, which is a change in the vertical dimension.

THE NEED TO CONSIDER INTERACTION BETWEEN DIMENSIONS

One does not have to set about changing/increasing minimum standards as in the case of the radius of a steep downhill curve, but rather just to ensure that all standards are fully complied with, particularly in applying decision sight distance where it may be necessary.

It is important to identify situations with a real interaction between dimensions because of the real need to be more generous with standards for them. Due to their importance and to the effect of the combinations of changing dimensions creating particular problems and a special need for designer awareness, a number of such cases are considered here.

PROBLEMS ARISING FROM INTERACTION

An inadequate consideration of the three dimensions of the road as a unit can give rise to a host of problems which fall into three categories, namely:

- reduction in safety
- optical illusion
- apparent discontinuities

PROBLEMS ARISING FROM INTERACTION

Reduction in Safety

Often a change in a road element will require a specific response from the driver. If this occurs at a point where he is not afforded much time to perceive and respond to the change, it is a problem.

One changing element may form a concealing element which hides a change in another element. Such a concealing element could be a crest vertical curve or a horizontal curve in cut. In the latter case, the critical case is on a left-hand curve in a cutting, when a vehicle is in the lane closest to the cut face and its sight-distance is most severely affected. Who has not gone a bit too fast up a steep left-hand bend in cut and almost finished up under a slow-moving truck concealed in the bend?

PROBLEMS ARISING FROM INTERACTION

An example of the “combination” problem is the location of a horizontal curve immediately beyond the crest of the vertical curve.

It is also a common tendency to “overdrive” vertical curves by a substantial margin so that the location of a horizontal curve immediately beyond a crest curve could be an open invitation for the vehicle to part company with the road.

If the horizontal curve is at the end of a long straight and is anywhere near minimum radius, the invitation will, in all probability, be accepted.

PROBLEMS ARISING FROM INTERACTION

Another example is the location of an intersection immediately beyond a crest curve. This is a particularly dangerous example of dimensional interaction.

Because of the vertical curvature of the road, road markings will not be visible, and the intersecting road surface may also be obscured. The only indication of the existence of the intersection may be its stop sign. This is hardly good enough.

When an intersection is located beyond a horizontal curve in cut the problem may be more severe.

PROBLEMS ARISING FROM INTERACTION

The driver is being distracted by a continuing change of vista and, at the same time is required to negotiate the curve. The intersection is a third element demanding his attention simultaneously with the other elements referred to.

There is no substitute for the proper separation of alignment changes and thus the provision of space for driver decisions and actions.

The road changes require proper visibility and distance between them, and that will then ensure sufficient time-separation between successive driver decisions and actions.

PROBLEMS ARISING FROM INTERACTION

Another way that features requiring a driver response are disguised is by hiding them within other features. The designer suffering a rush of architectural blood to the head can, by the cunning use of different radii of curvature for the edges of a carriageway conceal a lane drop within the length of a horizontal curve.

The driver is then not only required to attend to negotiating the curve but must also execute a merging manoeuvre which may also require a speed change on the curve.

PROBLEMS ARISING FROM INTERACTION

Optical Illusion

The intention at all times should be to ensure that the driver does what is expected of him when it is expected. Illusion can actually be used to “trick” or mislead drivers into performing the correct action. In this context, illusion can be a useful item in the designer's armoury. An example is COSBI (control of speed by illusion). Unwanted illusions can however deceive the driver into a course of action which is unanticipated by others or unsafe or both.

The “wrong” illusion can be created by the combination of a road element with an external element or by interaction between the dimensions of the road.

PROBLEMS ARISING FROM INTERACTION

More often the illusion arises from interaction between road dimensions. A horizontal curve located on a sag curve looks sharper than it really is, especially when the topography gives an almost plan-like view from a distance. Distracted drivers have been known to drive off the inside edge of the road as a result.

When located on a crest curve the horizontal curve appears to have a larger radius than it actually has, encouraging a false sense of security dispelled only by sharply striking a cut face or a guardrail.

PROBLEMS ARISING FROM INTERACTION

If a horizontal curve commences at a distance of about 60 metres beyond the start of a vertical curve, the superelevation development can create the impression of a straight grade by the outer edge rising relative to the centreline which is actually dropping away. The vertical curve is thus only perceived as such some way along its length and consequently appears much more severe than it really.

The superelevation development on the inside of the curve causes this road edge to drop away very sharply heightening the illusion of a vertical curve which is more an instantaneous change of gradient than a curve.

PROBLEMS ARISING FROM INTERACTION

Apparent Discontinuities

This refers to combinations of changing dimensions resulting in kinks or breaks in the alignment of the road edges whereby the aesthetic harmony of the road is destroyed. The combination of horizontal and vertical curvature, (the last-mentioned of the illusions discussed above) is also a special case of this problem. Regardless of where on a vertical curve the superelevation development commences, the effect will always be of a break in an otherwise smooth curve, unless special care is taken. (refer to the profiles, pages 8 & 9).

RESOLUTION OF PROBLEMS CREATED BY INTERACTION

The best warning that a driver can be given of an impending change of direction is to commence the horizontal curve at or prior to the commencement of the vertical curve. Seeing that the road can be traversed in both directions it follows that the vertical curve should be contained within the horizontal.

A common aesthetic problem is that caused by super-elevation development. It must be noted that the development of super-elevation provides two possible kinks in the smooth flow of the road edge, both on a straight grade and also on a vertical curve. If there is an unfavourable overlap, i.e. where the horizontal curve is within the vertical, the appearance of a kinked edge is heightened.

PROBLEMS ARISING FROM INTERACTION

PROBLEMS ARISING FROM INTERACTION

RESOLUTION OF PROBLEMS CREATED BY INTERACTION

This can possibly be reduced by rotating the road around a line other than its centreline, (as is commonly done on interchange ramp design). It is also important to design super-elevation in two stages, in which the drawing of calculated edge lines is followed by a graphical smoothing process.

This is illustrated in two diagrams at the end of this paper, which show for two different alignment cases, a plan, a calculated set of profiles and a smoothed set of profiles. It is always necessary to check and ensure that the final amount of super-elevation after smoothing of the initial calculated profile is still suitable at all points along the profile.

RESOLUTION OF PROBLEMS CREATED BY INTERACTION

It is always preferable and often essential, when confronted with adverse combinations of horizontal and vertical alignment, to avoid the use of minimum radii for horizontal curvature.

A general aim would be to try to add about 50 % to the minimum radius specified for the design speed. However, steeper downgrades in combination with horizontal curves require that the designer be even more generous with the stopping sight distance he provides, and three times the minimum radius may be a worthwhile goal.

RESOLUTION OF PROBLEMS CREATED BY INTERACTION

It has already been stated that lane drops should not be concealed in horizontal curves. They must always be clearly visible and emphasised by an abrupt change of the edge line (using a kink).

In a rural environment, the lane drop is very often a case of terminating a climbing lane. The lane drop should be sufficiently far beyond the crest to allow the vehicles that have been using the climbing lane to accelerate to a speed more closely matching that of the through lane and furthermore, the location of the lane drop should be such that its presence is very clear to all road users.

RESOLUTION OF PROBLEMS CREATED BY INTERACTION

Much discussion above, particularly on aesthetics, has been aimed at kinks. It referred to their general undesirability on a continuous line, and to measures that can be adopted to avoid them. Nonetheless the need to convey clear messages to drivers very often requires that a kink be introduced into the alignment deliberately.

For example, a deliberate discontinuity will highlight the fact that an off-ramp is a road leaving the freeway and is not a continuation of the freeway itself.

RESOLUTION OF PROBLEMS CREATED BY INTERACTION

An "architectural" approach to the design of an interchange off-ramp on the outside of a horizontal curve might be to treat the ramp edge as a tangent to the curve and to create the separation between the ramp and the through lanes by using the curvature of the latter. The unfamiliar driver, particularly at night or in bad weather, will invariably perceive the tangential ramp edge as the end of the freeway curve, and go down the ramp thinking that he is still on the freeway – then at a speed of 120 km/h, when the stop sign for the cross road ramp terminal pops up....surprise!