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ROAD SAFETY AUDIT GUIDELINES FOR THE SAFETY AUDIT OF ROADS AND ROAD PROJECT IN MALAYSIA JKR

JABATAN KERJA RAYA MALAYSIA

ROAD SAFETY AUDIT

GUIDELINES FOR THE SAFETY AUDIT OF ROADS AND ROAD PROJECT IN MALAYSIA

Road Safety Audit

Guidelines For The Safety Audit Of Roads And Road Projects In Malaysia

PUBLIC WORKS DEPARTMENT (MALAYSIA)
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PREFACE

The traffic accident problem in Malaysia is one of the most serious facing the nation. The cost to the community is over RM 4 billion annually along with the huge price in terms of pain and suffering of the people involved in traffic accidents.

It is now recognised that traffic accidents rarely have a single cause and involve many factors, not all of which can be significantly influenced by those involved in the engineering of roads and in managing the traffic on them. However it is accepted that at least 25% of traffic accidents involve engineering factors combined with human factors and while many of the human factors are difficult to change, there is much we can do in respect to engineering which can eliminate common accident causes or to minimise the severity of those crashes which do occur.

In its effort to meet the Government's target of 30% reduction in traffic accident deaths by the year 2000, JKR's Road Safety Strategy includes both 'Re-active' initiatives, such as the 'Accident Blackspot' Program, and 'Pro-active' measures such as Road Safety Auditing and improved road design practices.

Road Safety Audit is a relatively new aspect of road engineering which requires specialist skills based on a sound knowledge, experience and understanding of Traffic Engineering and Road Safety principles and practices. An important focus of Road Safety Audit is its consideration of the specific safety needs of ALL road users, not just motor cars and trucks. This is particularly relevant in Malaysia where vulnerable road user groups: motorcycles, pedestrians and bicycles, contribute more traffic deaths than all other road users combined.

This guide presents practical information on Road Safety Audit practice, procedures and methodology applicable in the Malaysian context. It also includes an important discussion on the legal implications of Road Safety Auditing and of road engineering in general as might arise from the consequences of traffic accidents. This area is expected to become increasingly relevant in the future as road users become more aware of their legal rights and of the accountability of organisations and individuals involved with providing public infrastructure.

Road Safety Auditing is not expected to eliminate all or even the majority of accidents but experience in other countries indicates that if it is applied at the various stages in the development of new road projects positive benefits can be obtained. Road Safety Audit costs in the order of 4% to 10% of design costs for new major projects but can provide very much higher benefits to the community in reduced accident costs, and in minimising the trauma suffered by people as a result of traffic accidents.

JKR has adopted as policy the need for Road Safety Auditing at the four recommended stages in the development of all significant new road projects. A program to systematically carry out such audits along all Federal Routes and the more important State Routes on a progressive basis over the next 10 years is also being adopted. This manual is expected to be used as the primary guide for Road Safety Auditing both within JKR and by Consultants engaged on this work. In the interests of consistency, its use by other organisations responsible for roads and traffic facilities in Malaysia is recommended.

Dato' Dr. Ir. Wahid Bin Omar
Director of Roads, Public Works Department, Malaysia.

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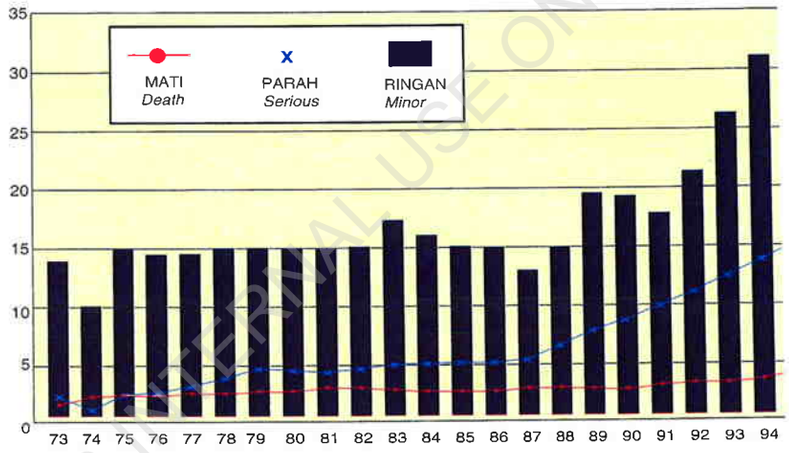
1 Introduction

Traffic accidents in Malaysia have been increasing at a rate of approximately 10% per annum over the last 10 years, (see Fig.1.1). The seriousness of the problem was recognised by the Government in 1989 when it set a target of 30% reduction in traffic accident deaths by the year 2000. More recently, this goal has been translated into a projected number of deaths as shown in Fig.1.2 (Radin Umar 1997). Achieving this target requires concerted and sustained actions on a number of "fronts" covering the traditional areas of Engineering and Environment, Education, Enforcement and Emergency Services.

This multi-faceted approach recognises the fact that traffic accidents are rarely the result of a single cause or factor. They are generally the outcome of the interaction of many factors in a "chain of events" involving the driver, the vehicle and the environment, that ultimately leads to the occurrence of an accident. The contributory factors in traffic accidents can be broadly categorised into 'Human' Factors, Road and Environment Factors and Vehicle Factors. Studies in various developed countries reveal a good degree of consistency in the inter-relationship and relative proportions of these contributory factors in overall traffic accident statistics. This is illustrated in Fig. 1.3 (Source RTA NSW1993).



SOURCE: STATICS ROAD ACCIDENTS MALAYSIA 1995

Figure 1.1 ROAD ACCIDENT CASUALTIES (1973-1995)
Source :Statistics Road Accidents Malaysia(1995)

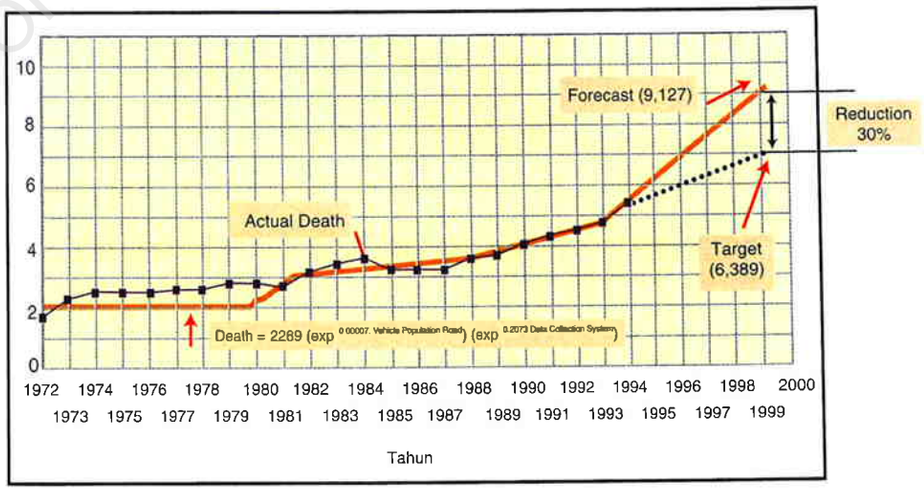


Figure 1.2 ACCIDENTS DEATHS TREND AND PROJECTION
Source :Radin Umar (1997)

It is evident from Fig.1.3. that about 25% of traffic accidents involve the interaction of 'Human' and 'Road / Environment' factors. While the relative proportions of contributing factors in "less developed countries" may be different to that in developed countries, it is likely that the contribution of 'road / environment' factors is higher because of the generally lower 'safety standard' of roads in these countries.

It is in respect to this combination of human and environmental factors that engineering and traffic management actions can be used to eliminate some contributing factors, thereby breaking the "chain of events" and perhaps avoiding the occurrence of the accident or alternatively reducing the severity of its outcome.

JKR has adopted a strategy which includes two types of road safety action:

- Accident Reduction, which is focussed on the identification and elimination of accident "Blackspots", and
- Accident Prevention, the focus of which is on designing safer roads and improved traffic management for all road user groups. A major emphasis in this regard is on Road Safety Auditing.

Road Safety Audit (RSA) is a relatively new road engineering technique aimed at identifying potential safety problems during planning and design of projects. Applied to existing roads, RSA can identify potential safety hazards before they become accident prone locations.
Thus Road Safety Audit is very much based on the premise that:

"prevention is better than cure".

Road Safety Audit is also an important part of the 'Quality Assurance' process in road engineering, giving special emphasis to the principle of:

"getting things right the first time".

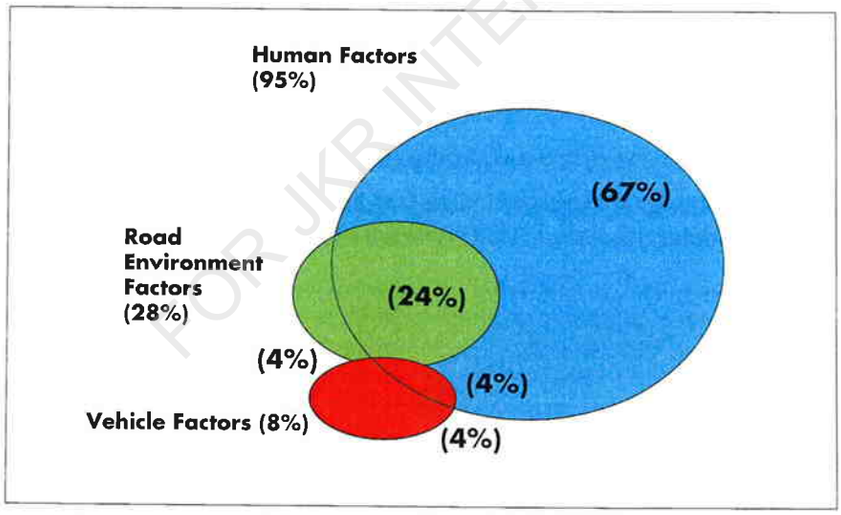


Figure 1.3 FACTORS CONTRIBUTING TO TRAFFIC ACCIDENTS
Source :Austroads (1994)

1.1 What Is Road Safety Audit ?

Road Safety Audit may be defined as the formal examination of the planning, design and construction of a road project, and of the characteristics and operation of an existing road, by independent and qualified examiners, to identify any potentially unsafe feature or operational arrangement that may adversely effect the safety of any road user.

The important emphasis in this definition is that:

- it is a formal process not just an ad hoc check,
- the examination needs to be done at various stages in the development of a project,
- the Auditors must be properly qualified and experienced to undertake the task and they must be independent of the planning, design, construction teams involved with the project,
- the audit must consider the safety of all road user groups,

1.2 Goals And Objectives of Road Safety Audit:

The goal of the RSA process is to ensure that all road projects and all existing roads are capable of providing the highest practicable standard of traffic safety for all road users.

This goal is translated into the following RSA objectives:

- the identification of potential safety hazards on new road projects, at the appropriate stage, so that they can be eliminated or otherwise treated to mitigate their adverse effects, at minimum cost;
- the identification of hazardous features of an existing road so that they can be eliminated or otherwise treated before they become accident prone locations;
- to ensure that the safety requirements of all road users are explicitly considered in the planning, design, construction and operation of road projects;
- to reduce the overall "through life" costs of a road project to the community.

1.3 Why do we need RSA?
(And how will it help the road safety situation in Malaysia?)

It is not uncommon to find that safety and operational problems become evident shortly after many new road projects become operational. In most cases these problems could have been anticipated, their causes identified and eliminated, or at least their effects could have been mitigated, at little extra cost if they had been identified at the appropriate stage in the development of the project. RSA is specifically aimed at achieving this and is therefore very much a 'Pro-active' approach to road safety.

Projects for which the responsible organisation has made a real commitment to road safety practices and which have undergone thorough RSA will rarely exhibit accident black-spots throughout their economic life and will provide the community with safe and cost effective transportation.

The adoption of RSA procedures not only helps to eliminate accident causes before they are built into a project, it also helps develop a 'road safety culture' within the organisation, in which the various 'team players' will have a greater commitment to achieving safety and excellence in the product and services they provide. RSA is 'customer (ie road user) focussed' and it is not so much concerned about the processes

involved in achieving the product (ie the road itself) This is a major distinction between financial audits and road safety audits.

On existing roads, particularly those which have not been subject to RSA during their design, many hazardous features exist which inevitably contribute to the occurrence of traffic accidents, or severity of their outcome. Systematic road safety auditing can identify these 'Booby Traps' and they can be eliminated before they become involved in a traffic accident or develop into accident 'Blackspots'.

The adoption of the RSA process, involving audits at various stages in the development of a project, can make a significant contribution to achieving safe and efficient road performance in the following ways:

- RSA will detect and eliminate unsafe features at the stage when changes to a design are most easily made, thus avoiding costly redesign or later reconstruction. Action at an early stage in the planning and design process also avoids 'locking in' conditions which leave designers with little flexibility to achieve effective solutions to problem areas. Alternatively, if desirable changes to a design cannot be made, early detection of potential safety deficiencies often allows other 'mitigating' works to be included which can reduce the undesirable effects of design inadequacies.
- RSA at various stages can identify and eliminate inappropriate or 'out of date' standards and practices. This can be very beneficial where resources do not permit continual updating of standards and practices and where design resources are decentralised or distributed amongst numerous consultants.

Other situations where RSA can have a significant beneficial effect are:

- detecting potential safety problems resulting from the combination of various elements of a design, eg. combinations of horizontal and vertical alignment which create momentary sight distance restrictions, which otherwise may go.
- reviewing compromises which often need to be made during design in the application of standards or compromises resulting from 'trade-offs' eg. of safety against speed or continuity of traffic flow.
- reviewing changes to a project design which are sometimes made during construction to achieve benefits to the road builder. These changes are often made at the expense of later operational performance.
- ensuring that road safety enhancements, eg. due to improvements in technology, are included in the project throughout the planning and design processes.

1.4 Organisational Commitment To Road Safety:

As described at the beginning of this Guide, the traffic accident situation in Malaysia is one of the most serious problems faced by the nation. There is a Government commitment to tackle the problem and this must be translated into a similar commitment by all organisations involved in roads, transport and traffic management. Such commitments are only evident in the policies and practices adopted, and in the resources that are allocated to implement them.

JKR has adopted a policy which requires RSA to be carried out on all new road projects and that RSA be systematically done on all Federal Routes throughout Malaysia. This is only part of JKR's overall road safety strategy, which includes a stronger focus on traffic safety issues related particularly to the vulnerable road users such as Motorcyclists, Bicyclists and Pedestrians.

It is acknowledged within the organisation that there is a need to develop a 'Safety Culture' in which the consideration of 'traffic safety', in every aspect of the departments work, becomes the normal rule rather than the exception. This is an essential 'Paradigm Shift' for all road and highway authorities if they are to achieve the degree of excellence necessary to provide safe and efficient road transport which the community has a right to expect

2 Legal Liability Issues In Road Safety Audit

2.1 Introduction:

The process of safety audit aims to identify potential safety problems and to ensure that measures to eliminate or reduce the problems are fully considered. The adoption of safety audit is intended to improve awareness of safe design practices. It is intended to be proactive and to prevent accidents from occurring rather than to allocate blame and compensation after the fact. It naturally follows that the legal system would embrace such a development, would encourage its adoption and would not intentionally penalise those that adopt such a process. At the same time, the law regards the method by which the road environment is made more safe examine its practices with regard to safety in order to minimise the adverse effect on its annual budget of amounts ordered by the courts to be paid to victims due to the highway authority's negligent acts or omissions. The law intends through this shifting of damages to heighten the safety awareness of highway authorities, and to cause them to institute safer practices in order to avoid costly payouts.

In Malaysia, the issue of public authority liability for acts of negligence is an evolving area in which the courts are still searching for a definitive answers. Highway authority liability in particular remains subject to further development. The trend is clear; in more instances than in decades past, courts are holding highway authorities responsible. The views expressed in this chapter are intended to sensitise readers to broad concepts and developments. This discussion on the legal implications of road safety audit is no more than a guideline and a general introduction and cannot be relied upon in any individual case. It is recommended whenever decisions are made which may involve potential legal liability, professional legal advice be sought to guide that decision.

Though adoption of road safety audit is in its infancy in Malaysia, highway authorities are entitled to understand the effect of the adoption or non-adoption of road safety audit on their potential legal liability. Assume a highway authority adopts road safety audit as part of its design process and a motorist or pedestrian is injured on that portion of the highway which was included in the audit. Will the undertaking of road safety audits expose those authorities that adopt them to greater liability than at present? The answer is "no". Will the undertaking of the process of road safety audit be likely to reduce exposure to liability. The answer is "yes".

If a highway authority fails to adopt road safety audit as part of its design process and a motorist or pedestrian is injured on that portion of the road which would have been the subject of an audit, will that authority be exposed to a greater liability than at present? The answer is "no". Will the authority be exposed to a lesser liability than at present? The answer is "no". A highway authority is held liable for the defects in design, construction and maintenance in the roads under its care be adopted by any given highway authority. It is envisaged that the relevant statutes and rules permit the highway authority to undertake the process. The government could decide to make road safety audit a duty rather than a power in the future. Alternatively it could link road construction and maintenance funding to the undertaking of road safety audit. In most jurisdictions, road safety audit has been left as a power. There are a number of options for any highway authority to consider when it undertakes the process. Will it be done at all stages of a project? Will it be undertaken on all projects, or only those above a certain cost figure? To what degree will the existing network be subject to road safety audit as compared to projects at the design or construction stage? Will a certain percentage of the road network be subject to road safety audit in any given year? Will road safety audit be undertaken by a completely independent team of auditors from outside, or will it be from an independent group or single person within the particular highway authority? Most jurisdictions in which road safety audit has been instituted have left those decisions to the individual highway authorities rather than imposing them by a legislative framework.

In order to understand any changes in potential liability as a result of adopting road safety audit one must first examine the present liability of highway authorities in general and then look to see the effect that road safety audit will have upon the present state of liability. The division of the law which presently sets the rules for liability is 'tort' and within tort it is negligence, and to a much lesser extent, nuisance.

2.2 Elements Of Legal Liability:

Any person injured as a result of the alleged negligence of a highway authority must prove, upon the balance of probabilities, that the authority owed a duty of care, failed to act reasonably, and caused the damage suffered.

A highway authority owes a duty of care to all those that it can or ought to foresee might be affected adversely by its acts or omissions. The class of person who could be potentially injured by the acts of a highway authority include drivers, passengers, pedestrians and occupiers of land adjacent to the roadway. Though there are some exceptions which will be discussed later in this chapter, in most instances a duty of care will be owed by the relevant highway authority to the injured motorist. Resolution of the issue of liability will depend on whether there was a breach of the duty of care owed. In order to avoid liability the highway authority must act reasonably. The acts or omissions of the road engineer, the designer, or the traffic engineer must be reasonable as measured by a hypothetical reasonable person trained and employed in that position. The highway authority will be held responsible for the acts of its employees. The standard is easy to state and to understand but rather more difficult to apply.

At the risk of over-simplification, there are two types of behaviour that the courts are asked to review. One is where the highway authority has acted wrongly and the highway authority knows that it was wrong. That situation usually poses little difficulty. The second instance is where the highway authority believes that it acted reasonably and yet sometimes it is found not to have. This is a result where many road or traffic personnel are aggrieved at the decisions which are reached by the courts. It must be remembered that the courts view any particular incident from a rather different perspective than that of the personnel of the highway authority. The highway authority officer will have acted or decided not to act taking into account safety as well as several other factors such as cost, road capacity, varying types of road user and the like. The judge, on the other hand, will view the situation after a particular incident has occurred. The judge or jury will have the benefit of hindsight and considerations of safety, deterrence and compensation will predominate. It is therefore perhaps not totally surprising that the question of whether the authority has acted reasonably will not always be easy to answer.

The question that the court poses is 'What would a reasonable person do by way of response to the risk?' The reasonable person's response calls for a consideration of the magnitude of the risk and the degree of the probability of its occurrence, along with the expense, difficulty and inconvenience of taking alleviating action and any other conflicting responsibilities which the defendant may have. The area of breach is the usual battleground in allegations of professional negligence against public authorities. A trial is often dominated by the testimony of expert witnesses presented by each side. The court will look at any published, as well as unpublished, standards and guidelines which will help inform the court of what is acceptable and reasonable practice. The present practises of road authorities in any given community, its customs and standards are generally accepted as evidence of what is considered reasonable.

The courts are aware that standards and practices evolve over time. Judges are not expert in road construction and maintenance; they will be guided by best practice in any given community by receiving evidence through experts of what is customary in, say, Malaysia in 1997. But if world best practice differs from the standards of any given place, a court can take the view that 'a reasonable authority' would adopt such standards even if those standards are not yet widely practised within a given community. For example, if a given road authority's standard did not require the installation of a guard rail in areas of high risk should a vehicle run off the road, and in other localities, guard rails were provided, the local authority with the 'lower' standard could be held liable.

The court will receive evidence including the statistics of past incidents at the location, the cost of treating the particular area and the likely benefit to be gained by such treatment. In many instances, the court will consider whether, at the least, the motorist was properly alerted to the hazard by warning signs etc, as an alternative to any better and more permanent treatment that could not have been undertaken at the relevant time.

The state of knowledge of the relevant public authority may also be in issue. Is it better for a traffic authority to remain in ignorance of the potential hazards within its given geographical area? In general, the test that is applied is whether the authority knew or *should have known* of the particular danger. Therefore, the mere fact that an authority has remained in ignorance of a particular situation will by no means necessarily exonerate it from liability. As a general rule the law would hardly wish to reward an authority that, as a policy, sought to minimise its knowledge of high risk areas on roads within its care or management.

Whenever an authority considers a particular treatment, whether of a specific spot or a larger project, it is important that the authority formally records in permanent documentary form any decision which is reached with regard to the particular treatment. When a cost benefit analysis is conducted, or alternative actions considered, whether formally or informally, all factors which influenced the decision should be recorded in a permanent document. Courts recognise that public authorities act in the public interest and may be differentiated from private organisations by the law of torts because their statutory responsibilities to the public may require them sometimes to run the risk of inflicting injury on private individuals which it would not be appropriate to compensate through the law of tort.

The act or omission of the highway authority, if it is found to be unreasonable, will only be productive of a damages award if the act or omission itself produced or caused the damage suffered by the victim. The behaviour of the driver or victim is also relevant. The unreasonable act or omission by a highway authority is not intended to relieve the wrongdoing driver or passenger or pedestrian from the consequences of his or her own misbehaviour.The defence of contributory negligence, that is, the failure by the victim to look after his or her own safety, will result in a reduced award to the plaintiff depending upon the degree to which the plaintiff failed to act reasonably for his/ her own safety, and the way in which the accident occurred.

2.3. Principles Of Negligence Applied To Road Safety Audit:

The previous discussion illustrates the elements of negligence as they presently apply to the activities of highway authorities. Only with an understanding of that background can one turn to road safety audit and ask how the adoption or non-adoption of road safety audit will affect public authority liability. In order to better illustrate the issues, a hypothetical based upon case study Y found at page Z of these draft guidelines is used. Assume that a motor cyclist is proceeding in a westerly direction on Jalan Damansara and proceeds in the left hand (exit) lane as illustrated in photo no. X. A motor vehicle approaches on the right of the motorcyclist forcing the motorcyclist towards the extreme left hand edge of the motorway. The rider loses control and leaves the roadway falling into the open "monsoon" drain near the edge of the motorway. The motorcyclist suffers severe injury and is left with a permanent partial incapacity. The identity of the driver of the motor vehicle which allegedly caused the motorcyclist to take evasive action and head towards the extreme left hand edge of the roadway is unknown. The motorcyclist commences a civil proceeding against the responsible highway authority, alleging that the deep open monsoon drain was too close to the traffic lanes and therefore created an unsafe roadway.

The identification of the defendant will be obvious in some instances but will pose difficulty in others. The defendant in, general terms, will be the organisation which has the authority to do something about the unsafe road feature and fails to take that action. If the defect is in design or construction, it will be the organisation that designed or constructed the highway. If the defect is attributed to maintenance, or to allowing an obstruction to be placed on the road, then the organisation which has the care and management responsibility for the road is the proper defendant. At times, the responsibility may be shared : the highway is designed by one organisation, constructed by another, then handed over to yet another. In such instances, responsibility may be shared, and more than one organisation will be named as the defendant. In this case study, and only by way of illustration, it will be assumed that JKR is the organisation which has the authority to do something about the highway (or road).

Let us assume that the [JKR] had adopted the process of road safety audit, and that the auditor indicated that the open monsoon drain near the roadway less than a metre from the edgeline at a critical exit location posed a danger to road users. Let us further assume that the [JKR] had accepted a recommendation that attention be paid to reducing the hazard in an appropriate way. [Such recommendation may have been by positioning the drain further away from the carriageway, or covering the drain with a grating', or the placement of guardrail to protect motorists from straying into the drain.] As a result it can be hypothesised that there would have been no severe injury accident as the errant motorcyclist even if he left the motorway would have had an adequate recovery zone or would not have fallen into the open drain. If the motorcyclist left the road and even if serious injuries ensued notwithstanding the improved treatment of this critical exit location, then it is improbable that the JKR would be enmeshed in litigation as there would be no allegation that the highway authority's activities contributed in any way to the collision and its aftermath.

Let us use the same case study but in this instance let us suppose that JKR did not adopt the road safety audit process and that it found itself involved in the litigation initiated by the motorcyclist. JKR owes a duty of care to drivers travelling along roads within its care and management and will be required to act as a reasonable and prudent highway authority vis a vis motorists that use its roads. The allegation by the victim in this case would be that the highway authority was negligent in allowing a roadside hazard to be located near the roadway at a critical exit location. Experts would be likely to present evidence at the trial in an attempt to prove whether it was consistent with sound highway engineering practice to have allowed the open monsoon drain to continue less than a metre from the edge line. It would also consider the cost of taking remedial action such as relocating the drain, or covering it with a grating', or placing a guardrail, or using warning signs or other delineation devices to bring to the attention of motorists the hazard. The court would then make a finding upon on whether the highway authority had been negligent or not.

Note that it is unlikely that the court would concern itself directly with the issue of whether or not a safety audit had been conducted. The principal allegation against the highway authority would be its failure to remove a hazard which it has created or permitted to remain, or which had become a hazard as a result of the upgrading of Jalan Damansara. In a physical sense the cause of the incident, or at least an alleged cause of the incident, was the location of the open drain – not the non-adoption of a road safety audit. It has been hypothesised that a road safety audit would identify the potentially hazardous condition and could lead to its elimination or improvement. A court will focus upon the actual act or omission which occurred on the highway rather than the individual steps in the road engineering process. Of course, the court will receive evidence of what steps were taken to ascertain that the exit lane was safe. Why wasn't the situation of an open drain in that location discovered and remedied? Road safety audit is not the only method available to highway authorities. A highway authority that neither employed road safety audit, or another reliable process for identifying high risk situations, could be in danger of being found liable for its omission as the process of adoption of road safety practices becomes widespread in Malaysia.

2.4 Procedures For Non - acceptance Of Auditor's Recommendations:

Let it be assumed that the JKR has adopted a policy of road safety audit. It receives a road safety audit report from its auditors in the form which suggests that the deep (monsoon) drain less than a metre from the edgeline at a crucial exit location poses a danger to motorists and ought to be remedied in a particular way. As this is a Stage 5 audit the road and the drain are in place and the budget for that particular project may well have been exhausted. JKR decides not to accept the recommendation that the open drain near the roadway be remedied. Further assume that the accident earlier described takes place and that the allegation is made that the presence of the open drain was a cause of the accident in that the motorcyclist had no opportunity to recover, or that it contributed to the severity of his injuries. Would this be a likely

source of liability for the JKR? An immediate cause of the accident was, it is alleged, the presence of the open drain near the roadway. A court would have to determine whether a reasonable highway authority would have relocated or otherwise treated such a roadside hazard. Evidence that JKR knew of the accident potential of the drain but failed to act upon the recommendation would not necessarily be determinative but certainly would be an issue that would be directed to the court. ***Any highway authority should be very careful, when rejecting any recommendation in a road safety audit report, to document the reasons why the recommendation was not accepted.*** The thought process, and the considerations which were weighed, should be documented in writing, with the reasons which led to the rejection of any recommendation. Each of the reasons such as budgetary considerations, social or political factors, which led to the rejection should be separately listed. It would then remain for the trier of fact to determine whether the decision to leave the drain in place was consistent with sound road traffic engineering practice. The adoption of a practice of listing priorities consistent with budgetary considerations is highly recommended. While certain works cannot be carried out within a given budgetary period or indeed perhaps within the next year, a court is much more likely to be impressed with a highway authority that has given consideration to the matter, and which plans to remedy them in, say, 3-5 years, than with an absolute rejection with no consideration of future action.

2.5 Negligent Audit:

Let it be assumed that the JKR had adopted the process of road safety audit and had submitted the reconstruction and upgrading of Jalan Damansara for road safety audit. What would be the legal implications if the road safety auditor failed to alert JKR that the open drain near the roadway could pose a hazard to motorists? In this case study, the drain would remain untreated. The injured motorcyclist again has the misfortune to leave the roadway and is severely injured in the fall into the open drain. The legal position is that JKR can add the road safety auditor to the proceedings seeking a contribution or indemnity; that is JKR would be alleging that if it were liable to any of the injured parties, it had reasonably relied upon the road safety audit and it ought to be reimbursed fully or in part for any damages that it has to pay to the injured driver.

This situation is roughly analogous to the position that financial auditors sometimes find themselves in as a result of an allegedly negligent audit. Recent cases in England, Australia and Malaysia have considered to whom an auditor owes a duty of care. It is clear that the auditor owes a duty of care to the client (in this case, JKR) but unclear whether, if the audit causes harm to anyone else (in this case, a motorcyclist), a duty of care is owed to persons other than clients. Courts will more readily find a duty of care is owed to persons who suffer physical injury or property damage than those who suffer only financial loss. Assuming a duty of care is owed by road safety auditors to motorists, the crucial legal question would be whether the person or persons who conducted the road safety audit acted reasonably in conducting the road safety audit. Whether the failure to direct attention to the location of the drain constitutes negligence could depend upon the size of the project, the time allowed for the audit, whether the audit was paid or unpaid and whether it was merely an error of judgment or rather, something no reasonable auditor would have omitted. In the case study, the auditor would be likely to be considered negligent. The use of road safety audit does not totally relieve the council of its own responsibility to use care in the design and construction of its projects. The responsibility for paying compensation would be apportioned between the auditors and the council. Financial obligations between the auditors and the highway authority can be regulated by an indemnity agreement.

No case involving road safety audit has yet come before a court. Therefore the legal implications must be speculative, not certain. But the predictions are not guesswork; they are based upon well established principles of tort law.

Safety audits will create a safer road environment. A major aim of litigation in this area of law is to encourage safety. It follows that the use of road safety audit will be encouraged by the legal system. But the major focus of the law in this area is the end

product — the state of the road itself — and not the method by which an authority achieves this.

Roads can be made safe by a variety of methods — including black spot treatment, periodic inspection, the adoption of higher standards of engineering practice, greater allocation of funds and road safety audits. It is for highway authorities to decide which mix of these is best for any given project, and as an overall policy.

It is obvious that the process of road safety audit can play a vital part in achieving safer roads. Highway authorities that fail to adopt the process run the risk that avoidable defects on the road will not be discovered, and that the defects will cause accidents. Highway authorities that fail to adopt safety audits or comparable processes run a higher risk that legal liability will be imposed.

2.6 Conclusion:

This chapter has suggested that the issue of liability or non-liability of any highway authority in the area of road safety audit will be determined on the basis of whether the highway authority acted reasonably, or instead, fell below the standard of care to be expected of a reasonable highway authority. It has been assumed throughout the chapter that a duty of care is owed because in matters involving road safety audit a court will be faced with a situation in which a duty of care must be conceded. It should be pointed out that there are two areas in which highway authorities may not be found to owe a duty of care. The first of these is for policy reasons and the second is for nonfeasance. Neither is likely to apply in the case of road safety audit. For the sake of completeness a footnote is provided to sensitise officers of highway authorities of the existence of these two instances of a qualified immunity for public authorities.

2.7 Note On Duty Of Care:

When a public authority is given power under a statute to take certain actions and it is within that authority's discretion to determine to what extent such action should be taken, sometimes the courts will not second guess the exercise of that discretion. When parliament has left the decision to be exercised by a public authority as to which powers it should exercise, and when and to what extent it should exercise them, a doctrine has grown that such questions should not be submitted to the subsequent decision of a judge.

The difficulty for the courts is to determine which of these discretionary decisions by public authorities are of such a character that they ought not to be reviewed by the court. The courts have sought to distinguish "policy" decisions which, it is said, should be left entirely to the public authority from "operational" decisions which ought to be subject to review by the courts if they are performed negligently. The dichotomy between policy and operational is difficult to ascertain; no court – English, Malaysian or Australian – has yet been.able to define the term. To characterise a decision as one of policy, which ought not to be reviewed by the court, judges test whether the decision has been affected by financial, economic, social or political factors or restraints; whether it involved an allocation of resources; a budgetary allocation; was reached at a level of generality; and whether the decision was taken at a high level within any given organisation. On the other hand, those decisions which result from administrative direction, expert or professional opinion, involve the application of technical standards or general standards of reasonableness, have a degree of specificity and are taken at a lower level within the organisation will be characterised as "operational" and the authority may be held to owe a duty of care to persons injured by the authority's actions.

The trend appears to be to narrow the definition of "policy" decisions and to allow judges to hear whether the authority has acted reasonably. The area of road safety audit does not appear to present a question of "policy". The issue of whether a given

highway authority chooses to adopt the process of road safety audit, or whether it chooses not to, would be considered a question of operational act, that is, its failure to repair the road. This failure to act is termed nonfeasance and is distinguished from misfeasance, taking positive action but acting carelessly. This immunity exists even if the road authority knew of the pot-hole and failed to take any action to correct it. This immunity is limited to a simple failure to repair or maintain the road. The exemption is lost, that is, a duty of care will arise, if the authority undertakes a negligent action. The immunity is considered an historical anachronism and its ambit is strictly limited. Only highway authorities enjoy this immunity. Any government agency which undertakes the construction, maintenance and repair of roads, including state or local government, is included in the concept of a highway authority. The authority must be acting in its capacity as a highway authority and not in any other capacity. For example when an authority is creating a drainage system or improving the environment, it cannot take advantage of the immunity.

Only the highway and structure related to highway purposes are subject to the immunity; not artificial structures. Drains which serve the highway, and bridges and culverts are considered to be part of the highway for purposes of the immunity, but trees and other roadside furniture are not within the scope of the immunity.

3 Road Safety Auditors

3.1 Skills and Experience required:

Road Safety Auditing is a 'specialised task' which requires specific knowledge and experience related to traffic engineering, traffic management and road safety principles and practice. A good understanding of traffic engineering, traffic management and the human factors involved in the Driver/ Vehicle/ Road Environment interaction is necessary, and preferably some experience in traffic accident site investigation and countermeasures. Experience in the various aspects of planning, design, construction and maintenance of roads is also desirable.

Usually people competent and experienced in the work associated with traffic accident investigations and countermeasures have most of the basic skills required for RSA.

For large complex road projects, which will be audited at all recognised audit stages, it will be generally desirable to use an 'Audit Team', the composition of which may change for the different audit stages. Such a team approach has a number of advantages such as having the ability to include people with special knowledge or experience in respect to a particular aspect of the work being audited, or in respect to the specific safety requirements of various road users. It also allows different viewpoints and perspectives to be considered, eg. in regard to the degree of hazard associated with a particular road feature. A team approach also allows "more pairs of eyes" to view the safety attributes of a project.

Where a team of 2 or more auditors are selected, and this is desirable where it is difficult to find one person with the necessary skills, one of the team should be nominated as the 'Team Leader' or RSA Manager.

3.2 Independence Of Auditors:

The credibility and effectiveness of a RSA, (as with any type of audit) is greatly influenced by the degree of independence of the auditors from the planning, design or construction teams involved in the development of the project. Auditors need to be free of any inhibitions arising from a close association with the designers, and the fear of being critical of the work of professional colleagues. They need to view the project with 'fresh eyes' and without the encumbrances of design ideologies that often develop around a particular office or project. However auditors need to be mindful of the need to maintain good communications with designers, builders etc. as their co-operation is often essential in finally correcting any identified deficiency. They also need to be sensitive to the fact that no one likes criticism and comments and recommendations need to be stated in a constructive (rather than a destructive) manner. In considering the independence of auditors, it is important to recognise that independence must not only be achieved but must be 'seen to be achieved'.

3.3 Accreditation Of Auditors:

It is the policy of JKR that the individual people undertaking a RSA must have an accreditation for this work and be identified in the Audit Report. The accreditation requirements may change from time to time, but will be based on an assessment of the person's knowledge of road safety principles and practices, completion of an approved RSA training course, and general knowledge and experience in road and highway engineering.

4

Organisational Arrangements For Road Safety Auditing

The following discussion on auditing arrangements focusses on two issues which organisations involved in road safety auditing need to resolve:

- Organisational arrangements for doing an Audit,
- Assessment of an Audit Report and its findings.

4.1 Arrangements For Doing The Audit:

There are a number of ways to arrange Road Safety Auditing to achieve the above requirements and different arrangements may be adopted for different projects or different audit stages of a large project. In the following discussion, reference is made to the three parties usually involved in Road Safety Auditing:

- ***The 'Designer(s)'*** of the project, (or, in the case of 'Construction Stage' audit, the Contractor). The former may be from an 'in-house' design unit, or Consultants engaged by the 'Road Authority'.
- ***The 'Client'***, who is the Road Authority responsible for the project, but usually represented by the senior 'Line Manager' or the 'Project Manager' responsible for the project,
- ***The Auditor(s)***, who carry out the audit. Again they may be from within the Department, or be Consultants engaged by the client.

The following alternative arrangements for conducting a Road Safety Audit and for dealing with the resultant RSA report, are available and they are discussed in preferred order :

4.1.1 Audit by independent RSA Specialists:

This method is by far the most desirable auditing arrangement as it usually involves highly skilled auditors who are clearly independent of the original designers.

The RSA specialists may be "in-house", ie. a separate specialist group within the Department, or they may be available from Consultants with technical staff accredited in this particular field. As RSA is a relatively new field of expertise particularly in Malaysia, it is desirable that both options be encouraged to develop.

From a departmental point of view the development of an 'in-house' specialist Traffic and Road Safety Unit has advantages beyond those of RSA, and most Road Authorities throughout the world incorporate such specialists within their organisations. These 'specialist' units provide skilled services on traffic and road safety matters to other units or sections within the department and to outside organisations.

The development of competent Consultants in the road safety field is essential in view of the inevitable limitation of Government resources. Furthermore the use of Consultants provides the best opportunity to 'be seen' to achieve true auditing independence.

In this case, the Audit Report and Findings may be dealt with in a number of ways:

- Prior Agreement (between the Auditor and the Client, or the Designer, to accept the Audit Findings and to make any necessary changes to the design as part of the normal course of the design. This arrangement works best with 'in-house' auditors who can work closely with the design team. It is usual for the agreement to include a requirement that the work does not proceed to the next stage until a written approval or 'Safety Certification' is issued by the Road Safety Auditor.
- The Report may be considered by the 'Client' (represented by "an independent" senior Manager of the Department having no direct responsibility for the project or road being audited), or by an independent 'third party' (eg. a Consultant) on behalf of the Client. In respect to a 'design stage' audit, where the design is being done by Consultants, acceptable independence

would be achieved if the 'Client' was represented by the senior Manager having direct responsibility for the project.

- The Report may be submitted direct to, and be considered by, the Designer(s) or the 'Line' Manager having direct responsibility for the design of the project. The lack of true independence in this arrangement makes it imperative that the decisions taken as a result of the audit findings be fully documented to establish the accountability for the action.

4.1.2 Audit by other 'Road Designers' from within the Road Authority or Department:

Where the Design Unit of the Department is large enough to involve a number of separate 'design teams' working on different projects, and some members of the teams have the necessary RSA skills, it may be convenient for one team to audit another teams project. While the independence of such a method of audit may be questioned, it can be acceptable if the people concerned fully understand the objectivity and professionalism required. It is unlikely to be successful if the design staff are relatively unskilled in RSA work or if the overall Design Unit's design philosophy is based on 'prescriptive' techniques and 'blindly following standards'. Auditors particularly must be free of such encumbrances and be able to assess safety concerns from the application of basic principles of safe road design and traffic management.

In this case, the audit report should preferably be submitted to an independent Manager, (having no line management responsibility for the work being audited), who would decide what action should be taken. It would be understood that in this arrangement, the line manager responsible for the design would accept the decision of the independent assessor and direct the original designers accordingly.

The independence of the manager assessing the report is essential in this arrangement to help offset any apparent lack of true independence between the design team and the audit team when they come from within the one design office.

4.1.3 Audit carried out by a member of the project's Design Team:

This is the least favoured method for carrying out an audit because of the difficulty of achieving, and 'being seen to achieve' real independence in the audit. However, if other arrangements cannot be adopted, this method is better than no audit at all.

In this case the objectivity of the audit is so substantially compromised, that it cannot be offset by greater independence of the assessor and the report may be submitted to the manager of the Design Team or Unit for decisions on the actions required. Again, as with other auditing arrangements, the decisions and actions resulting from the Audit Report must be documented and recorded on project files, to ensure accountability for the actions taken.

This method of audit can work satisfactorily if at least one member of the design team is recognised to have strong skills in safe road design, commands the respect of other designers in the team, and can work closely with them providing advice and 'quick checks' as the design work proceeds. In such an arrangement, the audit report may take the form of 'minutes' and 'discussion notes' in which a safety concern is identified and the agreed corrective action is taken and recorded.

4.2 Arrangements For Assessing The Audit Report:

The major value of a RSA is in the action that takes place to correct the safety deficiencies identified by the auditors. The RSA report itself is of little value unless its findings are dealt with quickly by someone in the clients organisation who has the authority to direct that corrective action be implemented. Arrangements for this assessment and decision-making is an important commitment for the client organisation.

The person nominated to deal with the audit report has an important responsibility and ultimately will be accountable to the public in respect to the decisions made on the RSA findings. As is the case in respect to carrying out the audit, it is important that the person dealing with the report be as independent as practicable from the auditor(s) and from the Project Designers or, in the case of Stage 4 audit, the Works Supervisor. This is to ensure that decisions made to either accept or reject the audit findings are "made without fear or favour" and can be seen by all interested parties (including the public if necessary) to be entirely objective.

Arrangements for assessing the audit report may vary depending on the organisational arrangements for the audit and some guidelines for this are provided in the preceding section of this guide. The role of the nominated assessor is to consider each and every point raised by the auditor(s) and to decide, in each case, whether to accept the audit finding and direct corrective action to be taken, or to reject the audit findings. In both cases it is essential that the decision, and reasons for it, are properly recorded and documented, as this would be important evidence in any possible future litigation arising out of traffic accidents in respect to which the organisation or road authority persons involved may be alleged to be negligent.

5

When Should Road Safety Auditing Be Done?

One of the important objectives of RSA procedures is to enable action to be taken to correct an identified safety concern at the most opportune time to avoid costly re-design or even more costly re-construction. To achieve this the process must be staged at particular times in the development of a project.

The 5 Stages Of RSA:

It is now becoming commonly accepted that there are Five (5) Stages in the development of highway / road projects at which it is most appropriate to carry out RSA. However on projects of a minor scale, road safety auditing may be limited to just 2 or 3 stages. Auditing should start at the earliest practicable stage in the development of a project to avoid making planning or other early commitment which 'Lock-in' features which , at later stages in the design process, will not allow a safe design to be achieved and thus result in unsatisfactory safety performance.

Four of the five Road Safety Audit stages relate to new projects including reconstruction of existing roads and the fifth stage applies to the audit of existing roads. The following notes identify and discuss each of the five Audit stages:

5.1 Feasibility & Planning Stage (Stage 1 Audit):

This is the earliest recognised stage of RSA and it may not always be applicable, particularly on very simple projects or those involving only minor improvements such as some road rehabilitation works. It is particularly desirable to audit all major transport infrastructure projects at the Planning and Feasibility stage to avoid commitments which, in later stages, have unfortunate safety consequences.

Auditing at this stage will identify safety problems associated with the overall concept for a project, road network safety implications, route options, intersection and interchange types and locations. It will also consider the safety implications of strategic issues such as access control and provisions for various road user groups such as pedestrians, cyclists, motorcyclists, heavy trucks, etc. which may need special emphasis generally or on a particular part of a project.

5.2 Draft (Preliminary) Design Stage (Stage 2 Audit):

It is at this stage that many of the traffic engineering features of a project are established. Most of these, such as cross-section elements, intersection/interchange layout, lane and carriageway layout, traffic control options, vertical and horizontal alignment standards (and any constraints thereon) etc, have a very marked effect on the safety performance of a project. Furthermore it is generally at this stage that 'Right of Way' requirements are finalised and if this is not adequate it may 'lock-in' unsatisfactory design features.

5.3 Detailed Design Stage (Stage 3 Audit):

In carrying out detailed design, designers are continually making balances of judgement in the selection and application of standards and guides to meet the specific site conditions relevant to each particular project. RSA at this stage will 'test' the design decisions made against road safety objectives and will identify aspects in which safety has not been given high enough 'weighting' compared to other competing factors. It will also identify potential hazards resulting from adverse combinations of vertical and horizontal alignment, or from choosing a series of 'minimum' / 'maximum' design criteria. Other undesirable features associated with the final grading, drainage

and landscaping design as well as those arising from the traffic signing, traffic controls and street lighting which will be finalised in the detail design stage, can also be identified at this stage of Audit.

5.4 The pre-opening stage (Stage 4 Audit):

Audit at this stage involves site inspections of a project, both by day and at night, at, or just prior to, its practical completion or, just prior to opening a new project to traffic. The auditors can now see the project in three dimensions and including any changes/ modifications made during construction. The actual placement of items such as guardrailing, traffic signing, street lighting, landscaping etc. are looked at in detail and particular emphasis should be given to checking that the respective needs of **all** road user groups meet desirable safety standards.

This will be the last chance to make sure that the project opens to traffic in the best condition to provide safe and efficient operation.

The Stage 4 audit generally also includes the audit of traffic management in and around the works area during the period of construction. Such auditing is usually done as early as possible in the construction phase and periodically during construction as may be necessary to cover changes to traffic management as the work progresses.

5.5 RSA of An Existing Road (Stage 5 Audit):

Road safety audits are desirable also on existing roads regardless of them having been audited during planning, design and construction. An audit at this stage will identify safety problems which develop due to normal 'wear and tear' from traffic operation. It will also identify hazards due to the way the landscaping has matured, e.g. trees and foliage obstructing traffic signs or sight distance impaired. Inspections by day and night are essential to check inadequacies in delineation and visibility etc. Apart from any relevant plans, the auditor should have available data on the accident history along the route and traffic flows etc. so that a proper assessment can be made of the roads' safety performance. Again the stage 5 audit will particularly look at the way each road user group 'sees' the road from their particular safety viewpoint.

The stage 5 audit differs from 'Black Spot' identification and treatment in that it attempts to identify and correct potential hazards **before** accidents occur due to them (ie, it is pro-active rather than re-active).

Stage 5 type audits of existing roads may include sections under construction or undergoing maintenance operations. Such audits may include many of the items involved in Stage 4 audits such as traffic safety situations associated with roadworks signing and traffic management through the works area.

6

A General Procedure for Road Safety Audit

RSA need not involve a complex procedure but it is desirable for it to be a formal 'Step by Step' process, which can be properly integrated into normal design and construction programs, especially for large projects.

6.1 Key points in the procedure:

- Preparation of the 'Audit Brief ' setting out details of the audit arrangements and timing, appointing the Auditor(s) and deciding on the organisational arrangements for the audit and for dealing with the Audit Report.
- Assembling the background information, plans to be audited, design criteria and traffic information etc, including a statement of the projects objectives.
- Conducting the audit and preparing the report.
- Dealing with the Audit Report, making decisions on the findings and directing the action necessary to correct the traffic safety problems identified.

A 'Step by Step' approach to the auditing procedure is illustrated in Figure. 6.1.

ACTION		RESPONSIBILITY
Step 1.	Preparing Audit Brief; Appointing the Auditor(s), Appointing the Independent Assessor.	Client / Designer / Construction Manager
Step 2	Assembling Background Information, Plans to be audited, and other documents	Client / Designer / Construction Manager
Step 3	Initial Meeting with Auditor(s); Handing over of plans etc for audit; Discussions, arrangements for inspections etc.	Client / Designer / Construction Manager.
Step 4	Doing the Audit , examining the plans, site inspections etc	Auditor(s)
Step 5	Preparing the Audit Report	Auditor(s)
Step 6	Completion Meeting (if required), Presentation and discussion of Audit Findings.	Client / Designer
Step 7	Deciding the action required on the Audit findings	Client / Independent Assessor

Figure. 6.1 Road Safety Audit Procedure - Step By Step

6.1.1 Appointing the Auditor(s):

A RSA may be carried out by one appropriately skilled person or by a team of people bringing together a range of skills and experience. The latter is usually preferred for large complex projects and is generally favoured for most projects because it allows a range of perspectives and opinions to be considered. A team may comprise two to four people depending on the size and complexity of the project. Where specific skills or experience is desirable to properly consider a particular aspect of a project, a person with these skills may be invited to join the team for a limited time while the particular aspect is being considered. If a 'Team' approach is being used, it is desirable for one member of the team to be nominated as the Team Leader or Manager, who would be responsible for coordination of the team effort and the general running of the audit.

The basic requirements of people who can undertake RSA are discussed in Section 3. above and it is recommended that Client Organisations, such as JKR, maintain a register of people with the necessary skills and experience both from within the organisation and from external consultants. The important attributes sought in the auditor(s) are reiterated as follows:

- Independence (from involvement in or responsibility for the work being audited):
- Skills, Experience and Training: in Road Safety Engineering, Traffic Engineering, Traffic Management, Road Design, and Traffic Accident Investigation and Countermeasures.
- Good Conceptualising Skills and aptitude to foresee potential safety problems from the viewpoint of various road users.

6.1.2 Providing The Background Information Required For The Audit:

In preparation for a RSA, the Client or Designer of the project must assemble all the necessary plans, specifications, reports, including information on traffic volumes, operating speeds, where applicable, traffic accident data etc, that will be required by the Auditor(s). In addition, a statement of the project's 'Design Criteria', indicating the functional classification of the road, minimum design speed, cross-section standards, extent of access control, and any special provisions being made for particular road user groups, needs to be provided to the Auditor(s).

If the project has been subjected to 'earlier stage' auditing, the details of this, along with the decisions on audit recommendations must be made available to the auditor(s).

6.1.3 Meetings:

On medium to large projects particularly, it is desirable to initiate and maintain close liaison between the Auditor(s) and the Client throughout the process. In this regard, a formal meeting between the Client , the Auditor(s) and the 'Designers', or the Construction Contractors, (in the case of a Stage 4 Audit), is desirable to initiate the actual Audit. Further meetings may be necessary during the course of the audit and it is generally an advantage for a 'completion' meeting to be held to give the auditor(s) an opportunity to present and discuss their findings with the Client, the Designers and the Independent Person appointed to assess the report.

6.1.4 Equipment Needed By The Auditor(s):

The auditor (s) will need to have available most of the design equipment, manuals, guides and other references used for the planning and / or design of road projects. However whereas the original design may have been developed using computer techniques, auditors will usually carry out their checking by manual methods, thus they will need equipment such as scale rules, straight edge, curve templates, design vehicle turning path templates, hand calculator etc. In the case of Stage 4 and Stage 5 Audits, involving detailed field inspections, auditors will need equipment such as measuring tapes (or wheel) and desirably a photographic camera for recording features which are discussed in the report.

6.1.5 Audit / Review Of Design Plans And Specifications:

The audit should proceed in a logical and systematic manner so that all of the items which may influence operational safety are effectively reviewed. It is particularly important to be aware of and to check the situations which involve a combination of different design elements. For example Sight Distance at a particular location may involve a combination of horizontal and vertical alignment, cross-section and landscaping details and possible other items such as traffic sign placement and guard railing.

The use of a 'Check List'(discussed later), which sets out the items to be reviewed in a logical sequence, helps to ensure that important items are not overlooked and that the interdependence between various elements is recognised.

The Auditor(s) should confine their review to road safety matters and avoid issues such as aesthetics, amenity, and traffic capacity / level of service, unless these aspects can be related to a safety deficiency. For example it would be appropriate to discuss aspects of traffic capacity in a case where the lack of capacity may lead to excessive vehicle queues, particularly if such queues extend into a hazardous zone.

The safety review should consider the extent to which the design complies with current traffic engineering and road design standards, guides and practices. However it needs to be recognised that mere compliance with standards does not necessarily guarantee an adequate level of traffic safety. In many cases, standards and guides are based on an "average" condition which may not be applicable in all cases and designers (and auditors) should check any particular situation using basic road safety engineering principles. Not withstanding this, current JKR Standards and Guides should be the 'starting off' point and they should be complied with unless it can be shown that a better (safer) practice can be achieved by applying other standards and Guides, eg more 'up to date' standards or applicable overseas standards.

6.1.6 Site Inspections:

Site inspections are an essential element of Stage 4 and Stage 5 audits. They are also desirable for other RSA stages so that the auditor(s) have some familiarity with the location and general environment involved with a particular project, and can better visualise how the design will look to road users when it is completed. Arrangements for such inspections should be made at the initial meeting between the auditor(s) and the client.

In Stage 4 and Stage 5 audits, site inspections should be carried out both in the daytime and at night. In the Stage 4 audit, site inspections may need to take place at various times during the construction period as different parts of the works reach an appropriate stage of completion. It is particularly necessary to inspect the traffic management arrangements if these are changed significantly as the works progress. As with any other part of a RSA, at site

inspections auditor(s) need to view each aspect of the project from the perspective of the various road user groups who have different safety needs such as:

- Child pedestrians have a low 'eye height' and young children have difficulty in judging speed. Their small height often means their visibility is obstructed by trees, shrubs and low mounted road furniture.
- Pedestrians generally will not walk far 'out of their way' to use special facilities provided for them.
- Elderly pedestrians are less agile, have poorer eyesight and hearing, and have difficulty with high kerbs and steps.
- Truck and bus drivers whose greater 'eye height' improves their sight distance, but can be disadvantaged by this due to high mounted traffic signs and overhanging foliage and in respect to the effectiveness of retro-reflective delineators.
- Bicyclists, and to some extent light motorcycle riders, have more difficulty than other vehicles in coping with surface irregularities, manhole covers and grated drainage pits etc.

Inspections also need to consider the various manoeuvres and movements made by the various road users, such as pedestrians walking along and across a road, and vehicular movements along a road and turning into and out of the road.

6.1.7 The Use Of A Check List:

The systematic conduct of a road safety audit can be assisted by the use of a 'Check List' which itemises the key points and issues to be considered when auditing at the various stages of a project or auditing an existing road. However it is important to understand that check lists are intended only to be a 'Prompt', or a 'Reminder', to help auditors to avoid missing out important items, particularly in a large and complex project audit.

The Check Lists provided in this manual are not a prescription for the way to do an audit, although they have been set up in a logical way which may be used as a guide when organising the way to do an audit. In particular, Check Lists should not form part of the audit report and Auditors are cautioned against simply annotating a copy of a Check List and submitting it as the audit report. The use of a Check List by unskilled auditors must not be considered as a substitute for the use of properly skilled auditors with knowledge, experience and understanding of sound traffic engineering and road safety principles.

6.1.8 Recording Of Information:

There are various ways of recording the information observed during the site inspection of an existing road. The most basic method is to make written notes of each item, recording the observations made against the kilometer distance (Section Number) at each location. Each direction of travel may be dealt with separately or simultaneously. In the latter case items are recorded as 'left' or 'right' of the centreline for the direction of increasing kilometer (Section) distance.

When making field notes it is desirable to include references to a any plans etc. which the auditors may have illustrating the layout and other geometric details of the road. Such plans are very useful and can be marked up with various observations and comments. Where such plans are not available, it may be necessary for the auditors to make sketches of various road features to illustrate safety relate problems and observations.

In most cases it is almost essential to use 'still' photography, standard 35mm colour pictures, of the general and specific safety related features along the route. This is essential for the recording of traffic flow conditions, sight distance restrictions, traffic signing problems and many other items. These pictures are invaluable for inclusion in the final Road Safety Audit Report.

Where a video camera is available, it can be very useful in recording both the general

view of the road as seen by vehicle drivers and particularly for recording traffic operation at critical locations. Such recordings can later be used to obtain counts of vehicles, dynamic records of high risk traffic behaviour and other notable traffic operation. The video recording is particularly useful as it allows the auditors to re-view site conditions and traffic situations as often as necessary during the formulation of the final report in the office. Although the video recordings may be submitted with the RSA report, it is usual for the written report to be prepared is such a way as to not require reference to the video.

6.1.9 The Road Safety Audit Report:

The report should provide the client or other decision makers with a full and comprehensive statement of the road safety concerns and implications of the project planning, design, construction or of an existing road as the case be. It needs to be set out in a logical format, be as brief as possible consistent with adequately describing and discussing the items identified as safety deficiencies. There is no rigid format for such reports but it should contain the following items:

- Introduction

  This should set out the scope and objectives of the required audit, the location details, timing etc, and any administrative arrangements for submission of the report.

- Details of the Auditor or Audit Team.

- A summary of all information made available to the Auditors.

  This would include proper identification of any plans and maps, reference to any traffic data such as accidents, traffic volume, composition, speed survey data etc.(details of which may be included as an appendix to the report). This part should also include reference to any previous stage audit and decisions on the findings of such audits.

- Details of the road safety audit / review carried out.

  This will form the bulk of the report and will discuss the safety implications of the plans and other relevant documents associated with the project including site inspections, field observations and comments. A summary of the safety deficiencies and issues identified in the audit together with an indication of the relative importance or severity of the deficiency or the urgency of corrective action should be included in the report.

  This part of the report may also include any comments and discussion of possible corrective treatments, although this is not an essential requirement of RSA generally.

  To set up the report in a logical way the various items may be discussed under headings in the order set out in the 'Check List' for the particular audit stage being conducted, e.g. for a Stage 3 Audit:

  Horizontal and Vertical Alignment, Cross-section, Interchanges, Intersections, traffic signals, traffic signs, road marking and delineation, traffic signals, street lighting, landscaping, roadside safety, General traffic management, etc, or could present the audit findings in a sequential order or in 'Chainage Distance' order.

  The report should include any 'mark-up' of plans, maps, and any sketches and photographs necessary for the clear description of the safety concerns identified in the audit.

- Conclusion and Signature of the Auditors. The conclusion will usually be quite brief, consisting of a general summary of the key findings only and highlighting any particular feature which may merit special reference or attention.

  In respect to the auditor's signatures, where an 'Audit team' approach has been used, and an audit manager has been appointed or nominated, it is usually acceptable for the report to be signed by the audit manager on behalf of the team.

7.1 STAGE I AUDIT - PLANNING AND FEASIBILITY STAGE.

One of the major objectives of road project planning is to ensure that feasible alternatives are identified and adequately evaluated against set performance standards. Such evaluation standards should always include desirable safety criteria along with other performance measures such as traffic capacity and level of service (mobility), economic and environmental considerations.

Safety audit at the early stages of a project will identify unsatisfactory safety characteristics and associated planning and design aspects which may 'lock-in' solutions and constraints on detailed design, construction and operation which may ultimately lead to unsatisfactory safety performance.

7.1.1 Traffic Planning Strategy and Route Standards:

The general geometric standards adopted for various routes and the structure of the existing or proposed road network in the region of major road projects has significant implications for traffic safety. The planning of major road projects should include a clear statement of the proposed traffic management strategy, its goals and objectives for the route or the region in question, as this sets the framework for the traffic safety requirements of the project.

7.1.2 Road Network Considerations:

The safety effects of large road projects often extend into the surrounding road network and the effects may be either beneficial or detrimental in terms of road safety. The following aspects would be considered in respect to this:

- the adequacy of the road heirachy and suitability of network connections, particularly to ensure adequate capacity for the expected traffic demands throughout the life of the project, and to achieve a balanced traffic loading and 'level of service' on different parts of the road network;
- changes in traffic patterns which may place additional traffic on routes which have low safety standards;
- the location, spacing and type of interchanges and/or intersections, to ensure adequate lengths for acceleration, deceleration and weaving;
- the location of the terminals of the project and adequacy of proposed traffic management arrangements at these locations.

7.1.3 Geometric Standards:

The general route standard must be consistent with the intended function of the route in the road hierarchy of the region and should cater for the expected traffic demand at an acceptable level of service throughout the expected life of the project. The route standard must also be consistent with the nature of the topography and the environment through which the road passes. The finished project must meet community expectations both in respect to safety as well as mobility.

Some safety aspects of route geometric standards to look for in a Stage I Audit for include:

- the suitability of the general route functional classification, as this sets a number of important design criteria,
- appropriate standards of horizontal and vertical alignment,

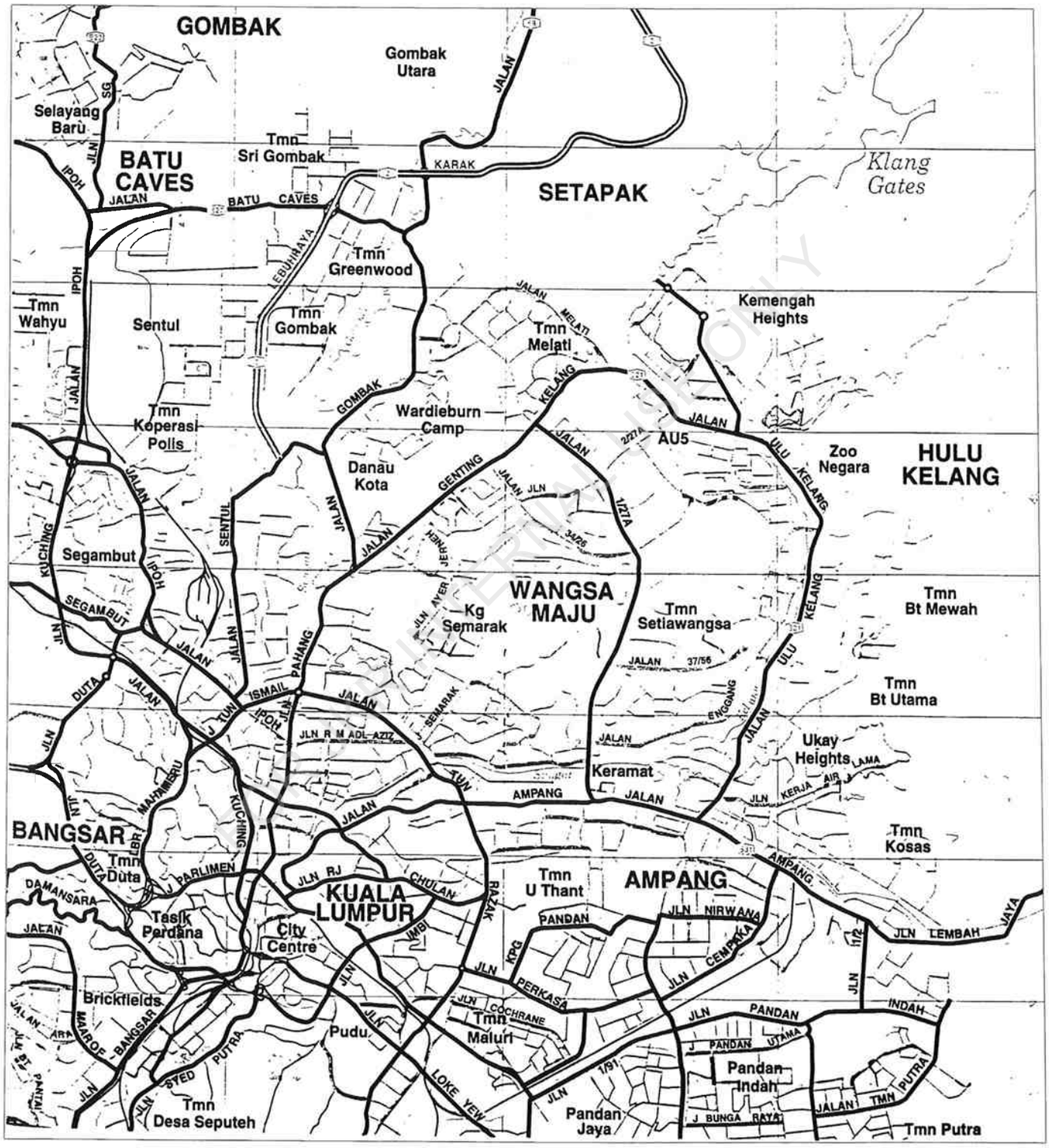


Figure 7.1 : Road Network Considerations

- lane and carriageway arrangements which provide 'through route' continuity and consistent application of design standards along the route,
- appropriate cross-section to meet projected traffic demand, including adequate allowance for safety clearances to landscaping, noise attenuation walls (where necessary), road furniture, utility poles etc, and for the requirements of grading and drainage etc,
- spacing and form of interchanges and/or intersections in as much as these may influence the need for and the length of auxiliary lanes and weaving sections etc.

7.1.4 Provisions For Special Road Users:

There is a tendency in most road planning to focus attention on motor vehicles, especially cars. The particular requirements of various road user groups need to be highlighted in the planning and preliminary design (feasibility) processes.

In particular the safety needs of vulnerable non-motorised road users, - pedestrians, bicyclists, and where relevant, the needs of people with disabilities, elderly citizens and children, demand specific attention.

On some projects, special provisions may be necessary for particular classes of motor vehicles e.g. motor cycles, trucks and buses, which can form a substantial proportion of the total traffic flow at some locations. Each of these road user groups have specific safety related needs which may influence overall concept planning and later functional and detail design. In view of the high proportion of motorcycles in the traffic stream and their high accident rate, specific provisions need to be made for them. The audit should take particular note of the adequacy of such provisions in the planning of road projects.

Motorcycle safety is enhanced by segregating them from other vehicular traffic

Positioning the signal pole too far ahead of the 'stop' line results in motorcycles, and sometimes cars, encroaching into the pedestrian cross-walk.

Uncontrolled children / pedestrian movements, vehicles stopping, loading and parking at schools produces high risk situations.

Pedestrians at risk walking along roads with no footpaths

Bicycle Riders also need to be catered for particularly near schools

7.1.5 Access Control:

The decision to adopt a particular functional classification for a road includes an acceptance of appropriate forms and extent of access control. The location and type of connections where traffic enters, leaves or crosses the main route, and the adequacy of these to serve the adjacent land uses and developments have critical road safety implications. The audit will note any inconsistency in, or any lack of provisions for access control where appropriate.

Due to the wide range of situations encountered, particularly in developing areas, it may be proposed to stage develop the access control and the safety implications of this needs to be investigated at the planning and preliminary design stage. For example. 'At-grade' intersection may be proposed on an expressway route at the initial construction, with these to be later converted to fully grade-separated interchanges.

The development of a strategic approach to access control is important in achieving consistency in the treatment of traffic conflict along a route and thus enhancing driver expectations. These are desirable road safety objectives which would be considered in RSA at this stage. In formulating access control strategies, it is also important to consider the requirements of the various road user groups as discussed above.

7.1.6 Consideration of Alternatives:

At the planning and feasibility stage it is usual for a number of alternatives or variations to be investigated. These may include alternative route locations and different geometric standards, or alternative forms of interchanges/intersection, variations in the way access control is handled or in the particular provisions made for various road user groups.

Such alternatives and variations are usually evaluated against set criteria and it is important to check that the road safety implications are included in the evaluation criteria and that these factors have been properly evaluated.

CHECK LIST

ROAD SAFETY AUDIT - STAGE 1

Planning and Feasibility Stage

Information Required For The Audit:

- Maps/Plans of the region and road network;
- Traffic Reports showing existing and projected Traffic Flow information on the arterial road network;
- Details of any proposed local and area-wide traffic management stategies;
- Maps/Plans showing existing and proposed land-use strategies;
- Planning reports and associated plans, typical cross-sections, proposed gradelines etc comprising the plans to be audited.

Audit Items:

- **Road Network Effects:**
  General Traffic Management Strategy;
  Functional Classification of the road in question;
  Network Sturucture & Heirarchy;
  Major Traffic Generators;
  Location & Spacing Of Intersections/Interchanges;
  Terminal Problems;
  Access control strategy;
  Traffic Management during construction
- **General Geometric Standards:**
  Appropriate to Route Class, Function, Topography & Environment;
  Meeting Community and Road User Expectations;
  Route Continuity & Consistency;
  Stage Development Of The project;
  Unusual Features such as Tunnels, Long Bridges which may have reduced standards.
- **Outline Provision For Users with Special Needs:**
  Pedestrians;
  Pedal Cyclists;
  Motorcyclists;
- **Access Control Details:**
  Use of one-way or two-way service roads?
  Consider the needs special road user groups;
  Adequacy of alternative routes of access where access is restricted.
- **Environmental Considerations:**
  Prevalence of High Winds, Fog etc;
  Scenic vistas and outlooks which may distract driver attention.
- **Consideration Of Alternatives:**
  Is Road Safety Performance includeed in the evaluation criteria.

7.2 STAGE 2 AUDIT - PRELIMINARY (DRAFT) DESIGN STAGE.

The early project planning and feasibility studies usually involve small scale drawings and topographic maps and it is not practicable to evaluate many of the safety implications of the proposed geometric layout on these. The first opportunity for auditing these aspects occurs at the preliminary design (functional layout) stage when the project really starts to take shape.

Safety audit at this stage needs to be carried out towards the end of this phase to ensure that all aspects of the layout in plan form and the preliminary vertical alignment are available.

The following aspects will be subject to detailed review to determine their safety implications.

7.2.1 Cross-section And Reservation Width:

The various elements of the cross-section need to be examined in terms of their safety effects. For example: is the shoulder width adequate and consistent along the route; have auxiliary lanes been provided at the relevant locations to segregate high speed through traffic from turning, 'exiting' or 'entering' traffic? The auditor will consider whether the number of traffic lanes along the route are adequate to ensure a balanced 'Level Of Service' and the avoidance of 'bottlenecks' or isolated locations with substantially lower level of service (at the 'design traffic demands') than that available along the route generally. The audit will check, in a general way, that appropriate provisions have been made for superelevation on curves, particularly for reverse curves, curves through intersections and interchanges etc, and the effect of curves on steep down grades.

The auditor will check the proposed typical cross-section to see if appropriate provisions have been made for motorcycles, pedal-cycles and pedestrians.

While a general reservation width may be set at the planning stage, details of the 'right of way' requirements will usually be set at the preliminary design stage. The audit should check the safety implications of the proposed 'right of way' provisions and identify any aspects which tends to 'lock in' constraints on the designer and result in a reduced standard of safety. Decisions made at this stage in respect to reservation width and land acquisition are usually crucial to the achievement of safe and efficient geometric design.

7.2.2 Horizontal and Vertical Alignment:

The safety effects of the general standard of horizontal and vertical alignment needs to be carefully evaluated. The auditor will look for consistency along the route, meeting driver expectations, providing adequate sight distance and avoiding hidden pavement areas, (which could arise from unsatisfactory combinations of vertical and horizontal alignment). The audit will also check the occurrence of long lengths of steep grade and the need for overtaking lanes or other auxiliary lanes, the locations of intersections, traffic islands, exit and entry ramp noses, merge areas and weaving sections etc. which are other features where good sight distance is essential and where the combination of horizontal and vertical alignment (and cross-section) needs to be considered.

7.2.3 General Layout Features:

The following general layout aspects will be of particular interest to the safety auditor in a Stage 2 Audit:

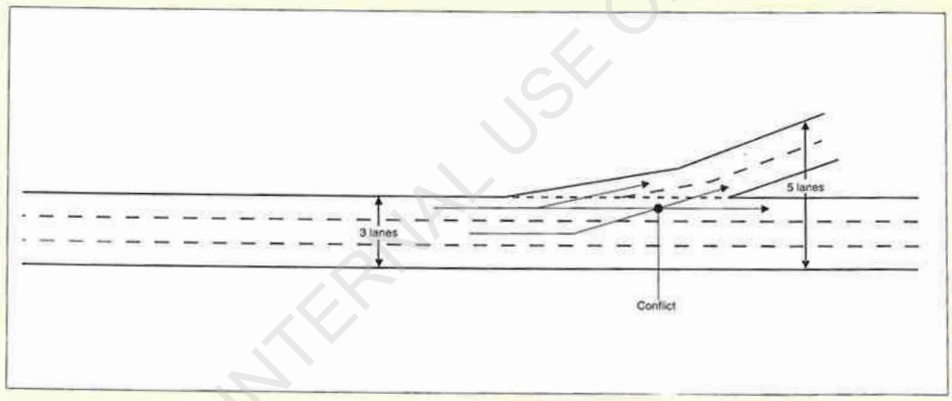
(a) Expressway Type Arterial Roads:

- the use of a consistent exit and entry arrangement. Desirably these should always be on the left hand side of the through carriageway, except where the majority of traffic is exiting the route.
- the provision of auxiliary lanes, achieving proper 'lane balance' and 'through-lane' continuity and the avoidance of 'trap lanes', to avoid unsafe exit and entry manoeuvres and to ensure a uniform level of service.
- the avoidance of large level differences between ramps and through carriageways in the vicinity of the ramp nose (this ensures adequate visibility of the ramp direction and avoids having guardrails or barriers in the vulnerable 'gore' area), of a curve and entry ramps on the inside of curves, or where these are unavoidable, checking that the proper treatment is provided to ensure their safe operation.
- the minimisation of weaving situations, or where they must be used, the provision of adequate weaving length and the inclusion of auxiliary lanes where such features are required.

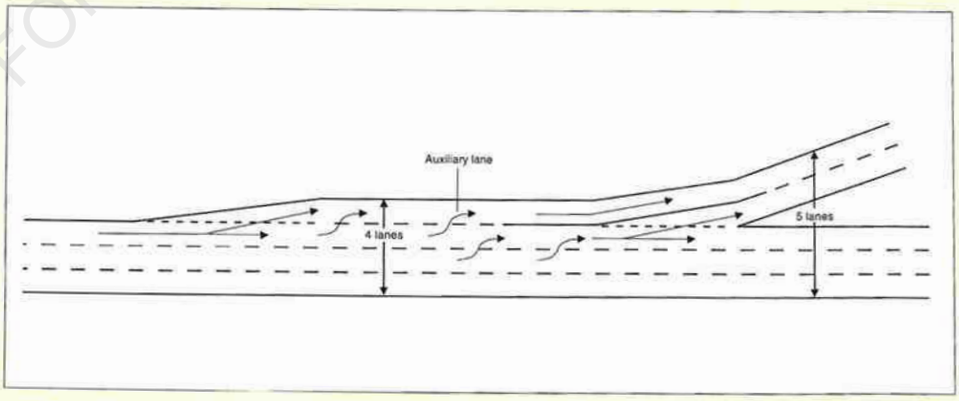
(b) Non-Expressway Type Arterial Roads:

- The provision of traffic control at intersections appropriate to the class of road, the environment and the traffic flows.
- the provision of adequate auxiliary lanes to segregate through traffic from turning traffic maintaining continuity of through lanes and avoiding 'trap' lanes.
- the provision of adequate widths for turning vehicles, taking into account the needs of trucks and buses. This includes appropriate 'curve widening' at low radius curves and in left turn slip roads, and the provision of adequate clearance between opposing right turn vehicle paths at intersections.
- the provision of appropriate median and island widths/size to accommodate the staging or refuge of pedestrians and to cater for any necessary traffic signals, traffic signs or other road furniture items. On 'dual carriageway' roads the median width needs to be sufficient to cater for 'indented' right turn deceleration/storage lanes at intersections and mid-block U-turn openings.
- the provision of adequate sight distance on all approaches to intersections, pedestrian crossings, railway crossings, etc. Several different sight distance criteria may be applicable and each needs to be checked. (As all of the grading details, traffic signing and landscaping etc. are not usually available at this stage, sight distance will need to be checked again at the Stage 3 Audit).
- The appropriate treatment of deceleration and acceleration lanes where these occur on curves. The particular safety concern here is with the 'start' and 'end' tapers which, if not done carefully, may lead 'through' traffic un-intentionally into the auxiliary lane.
- the avoidance of high angles of skew at intersections which can result in high relative speed crashes and difficulties of sight distance.
- Proper and adequate provisions for pedestrians to cross busy roads with continuous traffic flow, and the provision of adequate footpaths along such roads.
- Adequate provisions for motor cycles, such as special marked lanes (or separate carriageways) where these can be justified.
- Provision of appropriate layout at access driveways, consistent with the access control strategy.
- achieving sight distance standards to traffic control signals, regulatory and direction signs (as far as this can be assessed at this stage. The auditor will look particularly at locations where intersections occur just over crests in the vertical alignment or at sharp bends in the horizontal alignment.

The design of two-lane exits from an expressway without auxiliary lanes results in high risk traffic conflicts.



(A) Incorrect Exit Layout
- *Lacks lane balance*
- *reduces capacity,*
- *encourages high risk conflicts*



(B) Correct exit layout,
- *Achieves lane balance,*
- *avoids 'trap' lanes*
- *eliminates conflicts*
- *gives full 2 lane exit capacity*

7.2.4 Road safety audit of major land use developments:

Land use development ranging in size from local drive-in 'fast food' stores up to major shopping centres, commercial and industrial developments and cultural, recreation and sporting venues, all have significant implications for road safety. The safe and efficient operation of these facilities is as important to their economic viability as it is to the country's road safety objectives.

The driveways and access roads serving the major developments need to be considered in the same way as intersections and interchanges on the road system generally. However the following additional aspects should be considered in any safety audit at the planning and preliminary layout stage.

- the extent of congestion which is likely at peak periods due to the development and the safety implications of this in terms of increased numbers of turning vehicles on the arterial road, and the possibility of traffic diverting to local streets causing increased accidents and adverse environmental impacts.
- the likelihood of concentrated pedestrian movements across the arterial road and how this is to be catered for safety.
- the adequacy of parking provisions within the site to avoid any 'spill-over' into adjacent streets and/or queueing of vehicles (waiting to enter the development) back into the arterial road.
- the safety of public transport access.

7.2.5 Stage Development Of Major Road Projects:

The provision of new major roads in both urban and rural areas often requires funding on such a large scale that stage development becomes inevitable.

The decisions relating to the strategy for stage development of a project take into account factors such as transport policy objectives, funding arrangements, availability of right of way, relative usefulness to the community of optional segments, topography, construction difficulties, provision of adequate temporary connections and traffic management implications in respect to capacity and safety.

All too often however, matters of traffic safety are not given sufficient importance in the considerations with the result that accident 'blackspots' sometimes develop at the stage terminals as soon as sections of the project are opened to traffic.

A planning stage safety audit should look for the following potential problem areas of the staging proposal:

- Low Geometric Standard 'temporary' layout Arrangements.
- There is always a temptation to apply lower geometric standards to a stage terminal in order to reduce costs. The normal principles of transitioning alignment standards so that the Design Speed of successive curves do not differ by more than 15 km/h should be applied at stage terminals. It is also necessary to ensure that the standard of alignment of existing roads leading directly from a new or upgraded road is consistent with driver expectations.
- Whilst some narrowing of traffic lanes and shoulder provisions may be acceptable - particularly if they contribute to speed reduction objectives, stage terminals should not involve abrupt changes in cross section. Of particular concern would be a stage terminal with inadequate tapering of width leading directly up to (say) a narrow bridge.
- Stage terminals of new or upgraded roads should avoid intersection zones, crests, sharp horizontal curves and locations where there is a significant difference in level between the new and existing carriageway. In all of these situations provision of the relevant sight distance requirements is essential.
- Where an ultimate dual carriageway road is proposed to be stage developed by finishing and operating one carriageway only as a 2 lane 2 way road, particular care

needs to be taken with the alignment design. This needs to consider the possible lack of overtaking opportunity due to sight distance limitations which may be satisfactory for dual carriageway operation but not for 2 way operation.

- Where a long length of expressway is to terminate by running traffic directly into a surface arterial, the layout needs to help the driver adjust to the changed traffic situation. The driving task in this situation usually involves a substantial reduction in speed and requires increased driver alertness to traffic conflicts associated with other vehicles turning, parking or entering and leaving the road and the likely presence of pedestrians and cyclists etc. The provision of good traffic signing, pavement delineation and street lighting is necessary to avoid these locations becoming accident prone.

7.2.6 Case Study.(A Road Safety Audit at the Preliminary Design Stage)

Upgrading of the interchange between Johor Bahru - Kota Tinggi (Federal Highway Route 3) and the Tampoi - Pasir Gudang Highway (Federal Highway Route 17).

The Federal Highway Route 3 is a non-expressway route running from Johor Bahru to the East coast of Malaysia. Kota Tinggi, about 32 km from Johor Bahru, is the first major town along the route.

The Tampoi - Pasir Gudang Highway is a circumferential arterial route, in outer area of the city of Johor Bahru, connecting the port of Johor to Federal Highway Route 3, the North - South Expressway and Federal Highway Route 1 at Tampoi. It functions as an 'outer ring road' and is being upgraded progressively to expressway standard to improve access to the Port of Johor.

An existing 'Diamond' type interchange at the location in question is being upgraded because of serious traffic congestion and other adjacent intersections along the Pasir Gudang Highway are proposed to be progressively replaced with full grade-separated interchanges.

The information provided for the RSA was limited to the Consultants Report titled "Upgrading of Johor Port Access Road Interchange, Traffic Study". This included a preliminary layout plan of the proposed interchange, which is reproduced in this guide as Figure 7.2. It can be described as a three level, grade-separated and signalised rotary (roundabout) layout.

The proposal envisages the two highways being developed to 6 lane (3 lanes in each direction) dual carriageway standard. As stated above the Pasir Gudang Highway is proposed to be ultimately developed to expressway (freeway) standard with full control of access and (grade separated) interchanges. It is expected that Federal Highway Route 3 in this vicinity will at best have only partial control of access and adjacent intersections will be 'at-grade' with the more important locations being signalised.

The following are the main items identified in the RSA as having possible adverse safety implications:

- **Planning And General Road Network Implications.**

There was little or no discussion in the traffic report about the safety implications of the functional classification of the intersecting routes. This is an important issue in respect to road safety as there will be quite different operating conditions and different traffic management strategies, depending on the functional classification of the route. There will also be different driver expectations in respect to operating speed, likelihood of conflicts associated with intersections and other points of access, pedestrian movements, parking manoeuvres, etc, depending on the degree of access control and the treatment of intersections.

For example, the provision of a high geometric standard 'grade separated' arrangement in the Johor Bahru- Kota

Tinggi route, via the high level 'fly-over' at the proposed interchange, will encourage high operating speeds which will be inconsistent with operational safety of turning movements at nearby points of access, the safety of pedestrian crossings and possible bus operations etc in the adjacent sections of the route. The question is also raised about whether the high capacity provided by the high level grade separation on this route can be matched at the adjacent intersections or will the 'bottleneck', along with the higher accident rates associated with it, be simply moved to the adjacent intersections. Experience has shown that where at-grade intersections are interspersed with interchanges giving the impression of 'freeway' or 'semi-freeway' conditions the safety performance is usually unsatisfactory. In principle, the use of such 'split personality' roads should be avoided in the interests of road safety.

- **Interchange Form**

Various forms of interchanges have been developed to suit different road and traffic situations. (This subject is discussed in considerable detail in AASHTO 1994. However in principle it is desirable to try to provide a consistent form of interchange along a particular route if it is practicable. This enhances driver expectation and leads to more uniform traffic behaviour and reduced accident potential. Conversely, the adoption of unconventional interchange arrangements is likely to lead to erratic driver behaviour and higher accident rates.

In this case the use of a signalised rotary form of interchange is questionable both on capacity grounds and on likely safety performance. In general, signalisation of a roundabout (or rotary) layout is 'a last resort' to avoid costly reconstruction of an existing layout. It is somewhat extraordinary to plan this into a new project as the capacity is inevitably limited, due to queuing problems within the roundabout, and operation is invariably accident prone due to excessive congestion.

- **Geometric Features**

The following geometric features are questionable from a road safety viewpoint:

* The absence of auxiliary lanes to support the 3 lane exit on the Southbound approach (from Kota Tinggi). At the outset, the use of a 3 lane exit cannot be justified on capacity grounds. Without appropriate auxiliary lanes, serious conflicts usually occur between through traffic in the left lanes and vehicles cutting across from the inner (through) lanes to enter the extra exit lanes. Even on a 2 lane exit, for operating speeds <80 km/h, a 200m to 300m length of auxiliary lane should be provided for safe and efficient operation.

* Inadequate length of exit ramps for the Southbound exit (from Kota Tinggi) and the Westbound exit (from Pasir Gudang). The signalised rotary arrangement is likely to involve long cycle times at peak periods and thus the potential for long queues to form along these exit ramps. The ramps are only approximately 100m long from the 'stop' line to the exit nose. Good design practice provides for vehicles exiting the main carriageways of the expressway to carry out most of their deceleration after passing the exit nose. This ensures smooth flow of 'through' traffic and reduces the risk of high speed 'rear-end' collisions. Even for an operating speed of say 80 km/h, deceleration to a stop condition (eg. to queued vehicles) requires 120m, so it is obvious that the ramp length is inadequate and there will be a high potential for rear end collisions.

* The left turn slip lane from the eastbound exit ramp (Tampoi - Pasir Gudang Highway) merges with the northbound entry ramp at the point where that ramp merges with the main Kota Tinggi bound carriageway. This concurrent merge complicates traffic operation in an already operationally critical area and will result in an unsatisfactory safety performance.

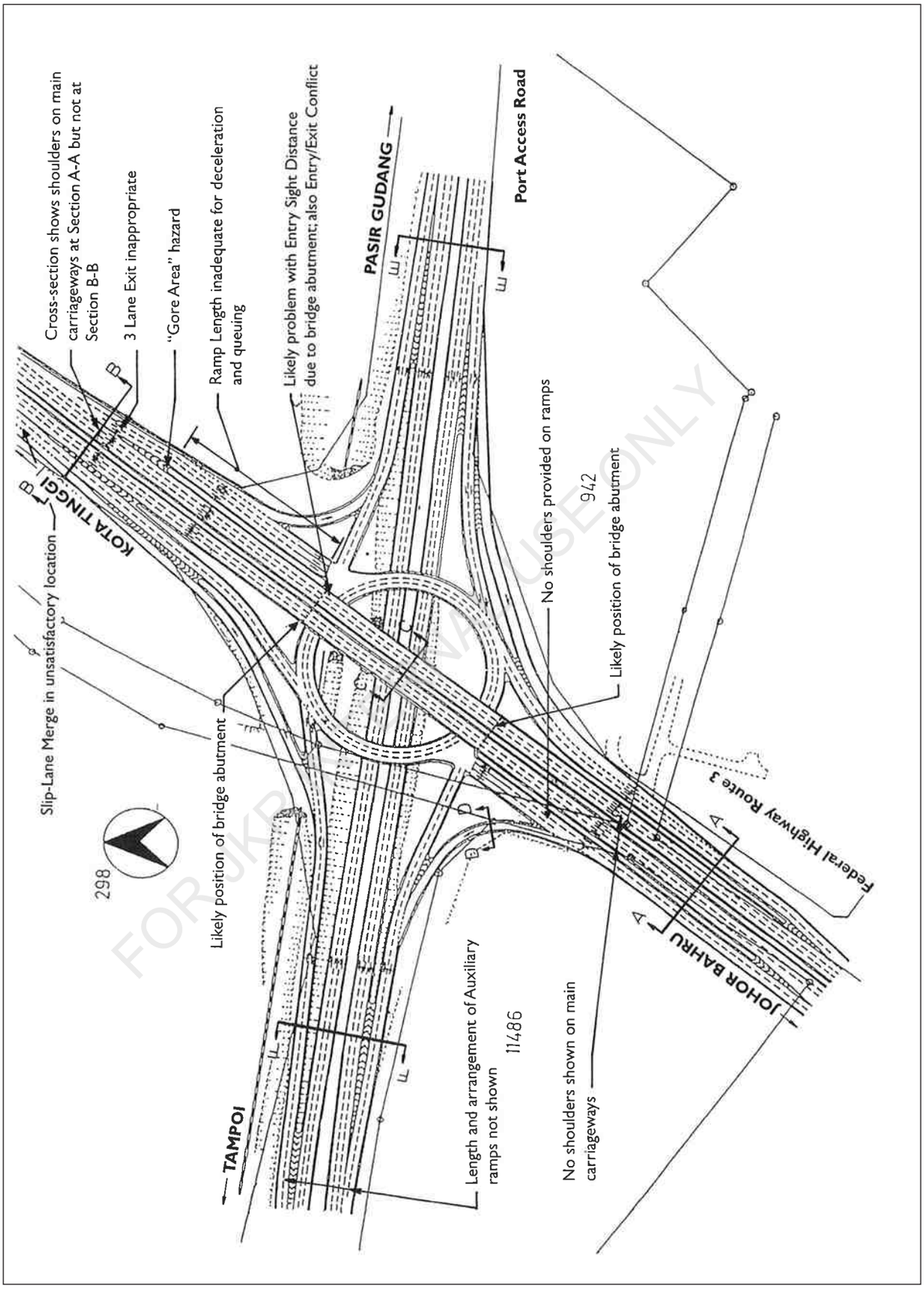


Figure 7.2 : RSA Stage 2 Case Study

* The expected locations of the abutment/ piers for the high level bridge (Johor Bahru - Kota Tinggi Highway) are very likely to restrict sight distance at both exit ramp intersections on this route. While these intersections are to be signalised, the lack of sight distance can create a hazard both at the phase change periods and at times when the signals are malfunctioning.

* The restrictive cross-section in the Johor Bahru - Kota Tinggi Highway necessitates the use of retaining walls between the main carriageways and the exit ramps, (this may also be the case for the other exit ramps). Thus guard railing at the top of the retaining walls will likely be terminated in the critical (hazardous) exit ramp 'gore' areas. The extreme hazard which results from this arrangement will need special treatment, e.g. the installation of an "impact attenuator" to achieve an acceptable level of safety.

* The preliminary layout plan shows an absence of shoulders on the on the main carriageways of the Tampoi - Pasir Gudang Highway. The proposed median in this route appears to be wide enough for some of it to be sacrificed to provide at least minimum width shoulders through the interchange area. The absence of shoulders will inevitably lead to a lower safety standard and reduced capacity when the occasional vehicle breaks down or otherwise stops in this area.

CHECK LIST

ROAD SAFETY AUDIT - STAGE 2

Preliminary (Draft) Design

Information Required For The Audit:

- Details of any Stage 1 (Planning Stage) Audit, including decisions made on the matters raised in that audit;
- Planning and 'Route Adoption' reports, on which the Preliminary Design has been based
- Traffic Reports containing existing and predicted traffic flows, including 'design flows, for all movements at intersections and interchanges;
- Preliminary Layout Plans, Cross-sections, Gradelines etc to be audited.

Audit Items:

Design Criteria:

Check:

- that the creteria is appropriate to the functional class of road, the nature of the topography, and the volume and type of traffic.

Cross Section:

Check :

- adequacy of Lane Widths, Shoulders, Roadside clearances, width of medians & separators, including the provision of adequate Right-of-Way width for grading, verges, footpaths etc;
- that, if special lanes or carriageways are required for motorcycles, or bicycles, the widths are adequqte;
- for consistency of the cross section along the route.

Horizontal & Vertical Alignment:

Check:

- the design speed of all horizontal curves for consistency;
- for any sub-standard curves;
- that vertical alignment standard is consistent and coordinated with the horizontal alignment;
- adequacy of Stopping Sight Distance, and the availability of Overtaking Sight Distance;
- for unsatisfactory combinations of vertical and horizontal alignment, which may mislead drivers in respect to overtaking or in respect to the direction of the route ahead.

Interchanges and Intersections:

Check:

- the appropriateness of type of interchange or intersection;
- the adequacy of the layout from a capacity viewpoint;

- the provision of Auxiliary Lanes and the achievement of proper 'Lane Balance' and 'Through Lane' Continuty and the avoidance of 'Trap Lanes'

- the achievement of the various sight distance criteria, including Approach Sight Distance, Entering or Crossing Sight Distance, Safe Intersection Sight Distance, Sight Distance to queued vehicles, Sight distance for Pedestrians, Sight Distance at interchange Entry and Exit ramp noses;

- that the layout caters adequately for large vehicles, and for public transport vehicles where applicable; the need / provision of specific safety related features, eg. Median Barriers, Street Lighting;

- that the need for any special arrangements of traffic signing for safe operation, is identified for action at the detailed design stage;

- that the specific needs of particular road users, such as Motorcyclists, Bicyclists and Pedestrians, has been considered and any action required at the detailed design stage has been noted.

Access control / Provisions:

Check:

- the appropriateness of access control, particularly in the vicinity of interchanges and intersections;

- where access is to be restricted, check the suitability and adequacy of alternative access, particularly to large traffic generators;

- where pedestrian access is to be restricted, check that the need for appropriate fencing is noted for action at the detailed design stage.

Major Land Use Developments:

Check:

- that major land use developments adjacent to highways properly consider the road safety implications;

- the adequacy of access and egress arrangements, e.g avoidance of entry and exit driveways too close to interchanges and intersections and the avoidance of queues from driveways extending onto the highway;

- that the layout of driveways and type of traffic control is approriate to the function of the highway; that the needs for Pedestrian and Public Transport access to the development have been identified and provided for;

- the adequacy of 'off-street' parking, and the provision of parking controls on the highway.

Stage Development Of Major Projects:

Check:

- that the stage development strategy take account of traffic safety requirements;

- the arrangement and siting of temporary terminals, avoiding locations of poor sight distance, locations complicated by busy intersections and restricted alignment standards;

- for unexpected changes in geometric standards, and situations which are likely to result in the unexpected onset of traffic congestion;

7.3 STAGE 3 AUDIT - DETAILED DESIGN STAGE.

At the detailed design stage in the development of road projects the geometric design and the traffic management features are determined. At the conclusion of this stage, the project moves into the construction phase involving contractural commitments which makes it difficult to significantly change aspects of the project. It is a particularly important stage from a road safety viewpoint because the interaction of various design elements, such as vertical and horizontal alignment, cross-section and other grading, which sometimes produces unsafe traffic situations becomes evident. It is also at this stage that all of the traffic management aspects are finalised and it is these perhaps more than anything else that determines the safe and efficient performance of the project.

The stage 3 audit is best carried out towards the end, (but not at the end) of the detailed design of a project. A suitable time needs to be chosen when the design is far enough advanced to enable all of the safety implications to be assessed and when there is still time to change any elements found to be deficient in the Road Safety Audit (RSA).

At the outset, it needs to be understood that the audit is not simply a check on whether or not the Design Standards are met. Satisfactory road safety is not always achieved by meeting set design standards, particularly where minimum criteria has been adopted. Often, due to the combination of various design elements, each of which may meet a minimum standard, the design can result in unsafe situations. On the other hand if the applicable standards are not met it is probable that operational safety will be compromised.

7.3.1 Information Required For The Stage 3 Audit:

The following information should be made available to the Road Safety Auditor(s):

- Details of any earlier stage audits, i.e. any RSA report at Stage 1 (Planning and Feasibility) and Stage 2 (Preliminary or Draft Design).
- Maps or Plans of the area through which the project passes showing the location of the project, general topographic details, the road / street network and the land-use in the region of the project.
- A full statement of the Design Criteria, indicating the proposed Road classification, Design Speed, Cross-section standard, Degree of Access Control, etc, and any special provisions e.g. for specific road used groups.
- Information regarding Design Traffic Demands.
- Horizontal and Vertical Alignment design plans (at the stage reached) including those for any intersecting side roads and major driveways. These should show all the alignment details such as horizontal curve radius, transition curve lengths, superelevation rates, vertical curve lengths, K values and grades.
- Cross-sections and details of Barriers and Guard Railing.
- Road surface drainage plans, e.g. contour plans (if available) including the location of drainage structures such as culverts, side drains and pits etc.
- Layout Plans of Bridge Structures including some design details of bridge railings.
- Layout plans for intersections and interchanges (where applicable) including any traffic signal details, traffic signing, road marking and delineation treatments and any other traffic management items such as bus stops, pedestrian crossings, parking arrangements etc.
- Street lighting layout and details such as luminaire mounting height, type of luminaire and the lighting standard achieved.

- Plans showing the layout of Overhead Services showing location of poles and other structures which may influence traffic safety considerations.
- Landscaping plans and proposals.

Some of these items may be available only in preliminary form, depending on the timing of the audit, but this is satisfactory as it will be easier to make any necessary changes arising from the audit.

7.3.2 Audit Equipment and Aids:

The auditor will need to have available most of the design equipment, manuals, guides and other references used by the original designers, except that the auditor will generally carry out any checks manually rather than (say) by computer. Thus they will need items such as Scale rulers, Straight Edge, Curve Templates, Design Vehicle Turning Path Templates, Hand Calculator, etc. The auditor should also have available the relevant 'design Guides' - Arahan Teknik (Jalan), AASHO etc. and the various road safety Audit Texts.

7.3.3 Stage 3 Audit Procedure:

The audit should proceed in a logical and systematic so that all of the items which may influence operational safety are effectively reviewed. It is particularly important to be aware of and to check the situations which involve a combination of different design elements. For example Sight Distance at a particular location may involve a combination of horizontal and vertical alignment, cross-section and landscaping details and possible other items such as traffic sign placement and guard railing.

The following notes discuss the items to be reviewed in a suggested sequence which should ensure that important items are not overlooked and that the interdependence between various elements is recognised:

7.3.4 Audit of General Items Of The Project:

The following general items are best considered at the start of an audit at the detailed design stage. These provide auditors with useful background on the project which will help to develop the proper perspective when considering the more detailed items later in the audit.

(a) Earlier Stage Audits:

The auditor needs to be aware of the details of any earlier stage audits (i.e. stage 1 or Stage 2 Audits) and the decisions and outcomes in respect to any items identified as safety deficiencies in those audits.

If an earlier stage audit has reported safety deficiencies which have purposefully been allowed to remain in the design, this may influence the auditor's consideration of such features. For example the auditor may look for something in the detailed design which may offset or otherwise mitigate any adverse safety effects identified in the earlier stage audits.

(b) Design Criteria:

It is important at the outset to have a clear understanding of the general design criteria for the project. The design criteria will be influenced by the functional classification of the route, the nature of the topography, the expected overall traffic demands and the general purpose of the route. It will usually include items such as:

- the functional classification of the route,
- the general (minimum) design speed of the alignment,
- the extent of access control,
- typical cross-section details,
- horizontal curve criteria such as minimum radius, maximum superelevation rate,
- vertical curve criteria such as K values for crest and sag curves,
- limiting values of grades.

The auditor should check that these items logically reflect the desired performance of the road and that there are no contradictions or incompatible aspects. For example specifying (say) expressway classification but with no access control, or specifying a low Design Speed in (say) flat open rural environment, or setting design criteria which is going to encourage high operating speed in busy shopping environment.

(c) Reservation Width And Other 'Design Constraints':

Consider the safety implications of 'right of way' width constraints and locations where other site controls such as natural geographic features, services and utility relocations etc constrain the design at the expense of traffic safety. Check to see if there is a need for any works, eg warning signing, to mitigate any adverse safety effects.

(d) Driveways And Access Points:

The general question of access control throughout the project is usually made at the planning or the preliminary design stage. However the detail of it is not often apparent until the detailed design is well advanced. The safety of traffic operation at points of access need to be checked by considering items such as sight distance, the provision of auxiliary lanes, possible queuing effects and the type of traffic control in respect to direct conflicts between 'through' traffic and vehicles entering or leaving at access points. Consider whether or not points of access will be recognised by 'main road' traffic as locations to expect traffic conflict.

(Where substantial property developments are provided with direct access via major driveway intersection treatments, these may be audited under the heading of Intersections covered later in these notes).

Where direct access to adjacent property is denied, the auditor should check to ensure that reasonable alternative access is provided and that adequate direction signing for this is included in the traffic signing scheme. This aspect is particularly important for large traffic generators which may be visible from the road in question.

The auditor should consider whether the form and details of access control have created unexpected or otherwise hazardous vehicle maneuvers such as uncontrolled crossing movements, U Turns, weaving or queuing, particularly in high speed environments.

In general the provision of direct access to arterial roads particularly in the vicinity of interchanges and important intersections should be avoided. Any access control arrangements which do not achieve this should be identified as a safety deficiency in the audit.

Insufficient sight distance.

Note bus trying to enter busy, high speed arterial road from unexpected local access.

Hazardous access (to and from) petrol station on expressway type road.

Lack of sight distance

(e) General Traffic Management:

The following items of general of general traffic management arrangements proposed for the project should be checked:

- the general speed limit to be imposed,
- any proposed prohibition of specific road user groups or proposed segregation of specific vehicle types such as motorcycles, buses etc,
- special provisions relating to on-street parking,
- the provision of motorists facilities such as emergency telephones, roadside stopping places, including those for trucks, the provision of rest areas and 'service centres' where applicable,
- any special provisions for pedestrians,
- any special provisions for buses and public transport patrons.

(f) Climatic and Weather Implications:

The auditor should consider whether the climate or weather conditions are likely to require special provisions to be made to ensure safe traffic operation under all likely conditions. For example special traffic signing in fog or flood prone areas, or at locations which experience high cross winds etc.

7.3.5 Audit Of Geometric Design Elements:

The geometric design elements of the project will be the major focus of the Stage 3 Audit and the auditor will consider the following aspects:

(a) Horizontal Alignment:

- Check the details of each curve by reviewing the radius, superelevation rate, (and possibly the 'friction' value) adopted to determine the 'Design Speed'. Identify any curves which do not meet the overall route design criteria.
- Check the general consistency of horizontal alignment along the route and identify any curves which may be considered to be 'sub-standard, or which otherwise may be likely to be incompatible with the expected vehicle operating speed (A curve is sub-standard if its design speed is more than 10 km/h to 15 km/h below the likely vehicle operating speed, - usually taken as the 85 percentile vehicle speed, on the immediate approach to the curve.). The first curve at the end of long straight sections of road is often sub-standard because of the high speeds attainable on the straight, which may be in excess of the speed limit and the general design speed adopted in the design criteria.
- Check that transition curves (spirals) are provided where appropriate and that the superelevation is introduced in the proper way (see Arahan Teknik Jalan 8/ 86). Reverse curve situations and curves on interchange ramps often present difficulties in respect to the 'running in or out' of superelevation.
- Check the suitability of horizontal alignment at the 'interface' between the proposed construction and the existing road network, i.e. at the terminals and 'limits of contract' on side roads. Identify any locations where the alignment of the new road is inconsistent with the approach speeds of vehicles entering or leaving the project.

(b) Vertical Alignment:

The main aspect of vertical alignment which affects traffic safety is Sight Distance. A number of different sight distance criteria need to be evaluated by considering the combination of both horizontal and vertical alignment and other elements of design as discussed below. However in a more general context the following aspects need to be reviewed:

- Check that the vertical alignment standard meets the general design criteria.
- Check for consistency along the route and identify any location where the standard of vertical alignment changes significantly and which may not be expected by drivers.

(c) Combination Of Horizontal And Vertical alignment:

The combination of horizontal and vertical alignment influence sight distance which is of major importance in achieving a safe road. It can also create visual illusions which can result in hazardous traffic situations. The various sight distance criteria which need to be evaluated at various locations as discussed below.

- Check Stopping Sight Distance (SSD) along the route generally. If the length of each vertical curve has been determined using the appropriate K value (usually included in the design criteria or otherwise calculated from the minimum stopping sight distance for the adopted design speed) then where the line of sight remains over the roadway, stopping sight distance will be achieved. Otherwise the auditor will need to check graphically that the minimum stopping distance is or is not achieved and will identify deficient locations on the vertical alignment plans. (refer to Arahan Teknik Jalan 8/86 for details of required SSD and K values).

  Check locations where there are overbridges in sag vertical curves at which the bridge superstructure may obstruct the achievement of SSD.

  Remember that where the drivers line of sight falls outside the edge of the roadway, the horizontal alignment plan and possibly the cross-sections and landscaping plans will also need to be checked to effectively determine that the sight distance is satisfactory.

- Check the achievement of Overtaking Sight Distance (OSD), where it is applicable, noting the locations where it is unattainable and check to see that Double Lines (barrier line) is provided for on the road marking plans. (Refer to Arahan Teknik Jalan 8/86)

- Check Approach Sight Distance (ASD) At Intersections. This may be done as discussed under the heading of 'Intersections' below. The method of checking is the same as for SSD above except that different K values are applicable as visibility is measured to a Zero object height, i.e. the surface of the roadway rather than an object 0.15 m high. (This criteria is not included in Arahan Teknik Jalan 8/86 but further details are given in Reference 10)

- The combination of horizontal and vertical alignment will also influence the effective design speed of horizontal curves on steep down grades. This effect is only marginal in most cases but it needs to be carefully checked where sharp curves occur on down grades (e.g. on interchange ramp loops) and where vehicles turn at intersections on steep down grades. At these locations vehicles with a high centre of gravity can overturn due to inadequate or negative (e.g. turns at intersections) superelevation effects. Any such locations need to be identified and checked against the traffic signing plans to see if special warning signs and 'advisory speed' signs are provided.

- Check the adequacy of sight distance at locations where there is a discontinuity in the cross-section standard. For example at bridges where the shoulder width may not be carried across the bridge, at places where the roadway narrows, and at the interface between the project and the existing road network. These locations should always be given better than the 'minimum' sight distance standard.

- Check that the combination of horizontal and vertical alignment does not result in unexpected areas of 'hidden' pavement or areas where the alignment of the roadway ahead is not evident to a driver of an approaching vehicle. If such locations are identified, check that the traffic signing plans include appropriate warning signs and that the road marking plans include markings to prohibit overtaking (on 2 lane 2 way roads).

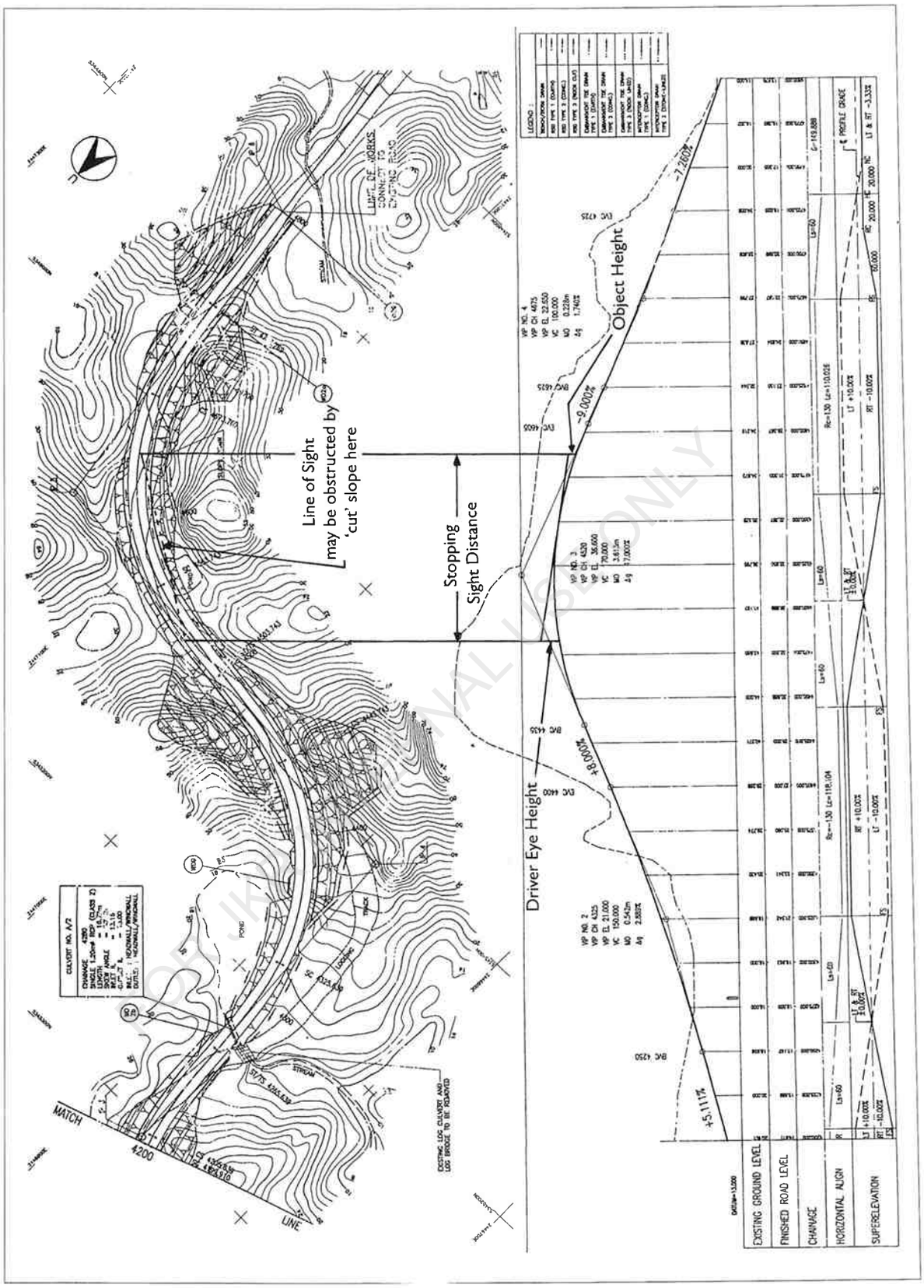


Figure 7.3 : Horizontal And Vertical Alignment.

The horizontal and vertical alignment should have a consistent speed and sight distance standard .The design speed of the horizontal curve (left) at the end of the straight from the south in this example would be carefully checked. In this case the relatively steep up-grade (7.26%) would help reduce vehicle speeds as they enter this curve, so while it may appear to be sub-standard it could be satisfactory.

(d) Grades:

Grades by themselves are not often a major safety concern except that special traffic signing (warning signs) may be needed where long lengths of steep downgrade occurs. On the other hand steep 'up-grades' can have a significant effect on traffic capacity and level of service. The occurrence of traffic congestion which leads to driver frustration and consequential erratic and high risk maneuvers is likely to result in increased accidents. Thus the auditor should check to see if auxiliary (climbing or slow vehicle) lanes are provided where warranted.

(e) Cross - Section:

The cross-section of a road is the main factor which influences the capacity of the roadway between intersections, but apart from the adverse safety effects of traffic congestion resulting from inadequate capacity, most of the cross-section elements such as, number and width of traffic lanes, the provision of shoulders or emergency stopping lanes, median and separator widths (where applicable), batter heights and slopes, kerb types, the provision of footpaths, clearances to barriers and barrier types etc. all influence safe traffic operation in various ways. The design stage audit should review the following aspects:

- Any locations where capacity is obviously deficient and which could be expected to lead to a lower standard of safety should be identified.
- Check that the lane and roadway widths are appropriate for the type of vehicles expected to use the road and for the likely operating speed and other relevant conditions. Check also that appropriate 'curve widening' is provided where applicable. Check and identify areas where there is excess roadway width which is 'un-allocated' or which may lead to undisciplined lane behavior and thus a lower standard of safety. Remember that wider roads do not automatically result in increased capacity or safety.
- Check that the shoulder width is adequate and that there are no unreasonable discontinuities in the shoulder provisions. Check that the type of shoulder surface is appropriate, bearing in mind that safety is greatly enhanced by fully paved or 'sealed' shoulders, this is particularly desirable where there are significant numbers of motorcycles, and bicyclists and, in rural areas, where there is likely to be significant pedestrian usage of the shoulder. Even partially paved shoulders significantly improve safety.
- Check that appropriate transitions are provided at locations where the cross-section changes significantly, particularly at the terminals of the project and at the interface between the project and the existing road system, e.g. at side roads.
- Check and identify any locations where the cross-section design does not adequately cater for vulnerable road users such as pedestrians, bicyclists, and also for motorcyclists where the numbers of these road user groups warrant specific provisions.
- Where kerbs are required, check that the correct type of kerb, in terms of its height and shape, has been specified. Note that the use of barrier type kerbs is applicable to inner city, low speed environments and that these kerbs constitute a significant roadside hazard when used where traffic speeds are in excess of about 50 km/h.
- Check that side drainage channels do not represent a hazard to vehicles accidently running off the roadway.
- Where medians or dividers are provided to separate the various roadways, check that they have adequate width at the relevant locations to cater for pedestrian refuge, traffic signs, street lighting poles, bridge piers and any associated barrier systems etc.
- Check that any differences in level between the roadways of divided roads does not present sight distance problems at intersections or access driveways.
- Check that batter slopes through cuttings on curves do not obstruct sight lines, where such obstruction cannot be avoided advisory speed signing and barrier lining should be provided for in the traffic plans.

Consistent alignment standard with good cross-section and roadside safety features leads to lower accident rates.

Narrow shoulders at critical locations such as this can produce unsafe traffic operation.

7.3.6 Auditing The Design Of Interchanges And Intersections:

Intersections and interchanges are parts of the road system which involve the greatest potential for conflict between road users and consequently these locations incur the most traffic accidents. The audit at these locations needs to be detailed and thorough.

The following items will be the main focus of attention in a detailed design stage audit.

(a) General layout logic :

The auditor should check that the layout is logical and "readable" by road users. Any feature which is likely to be unexpected by vehicle drivers, such as unusual paths of travel, complicated channelisation, small traffic islands in unusual positions, trap lane situations, etc, should be identified.

(b) Visibility And Sight Distance:

The achievement of sight distance criteria needs to be thoroughly checked taking into account horizontal and vertical alignment effects, grading and landscaping obstructions etc. There are several sight distance criteria applicable at intersections, each needs to be checked and the audit should identify any situation where a deficiency is evident:

Intersection Approach Sight Distance is often difficult to achieve when the intersecting road occurs on the outside of a curve.

Drivers have difficulty judging their deceleration when they cannot see the highway carriageway or the location of the STOP line.

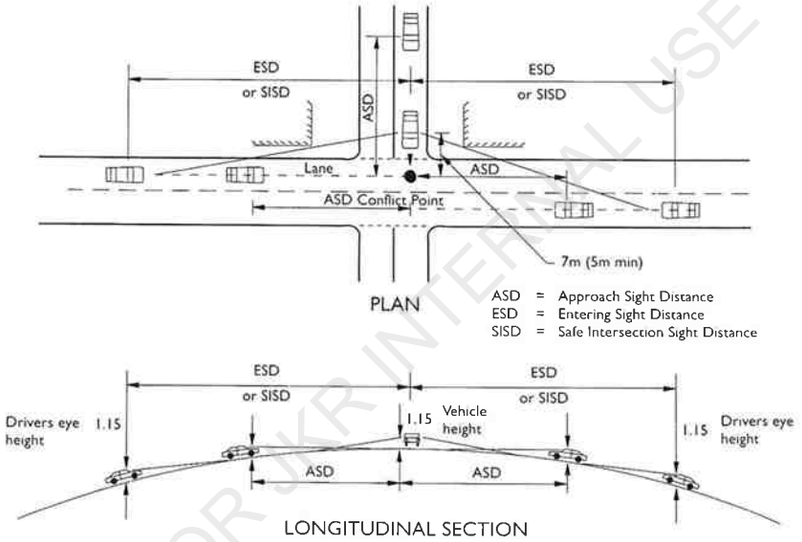


Table 1 : Approach Sight Distance (ASD)

Speed (km/h)	d	Stopping Sight Distance (m) Rural Normal R_t=2.5s	Rural Alerted R_t=2.0s	Urban R_t=1.5s
40	0.56		35	30
50	0.52		45	40
60	0.48		65	55
70	0.45		85	70
80	0.43	115	105	95
90	0.41	140	130	
100	0.39	170	160	
110	0.37	210	190	
120	0.35	250	230	

Table 2 : Grade Corrections to ASD

Design Speed (km/h)	Correction (m)* Upgrade 4%	Upgrade 8%	Upgrade 12%	Down Grade 4%	Down Grade 8%	Down Grade 12%
40	-	-	-	-	-	5
50	-	-	5	-	5	5
60	-	5	5	-	5	10
70	-	10	10	5	10	15
80	5	10	15	5	10	25
90	10	15	20	10	20	30
100	10	20	25	10	25	45
110	15	25	30	15	35	60
120	20	30	40	20	50	85

* Correction to be added to ASD for downgrade and sub-tracted for upgrade Ignore grades of 2% or less

Table 3 : Intersection Sight Distance

Design Speed (km/h)	Entering Sight Distance (m)*	Safe Intersection Sight (m) Rural R_t=2.0s	Urban R_t=1.5s
40	100	70	60
50	125	90	80
60	160	115	105
70	220	140	130
80	305	175	165
90	400	210	
100	500	250	
110	500	290	
120	500	330	

* Distance computed using lengths given in Jarvis (1987). Based on ASD as per Table 1. Limiting value based on the assumption that drivers are unlikely to seek gaps greater than 500m

Note that distances assume

- level pavements
- minor road vehicle stopped 7m (5m min) back from conflict point
- measurement along centre of path of major road vehicle

Figure 7.4 : Intersection Sight Distance Criteria
Source : Austroads 1988a

(i) Approach Sight Distance (ASD):

Drivers approaching an intersection need to be able to see the pavement in the conflict area and the arrangement of traffic islands, lane lines, 'stop' lines and other pavement markings, in sufficient time to take any necessary action. The criteria for this is ASD, which is similar to SSD (referred to earlier in these notes), but the significant difference is that ASD is measured to a Zero object height (i.e. the identify any instances where there is a deficiency and also check to see if the sight lines are likely to be obstructed by traffic signs, landscaping or any other roadside structure.

(ii) Entering Or Crossing Sight Distance (ESD):

This is the sight distance required for a vehicle driver or a pedestrian to observe a 'safe gap' in uncontrolled traffic flow in which to enter or cross the roadway. It is essential to achieve this criteria at all unsignalised conflict points including entry to roundabouts and at left turn slip roads, and, for pedestrians at pedestrian crossings etc. It is also desirable to achieve this sight distance criteria at signalised intersections to ensure that they can operate safely when the signals may have 'broken down'.

Designers and Auditors need to be aware that different values of ESD are applicable to Left Turns, Right Turns and Crossing movements and quite different values are applicable to pedestrian crossing movements. Note also that ESD is measured from driver (pedestrian) eye height (1.15m) to an object height of 1.15 m , (ie to driver eye height), and from specific vehicle positions in the entry or side road. In some cases the extra height of drivers of trucks and buses may need to be considered. See Reference 3 for further details and values of ESD

The audit should identify any instances where there is a deficiency and also check to see if the sight lines are likely to be obstructed by traffic signs, landscaping or any other roadside structure.

(iii) Safe Intersection Sight Distance (SISD):

In situations where ESD cannot be fully achieved, a "fail safe" criteria SISD may be applied. This criteria ensures that main road drivers (vehicles which have priority) will have sufficient sight distance to an entering vehicle, to enable them to avoid a collision if that side road driver enters the intersection with insufficient 'gap' in the 'priority' traffic stream. The criteria provides sight distance (driver eye height to driver eye height) equivalent to Stopping Distance for the expected 85th percentile operating speed plus the distance travelled in 3 seconds of travel time. This sight distance is measured from the position of the vehicle waiting to enter a major road, to a vehicle approaching the intersection in the major road. See figure 7.4 for values.

(iv) Sight Distance To Queued Vehicles:

This sight distance is important where vehicles may be expected to stop in the path of through traffic, e.g. at a signalised intersection, or at the entry to a roundabout etc. In this case the sight distance criteria is stopping distance measured from driver eye height to 'tail light' height, (usually taken as 0.6m).

(v) Sight Lines and Visibility to Traffic Signals and Signs:

These important traffic management items need to be visible to approaching drivers sufficiently far ahead to enable them to observe, read and act on the information provided in a safe manner. For traffic signs the visibility distance necessary is dependent on the 'offset' of the sign from the traffic lane, the number of words and/or symbols on the sign face, the height of the lettering and the speed of traffic.

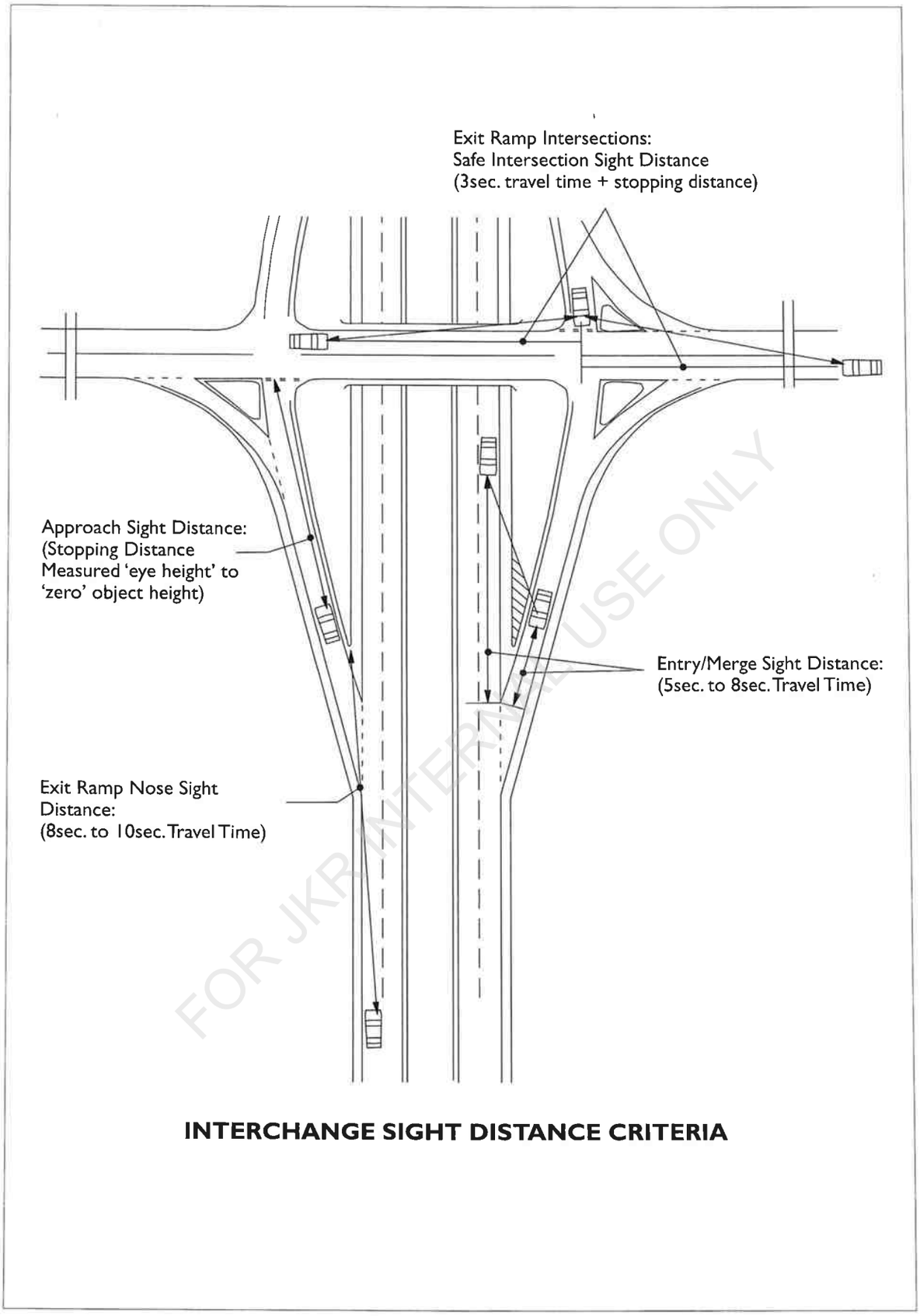


Figure 7.5 : Sight Distances at Interchanges

(Arahan Teknik Jalan 2E/87 tabulates minimum letter heights for various situations but a more appropriate evaluation is described in Reference 12).

The above sight distance criteria apply to intersections generally. However at interchanges the following additional sight distance criteria should be checked.

(vi) Sight Distance To Exit Nose and 'Gore' Area at Interchanges:

The exit nose and 'gore' areas are key 'decision' points for drivers on expressways and other 'freeway' type roads. They also tend to be highly vulnerable areas for vehicle collisions and a high standard of sight distance should always be provided at these locations. The sight distance criteria applicable is that the exit nose and at least 40 m of the ramp beyond the nose should be visible to an approaching driver at the start of the exit taper. This criteria is measured from driver eye height to Zero object height (i.e. the surface of the road as for ASD). See Figure 7.4 and figure 7.5.

(vii) Sight Distance To the Entry and Merge Area:

Drivers entering an expressway, freeway or grade-separated road along an entry ramp in the vicinity of the entry nose need to be able to observe vehicles in the nearside lane of the main roadway into which they must merge.

The sight distance criteria here is to ensure that at least 200m of the near side lane of the expressway (or main roadway) is visible to a driver on the entry ramp at a point 60m in advance of the entry nose. (See Figure 7.5)

(c) Interchanges And Interchange Ramps:

Interchanges are grade separated intersections and the interconnecting roadways are generally referred to as 'ramps' (as distinct from 'slip roads' or 'slip lanes' which are roadways providing 'free' flow at at-grade intersections.

Interchange ramps can take many forms depending on the functional classification of the roads involved and the type of interchange being adopted. Ramps need to be carefully designed to ensure the safe movement of traffic from one road to the other and the safety auditor will consider the following points :

- Horizontal and vertical alignment of the ramps: Standards need to be consistent with the expected operating speed of traffic, taking into account whether the ramp is 'free flow' or terminates at a controlled intersection or roundabout.

  Short radius curves should not occur close to the exit nose from a high speed expressway. As a general rule the safe speed of the first curve after the exit nose should not be more than 20 km/h below the 85th percentile operating speed of the expressway.

  Steep grades (>6%) should be avoided on exit ramps leading to a controlled intersection where vehicles may need to stop before entering.

- Ramp Cross-section needs to satisfy capacity requirements, provide for passing slow or 'broken down' vehicles and allow a safe operating clearance to roadside barriers and items of road furniture.

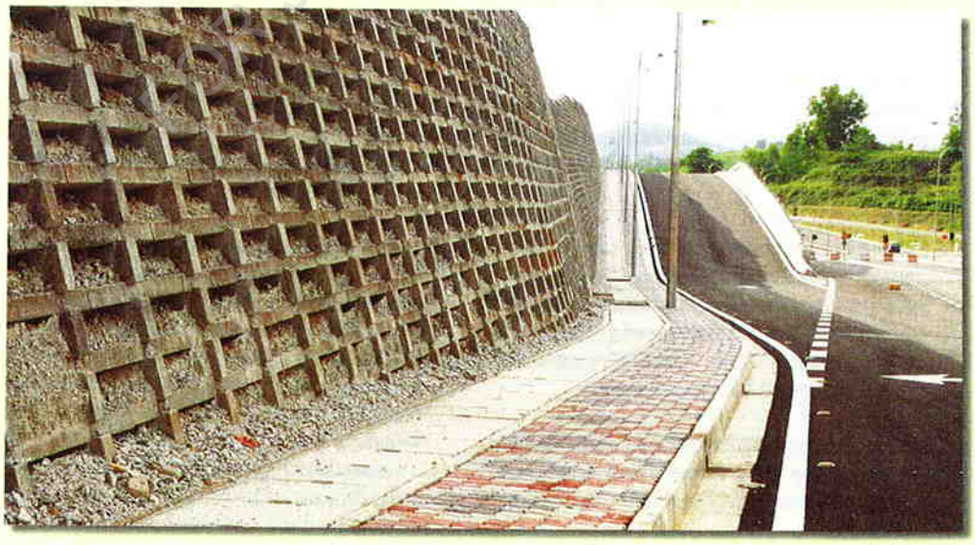
  At exit and entry nose points the number of lanes provided must be no more than is required to achieve the required for capacity, complying with the proper rules for 'lane balance' and route continuity. (See AASHTO 1994, for details). This will normally be only one or two lanes, except in rare cases at expressway to expressway type interchanges where occasionally a three lane exit may be required. If additional

  lanes are required for intersection or roundabout capacity, these must start after the exit nose position, not before it. If total queuing space is insufficient, the ramp length should be extended

- Ramp length, (usually measured between exit and entry nose points or exit nose point and the STOP line where the ramp terminates at an intersection), needs to be sufficient to allow drivers to make any necessary speed changes clear of through traffic on the expressway. Where ramps terminate at an intersection (including signalised and roundabout), the length of expected queuing plus deceleration distance (enabling drivers to stop at the back of the queue), must be provided after the exit nose point

'Trap' Lanes occur where normal 'through' traffic lanes are marked as right turn lanes. This discontinuity of the 'through lanes results in lane-changing conflicts and higher accident rates.

Note here how the 'through' traffic on the highway must merge with the left turn entry traffic. Note also the absence of a footpath places the pedestrians at risk on the shoulder



The lack of a deceleration lane at this high speed exit ramp will be a a safety problem.

Note also:

- *the unprotected 'gore area' hazard,*
- *inappropriate high barrier type kerb,*
- *the rigid light poles in a vulnerable area*

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(d) Exit And Entry Layout, Auxiliary Lanes And Lane Continuity:

The audit should check to see that the layout geometry of expressway exits and entry's are in accordance with appropriate practice. (See Figures 7.6 and 7.7, or AASHTO 1994, or other acceptable standards). This should include the provision of auxiliary lanes wherever two-lane exit or entry is proposed.

At at-grade intersections, check that auxiliary lanes are provided on heavily trafficked and/or on high speed routes where vehicles wishing to turn right or left at an intersection will be decelerating and possibly stopping. The length and layout of any auxiliary lanes should be in accordance with Figures 3-15 to 3-18 of Arahan teknik (Jalan) 11/87, or refer to Austroads 1988 (Part 5). Note that the effect of vehicles waiting in a queue must be taken into account.

On 2 lane 2 way rural roads, a range of treatments are available giving various degrees of protection for 'turning' vehicles. The auditor should check that appropriate treatments are provided at any important intersections and at other locations where the risk of 'rear end' collisions is high because of geometric features such as curves or crests etc.

The auditor should also check that the geometric arrangement of auxiliary lanes (and queuing or 'storage' lanes) is appropriate to avoid 'through' vehicles unintentionally driving into or otherwise being trapped into the auxiliary lanes. This can be a serious problem at signalised intersections where multiple lanes may be allocated to turning movements, and also at multi lane exit ramps at expressway/ freeway interchanges. The auditor should identify as a safety deficiency any case of such 'trap' lane arrangements.

(e) Island Size And Shape:

The auditor should check to see that traffic islands are large enough to be easily visible to approaching traffic, and that they cater adequately for any traffic signs, signals, street lights and provides adequate refuge for pedestrians where they may be expected to use the island when crossing at the intersection. Check also that the shape of the islands guide vehicles into the correct travel path and that the approach noses are properly offset to reduce the risk of vehicles accidently running onto them.

In addition to the above, it is important to check that the lane and turning roadway widths provide adequately for the large / heavy vehicles turning at low speed. This can only be checked using the appropriate 'Design Vehicle' Turning Path Templates, or in complex situations involving reverse turns (as at roundabouts) an accurate plot of the swept path as the vehicle traverses the intersection can be made using commercially available software.

At roundabouts the shape and positioning of the approach deflection islands are important to achieve the necessary approach and entry speed reduction. Any deficiency in this respect, such as island shapes and positions which allow vehicles to pass directly into or through the roundabout without deflection and slowing down should be recorded as a substantial safetydeficiency.

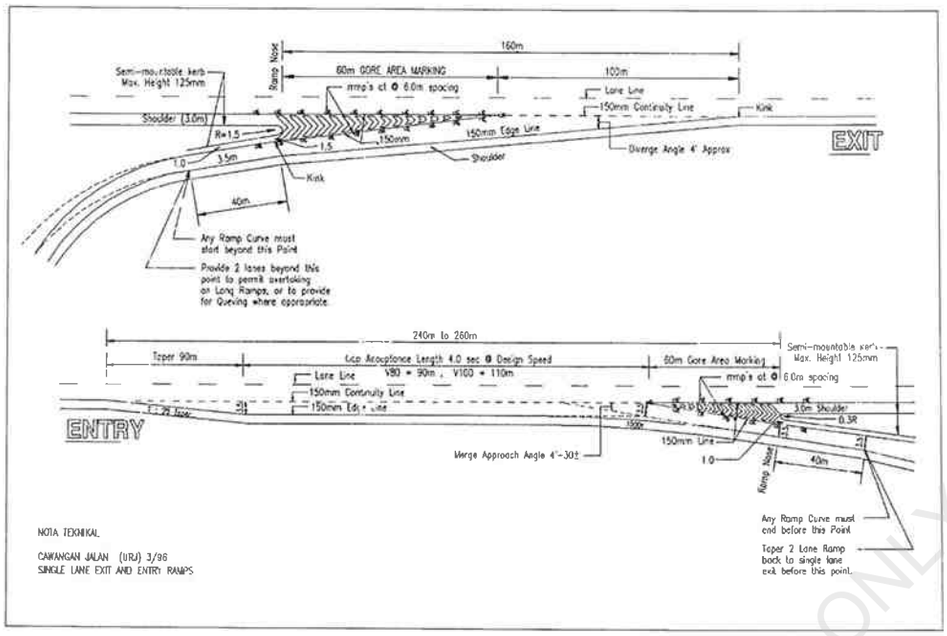


Figure 7.6 : Interchange Layout Geometry: Single Lane Entry and Exit

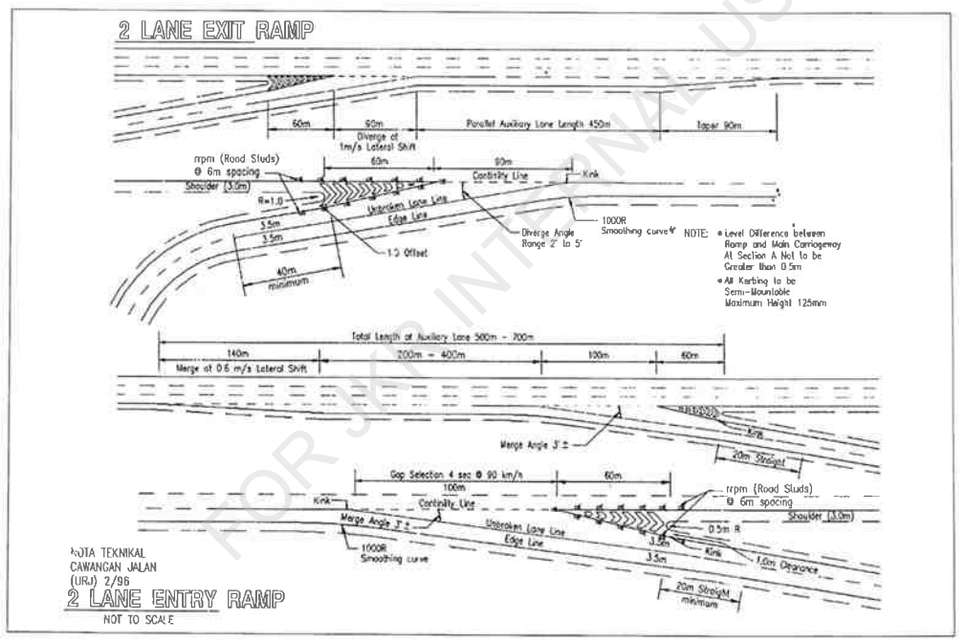


Figure 7.7 : Interchange Layout Geometry: Dual Lane Entry and Exit

(f) Kerb Types:

The auditor should check the type of kerb proposed at various locations on the project and identify any case of incorrect kerb usage which may constitute a hazard to road users. In general, barrier type kerbs should not be used except in low speed inner city environment. In most other environments semi-mountable kerb types should be used. In high speed environments such as on expressways, the use of kerbs should be minimised and where necessary low (125mm maximum height), easily mountable kerbs should be used.

This semi-mountable type kerb produces a safe and well defined, strong edge to the carriageway, enabling errant vehicle drivers/ riders to maintain control of their vehicles.

(g) Provisions For Pedestrians:

Intersections are usually locations where pedestrian activity tends to be high. The auditor should identify any lack of provisions for this vulnerable road user group to cross the roadway safely. Appropriate provisions would include specific traffic signal aspects and phasing at signalised intersections, the provision of kerb ramps at crossing points, adequate area / width for refuge on traffic islands, medians and roadway separators, etc. Careful consideration needs to be given to sight lines and visibility as discussed above to ensure that pedestrians are not hidden from the view of vehicle drivers at points of conflict.

(h) Location Of Signals, Signs, Lighting And Other Road Furniture:

These items need to be accommodated at intersections and positioned so that they meet their respective visibility requirements. They also (unfortunately) create significant roadside hazards if placed in vulnerable locations such as at the nose of traffic islands, in narrow medians, in very small islands or otherwise at locations where there is a high risk of vehicles running off the roadway. These items should also not be placed in such a way as to obstruct normal pedestrian movements, or significantly obstruct sight lines and sight distances as discussed above.

The use of this Barrier type kerb creates a serious roadside hazard, especially for motorcycles

(i) Vehicle Parking And Bus Stops:

The presence of parked vehicles and the occurrence of parking maneuvers in close proximity to an important intersection can seriously effect safety. The auditor should identify locations where parking restrictions are inadequate to ensure the safe and efficient operation of the intersection. For example identify locations where parked vehicles may obstruct visibility, or where parking maneuvers interfere with traffic moving through the intersection.

In respect to bus stops, the auditor should identify locations where buses waiting at bus stops may obstruct critical sight lines, or where stationary buses at bus stops interfere with the movement of other traffic at the intersection, or locations where the movement of buses into or out of bus stops creates undue traffic hazard.

(j) Property Access Points:

The presence of property access points within or close to important intersections can create unexpected or otherwise hazardous traffic conflicts which lead to accidents. Cases where this occur should be identified in the audit along with any other unusual traffic movements or conflict situations due to inappropriate channelisation.

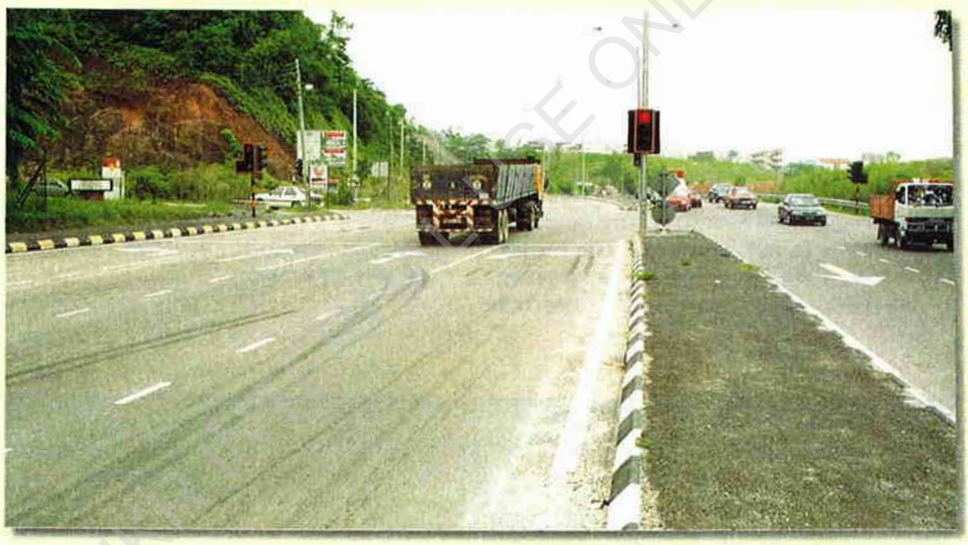
7.3.7 Audit Of Traffic Signal Installations:

Where a project includes traffic signal installations the design stage audit should consider the following items:

- Check that traffic signals are proposed only where they are warranted (Refer to Arahan Teknik Jalan 13/87)
- Check that the proposed signal phasing provides adequately for the required traffic movements, including pedestrians, with no unexpected conflict situations, and that special phases for right turn movements are provided where justified. Also check that the required 'inter-green time' for each phase change is sufficient to allow safe operation. This aspect may need special consideration at traffic signals where the traffic operating speed is greater than 70 km/h.
- Check the location of signal heads and posts to ensure that each separately controlled vehicle movement has at least 2 (and preferably 3 or 4) signal heads controlling it and that the minimum visibility requirements, as specified in Arahan Teknik Jalan 13/87, are met and that at least one signal display is visible to drivers waiting at the 'stop' line. Check and identify any locations where queued traffic may obstruct the visibility of signal displays. At least one signal display should be visible to the respective traffic movements at all times. This means that on approaches with more than 3 lanes, overhead signals will usually be required.
- Check that adequate clearances are provided between the face of kerb and the signal head and posts, and that they are not located in islands and medians too small or narrow to afford the equipment adequate protection from vehicle impacts.
- Check that the correct signal size and brightness is provided and that backplates are provided wherever practicable to ensure adequate visibility of the signal. Check also that the correct signal face arrangement to control the various traffic movements is shown in the plans.
- Check and identify any locations where pedestrian displays and associated 'call buttons' are not provided at sites where it is expected that pedestrians will cross signal controlled roadways.

These signals lack visibility and prominence, thus increasing the risk of rear-end and other accidents

Note the skid marks on the pavement and the position of the signal /light pole too close to the kerbline for safety or protection of the signal equipment.



7.3.8 Audit Of Traffic Signing And Road Marking:

The importance of traffic signing, road marking and general roadway delineation to safe and efficient traffic operation cannot be over stressed as these items have a major influence of driver actions and behavior.

(a) Traffic Signs:

The auditors should check that all the necessary regulatory signs are provided and are properly positioned to control, both legally and practically, the movement of traffic along or across the roadway. This will include the provision of 'stop' or Give-way signs at unsignalised intersections, any turn prohibitions, e.g. U turns or right turns, where required by the traffic management strategy, and the provision of speed restriction signs at the appropriate locations.

Where potential hazards, which drivers may not expect, are evident from the design plans, the auditor should check to see that appropriate warning signs are shown on the traffic signing plans. This will include locations where, for example, sub-standard curves occur, or where the visibility of traffic islands or median ends have reduced sight distance, and locations where 'transient' hazards may periodically occur such as high cross winds, flooding of the roadway or

where heavy trucks may be expected to enter the roadway. The auditor should also identify and recommend removal of any unnecessary warning signs, i.e. where the hazard itself is quite obvious to approaching drivers.

The auditor should give particular attention to the adequacy of proposed direction and guide signing in respect to:

- the provision of destination names which meet the needs of drivers who are unfamiliar with the locality or region.
- the provision of road / street names and route numbers (where applicable) both on the major route and on each intersecting side road within the project,
- the specification of adequate letter/ legend size to enable drivers to read the information displayed in the time available, and limiting the amount of information displayed at any on location,
- the correct positioning of direction signs to enable drivers to take any necessary action in a safe manner. This usually involves the provision of advance direction signs, intersection direction signs (located at an intersection) and re-assurance direction signs, (placed after an intersection) on heavily trafficked or high speed arterial roads,
- the provision of appropriate reflectorisation, internal or external lighting of the signs to ensure that they are effective at night.
- the provision of overhead (e.g. gantry mounted) signs where complex multi lane roadway layouts require vehicles to get into specific lanes in order to make particular turning movements or to reach particular destinations,
- the positioning of signs to avoid obstructing sight lines at intersections and on the inside of curves,
- the positioning of signs and the selection of the type of signposts to avoid these structures themselves being a significant roadside hazard. This will generally require the use of frangible type sign posts rather than rigid types and the provision of guard rail protection for the support structure of large overhead (gantry) type signs.

At a complex exit arrangement like this, is this standard of direction signing adequate? The signs here lack prominence and have poor legibility.

This sign is big enough but the important legend on it is too small. Note also the incorrect sign format for direction signing.

(b) Road marking and delineation:

The auditor should check that:

- the correct type of longitudinal line markings, in terms of line pattern and width, are shown on the plans at the relevant locations and that these are correctly positioned to properly guide vehicles in respect to the correct use of the various traffic lanes and to effectively designate the locations of merge and diverge situations, shoulders and emergency stopping lanes etc. The auditor should particularly identify any case of discontinuity in 'through' traffic lanes and any unavoidable and inadequately signed 'trap' lanes or other illogical lane marking arrangements which may confuse or be unexpected by drivers.

- all horizontal and / or vertical curves on 2 lane 2 way roadways at which overtaking sight distance is not achieved are shown properly marked with double (barrier) lines and that closely spaced short lengths of barrier lining which may lead drivers into unsafe overtaking maneuvers are avoided.

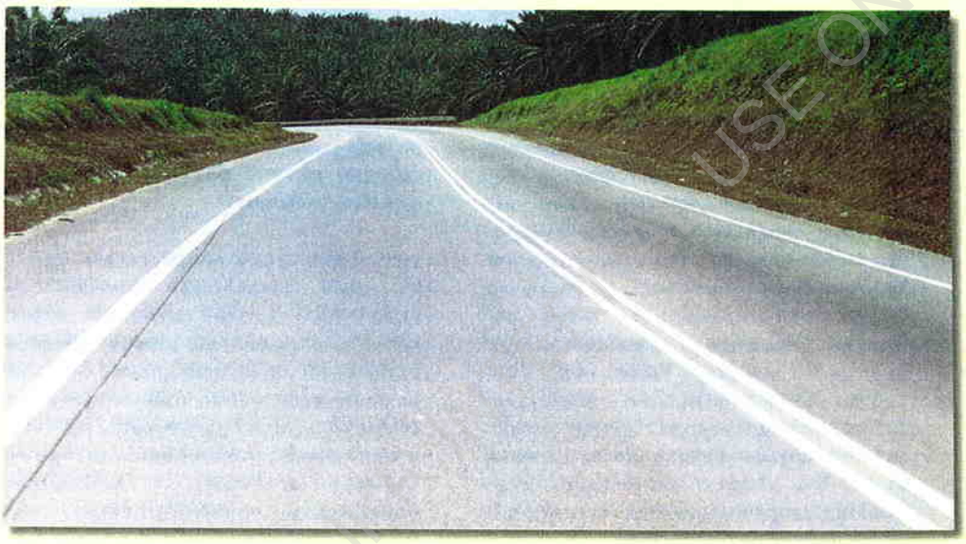
- approach hazard markings are shown on the plans at the approach end of all traffic islands, medians and separating islands and in the exit ramp 'gore' areas at expressway and other interchanges. These should be of sufficient size to be readily visible to approaching traffic and to 'warn' and guide drivers past the hazard.

- all transverse lines such as 'Stop' lines, 'holding' (or 'give- way') lines and pedestrian crossing lines are shown in the correct location on the plans.

- all road markings are specified to be reflectorised with glass beads to enhance nighttime visibility.

- retro-reflective pavement markers, (rpm's or road studs) are specified to supplement surface markings where there is a need for longer distance visibility at night and more effective pavement delineation under wet weather conditions. This is particularly desirable in high speed environment, on curving roadways particularly in combination with crests, on 'winding' mountain roads, on wide multi-lane roadways, at approach hazard markings and at intersections where traffic lanes change direction within the intersection. Not withstanding the considerable benefits of these devices, the selection of appropriate types of markers or studs is important to ensure that they do not represent a significant hazard to motorcycle riders.

Using the correct type of delineation is important. These 'flexible' delineator posts located on the centre line pose more of a hazard than a safety benefit.



Delineation of the route ahead often appears good by day but can be seriously deficient at night, in wet weather. Continuous guide post delineation and retro-reflective pavement markers would make this road safer at night.

7.3.9 Audit Of Street Lighting Design:

The lighting of roads / streets and other public areas has a number of community benefits, but in most cases the major objective or roadway lighting is to reduce nighttime traffic accidents. Experience has shown (Austroads 1988.) that street lighting can be very effective in reducing 'pedestrian involved' accidents and also (though to a lesser extent) accidents between vehicles. Its use is most cost effective in urban areas particularly at intersections and other locations where there are heavy traffic flows and a high intensity of conflict associated with vehicle maneuvers and pedestrian movements.

The road safety audit of street lighting design would consider the following items:

(a) The extent of street lighting:

Consider whether the proposed lighting covers the locations where it is warranted. The auditor should identify situations where unlit short lengths of roadway are mixed with lit sections.

(b) The standard of lighting:

Consider whether the level of illumination, particularly at intersections and interchanges, and of 'road pavement luminance' between intersections is appropriate to the traffic situation and the environment. Consider also the uniformity characteristics and possible 'glare' effects.

(c) Lighting Transitions:

Check to see that a reasonable transition in the lighting level is provided where vehicles go from areas with high levels of lighting into areas with no lighting or very low levels of lighting, e.g. going into a tunnel in daytime and out of a tunnel at night, and generally at the terminals of road sections where a good standard of lighting is being provided.

(d) Hazards caused by lighting poles:

As lighting is only effective at night, during the day time the lighting poles themselves can be a significant roadside hazard unless the type of poles and their positioning is carefully considered. The audit should identify any locations where rigid lighting poles are placed in vulnerable locations, such as on small traffic islands, narrow medians (unless located within a barrier system), near the entry points at roundabouts where vehicles are most likely to run off the road, etc. Effective 'frangible' type lighting poles are now commonly specified for use wherever poles are located within the 'clear zone' width (see further discussion below)

(e) Sight line obstruction:

As lighting is most often required at intersections, the auditor should check and identify any lighting pole locations which will obstruct the drivers view of traffic signals or traffic signs.

7.3.10 The Audit Of Roadside Safety Provisions:

Vehicles may run off the roadway for various reasons and if the roadside conditions are favorable many drivers will recover control of the vehicle and return to the roadway without crashing. A major objective of road design should be to provide a safe and forgiving roadside which allows this to occur wherever practicable.

The auditor should therefore check the roadside environment and the following are some of the items to be considered:

(a) Provision of a 'Clear Zone':

This is an area or zone adjacent to the traffic lanes, of width dependent on the traffic speed and road alignment, which if kept clear of obstructions and other hazards, will allow errant vehicles to recover without crashing. Experience and research has indicated the desirable width of this zone in various situations. (Reference 13). The auditor should consider to what extent and at what locations a 'clear zone' of the appropriate width can be achieved and identify any lack of this provision where its achievement is practicable.

(b) The use of Frangible Types Of Road Furniture:

The auditor should check to see if frangible types of sign posts and lighting poles have been specified where these items are located within the 'clear zone' width, or are not otherwise protected with guard railing placed there for other reasons. Note that it is always preferable to use frangible sign posts and lighting poles rather than install guard rail just to protect these items.

(c) Guardrail Provisions and Design Details:

The type, positioning and design details of guard railing should be checked and any locations where it does not meet current standards should be noted. The audit should identify any location at which guard rail is necessary but is not included on the plans, and also any locations where it appears to be provided without sound justification. Note that guard railing is not appropriate where the consequences of a vehicle hitting the guard rail are worse than the consequences of hitting or proceeding into the hazard for which the guard railing is proposed.

In respect to design details, the auditor should check that the length of guard railing proposed at any location is greater than the minimum length required to ensure that it functions properly, and that the ends are properly anchored and terminated in accordance with the approved techniques. (See Arahan Teknik Jalan 1/85.)

Unnecessary guardrail like this, ending in a high risk exit 'gore' area is a serious hazard to traffic.

Breaks in the guardrail (e.g. for pedestrian movements) need to be designed to avoid exposing the guardrail end to traffic.

The consequences of improper treatment of the guardrail ends can be disastrous.

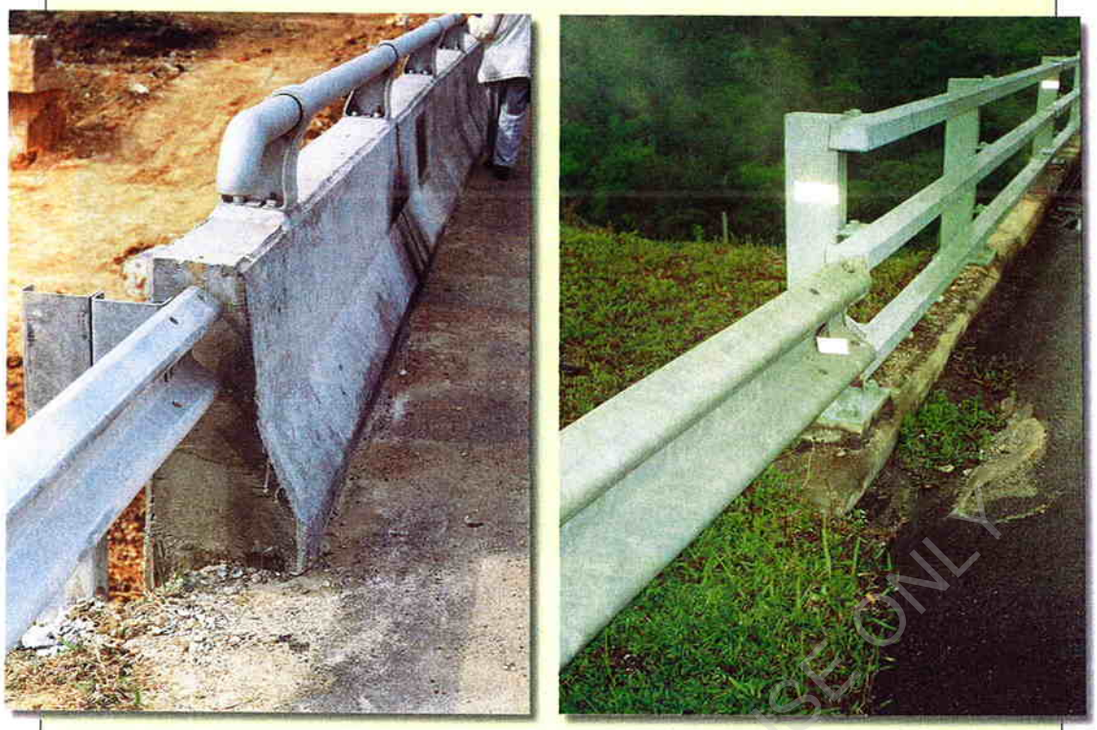
(d) Guard Rail Positioning Relative to kerbs and Objects being Protected:

The auditor should check that the clearance from the guard rail to the object being protected is sufficient to cater for the likely deflection of the guard rail during an impact. Identify also any location where guard rail is positioned within 0.15m and 3.0m behind kerbs, (other than fully mountable types), as kerbs in this zone can cause a vehicle to vault the guard railing.

(e) Bridge Ends And Guardrail To Bridge Rail Transitions:

The auditor should check and identify any locations where bridge ends which are exposed to approaching traffic are not protected with approach guard railing or other appropriate devices. The details of the proposed connection of approach guard railing to the a bridge railing system needs to be carefully checked to ensure that a proper transition (of the guard rail rigidity) is specified on the plans. Also check that the two railing systems are strongly connected to each other so that the two systems form a continuous barrier system of adequate strength to withstand vehicle impacts as desired.

The lack of guardrail continuity and transition of rigidity past this pedestrian bridge pier could endanger the bridge as well as an impacting vehicle



Inappropriate connection and transition of the approach guardrail to the bridge rail system in these photo's will have serious consequences for an impacting vehicle.

(f) Barriers and Railings on Bridges and Elevated Roadways:

Bridges and elevated roadways always require well designed barrier systems to ensure that vehicles are retained within the roadway limits. Well proven barrier systems are available which are designed to take the likely impacts from modern vehicles including trucks traveling at the expected traffic speeds. Some details of these are given in Arahan Teknik Jalan 1/85. The audit should identify any location where the adequacy of the bridge railing or barrier system appears to be deficient or does not meet current standards.

Particular attention needs to be given to situations where over-bridges and elevated roadways pass over or close beside lower level roadways. In these situations, apart from the railing or barrier system restraining vehicles from 'breaking through', attention needs to be given to the possibility of vehicle loads (or parts thereof) falling over the barrier onto traffic on the roadway below if a loaded truck hits the barrier. This can be a significant problem where vehicles are required to turn at intersections on elevated roadways, and also on wide elevated roadways where the probable angle of impact is large. (E.g. greater than 20°) In such cases the auditor should look for the inclusion of higher than normal barrier systems, which are designed to reduce the probability of loads falling over the barrier during an impact.

(g) Landscaping And Beautification:

It is important that landscaping and beautification design takes into consideration road safety implications. Apart from the references to obstructions to sight lines caused by landscaping as discussed earlier in this paper, there are other safety implications that need to be evaluated in a road safety audit. The audit should identify any situation where the type of trees to be planted and their location, particularly within the 'Clear Zone' width, is likely to become a roadside hazard when the trees mature. Check also for any inclusion in the landscaping plans of structures such as large rocks and boulders, monuments, ornamental gate posts etc, which may represent a significant hazard to vehicles running off the road.

(h) Other roadside hazards:

The roadside safety check should also consider:

- the location and safety treatment of uneven rock cut slopes close to the traffic lanes,
- roadways close to permanent deep water, such as rivers, lakes or seashore, which may justify guard rail regardless of embankment details.

7.3.11 Audit of Provisions For Special Road Users.

(a) Pedestrians:

Pedestrians are highly vulnerable road users who require specific consideration, particularly in 'built up areas' and other locations where their numbers are significant and/or where their risk is higher than normal, e.g. due to high traffic speed. Safety deficiencies which need to be identified include:

- Lack of footpaths or locations where footpaths are obstructed by posts and other road furniture,
- lack of kerb ramps or 'dropped kerbs' at pedestrian crossing points particularly at signalised intersections, as this will make it difficult or impossible for disabled or elderly people to use the facilities,
- lack of specific crossing facilities such as signalised crossings, refuge islands, Zebra Crossings, or grade separations where warranted. This is particularly desirable where school children are the predominant users,
- lack of specific pedestrian signal heads and signal phasing at signalised intersections,
- Inadequate street lighting or specific pedestrian crossing lighting at locations where there is significant nighttime pedestrian activity,
- Insufficient space for pedestrian refuge on traffic islands, medians etc,
- Traffic management and devices to enable pedestrians to cross wide roadways with continuous uninterrupted traffic flows.

Pedestrian bridges can be very effective at some locations,

but at many places they are poorly utilised, are not cost effective and create a severe roadside hazard.

Pity the poor pedestrian wishing to walk along this footpath.

(b) Motorcycles:

Motorcycle riders are another very vulnerable group of road users. They comprise between 30% and 50% of the traffic stream at many locations and contribute more than 50% of all traffic accident fatalities.

In a design stage audit the auditor should establish whether or not special facilities or provisions have, or should have been made for motor cycles and check that these are included in the plans. Where segregation is proposed via a separate motorcycle roadway, the auditor should check the safety related geometric design elements such as:

- horizontal and vertical alignment and sight distances appropriate to the expected operating speed,
- cross-section standards which provide adequate width of lanes or roadway, with appropriate clearances to roadside objects,
- merge and diverge areas properly designed to ensure safe and efficient operation, including the provision of auxiliary lanes where large speed differentials is expected,

- clear designation of 'priority' between conflicting streams of traffic at junctions',
- adequate line and pavement marking to ensure an orderly flow of vehicles and good delineation of the route ahead,
- appropriate regulatory, warning and direction signing with legibility and sign positioning consistent with the expected operating speed.
- appropriate types of guard railing or barriers, bearing in mind the 'unprotected' nature of motorcycle riders.

Where no separate motorcycle roadway is proposed, the auditor should check to see if other provisions such as fully paved shoulders or special treatments at signalised intersections have been or should be provided.

Apart from the above, the auditors should check that roadside features which pose a significant risk to motorcyclists, e.g. high (barrier) kerbs, drainage structures, deep side drains, guard rails, barriers and fences are kept clear of the edge of their roadway or are otherwise treated to reduce the degree of hazard associated with them.

Motorcycles form a large proportion of traffic. These high risk road users need to be segregated from other vehicular traffic wherever practicable.

Motorcycle riders invade the pedestrian crossing area where there is insufficient space provided for them to wait in front of other vehicles at traffic signals

7.3.12 Case Study
Road Safety Audit Stage 3 - Detailed Design

Lebuhraya Damansara Puchong (LDP) **Project.**

This project involves the design, construction and operation of a 'Toll Expressway' along the route of the existing Jalan Damansara - Lebuhraya Petaling Jaya. A Road Safety Audit was carried out only at the detailed design stage of Package 1 of the project and some of the items identified would normally have been considered at the planning and preliminary design stage.

An example comprising a short section of the project is shown in the design plans (the vertical alignment is not shown here), of Figure 7.8 The following notes describe various items which have been identified as road safety concerns which need to be addressed:

(A) Geometric details of the proposed bridged roundabout interchange.

- No vehicle path deflection at the LDP northbound entry to the roundabout;
- Inadequate approach sight distance at the northbound entry due to the 'fly-over' structure
- Steep downgrade on northbound approach will result in high entry speed at the roundabout;
- Right hand (through) traffic lanes are trapped into the exit to the roundabout;
- No offset (clearance) is provided at the roundabout exit noses;
- Inappropriate lane arrangement in the circulating roadway of the roundabout. (B1 to B 5)Access provisions between the Expressway and the local street system.
- In principal, direct access from the expressway to the local street system is undesirable from a road safety, traffic efficiency and local street amenity point of view;
- The length of auxiliary lanes (in this case simple tapers) provided at these access points is quite inadequate to allow safe operation on the expressway;
- All of the proposed access points involve high risk, complex traffic movements due to the close proximity of the two-way service road operation;
- The entry at location B4 is particularly hazardous because it occurs right at the exit nose on the expressway, where high speed exit traffic will not be expecting such conflict. At this location it also will be nearly impossible to prohibit vehicles (especially motorcycles) from exiting 'wrong-way' into the service road. Similarly the proposed access point at B5 is undesirable as it will cause unexpected conflict and accidents which will inevitably disrupt the smooth flow of traffic onto the expressway from the signalised ramp intersection.

(C) A Bus Bay is provided on the northbound carriageway of the expressway, but there are no provisions for pedestrians (e.g. bus passengers) to get from the east side to and from the bus stop. In addition, no bus bay has been provided on the southbound carriageway in this vicinity.

(D) From the vertical alignment design, the retaining wall and associated guardrailing between the main carriageway of the underpass and the exit ramp will terminate at the exit nose at point E. No shoulders or clearance is provided to this hazard. Some form of 'Crash Cushion' is essential to reduce the severity of probable impacts on the end of the guardrail/ retaining wall end

(E) The local street access point B3 creates a difficult and hazardous weaving problem as northbound traffic heading to this access point must cross 2 lanes of traffic coming onto the expressway from the entry ramp.

(F) The geometry at the signalised ramp intersection is very restrictive. The length of right turn lanes on the LDP exit ramps is too short to be effective. The layout does not permit opposing right turn traffic movements to run concurrently, thus signal operation will require 4 phases (instead of 2). This will result in the early onset of congestion, long traffic queues and increased accidents.

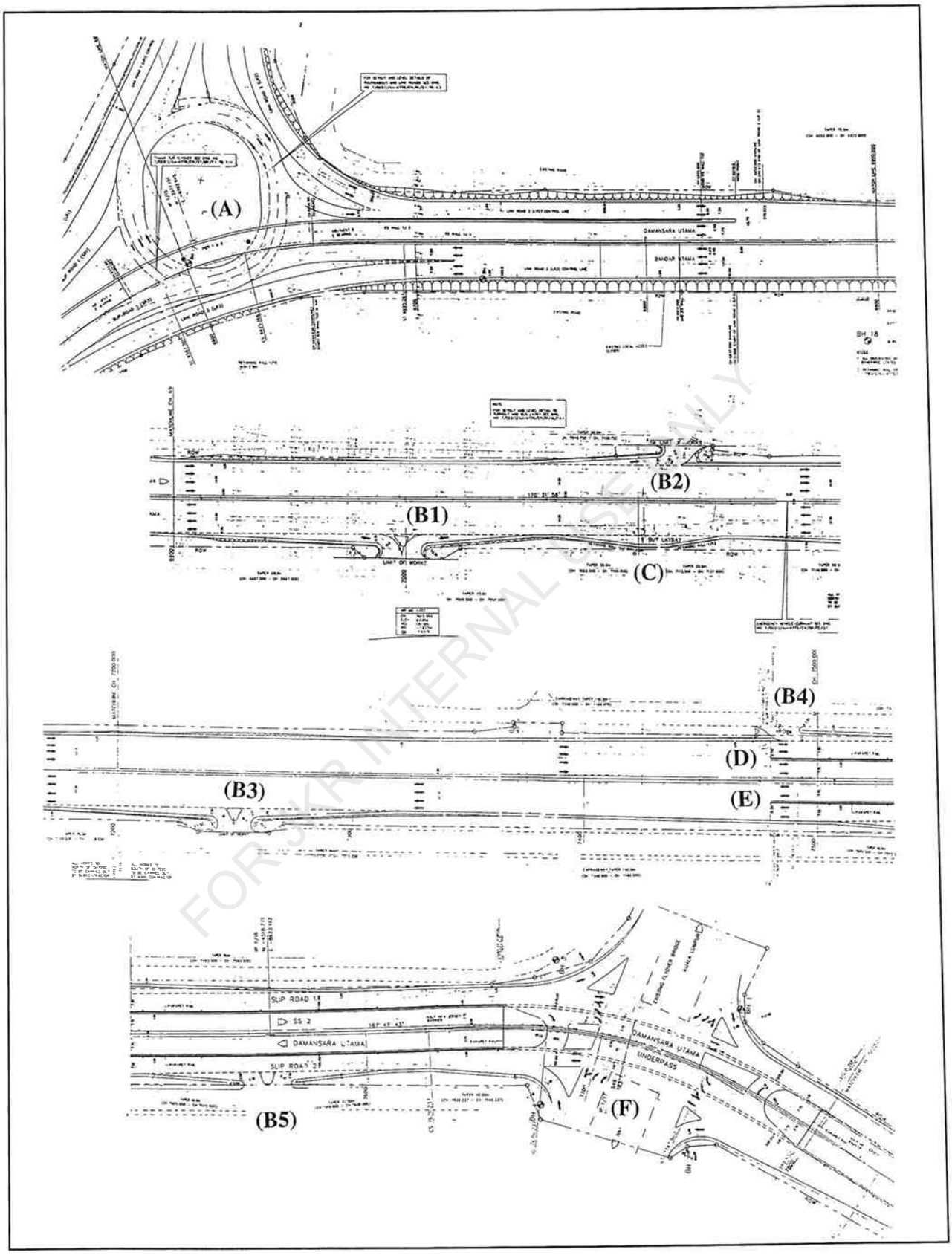


Figure 7.8 : Detailed Design Plans For Section Of Lebuhraya Damansara Puchong as Audited at Detailed Design Stage.

CHECK LIST

ROAD SAFETY AUDIT STAGE 3
Detailed design

Information required for the Audit:

- Audit Report and decisions on earlier stage audits;
- Locality plan showing road network and general topographic details in the region of the project;
- Statement of the Design Criteria;
- Relevant Traffic Demand information;
- Horizontal and vertical Alignment Plans;
- Cross-sections;
- Grading and Drainage plans showing the location and general details of drainage structures;
- Bridge layout plans including cross sections and details of barrier systems;
- Interchange and / or intersection layouts;
- Traffic signal layouts and design information;
- Traffic signing and road marking plans;
- Street lighting layouts and design information;
- Landscaping and beautification plans and tree planting details;
- Plans showing relevant overhead services / utilities.

Audit Items:

General Items To Be Checked:

Design Creteria:

Check for consistency amongst the items relevant to road safety;

Route Planning and Location;

Identify any aspect which has adverse safety implications, or previous decisions which have 'locked in' constraints to the detailed design which may lead to unsatisfactory safety performance;

Adequacy of Reservation Width to achieve a safe cross-section, considering the needs of all road users;

Consider the appropriateness of the proposed Access Control;

Check that the design is consistent with the general traffic management strategy proposed, considering such aspects as:

- Proposed Speed Limit;
- Vehicle Type restrictions;
- Proposed segregation of vulnerable road users;
- On-street parking provisions / restrictions;
- Turn restrictions;
- Special provisions for Pedestrians and or Bicylists;
- Special provisions for Motorcyclists;
- Special provisions for Trucks and/or Buses;
- Provision of 'Motorist Facilities' such as rest and service areas, laybys etc;

Check that climatic and weather implications have been taken into account eg:

- Wet weather and Flooding effects;
- High Winds;
- Fog prone areas.

Geometric Design Elements:

Check the Horizontal Alignment in respect to:

- correct choice and application of Design Speed;
- Consistency of horizontal alignment along the route;
- Check for 'sub-standard' curves;
- Transition curves (spirals) are provided where appropriate;
- Horizontal alignment at the 'interface' between the proposed construction and the existing road network;

Check the Vertical Alignment in respect to:

- Consistency along the route;
- Sight Distance.

Check combination of Horizontal and Vertical Alignment for:

- adequacy of Stopping Sight Distance (SSD);
- the achievement of Overtaking Sight Distance (OSD);
- the achievement of Approach Sight Distance (ASD) at Intersections;
- adequacy of sight distance at locations where there is a discontinuity in the cross-section standard;

- combinations of horizontal and vertical alignment which results in unexpected areas of 'hidden' pavement or areas;

Grades:

Check for:

- sections with steep down-grades;
- sharp curves on steep down-grades, check adequacy of superelevation rate to achieve appropriate design speed;
- sections with steep up-grades and the need for 'Slow vehicle' provisions.

Cross-Section:

Check for:

- number and witdh of traffic lanes, width of shoulders or emergency stopping lanes;
- median and separator width (where applicable);
- batter heights and slopes and guardrail requirement;
- use of correct types of kerbs (avoid barrier kerbs);
- the provision of footpaths;
- clearances to barriers and barrier types;
- appropriate transitions at locations where the cross-section changes significantly;
- special provisions needed for vulnerable road users such as pedestrians, bicyclists, motorcyclists;
- differences in level between the roadways of divided roads at intersections or access driveways;
- sight line obstruction by batter slopes through cuttings on curves.

Interchanges And Intersections:

Check:

- General layout logic;
- Visibility and Sight Distance:

  Several sight distance criteria applicable at intersections, each needs to be checked and the audit should identify any situation where a deficiency is evident:

  - Approach Sight Distance (ASD);
  - Entering Or Crossing Sight Distance (ESD);
  - Safe Intersection Sight Distance (SISD);
  - Sight Distance To Queued Vehicles;
  - Sight Lines and Visibility to Traffic Signals and Signs.

  At Interchanges the following additional sight distance creteria should be checked:

- Sight Distance To Exit Nose and'Gore' Area;

- Sight Distance To the Entry and Merge Area.

- Auxiliary Lanes And Lane Continuity:
  protection for 'turning' vehicles at any important intersections;
  avoidance of 'trap' lane arrangements.

- Island Size And Shape:
  - traffic Islands should be large enough to be easily visible and that they cater adequately for any traffic signs, signals, street lights and provides adequate refuge for pedestrians;

  - shape of the islands should guide vehicles into the correct travel path;

  - approach noses, properly offset from the edge of traffic lanes;

  - At roundabouts, the shape and positioning of the approach 'deflection/splitter islands' to ensure control of entry speed;

- lane and turning roadway widths to provide adequately for the large / heavy vehicles turning at low speed;

- Kerbs Type:
  incorrect kerb usage, which may constitute a hazard to road users particularly motorcyclists.

- Provisions For Pedestrians:
  lack of provisions of Footpaths and kerb ramps at crossing points;

- Adequate area/width for medians and roadway separators, including pedestrian refuge islands;

- Location of Signals, Signs, Lighting and other road furniture:

  not to be placed in vulnerable locations such as at the nose of traffic islands;

  should not obstruct normal pedestrian movements:

- Vehicle Parking And Buses Stops:
  - identify need for parking restrictions and check that proposed bus shelters and 'waiting' buses will not obstruct sight lines important for the safe and efficient operation of the intersection;

  - check that where on-street parking is to be provided, parking maneouvres will not interfere with traffic moving through the intersection;

  - identify sites where stationary buses at bus stops will interfere with the movement of other traffic;

- Property Access Points:
  are they likely to create unexpected traffic conflicts or otherwise hazardous traffic conflicts?

Audit Of Traffic Signal Installations

Check that:

- traffic Signals proposed only where they are warranted;

- proposed signal phasing provides adequately for the required traffic (and Pedestrian) movements;
- no unexpected conflict situations arise in the signal phasing, and that special phases for right turn movements are provided where justified;
- required 'intergreen time' for each phase change is sufficient to allow safe operation;
- the number and location of signal heads and posts ensures that each separately controlled vehicle movement has at least 2 (and preferrably 3 or 4) signal heads controlling it and that the minimum visibility requirements, as specified in Arahan Teknik Jalan 13/87;
- adequate clearances are provided between the face of kerb and the signal head not located in islands and medians too small or narrow to afford the equipment adequate protection from vehicle impacts;
- the correct signal size and brightness is provided and that backplates are provided;
- pedestrian signal displays and associated 'call buttons' are provided at sites where it is expected that pedestrians will cross signal controlled roadways.

Audit Of Traffic Signing And Road Marking

Traffic Signs:

Check that:

- traffic signing provides 'positive' guidance rather than abstract and indefinite information;
- the necessary regulatory signs are provided and properly positioned to control, both legally and practically, the movement of traffic along or across the roadway;
- appropriate warning signs are shown on the traffic signing plans;
- identify and recommend removal of any un-necessary warning signs;
- check the adequacy of proposed direction and guide signing (consider 'unfamiliar drivers');
- check that the letter / legend size is adequate to enable drivers to read the information displayed in the time available;
- check that the positioning of proposed direction signs will enable drivers to take any necessary action in a safe manner;
- check that appropriate reflectorisation is specified or that internal or external lighting of the signs is required;
- check the provision of overhead (e. g. gantry mounted) signs where complex multi lane roadway layouts require vehicles to get into specific lanes to reach particular destinations;
- check that the positioning of signs does not obstruct sight lines at intersections and on the inside of curves;
- consider the positioning of signs and the selection of the type of sign posts to avoid these structures themselves being a signficant roadside hazard.

Road Marking and delineation:

Check:

- that the correct type of longitudinal line markings, in terms of line pattern and width is shown on the relevant plans;
- that lines are properly positioned to guide vehicles in respect to the correct use of the various traffic lanes and to effectively designate the locations of merge and diverge situations, shoulders and emergency stopping lanes;
- for any case of discontinuity in 'through' traffic lanes and any unavoidable and inadequately signed 'trap' lanes or other illogical lane marking arrangement;
- that all horizontal and/or vertical curves on 2 lane 2 way roadways, at which overtaking sight distance is not achieved, are shown to be properly marked with double (barrier) lines and identify lane marking arrangeements which may confuse or be unexpected by drivers;
- that Double (barrier) lines are shown to be marked at any horizontal and / or vertical curves on 2 lane 2 way roadways at which overtaking sight distance is restricted, in accordance with the appropriate guidelines;
- identify cases of closely spaced short lengths of barrier lining which may lead drivers into unsafe overtaking maneouvres;
- that approach hazard markings are shown on the plans at the approach end of alltraffic islands, medians and separating islands and in the exit ramp 'gore' areas at expressway and other interchanges;
- the correct positioning of all transverse lines such as 'Stop' lines, 'holding' (or 'give - way) lines and pedestrian crossing lines;
- that reflectorised road marking are specified to enchance nighttime visibility;
- that retro-reflective pavement markers (rrpm's or road studs) are specified to supplement surface markings where there is a need for longer distance visibility at night and more effective pavement delineation.

Audit Of Street Lighting Design

Check that:

- the extent of street lighting is appropriate to traffic safety needs of all road users and identify situations where unlit short lengths of roadway are mixed with lit sections;
- the standard of lighting including uniformity and possible 'glare' effects is appropriate to the needs of the traffic sitution;
- lighting transitions are provided where street lighting ends;
- the lighting poles themselves do not constitute a roadside hazard;
- lighting poles do not significantly obstruct driver sight lines.

The Audit of Roadside Safety Provisions

The items to be checked include;

- provision of a 'Clear Zone';
- the use of frangible types of road furniture;
- guard rail Provisions and Design Details;
- minimum length of Guardrail required to ensure that it functions properly;
- guardrail positioning relative to kerbs and objects being protected;
- bridge ends and guardrail to bridge rail transitions;
- barriers and railings on bridge on bridges and elevated roadways;
- landscaping and beautification;
- other roadside hazards:
  - safety treatment of uneven rock cut batters;
  - roadways close to permanent deep water, such as rivers, lakes or seashore slopes close to the traffic lanes.
  - horizontal rails in pedestrian fencing close to roadways.

Audit of Provisions For Special Road Users

Pedestrians

Check for:

- lack of footpaths or locations where footpaths are obstructed by posts and other road furniture;
- lack of kerb ramps or 'dropped kerbs' at crossing points particularly at signalised intersections;
- lack of specific crossing facilities such as signalised crossings, refuge island, Zebra Crossings, or grade separations where warranted;
- lack of specific pedestrian signal heads and signal phasing at locations where there is significant nighttime pedestrian activity;
- insufficient space for pedestrian refuge on traffic islands, medians etc;
- traffic management and devices to enable pedestrians to cross wide roadways with continuous uninterrupted traffic flows.

Motocycles

Check for:

- horizontal and vertical alignment and sight distances, appropriate to the expected operating speed;

- cross-section standards, which provide adequate width of lanes or roadway for motorcyclists;
- appropriate clearances to roadside objects, merge and diverge areas;
- clear designation of 'priority' between conflicting streams of traffic at junctions';
- adequaate line and pavement marking to ensure an orderly flow of vehicles and good dilineation of the route ahead;
- appropriate regulatory, warning and direction signing with legibility and sign positioning;
- appropriate types of guard railing or barriers;
- provisions such as fully paved shoulders or special treatments at signalised intersections.

7.4 STAGE 4 AUDIT - DURING CONSTRUCTION AND PRE-OPENING OF A NEW PROJECT

The Stage 4 Audit will generally be the first opportunity for auditors to see a project more or less as it will appear to road users when it is finally completed. However at this late stage in the overall project development, the opportunity to make significant changes to the layout is usually quite limited. ***The audit therefore should focus on things that can be changed if necessary to eliminate potential safety hazards.*** Notwithstanding this, if a project has not been subject to earlier stage audits, the audit may identify planning and design features which have obvious safety deficiencies. In this respect, the guidelines for safety audit at the Detail Design stage (Stage 3 Audit) may be used to carry out a more comprehensive audit at the construction stage but recognising that it will be generally too late to change many of the critical design features.

In the case of large and complex road projects, the Stage 4 audit may involve a number of separate audits of various parts of a project as they get near to completion, e.g. auditing the general earthworks and grading at the time when embankment slopes and any associated guardrailing requirements are being finalised, or auditing the traffic signing at the time when the majority of signs are being placed. These 'sub audits' are often necessary to allow action to be taken at the most opportune time to minimise costs and to ensure that we "get things right the first time".

The other major focus of the Stage 4 Audit is on traffic management during the construction phase.

7.4.1 Site Inspections:

The Stage 4 Audit focuses very much on site inspections. These will generally be daytime inspections except that an audit of traffic management during construction must include a night time inspection.

Arrangements for site inspections should be agreed to at the initial commencement meeting and it is usually left to the construction manager to advise the auditor of the actual date and timing, bearing in mind the progress of the particular aspect of the work to be audited at that stage.

Auditors should review the overall check list for the Stage 4 Audit and extract from this a check list of items to be considered in any sub-audit of particular features of the project.

7.4.2 Things To Look For During Site Inspections:

(a) Horizontal and Vertical Alignment And Cross-section:

This needs to be first inspected when the major earthworks and grading are nearing completion, when it is practical to look at the general alignment standards and characteristics and their coordination with the topography of the area. The audit should identify locations where the alignment and topography result in areas of 'hidden pavement' or small depressions which may confuse a driver as to the direction of the route ahead or hide a vehicle momentarily in a potentially hazardous overtaking situation. These situations should have been identified at the design stage audit and while it may be too late at the construction stage to significantly change the vertical and horizontal alignment, there is an opportunity to pay particular attention to warning or control of traffic through provision of appropriate signs and roadmarking.

Check the sight distance (e.g .Stopping Sight Distance) across the inside of horizontal curves where cut batter slopes may cause a restriction Check this particularly on the

approaches to intersections and to 'Exits" at interchanges. In checking this keep in mind the likely effect of landscaping (which may not have been carried out yet) and identify any location which could be improved by setting the batter slope further back, (if this is practicable) or alternatively, check that the appropriate warning signs and pavement markings are provided.

In respect to cross-section elements, the general requirements for guard railing at embankments can be checked. It is often found possible to eliminate significant lengths of guard rail by using excess cut material, or material not acceptable for the structural parts of an embankment, to flatten batter slopes at the 'shallow' end of embankments to the extent necessary to eliminate the need for guard railing. This not only improves safety but also reduces project costs.

(b) General Roadway Layout Features:

This aspect relates more to intersections and interchanges rather than general route and cross section. As these features are constructed late in the construction phase, the inspection of them needs to be arranged accordingly. The aspects to look at are as follows:

- The layout of channelising islands and medians; check that the widths of roadway conforms to the plans and is adequate for the number of lanes required, including any allowances for lane widening on small radius curves and particularly for vehicles turning at intersections. Check that appropriate clearances and offset is provided at the approach noses of traffic islands, medians and other dividers. Check that the kerb being constructed is of a type appropriate to the situation. Identify any instance where 'barrier' type kerbs are provided as these should generally be avoided. If this aspect was not identified in the design stage audit, efforts should be made to have the kerb type changed to 'semi-mountable' type at the construction stage.

- Check that the width of medians and the size of traffic islands are sufficient for the proper protection of road furniture items that need to be accommodated within them and for any requirement for pedestrian refuge. Even at this late stage of construction it is sometimes possible to improve these features at little cost.

- Check the alignment of tapers into and out of auxiliary lanes, particularly where they occur on curved sections of the main alignment, and identify for correction any instance where 'through' traffic may be lead un-intentionally into the auxiliary lane. This can be corrected at this stage by lengthening the parallel part of the auxiliary lane and increasing the rate of taper. This aspect is often only clearly evident when the roadmarkings have been placed, but if this problem can be identified earlier, e.g. prior to the final surfacing being laid, it can be changed at little cost.

- Check that the location of drains and drainage structures are located clear of places where pedestrians are expected to stand or cross a roadway.

- Check the general alignment geometry, particularly in respect to sight distance and identify any location where the combination of vertical and horizontal alignment and any likely effects of guard railing or landscaping results in sight distance which is inadequate for the expected traffic operating speed. This needs to be carefully checked at critical locations such as the approaches to intersections, 'exit' ramp noses at interchanges and around the inside of horizontal curves.

(c) Traffic Signing And Roadmarking:

These features are generally some of the last items installed on a project and often only a few days before the project is opened to traffic. The stage 4 audit places particular emphasis on these traffic management items as they greatly influence the safety and efficiency of traffic operation. The following aspects need to be checked:

(i) Traffic Signs:

- Review the overall traffic signing strategy on the plans and if a design stage audit has not been done, identify any deficiencies such as inconsistency in the naming of destinations and road names and any lack of Regulatory, Warning and Guide (direction) signing. In respect to Direction signs check that the key destinations and route names / numbers are consistent with those used on adjacent projects.

- Check that the required Regulatory and Warning signs are placed at the correct locations (as per the plans unless site conditions necessitate a change). Identify and recommend removal of any unnecessary warning signs or other devices which are not specifically warranted

Check that the legend on traffic signs conforms to the sign design plans and that the size of the sign, the size (letter height) and arrangement of the legend, internal lighting, check that the necessary light fittings are provided and that these do not obstruct a drivers view of the legend on the signboard and that they are arranged to avoid 'specular' reflections which will reduce the legibility of the sign at night.

(ii) Roadmarking:

Check that the type, location and arrangement of roadmarkings are as specified and shown on the plans, e.g. the correct 'line 'and 'gap' dimensions and the correct line width. Check that the different types of line correctly designate (to road users) the traffic management requirements associated with each type of line, e.g. continuity line designating merge and diverge areas and indicating the boundary of 'through' traffic lanes; Check that Stop /Give Way lines are located exactly where we want drivers to stop (and look) before entering an intersection, that unbroken lane lines are marked where we want to discourage lane changing and that double unbroken lines are marked where we want to prohibit overtaking etc.

Identify any situations involving 'trap' lanes and discontinuity of 'through' traffic lanes and check that if these are unavoidable, the necessary direction, traffic instruction and warning signs are provided to minimise adverse safety effects.

Check that where specified, or where considered necessary for safe traffic operation, raised retro-reflective pavement markers (road studs) are provided to supplement road surface markings and that these conform in colour and arrangement to approved standards.

Identify locations and situations where Left or Right pavement arrows are required to designate traffic lanes which are restricted to particular traffic movements. Check that the correct type of arrow has been marked in these lanes and that where lanes involve no such restrictions, no arrows are marked. Note that a 'straight ahead' arrow should only be used where a lane is restricted to straight ahead movements and it should not be placed where the only possible movement is straight ahead. Check also that 'turn' arrows are not used in merge or diverge areas as there are specific arrow shapes applicable to these situations.

(d) Roadside Safety Features:

Auditors need to be familiar with the concept and requirements of providing a clear roadside 'recovery' area along arterial roads. This is referred to as the 'Clear Zone', the dimensions of which are discussed in the guidelines and notes for Stage 3 Audit. Auditors also need to have a good understanding how the various types of roadside barriers and guard railing function and of the warranting conditions for the provision of these devices. Particularly note that roadside barriers and guard railings are themselves significant hazards and their provision is only justified where the consequences of a vehicle hitting the hazard is likely to be worse than the

consequences of the vehicle hitting the barrier or guard railing. The following specific items need to be checked:

- The audit should confirm (e.g. by specific measurement), the locations at which 'protection' from a hazard for a vehicle running off the road needs to be provided, e.g. steep drop-offs, high embankments, especially embankments adjacent to deep permanent water etc. and check that the most appropriate type of guard railing has been provided. Check that the guard rail structural details are correct as per its design requirements, such as its location relative to the hazard, e.g. clearance for deflection of the guard railing, height of the railing, post spacing etc. and that the length is adequate to cover the extent of the hazard.

- Check that the hazard created by the approach end of a guard rail or barrier is properly treated to minimise the severity of impact if a vehicle runs into its end. Such approach ends must be 'flared' away from the traffic lanes, properly anchored and protected with an acceptable 'impact attenuating' device or treatment. The 'downstream' end of guard railing also needs to be anchored to ensure that its operation is effective to the full extent of the railing.

- In respect to bridges, check that an approved form of bridge barrier or railing system has been used and that it allows no horizontal rails to protrude beyond the end posts at the end of the bridge. Check that where the bridge is over or close beside a busy roadway below, the type and height of the railing is adequate to restrain a vehicle from going over the top of the railing or to ensure that part of the load of an impacting vehicle cannot fall over the barrier onto vehicles on the roadway below. The use of such high barriers may also be justified on steep winding mountainous roads where the combination of horizontal and vertical alignment significantly increases the probability of vehicles running off the road and where steep, deep drop-offs makes the consequences of such run-offs extremely severe

- Check the approaches to bridges to ensure that the ends of the bridge are treated with approach guard rail to eliminate collisions with the end of the bridge railing system. Where semi-rigid (Eg. 'W' beam guard rail) or flexible systems, such as 'cable guard' systems, are used on bridge approaches, check that the possible deflection (rigidity) of these systems is properly transitioned into, and strongly anchored to the rigid bridge railing system in an approved manner.

- Where a barrier or guard railing system is to be used in conjunction with a kerbed roadway, the audit should carefully check the position of kerb relative to the face of the barrier or guard rail. The kerb must be placed either in line with the face of the barrier or railing, or not less than 3 m in front of it, to avoid a vehicle first hitting the kerb and being vaulted over the barrier or guard railing.

- Where a median barrier is being provided, check that it is of an approved type for the situation in question, bearing in mind the width of the median, the likely vehicle speed, the likely angle of impact and the expected deflection of the barrier during an impact. Note that flexible barrier systems such as 'cable guard' may require up to 2 m deflection space, 'W' beam guard rail may require up to 1.0 m deflection, whereas Concrete barriers like the 'New Jersey' type require minimal or no deflection space.

- Where a fixed hazard such as rigid posts, poles or bridge piers are placed in a median or road divider in which guard railing or a barrier is provided, the auditor will need to check that there is sufficient clearance (space) for the barrier system to deflect without the impacting vehicle hitting the fixed hazard. Where such space is limited, any semi-rigid or flexible systems will need to incorporate 'rigidity transitions' at each of these locations. Generally in such situations it is better to adopt a rigid form of barrier such as the 'New Jersey' type. Where a 'New Jersey' barrier is used and lighting poles are supported within the barrier any gaps in the barrier at the poles must be suitably covered with a steel plate to avoid an impacting vehicle being 'snagged' in the gap. Any example of uncovered gaps should be recorded in an audit

- Where other narrow isolated hazards such as bridge piers and overhead sign gantry columns occurs, or a barrier or railing system ends, in the narrow Exit 'gore' area of an interchange, the auditor should check to see that:

- the item cannot be relocated out of the hazardous area, and if not,

- a suitable 'impact attenuator' or 'crash cushion' has been provided to reduce the severity of likely impacts.

- Check that culvert ends and 'end walls' and other drainage structures, including deep monsoon drains, do not create hazards within the 'Clear Zone'. Culvert ends and end walls can be designed flush with embankment slopes, or for large culverts, protected with guard railing. Monsoon drains may need to be treated with a 'grating' or concrete cover in the critical areas to achieve a satisfactory level of roadside safety particularly for motorcycles and light cars.

An improper guardrail to bridge rail connection like this can be corrected at the construction stage.

This bridge approach guardrail runs off the verge onto the embankment slope, resulting in inadequate ground support for the posts.

:he deep in at the ıing wall. will be a to traffic covered 'grating'.

(e) Landscaping:

Landscaping features can have a significant effect on road safety. Apart from providing a pleasant and stimulating road environment, which helps to keep drivers alert, trees often provide useful 'long range' guidance of the direction of the route ahead and where planted in a median they provide a useful barrier against the 'glare' from opposing vehicle headlights. However the main focus of the stage 4 road safety audit, is to ensure that the trees, bushes, shrubs etc. being planted, and other landscaping features, do not create unacceptable roadside hazards within the 'Clear Zone', or that they do not (or in the future will not) obstruct any of the essential sight lines needed by road users to operate safely.

The auditor(s) must make themselves familiar with the 'mature' characteristics of the various species of trees and other plantings and need to keep these in mind when checking potential obstruction of the sight lines or the extent of hazard caused to vehicles running off the roadway.

(i) Landscaping Obstructing Sight Lines:

- Sight lines across the inside of curves to ensure that 'Stopping Sight Distance', or 'Overtaking Sight Distance' (where applicable) will not be obstructed.
- Sight lines to the 'Exit' Nose at expressway and other interchanges, particularly where the approach to them is on the inside of curved alignment,
- The 'sight triangle' between drivers on an expressway interchange 'Entry' ramp and vehicles on the main carriageway, (and vice versa),
- The various sight distance criteria at intersections, including signalised intersections and roundabouts. The important aspect here is to ensure that the 'corner sight distance triangles' which enable road users on conflicting travel paths to see each other in time to avoid a collision, are not likely to be obstructed.
- The sight line across a median, required by the drivers of vehicles making a Right Turn at an intersection or a 'U' Turn at a median opening for this purpose.
- Sight lines between pedestrians and vehicular traffic, where pedestrians are expected to cross a roadway at-grade, whether signalised or not.
- Sight lines of vehicle drivers (including motorcyclists and pedalcyclists), to traffic signals and traffic signs.

(ii) Landscaping Features which may be Potential Roadside Hazards?

The audit should check that any species of tree, which matures to a trunk size greater than 150mm diameter, is not planted within the 'Clear Zone' unless guard railing is being placed in front of them for other reasons.

In general trees with a large trunk size should be planted furthest from the traffic lanes (even outside the 'clear zone') with shrubs and bushes and smaller trees planted in front of them to create a buffer or cushion effect for vehicles accidently running off the road.

(iii) Effects of trees on street lighting:

When trees planted in medians, or otherwise near to the roadway, mature with a large foliage spread, they can have a detrimental effect on street lighting. The audit should check the positioning of trees, relative to the lighting poles, their expected 'canopy' height and spread of foliage relative to mounting height of the luminaire and its 'outreach', and identify any situation where the illumination of the pavement is likely to be obstructed.

(iv) Other Landscaping aspects to consider:

Where trees planted near to the edge of a roadway develop foliage overhanging the traffic lanes, they may infringe the vertical and horizontal clearances for large high vehicles. This can cause the drivers of high vehicles to swerve out of their traffic lanes which increases the risk of collisions to other road users, who often do not expect such maneuvers. Any such potential situation should be identified in the audit.

Where trees are planted close behind semi-rigid guardrail such as 'W'Beam and flexible systems such as 'Wire Rope' types, sufficient clearance must be provided to allow for the expected deflection of the barrier during an impact. The audit should identify any locations where the planting of trees and other landscaping features is likely to interfere with the proper performance of barriers and guard rail.

7.4.3 Audit Of Traffic Management During Construction And Maintenance:

The lack of appropriate traffic management at a road construction site can not only result in serious traffic accidents, but it also can endanger road workers at the site. Special traffic signs and signing arrangements have been developed to control, warn, inform and guide traffic safely through and around roadwork sites. These need to be carefully placed and maintained to ensure effective and safe traffic management throughout the construction period.

The audit of these features is an important part of the Stage 4 Audit and it needs to be arranged early in the construction phase to maximise the road safety benefits. The timing for this part of the audit should be arranged at the 'initial commencement meeting between the Auditor(s) and the client. The traffic management strategy and the associated plans etc., throughout the project, including any 'stage development' of parts of the project, must be made available to the Auditors at the commencement meeting, at which time arrangements should be made for the necessary day and night inspections.

(a) Review Of Traffic Management Plans:

The auditor must first check the proposed traffic management arrangements from the plans, preparatory to any site inspection.

Where standard traffic signing arrangements are specified, these should be checked to see if they are suitable and adequate for the particular project or part of a project under consideration. This is best checked by answering the following questions from information shown on the plans:

- Will the 'advance' signing make a sufficient visual impact on drivers and adequately warn them of the existence and general nature of the works ahead?

Will the subsequent signing and other devices effectively reduce vehicle speeds to that required to safely enter and travel through the works area?

Will the directional signs and delineation of the traveled way safely lead and guide drivers through or around the works area?

Are road users being properly informed about where the works end and that they can revert to normal operation?

(b) Inspection Of Traffic Management Arrangements:

The second step is to inspect the traffic management arrangements at the roadworks site. Such inspections may need to be done more than once during the construction period of a large project and particularly at stages when, and if, substantial changes are made to the traffic management strategy as the works progress. These inspections must to be made both during daytime and at night. The auditor(s) need to bear in mind the different perceptions that road users may get when works are going on (say during the daytime) compared to that which may exist when work has ceased for the night or during holidays etc.

The Auditor(s) should look at the following aspects:

- Check that the advance signing complies in general with the arrangements shown on the contract drawings, commands the attention of road users and adequately warns them of the roadwork situation ahead, in sufficient time for them to take any necessary action.

- Check that the Speed Limit is appropriate for the situation and is prominently displayed and that other supporting devices are properly positioned to bring about the required speed reduction so that vehicles enter the roadwork zone at a safe speed.

- Check that sufficient guidance is provided by the various signs, delineators and pavement markings etc. to lead road users safely through the roadworks zone. Where side tracks and other detours are involved, check that the entry and exit curves or turns into and out of the detour are of adequate radius and width, and that the approach sight distance is appropriate for the expected operating speed.

Check throughout the works zone that any sharp 'drop-offs' or differences in level near the edge of the traveled way are properly delineated and, where deep (>1m) excavations are within 5m to 8m of the traffic lanes, appropriate temporary barriers are installed to avoid errant vehicles running into the excavations.

- Check that where pedestrians need to travel through the works zone, their pathways are clear of the vehicular traffic lanes, properly delineated and clear of posts, poles, pits or other obstructions or hazards. Check that the vertical clearances under any overhead construction is adequate.

- Check that any Regulatory, Warning or Directional signing, necessary within the roadworks zone is to an appropriate standard and achieves the desired objectives.

- Check that, where necessary, temporary street lighting, to an appropriate standard, is provided and that it does not result in 'glare' which may reduce the road user's visibility.

- Check that, where 'Traffic Control' persons are employed to manage the flow of traffic through the works area, they are appropriately designated, (e.g. with special clothing), are properly equipped, are fully instructed and that they carry out their task effectively.

Where traffic must operate in a construction zone, the roadway needs to be well delineated and separated from the works area

The objective of work site barriers is to protect the workers and the road users. Segmented barrier sections like this example do not achieve either objective.

Rehabilitation works such as this re-surfacing need careful attention to traffic management. Note the hazard caused by the electricity pole, which should have been relocated before the works began.

7.4.4 Case Study

Road Safety Audit Stage 4 - Prior to Opening, Seremban - Port Dickson Highway

Introduction:

This project consists of the construction of a dual carriageway Toll Expressway, 2 lanes each way plus paved shoulders, from Mambau, near Seramban, to Sua Betong, approximately 10 km south of Port Dickson. The length of the project is approximately 19 km and includes one interchange, (at Lukut), and several local road overpasses / underpasses, along with Toll Plaza's at Mambau and at the Lukut interchange and a Rest and Service centre.

Audit Arrangements:

A design Stage audit had been carried out only on the layout of the Lukut interchange.

This construction (Pre-Opening) stage audit was carried out by Mr E V Barton, Road Safety Expert, JKR Malaysia, on the 7th of July 1997 and a further inspection was made on 2nd August 1997. The project is expected to open to traffic towards the end of August 1997.

Representatives of the concession Company, their Consultants, JKR Headquarters, JKR District and LLM also attended the field inspection.

Audit Observations:

The following items were identified as road safety concerns during the inspection of the project :

(i) Guardrail Installation:

The Guardrail adopted throughout the project, (with the exception of some short lengths of concrete New Jersey type barrier), is the 'W Beam on Strong Post', type system. There are several aspects of the installation which, although in some cases complying with current JKR standards, are nonetheless unsatisfactory from a safety point of view as follows:

- The 4 m spacing of guardrail posts is twice the maximum recommended for this type of guardrailing.
- Guardrail posts concreted into the ground thus making them too rigid
- End anchorages improperly done, ***(see Photo 1)***

Improper or no connection of approach guardrail to bridge rail systems at structures,
(See Photo 2)

Unsafe gaps in the guardrail at the emergency telephones. ***(See Photo 3)***

Unnecessary guardrail located in the hazardous exit 'Gore' area at the Lukut interchange.
(See Photo 4)

Photo 1
Improper guardrail terminal.
Note the absence of nut and washer on the end of the anchor rod and the excessive height of the anchor point above the ground.

Photo 2
Failure to connect the approach gurdrail to the bridge barrier system. Note that there is no anchorage provided at the end of the guardrail.

Photo 3
Unsafe gaps in the guardrail at the emergency telephones.

Photo 4 Unnecessary guardrail located in the hazardous Exit 'gore area'

(ii) Bridge Barriers and Railing systems:

Most of the bridges have a conventional horizontal 'box-beam' railing system although the combination New Jersey barrier with a top rail is used at some locations. At one location , the bridge over the railway, an unusual shape concrete barrier wall which does not conform to any known safety standard has been constructed.

The following safety concerns have been identified with these bridge barrier / railing installations:

- Projection of the horizontal bridge rails beyond the end posts. This presents a serious danger of 'spearing' vehicles which impact the approach guardrail rail and slide into the end of the bridge. ***(See Photo 5)***
- Projection of the horizontal bridge rails in front of the concrete barrier system. This results in the same 'spearing' problem as indicated above. ***(See Photo 6)***

Photo 5 Unsatisfactory joining of the approach guardrail to the bridge railing system: No transition of rigidity of the guardrail as it approaches the bridge. Note also the 'spearing' danger created by allowing the bridge rails to extend beyond the end post of the bridge.

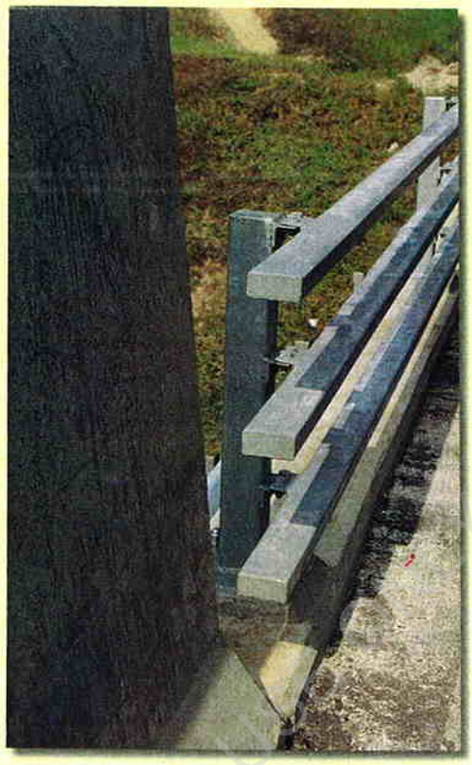


Photo 6
Misalignment of the concrete bridge barrier with the adjacent bridge railing and the 'spearing' projections of the rails result in a very unsafe arrangement.

(iii) New Jersey Barrier System:

This type of barrier has been constructed at the Toll Plaza's (Lukut Interchange), to separate the traffic which bypasses the Toll Collection from the traffic which must pass through the Toll Booths. The high speed approach end of this barrier presents a serious hazard to traffic ***(see photo 7)*** and needs to be fitted with an appropriate 'Crash Cushion'. The 'low speed approach ends' of these sections of NJ barrier also need some treatment to reduce the severity of any end impact, however as the traffic operating speed of traffic is likely to be below 50 km/h it may be acceptable to simply ramp the end down over a distance of 3m to 5m.

Photo 7
The ends of the New Jersey barrier past the Toll Plaza pose considerable hazard in an area where unpredictable traffic movements often occur. The 'high speed approach (beyond the Toll Booths in this picture) particularly justifies treatment with an appropriate 'crash cushion'.

(iv) Concrete Barrier at the railway bridge:

This barrier is substantially higher the conventional NJ barrier, which is not a problem, but the front face shape, while looking somewhat like the NJ shape, is not in accordance with any known or safety tested barrier and may not perform satisfactorily. In view of the difficulty of changing it at this stage, it is suggested that it be left as is and its performance monitored and it only be changed if it proves unsatisfactory.

(v) Drains:

At a number of locations there are roadside drains constructed at edge of shoulder pavement immediately in front of the guardrail. These are 150 mm to 200 mm deep and could seriously effect the proper functioning of the guardrail during an impact. ***(See Photo 8)***. It is preferable for such drains to be located behind the guardrail but at this late stage, it is agreed that the invert be concreted to reduce the depth of the drain to 100 mm maximum.

At other locations along the main carriageways the large 'V' shaped roadside drain and associated drainage pits are well within the likely 'run-off' area and while this may be unavoidable, they will present a significant hazard to vehicles, particularly motorcycles, which run off the road. It is agreed that it is not practical to treat this problem, which needs to be addressed at the design stage of a project.

At the southern terminal intersection of the project (at Sua Betong), a deep monsoonal roadside drain is located hazardously close to the edge of the traffic lanes, ***(see Photo.9)***. This presents a real danger to errant vehicles, particularly motorcyclists, especially as there is no kerbline to define the edge of the roadway and there is a steep embankment slope just beyond the drain. This terminal is in a relatively high speed environment and although the intersection is signalised, vehicle run-offs here are very likely. Again this unsatisfactory aspect would normally have been detected and hopefully eliminated at a 'Design Stage' audit, and at this stage the best solution may be to consider covering the drain, providing guardrail at the back of the drain, constructing a low semi-mountable kerb along the roadway edge of the drain and extending the asphalt paving up to the kerb.

Photo 8
Another case of inadequate guardrail to bridge rail connection. The lack of stiffness and strength in the last two sections of guardrail leaves a high probability of a heavy impact going through the guardrail onto the railway below.
Note also the deep roadside drain in front of the guardrail, which may alter the way the guardrail performs.

Photo 9
The deep roadside drain here is very close to the traffic lanes and poses a serious hazard especially for motorcycle riders. The embankment height and slope also increase the severity of 'run-off' accidents.
Note also the concrete foundation marking the position of a proposed traffic signal pole right on the edge of the pavement with no clearance or protection on this relatively high speed approach.

(vi) Kerbs:

Both at the Lukut Interchange and at the Sua Betong Terminal intersection, hazardous barrier type kerbs have been used ***(See Photo 10)*** in spite of the guidelines in Arahan Teknik (Jalan) 8/86 which advises against the use of such kerbs in the higher speed environment.

Photo 10
The visibility of the right hand primary traffic signal here is impaired by positioning the light pole in front of it. Note also the lack of prominence and legibility of the traffic sign on the far side of the road.

(vii) Traffic Signals:

Traffic signals have been installed at the ramp intersections at the Lukut interchange and at the terminal intersection at Sua Betong. Both of these locations are in a generally rural environment where high operating speeds (probably 80 km/h to 90 km/h approach speeds) are likely regardless of what speed limit is set. Traffic signals at such rural areas are generally unexpected by road users unfamiliar with the locality and therefore need to be designed with this in mind.

Unfortunately the general standard of the signal installation is very low with only one primary (stopping) signal head and no Mast Arm signals facing the high speed approaching traffic. The signals as installed have very little prominence and are difficult to see even from as close as 150 m. ***(See Photo 11)***.This is a serious safety deficiency which needs to be corrected before the project opens. The desirable treatment in this situation is to have three primary signal heads - One left one right and one overhead, located **at** the 'Stop' line on each high speed approach. There are three high speed approaches at the Lukut interchange and three at the Sua Betong terminal, (assuming that the damaged bridge is improved on the Port Dickson side of the intersection)

In addition to the mast arm requirements, large size (900mm x 900mm)'Traffic Signals Ahead' symbolic warning signs (WD22) need to be placed about 250m in advance of these signals.

At the Sua Betong terminal intersection some of the signal equipment had not yet been installed but Note in Photo 9 the extremely hazardous position of the footing (presumably for the traffic signal pole) right on the edge of the asphalt paving. This signal pole which needs to be a 'mast arm' overhead signal must be located outside the drain to give safe clearance for traffic and for the protection of the signal equipment.

In respect to the traffic signal operation, (which was not possible to inspect as the signals were not operating at the time of the inspection), it is emphasised that phasing which permits a right turn to occur at the same time as the through movement from the adjacent approach must not be adopted, as this creates serious conflict and has proved to be highly accident prone.

Photo 11
The traffic signals on this high speed approach are barely noticeable from only 150 m from the 'stop' line. Again the visibility of the right hand primary signal (the only one facing this approach will be obstructed by the lighting pole positioned in front of it.

(viii) Street lighting:

The layout of street lighting appears to be quite satisfactory however there are two aspects which are a concern from a traffic safety viewpoint as follows:

- Rigid type poles have been used, even where the poles are exposed to traffic (ie not located behind guardrail erected for other reasons). There are several such locations, eg on the ramps at the Lukut interchange and at the Sua Betong terminal intersection, where frangible type poles such as the 'slip - base' type should have been used to reduce the likelihood of injury if errant vehicles hit the light poles.
- There are a number of locations, (eg in the vicinity of the Toll Plaza), where the street lights have been located between the 'W' Beam median barrier railings. In principle this is good but in this case the poles have not been positioned in the centre of the median and thus from one direction there is insufficient clearance between the guardrail and the pole to allow the rail to deflect without hitting the pole. ***(See Photo 12)***. Any impact with the guardrail at these poles will be severe for the occupants of the impacting vehicle and will also damage the pole.

Photo 12
A median barrier like this offers an ideal and safe place to locate lighting poles, however in this case the poles have been positioned off-centre leaving inadequate clearance behind the guardrail for its deflection during a vehicle impact. Thus any impact will endanger the poles and result in more severe accidents.

(ix) Traffic Signing and Road Marking:

Many of the traffic signs had not been erected at the time of the inspection so the full traffic signing layout was not audited. However it was noticed that the legend size on some direction signs facing relatively high speed approaching traffic is too small.

Signs at the Lukut interchange, for example the 'To Nilai' sign has only 150mm height lower case letters even though the traffic is approaching at relatively high speed along the 'direct' off-ramp. These signs lack prominence and legibility distance.

It was also noted that the double diamond warning sign placed in the nose of the traffic island is likely to obscure the drivers view of the traffic signal on this approach. It is unnecessary and should be removed. This 'corner' (left turn) island which is quite large, is normally the correct location for the installation of the intersection direction signs, thus making it unnecessary to add the double diamond warning signs .

The traffic signing on the 'existing highway' approaches at the Lukut interchange also lacks prominence and legibility and the positioning of the signs does not appear to be satisfactory to provide drivers with sufficient advance notice of required traffic movements.

At the Terminal intersection at Sua Betong, the prominence of the direction signing is very poor and there is also insufficient emphasis in the traffic signing to alert drivers on the expressway that they are approaching the end of the expressway. ***(See Photo 13)***. Special large signs should be placed at the 2km, 1km and 500m advising drivers of the expressway end and of the directional destinations. It is suggested that special 'Reduce Speed Now' (Kurangkan Laju Sekarang) signs should be installed in the vicinity of where the 60 km/h Speed Limit is to start (see discussion below).

The Lukut interchange involves quite low speed (40 km/h and 50 Km/h) loops, one of which (the 40km/h loop) has traffic entering directly from the expressway. This will require a large reduction in speed and needs to have particularly good directional and warning signing. It is important at this loop to place the appropriate curve warning sign ***(See Sketch 3)*** together with an 'Advisory Speed' panel in advance of the curve.

It is also desirable that the 'Exit' direction signing from the 'to Seremban' carriageway into the 'Loop Ramp' at the Lukut interchange provide some advance indication of the restricted geometry of the loop. This is particularly necessary bearing in mind that the Expressway may be operated at 110 km/h and this 'loop' has a speed of only 50 km/h. It is recommended that an additional diagramatic direction sign as depicted in Sketch 3 be placed as shown. The other suggested modifications to the traffic signing shown in Sketch 3 should also be implemented prior to opening the project to traffic.

While the other loop takes relatively low speed traffic coming out of the Toll Plaza, it would be desirable to also provide drivers with the appropriate curve warning sign and the 'advisory speed'.

Note that the normal 'Regulatory' Speed limit sign should not be used to indicate the speed of these curves.

The pavement markings and roadway delineation are generally satisfactory except for:

- For such an important road as this and its 'Tourist' emphasis, bearing in mind the frequency of heavy rain in this country, the installation of retro-reflective pavement markers (rrpm's) is desirable (if not essential) throughout the project to enhance traffic safety at night and in wet weather.

- The use of 'Yellow Bar' treatments, such as at the approaches to the Toll Plaza's and sharp curves, should not have been carried out until it was established that a speed problem exists. In any case there is evidence (in Australia) that these treatments are largely ineffective in significantly reducing traffic speeds, they reduce the skid resistance of the pavement, often hide other important markings and are costly to maintain. At the entry to sharp curves it is better to provide the driver with positive information by installing Advisory curve speed and or 'Exit Speed' signs along with conventional warning and delineation devices.

- Roadside delineators have been installed on the face of the guardrail where this has been installed throughout the project.

These delineators should not be mounted on the face of the guardrail as in this position they create an added danger to motorcycle riders, they get dirty very quickly because of 'spray' from vehicle tyres in wet weather and get damaged whenever the guardrail is hit by a vehicle. The recommended position for these delineators is on the top of the guardrail post where they are relatively protected and not exposed to the above problems.

- In respect to roadside delineation, it is noted that a significant proportion of the length of the project has guardrail along the sides and throughout in the median. While good roadside delineation will be provided by the guardrail (and its delineators) there are many gaps where no left hand side delineation is provided. Some of these gaps are on curves and crests and route guidance will be deficient at these locations. It is recommended that guide posts be installed in these guardrail gaps to provide continuous roadside and route guidance which is particularly important for traffic safety at night and in wet weather. These are not expensive devices and consideration should be given to installing them, along with the retro-reflective pavement markers (mentioned above), even if it means an increase in the cost of the project

Photo 13
This picture looking back up the expressway from the terminal intersection, illustrates the high speed nature of the approach to this signalised T junction. Notice how insignificant the traffic signs appear. Signs this small cannot provide the prominence and emphasis necessary to alert the high speed approaching drivers of the ending of the expressway.

Landscaping:

The effort and cost expended on achieving superior aesthetics in this project is evident inthe attractive design of the bridges and landscaping and plantations rare expected to further enhance this. However it is unfortunate that in the landscaping palm trees have been planted in the verge area just outside the shoulder of the main carriageways. These are well within the desirable 'clear zone'(6m to 9m wide) for such a high speed road and they will create a significant hazard and are likely to obstruct the sight lines to traffic signs. There appears to be adequate space for these trees to be planted beyond the roadside drain, and at the toe of the cut slope where they would largely avoid the above problems and also be less likely to be injured by errant vehicles. ***(See Photo 14).***

Photo 14
In view of the high speed environment of the Expressway, is it appropriate to plant the palm trees so close to the edge of the roadway ? Note that there is ample space beyond the side drains and along the toe of the cut slope to plant trees, where they will be less of a hazard to motorists and motorists less of a hazard to the trees.

Conclusion:

This audit has identified a number of items which may adversely effect the operational safety of the project and in respect to which remedial work should be carried out before the project opens to traffic. These are:

- Improvements to the traffic signal installations, particularly adding mast arm signals at the 'stop' line on all high speed approaches,
- Placing nuts and heavy gauge washers on the anchor rods at the guardrail terminals,
- Treating the approach ends of the horizontal bridge rails to eliminate the 'spearing' potential,
- Placing advisory curve warning sign with Advisory Speed panel at the high speed entry into the loop ramp at the Lukut interchange, along with an additional diagramatic advance direction sign to properly advise drivers of the restricted geometry of the loop at this Exit.
- Removing the unnecessary guardrail from the hazardous high speed exit gore area at the Lukut interchange,
- Relocating the palm trees to beyond the roadside drain,
- Installing retro-reflective pavement markers throughout the project and guidepost delineation in the guardrail gaps.

Other items mentioned in the report, such as treating the guardrail to bridge rail connections, treating the gaps in the guardrail at the emergency telephones, and concreting the invert of the roadside drain in front of the guardrail should also be done if possible before the project opens or as soon as practicable after the project opens.

Some items identified may not be able to be economically treated at this stage, e.g. the light poles too close behind the median guardrail, and the proper flaring at guardrail terminals sections. These may be left untreated and only fixed if and when they really become a problem.

CHECK LIST

ROAD SAFETY AUDIT STAGE 4

During Construction

Information and Equipment Required for the Audit:

In the Stage 4 Audit there is less emphasis on reviewing plans and the major part of the audit will involve site inspection activities. The auditor will therefore require the following:

- A full set of Construction Plans, including plans for any traffic diversions and layouts associated with traffic management during construction;
- Tape for distance measurement;
- Photographic equipment;
- Note - taking and / or recording equipment.

Audit Iterms:

General Grading, Alignment And Cross-section.

Check:

- sight distance (e.g. Stopping Sight Distance) over crests, across the inside of horizontal curves and on the approaches to intersections and at 'Entry' and 'Exit' ramps at interchanges;
- combinations of horizontal and vertical alignment resulting in areas of 'hidden pavement' which may confuse a driver as to the direction of the route ahead or small depresions which may hide vehicle momentarily in a potentially hazardous overtaking situation;
- the general need for and provision of guardrailing at embankments and steep side slopes

Roadway Layout Features.

Check:

- the general alignment geometry, particularly in respect to sight distaance;
- the width of roadways (number of lanes), shoulder / parking lane width, widths of median and dividers and the size of traffic islands,
- the logic and 'clarity' of the layout of channelising islands and medians at intersections, as seen from a driver's perspective;
- the provision of appropriate clearances and offset at the approach noses of traffic islands, medians and other dividers;
- the type of kerb being constructed (eg, the incorrect use of barrier kerbs);
- the alignment of tapers into and out of auxiliary lanes and the avoidance of 'trap' lane situations;
- the location and treament of pedestrian walkways and 'standing' areas.

Traffic Signing And Roadmarking:

Traffic Signs:
Check for:

- review the overall traffic signing strategy on the plans and on-site;
- regulatory and Warning sign provisions and placement;
- type, size (letter height), amount and arrangement of legend on traffic signs and the adequacy of their legibility distance;
- the types of reflective sheeting, colours, grade etc. on traffic signs;
- the correct positioning of Direction and other Guide Signs;
- obstruction to the visibility of traffic signs by other road furniture items;
- the obstruction of essential sight lines by poorly located traffic signs;
- the mounting structure of traffic signs, (do not create a roadside hazard);
- general structural adequacy of traffic signs mounted over the roadway;
- the need for protection of gantry columns with guard railing;
- the adequacy of the mounting height of traffic signs;
- the adequacy of clearance under traffic signboards, particularly where mounted over footpaths and the avoidance of sharp edges or corners which could be a danger to pedestrians, pedal cyclists or motorcyclist;
- the need for, provision of and arrangement of external lighting for 'overhead' signs;

Roadmarking:

review the type, location and arrangement of roadmarkings, both on the construction plans and during the site inspections.

Check for:

- correct use of the different types of line to designate (to road users) the required traffic management requirements at particular locations;
- appropriate positioning of Stop/Give Way lines at intersections;
- the existence of 'trap' lanes and discontinuity of 'through' traffic lanes, and where unavoidable, the provision of appropriate warning and guide signing;
- the provision of raised retro-reflective pavement markers (road studs), where considered necessary for safe traffic operation;
- the correct provision 'arrow' pavement markings, required to designate traffic lanes which are restricted to particular traffic movements;

Roadside Safety Features:
Check for:

- The provision of guardrail or other barrier at hazardous fixed roadside hazards;

- the type of guard rail or barrier, the adequacy of its length in relation to the length of the hazard;
- structural adequacy of the guard rail, eg. height of the railing. post spacing, rail overlap etc;
- location of the guard rail or barrier relative to the hazard, e.g. clearance allowed for deflection during an impact;
- treatment of the approach end of aguard rail or barrier, end anchorage etc.
- the type of bridge barrier or railing system, appropriate to the situation and that it allows no horizontal rails to protrude beyond the end posts;
- the need for higher than normal barrier height on bridges over or close beside a busy roadway below and that the type and height of the railing is adequate to restrain a vehicle from going over the top;
- the treatment of the approaches to bridges, to ensure that the hazard caused by the approach ends of the bridge are treated with approach guard rail properly transitioned into, and strongly anchored to the rigid bridge railing system;
- the avoidance of kerbs directly in front of barrier or guard railing systems, or where it is unavoidable, the position of kerb relative to the face of the barrier or guard rail;
- the type of median barrier, where applicable, and the treatment of its ends;
- the provision and treatment of guardrail or barrier at fixed hazards such as rigid posts, poles or bridge piers located in a narrow median or road divider;
- the correct treatment of lighting poles placed within a median barrier;
- the treatment of other narrow isolated hazards such as bridge piers and overhead sign gantry columns within the 'Clear Zone';
- check that the item cannot be relocated out of the hazardous area, or
- that it is protected by guardrail, or
- check that a suitable 'impact attenuator' or 'crash cushion' has been provided to reduce the severity of likely impacts;
- the treatment of culvert ends and 'end walls' and other drainage structures, including deep monsoon drains, that they do not create hazards within the 'Clear Zone';

Landscaping:

Check:

- Trees and other plantations or landscaping features obstructing Sight lines:
  - 'Stopping Sight Distance', or 'Overtaking Sight Distance' (where applicable), particularly across the inside of curves.
  - sight lines to the 'Exit' Nose and at 'Entry' at expressway and other interchanges, particularly where the approach to them is on the inside of curved alignment,
  - the various sight distance criteria at intersections, including signalised intersections and roundabouts;

- the sight line across a median, required by the drivers of vehicles making a 'right turn' at an intersection or a 'U' Turn at a median opening for this purpose;

- sight lines between pedestrians and vehicular traffic, where pedestrian are expected to cross a roadway at-grade, whether signalised or not;

- sight lines of vehicle drivers (including motorcyclist and pedalcyclist), to traffic signals and traffic signs.

- Trees and Landscaping as potential roadside hazards:
  Check:

  - the species of trees and the expected 'mature' trunk size of trees planted within the 'Clear Zone'

- Effect of trees on street lighting:
  Check:

  - the positioning of trees, relative to the lighting poles, their expected 'canopy' height and spread of foliage relative to mounting height of the luminaire and its 'outreach'

Other effects:
Check for:

- Foliage likely to overhang the traffic lanes and infringe the vertical and horizontal clearances for large high vehicles;

  - planting of large trees too close behind semi-rigid guardrail such as "W' Beam and flexible systems such as 'Wire Rope' types, allowing insufficient clearance for the expected deflection of the barrier during an impact;

7.5 STAGE 5 AUDIT - AUDIT OF EXISTING ROADS

There are few, if any, existing roads in Malaysia which have been the subject of a Road Safety Audit (RSA) during their Planning and Design stages and it is inevitable therefore that many of them will contain features of various kind which increase the risk of traffic accidents or which may increase the severity of such accidents as do occur.

Even where some of the newer and better designed roads have been the subject of earlier stage audits, it is necessary to periodically carry out a stage 5 RSA because of the changes that occur naturally as the road and its environment matures.

Carrying out RSA of existing roads in a systematic way is a pro-active way of identifying high risk situations so that they can be eliminated or otherwise treated to reduce the likelihood of accidents or reduce the severity of accidents.
Stage 5 Auditing is thus an important accident prevention technique.

The procedure for the Stage 5 Audit is similar to that of other stages of audit, however the focus of the audit is almost exclusively on 'field observations' rather than on design plans, maps etc. Many of the items dealt with in Audit Stages 2 and 3, such as 'checking sight distance', legibility and positioning of traffic signs etc. are also the focus of attention during a Stage 5 Audit. A number of aspects included in the pre-opening Audit ***(Stage 4),*** such as guardrailing details, are also considered in Stage 5 audits.

In addition to the general procedures described above for Road Safety Auditing, in respect to the audit of existing roads, organisations responsible for a large road network need to establish a procedure for systematically auditing the whole network initially and subsequently, on a periodic basis. This will involve setting up a program of auditing the routes, road sections or parts of the road network on a systematic, or 'Priority' basis.

The responsible authority may select or otherwise prioritise routes or sections of road to be audited, based on a known accident history for the routes in question. (Where such information is available) or priority may be given to road sections with the highest traffic flow or the priority may be based on knowledge and experience of the operational performance of the routes concerned.

Some Road Authorities simply decide to systematically audit a percentage of their total road network each year (say 10%, based on budget and other resources constraints) and then break this up into manageable size RSA projects/sections.

The adoption of such a 'systematic approach to road safety auditing of existing roads does not preclude the carrying out of incidental road safety auditing of a particular section of road when the need arises. Such individual Stage 5 RSA's may be done on a single site, such as an intersection, or an individual curve, but it more commonly covers a substantial length of road.

As with any RSA, it is desirable that a systematic step by step process be adopted, (as described in Section.5. above), however the following additional points need to be considered:

- Where very long lengths of road are involved (say in excess of 100Km), it is generally better to break the length up into a number of Audit 'sub-projects' of about 50 km to 80 km lengths, except where the road and its environment are relatively uniform in character and with few adverse safety features.

- The auditor(s) need to be able to review the safety aspects of a road from an independent viewpoint.

In this respect:

* They must have Independence from the day to day operation and management of the road being audited, to achieve the degree of objectivity essential to the credibility of the audit.

* In most cases, it is an advantage to choose an auditor who is relatively unfamiliar with the route or section of road, as they will be more likely to see deficiencies in the road features and the various traffic management devices that are necessary for the safe and proper guidance of normal traffic.

- As discussed in Section 5 above, it is desirable for the responsible road authority (the RSA Client) to arrange for

an initial meeting with the selected Auditor(s) to officially start the Audit.

At this meeting the Authority or client should provide the Auditor(s) with a written statement or 'Brief' defining the scope and nature of the audit, the objectives, the timing and any other items which need to be agreed upon, including who the Audit Report is to be directed to and who the auditor(s) should liaise with in relation to matters arising during the audit.

The meeting should review any known operational history including seasonal and transient conditions which may effect safety, e.g. flooding, high winds, holiday/ festive season traffic problems, also existing or proposed construction and maintenance works etc. which the auditors may need to take into consideration.

The Authority should also provide the Auditors with any necessary maps, plans, traffic flow details and any available traffic accident data for the road section in question.

The meeting should also review any 'check list' proposed to be used, to ensure that it includes all the relevant items.

7.5.1 Site Inspections:

The site inspection is the key activity in the Stage 5 Audit and it needs to be carefully planned and executed thoroughly.

The following points are important:

- Inspect the site by Day and by Night and, if practicable, during periods of 'high risk', such as adverse weather, peak holiday periods, etc.

- View the road and traffic operation from the viewpoint of each type of road user. It is particularly important to consider the specific needs of the vulnerable road users such as pedestrians, bicyclists, motorcyclists. Also consider the safety implications for public transport vehicles and patrons, large trucks etc.

- Consider the requirements of the various road users in both traveling along the road and in crossing the roadway.

- Consider the safety implications of abutting land-use and the road network in the near vicinity and how it interacts with traffic operations on the road in question.

  Where long sections of road are involved, (say greater than 20 km length), it is usually an advantage to make the inspection in 2 or more phases:

- Firstly drive the road in each direction and identify the key areas of safety concern. At the same time noting down any other relatively minor matters. If a Video Camera is to be used to record information, use it on this initial 'drive through' to record the general features of the road and its environment. This will be useful later in discussing the details and formulating the report. Alternatively a 35mm 'still' camera may be used to provide a visual record of the road environment as seen by a driver or pedestrian.

Secondly, having identified the main areas of safety concern, the auditors then return to these locations and make a detailed 'on-foot' examination. This time detailed measurements, notes, video and photographs will be taken of each safety aspect to be reported. During these inspections it is also an advantage to record detailed comments on a hand-held tape recorder.

7.5.2 What to look for on the site inspection?

Appendix A of these notes provides a detailed check list of items which may be considered during the RSA of an existing road. The following notes discuss the important items which need to be checked during the site inspection.

(a) Vertical And Horizontal Alignment:

- Check the general consistency of the horizontal alignment and identify any 'sub-standard' horizontal curves. A curve is sub-standard if its speed value (Design Speed) is more than 10 km/h to 15km/h below the likely 'free vehicle' 85th percentile operating speed on the approach to the curve. Substandard curves most often occur at the end of a long straight section of road but may also occur on sections of winding road where a sharp radius curve occurs between curves of large radius. Check that the combination of horizontal and vertical alignment does not obscure the drivers view of a curve so that it is difficult for them to assess the safe speed of the curve. Where such substandard curves occur, check to see if the appropriate curve warning signs (including 'Advisory Speed') and enhanced alignment delineation, e.g. by the use of 'chevron alignment markers', or guide posts etc. have been provided. Any deficiencies in these matters should be recorded for inclusion in the report.

  It is often easy to identify sub-standard curves by looking for evidence of vehicles running off the pavement, such as badly worn edges of pavement and shoulders (where there are unpaved shoulders). Observations of driver behaviour such as heavy braking at the entry into a curve is further evidence of sub-standard curve geometry or inadequate curve delineation.

- Check and identify any location where the 'Stopping Sight Distance' is inadequate for the operating speed of traffic. Check also the limitations of 'Overtaking Sight Distance' and verify that double (barrier) line marking has been installed where appropriate.

(b) Cross-section:

- Again check for general consistency along the route and identify any location where the width of the road or the number of traffic lanes is suddenly reduced without proper advance warning to vehicle drivers.

- Check the general adequacy of the roadway from a capacity viewpoint and, from traffic observations, note any obvious locations of unreasonable or unexpected traffic congestion.

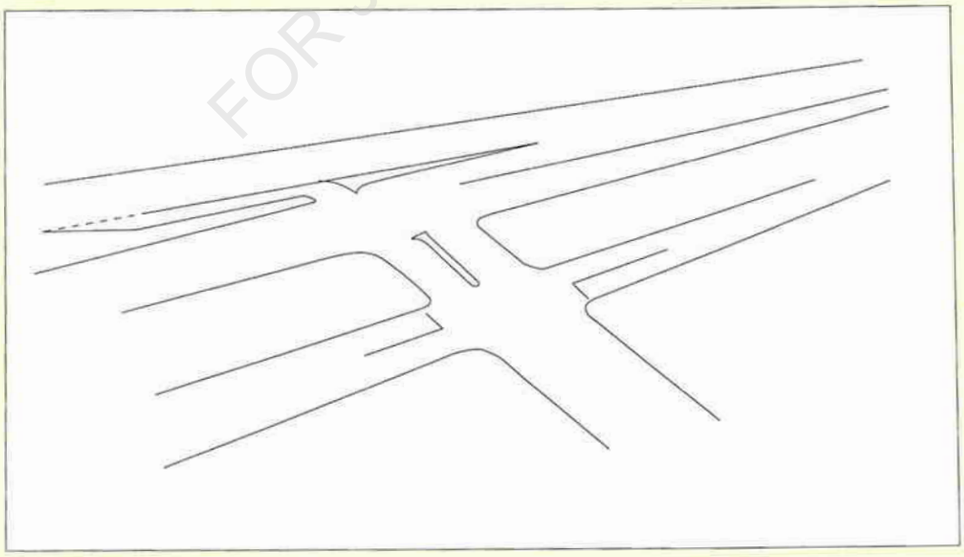
- Check other cross-section elements such as insufficient median width to allow 'protected' right turn/U turn lanes, inadequate shoulder or parking lane provisions, use of inappropriate type of kerb (e.g. barrier type kerbs should not be used where the traffic speeds are 60 km/h or greater), drop-offs at the edge of pavement (e.g. due to poor shoulder maintenance).

- Take particular notice of any lack of provisions for vulnerable road users such as pedestrians, bicyclists and motorcyclists. In respect to pedestrians, consider not only provisions for crossing roads, but also provisions for traveling along the road, e.g. are footpaths provided where necessary, particularly in the vicinity of schools or other locations where there is likely to be high pedestrian activity (i.e. virtually everywhere in villages towns and cities).

- Identify locations where the lack of service roads or of extra width of cross-section to provide for access control or to provide space for parking maneouvres etc. clear of through traffic.

The cross-section here is good except for the absence of a footpath.

Intersection layouts which may look OK in a plan view can sometimes be very confusing when viewed from driver eye height.



(c) Intersections:

More accidents occur at intersections than on road lengths between intersections and it is therefore necessary to pay particular attention to the identification of deficiencies at and in the vicinity of intersections. The following items should be carefully checked:

- ***Sight Distances:***

There are a number of sight distance criteria applicable at intersections as follows:

* Approach Stopping Sight Distance (ASD).
* Entering Sight Distance, (ESD).
* Safe Intersection Sight Distance, (SISD.

The standards for and application of these are discussed previously in Paragraph 7.3.6

Each of these, where applicable needs to be checked at all the critical locations during the site inspection. Any deficiencies identified should be recorded along with notes as to the cause of the deficiency and possible ways of improving the situation. Photographs of sight distance restrictions, taken from the 'road user's viewpoint' help illustrate these important safety aspects in the audit report.

- ***Layout Features Of Intersections:***

* Check that the general layout geometry appears logical to approaching drivers and caters adequately for the various traffic movements in terms of capacity.
* Identify any lack of auxiliary lanes for turning traffic and check that the length of such lanes is adequate for deceleration and storage (of waiting vehicles) clear of through traffic lanes. Also identify as a deficiency any location where the alignment of the roadway edge or kerblines tends to lead through traffic unintentionally int auxiliary lanes.
* Record any instances of discontinuity of 'through traffic' Lanes and 'Trap' lanes, i.e through traffic lanes which are suddenly marked with 'turning' arrows or which otherwise require vehicles to turn left or right.
* Note particularly any use of 'Seagull' type channelisation in towns or cities and consider whether pedestrian movements across the continuous flow are properly catered for. In general this type of channelisation is inappropriate in any 'built-up' area, town or city environment. If 'seagull' channelisation is used, (e.g. in a rural area), check that adequate merge length is provided for the right turn movement and that operation is not complicated by right turning vehicles needing to turn left only a short distance from the intersection.
* Check carefully the layout of any roundabouts and identify situations where the geometry of the approach entry roadways and the central island arrangement approaching does not adequately slow down traffic before they enter the circulating roadway. Also record as a safety deficiency any large roundabouts which allow high operating speed within the circulating roadway.
* Check that semi-mountable kerb and not barrier kerb is used at channelisation islands median and other traffic islands, that the approach nose of traffic islands are properly offset from the edge of traffic lanes, that the size of traffic islands is sufficient to provide refuge for pedestrians, or protection of traffic signal hardware, traffic signs and street lighting poles etc. Traffic islands also need to be large enough to be easily seen by approaching drivers even in the most adverse weather/lighting conditions.
* Check that adequate provision is made for the safe movement of pedestrians, bicyclists and motorcyclists. Deficiencies such as lack of footpaths, kerb ramps, pedestrian signal phasing and hardware, etc should be recorded.

The late movement of vehicles into this exit ramp may be due to inadequate sight distance to the exit nose. Trimming the foliage on the left hand side (on the inside of the bend), would improve an approaching drivers view of the exit.

Vehicles queuing back onto the expressway reduces capacity and increases the risk of rear-end, side-swipe and other collisions on the expressway.

(d) Expressway interchanges and other grade separated intersections:

- Check that the provision of the interchange meets a logical traffic management strategy along each of the intersecting routes, e.g 'through traffic' movements grade separated at one location should not find themselves stopping at traffic signals at the next nearby intersection. Check also that major traffic movements are not unexpectedly forced into difficult ramp geometry or are faced with unexpected conflicts with traffic movements from abutting land developments due to lack of access control.

- Check that entry and exit ramp geometry is to proper safety standards, with appropriate auxiliary lane provisions maintaining 'through lane' and 'route' continuity, avoiding 'trap' lanes and complex weaving situations. Note that all 2-lane entry and exit ramps must have auxiliary lanes to achieve operation and proper 'lane balance'. These should be at least 300m to 700m long (measured from the start/end of the normal exit/ entry taper) depending on the design speed.

- Check that the exit ramp alignment is appropriate for the speed of traffic leaving the expressway and that the length of ramp (from the exit nose to the 'stop' line where applicable) is adequate to provide for deceleration and queuing. Identify and record any deficiency in sight distance, (as illustrated in figure 7.5). Traffic operation

at peak and off-peak traffic flow periods should be observed and any evidence of rapid braking and queuing back to the exit nose or onto the expressway carriageway should be identified.

- Check that the entry ramp length is sufficient for vehicles to accelerate to merge speed and that the merge length (Taper) is adequate for safe entry onto the main carriageway. In the vicinity of the entry ramp nose, check that there is sufficient sight distance for drivers on the ramp to see traffic approaching in the near side lane of the main carriageway (into which they must merge). A sight distance of about 200m is desirable.

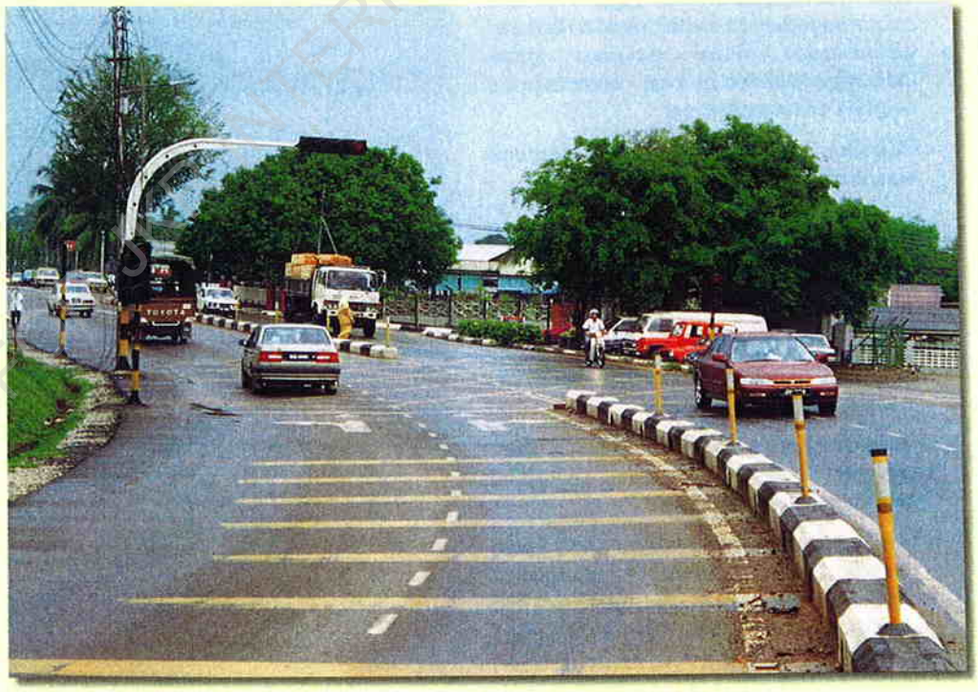
(e) Traffic Signal Installations:

- Check the logic and adequacy of the signal phasing. Identify any situation where conflicting traffic movements run concurrently and cause undue accident risk.

- Check that at least 3 signal faces are provided for each 'signalled' traffic movement and that the signal faces are properly aimed and that their visibility is not obstructed by traffic signs, trees, poles etc. Overhead signals should be provided on all high speed (>70km/h) approaches and where there are more than 3 lanes on an approach.

- Identify any instance where pedestrians are not provided with specific signal faces, 'call buttons' and signal phasing to control their movement.

- check that signal hardware such as signal pedestals, backing plates, visors etc. have sufficient clearance to the traffic lanes to avoid their damage.



The traffic signals here lack visibility and prominence, and some signal heads are hidden by traffic signs

Poorly located traffic signals increase accident risk and often endanger the signal equipment.

(f) Traffic Signing - General Aspects:

General aspects of traffic signing which should be identified in the audit:

- situations where traffic signs are too close together to enable them to be read, understood, and any necessary action taken and where one sign obstructs the visibility of another sign,
- locations where traffic signs obstruct essential sight distances
- signs with inadequate clearances to traffic lanes or pedestrian movements,
- the use of rigid sign posts where frangible posts could be used,
- the lack of adequate reflectorisation or illumination,
- the obstruction of lines of sight and essential sight distances by poor positioning of traffic signs.
- the use of unauthorised and non-standard types, colours or shapes of traffic signs or poorly designed symbols and other non-standard legend on signs.
- situations where there is a 'confusion' of traffic signs with advertising signs.

(g) Regulatory and Warning Signs:

- Check that all the necessary 'Regulatory' signs have been provided and positioned at the appropriate locations to give effective traffic control. These include 'Stop' signs, 'Give Way' signs, Speed Limit signs (including adequate 'repeater' signs), 'Turn Restrictions' or Prohibitions etc.

- Identify all the locations where warning signs are required and note whether the size of such signs are adequate to gain the attention of approaching drivers and that they are at the correct position to enable drivers to take the necessary action before encountering the hazard. Identify any unnecessary warning signs.

(h) Guide and Direction Signs:

- Check the general logic of the overall direction signing along the route to see that it meets the needs of drivers who are unfamiliar with the area.

- Check that direction signing at important locations is done systematically,. At major intersections there should be at least one 'advance' direction sign, followed by 'intersection' direction signs, positioned within the intersection, indicating the important destinations along each intersecting road, and this should be followed by a 'reassurance' sign (indicating distances to the named destinations) beyond the intersection in each road.

  At interchanges, there should be at least two 'advance' direction (exit) signs followed by an 'exit' direction sign located at the point of exit. On interchange ramps leading to at-grade intersections, the signing should be the same as that required for other important intersections.

- Identify any inconsistency in the naming of destinations on 'advance' direction signs, intersection direction signs and 'reassurance' (distance) signs.

- Identify any signs with poor legibility, i.e. signs with inadequate letter height and signs with too much legend, to be read in the time available.

The 'double diamond' warning signs at the island nose hide approaching vehicles at a critical point for drivers waiting to enter this intersection.

Traffic signs with too much legend create a potential hazard.

(i) Pavement Marking:

Things to look for in respect to pavement markings include;

- the general adequacy of the pavement markings in terms of their visibility and prominence both by day and at night, particularly in wet weather. Identify areas where the maintenance of the markings is poor,
- situations where the correct type of line marking has not been used,
- check that there is clear delineation and demarcation (by the correct type of line) of 'through' lanes and auxiliary lanes and that the markings correctly reflect the geometric design. This includes the correct placement, width and alignment of lanes, the correct positioning of edge lines (designating shoulders or emergency lanes or parking lanes), providing the correct offsets and approach hazard marking at traffic island noses etc.
- the provision of 'through' lane continuity and the proper designation of merge and diverge areas by the use of 'Continuity' lines,
- the correct provision of 'pavement arrows' limiting the use of specific lanes, and the use of the correct type of 'pavement arrows'
- the absence of or incorrect positioning of transverse lines such as 'stop' lines 'give way' lines and pedestrian crossing lines etc.
- the inappropriate use of 'yellow bar' marking
- check the effectiveness of the pavement markings at night and preferably in wet weather. This usually requires the use of retro-reflective pavement markers (rrpm's) or road studs.
- check that the type of road studs used (if any) e.g. colour, are in accordance with adopted practices and that the markers or studs do not constitute an undue hazard to motorcyclists and bicyclists.

This sharp curve at the end of a long straight in a rural area takes drivers by surprise and quickly becomes accident prone. The use of 'Advisory curve Speed' signs with a curve warning sign and good delineation of the curve is the preferred treatment.

Inadequate pavement marking leads to poor lane discipline and erratic traffic behaviour.

Road markings which are inappropriately used or appear illogical to motorists lose their credibility, are ignored and increase accident risk

(j) Roadside Safety and Landscaping:

- Check the extent to which a 'clear zone', into which errant vehicles may run without crashing, has been achieved along the road. Consider carefully the roadside safety requirements of all road users, particularly motorcycles.

- check and record the existence of fixed roadside hazards within a width equal to the 'clear zone' width, measured from the edge of the traffic lanes. (Suggested 'clear zone' widths are given in Appendix A). The safety implications of items such as deep unprotected drains, steep embankments without guardrail, culvert end walls and other above-ground drainage structures, bridge piers and abutments, overhead sign support structures, etc. should be checked. These items should either be removed, relocated to outside the 'clear zone' width or, if these actions are not practicable, and the consequences of hitting the hazard are worse than hitting a guardrail, guardrail protection should be provided.

- check particularly the safety implications of the various items associated with the structure of the road such as kerbs (Note that the barrier type kerb is a significant hazard to motorcycles and even to cars), drainage pits, manhole covers etc. and items of road furniture such as delineator posts (guide posts), road studs, pavement markings (these often have low skid resistance). Also check for evidence of low general skid resistance and poor pavement drainage, which could contribute to skidding, 'out-of-control' and 'run-off-road' accidents.

- Check that guard rail is provided only where properly warranted, that it complies with adopted standards in respect to mounting height, post type and spacing, end anchorage and treatment, e.g. check the approach end is properly flared away from oncoming traffic.

- Check that guardrails on bridge approaches are properly anchored to the bridge rail system and that the rigidity of the guard rail system (semi-rigid) is properly transitioned to that of the bridge rail system (rigid).

- Check that the railing system on old bridges meets acceptable safety standards. Such railings should ensure that most vehicle types will be adequately restrained if they impact the barrier at the speeds which might reasonably be expected to occur at the site in question.

- Check that the ends of median barrier are not left unprotected. These situations are difficult to handle where the median is narrow, e.g. where concrete New Jersey barrier is used, and may require the use of a "crash cushion" or "impact attenuator", to reduce the severity of any end collision.

- In respect to landscaping, the following items should be checked:

- trees and other vegetation which obstructs the visibility of traffic signs, or other essential sight lines, e.g. to and from pedestrians at crossing points, or a drivers view of the road ahead within the 'stopping distance', or to an exit or traffic island nose etc;

- large trees, boulders, monuments or other landscaping structures, located within the 'clear zone'. These can constitute a high risk if locate at the entry into sub-standard curves, at the entry to roundabouts and other places where there is a greater likelihood of vehicles running off the roadway.

The provision of a 'Clear Zone' by placing poles and sign posts well back from the traffic lanes allows errant vehicles to recover without crashing.

This above-ground drainage structure is not appropriate close to the traffic lanes.

Poles located in this narrow median close to the end nose are highly vulnerable to vehicle impacts. A minimum end clearance of 5m is desirable.

(k) Street Lighting:

The major reason for installing Street Lighting on roads is to improve the safety of road users at night. However the overall effectiveness of many installations is significantly reduced because the street lighting poles themselves are involved in collisions when vehicles run off the road. The RSA of an existing road should :

- identify locations where the lighting poles have been placed in hazardous positions with insufficient safety clearances, such as in small traffic islands, on the nose of medians and traffic islands, on the outside of sharp bends particularly at the start of the bend;

- identify situations where poles could be eliminated by joint sharing arrangements, e.g. joint use of lighting poles for mounting traffic signal faces, or mounting street lights on electricity distribution poles (where they happen to be or can be designed to be in the correct location).

- check that the level of lighting provided is appropriate to the situation, e.g. higher levels of lighting should be provided at locations where there is significant pedestrian activity, bicycle riding and vehicle parking maneouvres during the hours of darkness. Also intersections require higher levels of lighting than non-intersection locations. Hazardous features such as complex channelisation, roundabouts, the exit and entry area of expressway interchanges, the approach nose of medians and traffic islands also need a good level of lighting. Any deficiencies in the effectiveness of the lighting at these locations should be recorded in the safety audit.

(l) General Traffic Management Items:

The following items of general traffic management should be included in the RSA of an existing road:

- Check suitability of speed zoning or speed restrictions along the road in question. Identify any locations where the speed limit is inconsistent with the nature of the abutting development and/or the prevailing 85th percentile 'free' speed of traffic, ('free' speed means the speed of those vehicles which are uninhibited by slow vehicles or traffic congestion).

  Check also that the speed limit is adequately signposted, not only from a 'legal' point of view but more particularly from the motorists point of view. Thus the signs which start a restricted speed zone should be quite large particularly when coming from a high speed (say 90km/h) zone into a low speed (say 70km/h) zone. Also, 'repeater' speed limit signs (of a smaller size) should be placed at regular intervals (not exceeding 0.5km to 1.0km) throughout the restricted speed zone. Any deficiency in this standard should be recorded during the audit inspection.

- The treatment of sections of road with an inconsistent alignment standard and particularly at sub-standard curves needs to be carefully checked. All substandard curves should be treated with warning signs including 'advisory speed' sign plates and provided with guide posts and if necessary supplemented with properly spaced and positioned 'chevron alignment signs'.

- Special 'traffic calming' techniques should be provided in the vicinity of schools, shops and other high pedestrian activity areas on busy routes. These techniques include the provision of 'footpath extensions', roadway narrowing, pedestrian refuges, the use of roundabouts, etc.(to assist in slowing traffic down), signalisation of intersections and pedestrian crossings, effective parking control and good street lighting. The safety auditors should consider whether such techniques are warranted in the interests of traffic safety and include this in the safety audit report.

- The audit should check the correctness of 'overtaking prohibitions' (i.e. the provision of double lines) and the general adequacy of provisions for safe overtaking along 2-lane-2 way undivided roads. The audit report should identify locations where long 'platoons' of vehicles build up on a regular basis due to inadequate overtaking opportunity.

- Check also the adequacy of provisions for 'rest areas', 'truck stopping/ parking' and other wayside stopping places such as 'scenic viewpoints' etc.
- The audit should check the adequacy of the general delineation along the route, particularly at night and preferably in wet weather. Any location where drivers are likely to have difficulty in determining the direction of the route ahead at normal operating speed should be recorded.
- Check also the safety implications associated with 'bus stops' and any special provisions for police and other emergency vehicle operations.
- In the safety audit, consider also any special provisions that may need to be made to cater safely for holiday and festive season traffic demands, special events and unusual weather conditions such as 'flooding', 'high winds' etc.

Uncontrolled access and parking pose a safety hazard in this relatively high speed environment

Special attention to traffic management provisions: signs, road markings, street lighting, intersection layout , signal design, parking control, speed limit, pedestrian facilities, etc, are necessary to improve safety in this rural town situation.

7.5.3 Case Study (Stage 5 Audit)

[*The following Case Study is an extract from a Road Safety Audit Report carried out on Federal Route 1 and part of State Route B11, forming a continuous route through the town of Kajang, Selangor. The full report is too large to include in this Guide and only the general items identified in the audit along with the more detailed discussion of safety deficiencies observed in a short section of the overall project length is included here. The paragraph numbering used in the original RSA report has been retained for ease of cross-referencing with the original report.*]

1.0 Introduction

This audit has been carried out as part of a road safety project undertaken by UPM in the Kajang region. The project involves traffic accident 'blackspot' identification and treatment, and road safety audit along Federal Route 1 and State Route B11 through Kajang.

The Road Safety Audit was carried out by:

Assoc. Professor Ir. Dr. Radin Umar , UPM;
Ir. Edward V Barton, Road Safety Expert, JKR Malaysia;
Ir. Che Ali Bin Che Hitam, Cawangan Jalan, JKR Malaysia;
Abdul Wakil Bin Hasbi, UPM.

The audit involved a detailed site inspection of the Federal Route 1 from Km 350 South of Kajang to Km358.8 Kajang Police station and the B11 stretch from the Police station to Kajang 'Toll' interchange, some 6 kilometres away towards the North - South Expressway. The site inspection were done on Saturdays and included detailed observations of traffic operation, with particular attention being given to the safety needs of vulnerable road users such as Pedestrians, Bicyclists and Motorcyclists. A night inspection was also carried out to identify additional safety deficiencies which are apparent during the hours of darkness.

2.0 Prior Information Available to the Auditors

No detailed plans of the highway over this section were available. A 'sketch - plan'(not to scale) has been developed as part of the accident study to show the general layout of the highway and intersections etc. (Appendix 1) [*not included in this case study*]

Traffic accident data for the years '92 to '95 is available and the MAAP program has been used to identify the locations with a high accident frequency. Details of accidents at each location are available along with 'Collision Diagrams' which have been prepared under the 'Accident Studies' part of this project by UPM (Appendix 2). Some traffic volume / classification data is available (See Appendix 3). [*Appendices*]

3.0 General Characteristics of The Route/ Section.

The majority of the length of the section in question is located within the 'built-up' area of the town of Kajang, with highway frontages fully occupied with commercial, shopping, public use and residential development.

This section of Highway is characterised by heavy traffic flows with significant proportions of 'heavy vehicles' and motorcycles. Substantial pedestrian activity occurs in the central part where the highway has close abutting commercial and shopping development. Some sections, particularly in the vicinity of the several schools abutting the highway, have significant numbers of school children and bicyclists.

- In general the highway is operating at a relatively low 'level of service' as the capacity is severely constrained by inadequately designed intersections, lack of access control and lack of parking control or provisions. Long periods of

heavy congestion occur on almost every day of the week, particularly in the central (town) section.

- While vehicle operating speeds are controlled by the level of congestion for most of the day, the speed limits varies from 90 Km/h outside the town to 60 Km/h through the central 'town' section which is appropriate, but other sections should be reviewed and the general signing of the speed limit is inadequate and should be improved.

4.0 Observed Road Safety Deficiencies:

The site inspections identified many instances where the standard of traffic safety offered to the different 'road user' groups is considered to be below an acceptable level. The following notes discuss these in two categories as follows:

- general road safety deficiencies which exist regularly or continuously along the route, and
- specific road safety deficiencies noted at a particular location.

5.0 General Road Safety Deficiencies:

Inadequate roadway capacity:

This is a road safety issue because it generates frustration and increased risk-taking by all road users, which inevitably results in increased accidents. The section through the central 'town' area (Km 355.3 to Km 363.6) is particularly congested for most of the day. The key cause of this is the lack of capacity at the signalised intersections which have little or no 'flaring' (additional traffic lanes). This is fundamental to the proper design of signalised intersections.

Lack of access control and parking control:

Most of the length has uncontrolled access, with many driveways coming out directly onto the main carriageways at critical locations. Often this is combined with disorderly parking close to and within intersections. The few locations where service roads are provided, they are operated 'two-way' creating complex traffic manoeuvres and conflicts at intersections. At some locations access into the service roads is inappropriate and difficult to find, resulting in some instances to 'wrong way' movements.

Parking manoeuvres:

sometimes involving vehicles reversing out into through traffic lanes, create serious traffic conflict. Parked vehicles within and close intersections (including signalised intersections) obstructs critical 'lines of sight' to signals, traffic signs, other conflicting traffic and also for pedestrians crossing the roadways.

Inadequate provisions for Pedestrians, Bicyclists and motorcyclists:

While much of the length of the highway in this section is within a heavily 'built-up' area, there are few sections of footpath provided for pedestrians to walk along the highway clear of traffic. Although there are several schools abutting the highway, and considerable 'school children' activity at relevant times of the day, with the exception of one pedestrian bridge over the highway and one signalised pedestrian crossing in the central town area, there is little other specific provisions to cross the highway. None of the signalised intersections included pedestrian lights or phasing.

Also there are significant numbers of bicyclists, mostly school children, at some locations but there is only a short length (about 100m) of cycle track (combined with a footpath). There does not appear to be any specific provisions aimed at improving the safety and operations of the motorcycles along this section of highway.

Inconsistent cross-section along the highway:

The width and the nature of the highway cross-section changes markedly along the route. This is obviously controlled by lack of reservation width. Some section have a very narrow median intermittent with undivided sections. The provision of the shoulders is

not continuous along the section and the width and surface treatment of the shoulders vary greatly.

Roadside hazards:

A substantial number and variety of roadside hazards exist along this section of highway, some of which are located only centimetres from the traffic lanes. These include:

- rigid lighting and electricity poles,
- untreated guard-rail ends,
- mass concrete buttresses at traffic signal poles,
- concrete drainage structures, culvert end walls and deep open monsoon drains at critical locations,
- inappropriate bridge rail and median barrier systems,
- high 'barrier' type kerbs where semi-mountable kerbs should be used,
- numerous disused poles, posts and other miscellaneous items,

Poor Traffic Signal Arrangements:

At almost all of the signalised intersections, the number of traffic signal heads provided to control traffic movements is inadequate, the general mounting height of signal heads is too low to provide adequate visibility, there are insufficient overhead mast-arm signals used and where provided, they have been positioned on the wrong side of the intersection to provide affective visibility of the signals on the intersection approaches. Many of the signal heads are poorly aimed which further reduces their visibility. The noticeable skid marks on the pavement (and the prevalence of 'rear-end' collisions) at many signalised intersections is clear evidence of the lack of signal visibility on the approaches to intersections.

Inadequate provision and maintenance of pavement markings and lane delineation:

This is particularly noticeable at night and in wet weather. The addition of raised retro-reflective pavement markers would greatly improve this aspect.

Inadequate traffic signing:

The lack of street / road name signs those that exist are too small and improperly placed and the lack of systematic direction signing occur at various locations. In some locations unnecessary 'Stop' signs obstruct the drivers view of traffic signals and some signs obstruct the visibility of other important traffic signs.

Inadequate Street Lighting:

The lighting standard throughout the section varies greatly. On some sections, e.g. on the section from Km 356 to Km 357.5, the standard is quite good but in the central 'town' section where pedestrian activity, abutting access, parking and traffic is intense, the street lighting standard is only fair.

The general environment along the highway is untidy, with little apparent attention being given to shoulder maintenance, maintenance of roadside furniture and traffic signs, the collection of rubbish and debris, pavement sweeping etc.

6.0 Road Safety Deficiencies At Specific Locations

[Only a short section is included here as an example]

Km 357.4 Zalco Motors Junction.

This is a signalised 'T' junction on the west side of the highway, with the right turn out of the highway into the side road prohibited by signs and lane arrows (Figure 5). (It is difficult to see the reason for prohibiting this turn and a significant number of vehicles were noted ignoring the prohibition).

The traffic signal controller again is mounted in a highly vulnerable position near the left hand primary signal pole on the west side of the highway. This position is not only prone to vehicles running off the road, but it could obstruct important sight lines to the right for side road vehicles and pedestrians.

A large water pipe and valve is located close to the left turn into the highway is unprotected, putting it in danger of damage and creating a hazard for drivers accidentally running off the road at this location.

The narrow median in the highway at this intersection has traffic signal poles, street lights and traffic sign posts all mounted very close to the ends (nose). Such location of

this hardware is hazardous to traffic and leaves the equipment highly vulnerable to damage, particularly as large trucks often mount the median nose area when drivers misjudge their turns into or out of the highway (See Picture 14).

Again there is no provision made for pedestrians to cross the highway in the safety afforded by these traffic signals.

The reassurance direction sign for Federal Route 1 southbound is located within the junction where the normal 'intersection' direction signs should be placed (no such signs have been provided here). The reassurance sign should (correctly) be relocated 'downstream' clear of the intersection.

Street lighting at this junction appears to be satisfactory (See Picture 15).

A school located adjacent to the highway north of this intersection generates significant bicycle traffic which is not catered for safely in the present highway cross-section.

Picture 14 : Street lights and traffic sign posts all mounted very closed to the road edge.

Picture 15 : Street light condition in Zalco Motors Junction.

Km 357.5 Sungai Jelok Junction

This is a signalised 'T' junction on the east side of the highway, (which could be operated more effectively in conduction with the previous 'Zalco Motors' junction, as a 'staggered pair' in a linked signal system). This intersection also operates as a 'seagul' type arrangement (Figure 5).

Again this 'seagul' type treatment involves a 'trap' lane for the right turn out of the highway (See Picture 16). In the side road approach, two lanes are provided at the stop line which causes operational problems when vehicles from both lanes attempt to turn right into the single merge lane in the highway.

Picture 16 : 'Seagul' type treatment involves a 'trap' lane for the right turners.

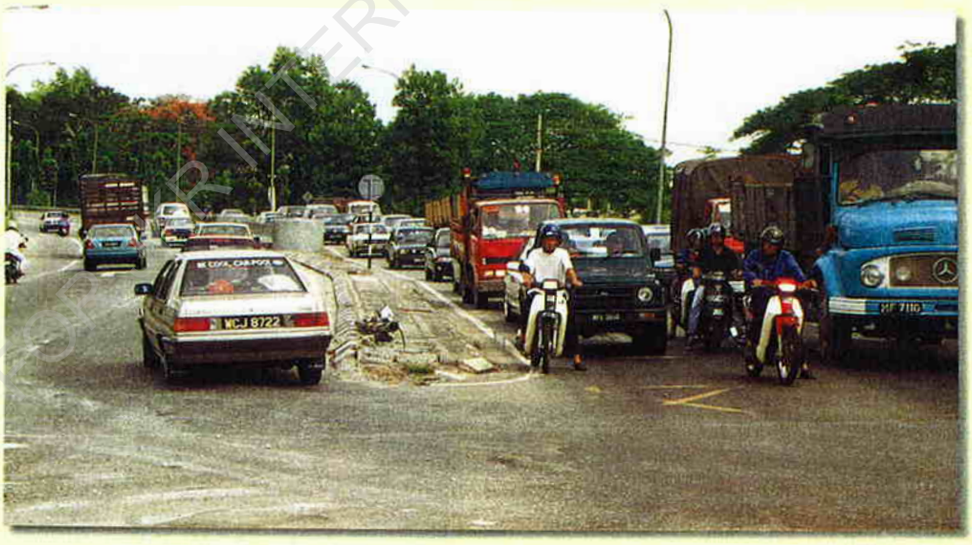
In addition, the old highway carriageway on the north east side of the junction acts as a service road serving a school and other development east of the highway and enters the intersection where the left turn slip lane from the highway enters the side road (See Picture 17). This creates complex traffic movements and unexpected conflict in what should be a simple 'T' junction. Again the existing left turn corner island (in North East corner) is constructed with a very high kerb. This is quite hazardous and should be changed to semi mountable kerb. This island should be made larger (by narrowing the left turn lane) to provide more protection for the signal pole.

Picture 17 : Complex traffic movements in addition to the old highway carriageway on the north east side of the junction.

The signal heads at this intersection also lack advance visibility and prominence due to overhead mast arm signals in the highway being on the 'departure' side of the intersection. There is a lack of channelisation in the side road and visibility of the highway (from the side road) is limited due to the curve of the highway and superelevation. (Picture18).

The signal pole and equipment located in the highway median, too close to the nose in the on the north approach has been demolished by a vehicle collision (See Picture 19). This was probably due to the lack of prominence of the signals.

Picture 18 : Lack of channelisation in the side road and visibility of the highway.



Picture 19 : Signal post located too closed to the median nose Note that the signal pole in the narrow media has been knocked down.

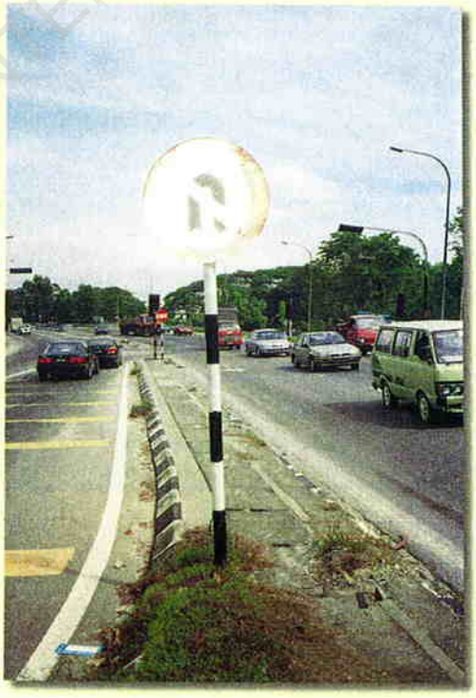
At this junction again there is no provisions for pedestrian movements and a number of school children were observed making risky movements through the junction.

Again here some signal poles which are located in vulnerable positions have large concrete buttresses to "protect" them and these create serious hazards for road users (See Picture 20). Just north of the junction, another large concrete buttress type hazard has been constructed in the median, presumably to "protect" each end of the concrete median barrier constructed across the bridge over Sg. Jelok.

A Further hazard is present at the junction in the form of a deep open drainage pit located at the edge of pavement on the 'sharp' left turn out of the side road into the highway.

Picture 20 : Large concrete buttress constructed in the median.

The 'NO U-TURN' sign is not effective as a regulatory sign, as it not in accordance with the specified sign in the Road Traffic Rules in respect to colour and shape and is worn out and therefore not clearly visible to drivers at night. (See Picture 21).



Picture 21 : The sign pole in a bad condition.

Km 357.9 High School Entrance Junction

The High School is located on the east side of the highway and the entrance is positioned at the north end of the median and on a slight right hand curve and over a slight crest in the highway (Figure 6).*[Not included here]*

Again a 'trap' lane is created in the highway by marking a 'through' lane as a right turn lane into the High School (See Picture 22). This causes all 'through' traffic to diverge left into the merge lane that has been provided for traffic re-entering the highway from the two Petrol Stations (Shell and Petronas) located on a short service road just south and opposite the High School (See Picture 23). This arrangement including the access and egress from the Petrol Stations needs to be reviewed as part of general traffic management improvements along this section of the highway.

Picture 22 : A 'trap' lane in High School Entrance. Note also the incorrect use of the 'Berhenti' (STOP) Sign.

Picture 23 : Two Petrol Stations (Shell and Petronas) located on a short service road just south and opposite the High School.

The slight crest in the vertical alignment combined with the horizontal curve limits sight distance both for drivers making the right turn into the High School and for drivers entering the Highway from the High School (See Picture 24). A safer situation would be achieved by signalising the entrance or (alternatively) signalising the next intersection to the north.

The present unsignalised entrance does not provide adequately for pedestrians to cross the highway. The median (end), provides 'staging' and protection for children crossing at the entrance.

Picture 24 : Poor visibility for right turners into the High School due to crest hill.

Km 358.1 'T' Junction on the east side of the highway

This junction is unsignalised and serves as the main access into 4 schools located east of the highway at this location (Figure 7). Access to the side road is prohibited during times of the day when Children are going to and from school. This may be reasonable but at least an exemption should be provided for vehicles taking children to and from the schools.

In spite of the substantial number of Children crossing the highway at this location, there is no specific provisions made for this to be done safely. The crossing is quite hazardous in view of the vertical and horizontal curves in the highway, the turning movements being made at the junction and the high volume of traffic on the highway. It is common to see children stranded in the middle of the highway for a considerable time waiting for a safe 'gap' to complete their crossing (See Picture 25 & 26)

Traffic management at this junction and at the nearby High School entrance (to the south) and also at the Hospital entrance (just to the north), needs to be considered together to improve the level of safety for School Children and other traffic associated with these sensitive public institutions.

Picture 25 : Inadequate pedestrian facility at Jalan Timur Junction.

Picture 26 : Dangerous unprotected child pedestrian at Jalan Timur Junction.

CHECK LIST

ROAD SAFETY AUDIT STAGE 5
Audit Of Existing Roads

Vertical and Horizontal Alignment:

- General alignment standard:
  - Check for consistency throughout the route, note any location where alignment standard changes abruptly and is not as expected by drivers.
- 'Sub-standard' Curves:
  - Identify any curve with a speed value of more than 10km/h below the 85th %ile approach speed. Note any evidence of vehicles running off the roadway.
- Inadequate Sight Distance:
  - Check and record any location with inadequate Stopping Sight Distance.
  - Check and record any location with inadequate Overtaking Sight Distance at which 'double lines' have been marked.

Cross Section:

- Note any location where the cross section standard changes abruptly along the route, or is otherwise inconsistent with driver expectations.
- Identify any locations where the Capacity of the roadway is restricted.
- Note locations of regular traffic congestion.
- Note any absence of provisions protecting 'turning vehicles' at intersections.
- Note any locations with inadequate Shoulder Width,
- Check that the correct type of Kerb has been used and note any location where speeds are greater than 50km/h and 'barrier kerb' has been used.
- Check that the cross section provides adequately for the 'Vulnerable Road Users':
  - Pedestrians: have paved footpaths, adequate refuge width on median & islands and proper ramps up and down kerbs, where there is regular pedestrian traffic;
  - Bicyclist: segregated areas (e.g. paved shoulders) where numbers are significant;
  - Motocyclist: segregated lanes (paved shoulders), separate roadways, where warranted by demand.
- Lack of access control: Identify any location where the cross section does not allow the development of approriate access control

Intersections:

- Sight Distances:
  Check that the various sight distance requirements, (applicable to the traffic speed) are achieved: (Refer to Arahan Teknik Jalan 8/86 and. Reference 3)

  - Approach (Stopping) Sight Distance
  - Entering Sight Distance
  - Safe Intersection Sight Distance (Refer to Figure 7.4)

- General Layout Features:
  Check:

  - that the general layout of the intersection caters safely for ***All Road Users***, (Pedestrian, Bicycles, Motorcycles);
  - that the layout is logical for various traffic movements, does the layout correctly favour the major traffic movement?
  - for any lack of Auxiliary (turning) lanes;
  - for any discontinuity of 'Through' traffic lanes,
  - for any instance where 'through' vehicles have to change lanes to continue on through an intersection.
  - for the occurrence of 'Trap' lanes, i.e. where a 'through' lane is suddenly marked, or aligned, as a lane for traffic turning off a roadway.
  - any location where 'Seagull' type layouts are used in urban or other 'built-up' areas. Identify any location where the length and width of the 'right turn' merge is sub-standard and instances where pedestrian movements across the continuous traffic flow movement is not properly catered for;
  - for operational problems at Roundabouts: e.g. inadequate deflection (and speed reduction) of traffic at entry points, high vehicle speeds within the roundabout, inadequate width of entry or circulating roadway etc.
  - for situations where channelisation islands are too smaall to be eassily seen by drivers, or for pedestrian refuge or for protecting traffic signs, signals and other road furniture.
  - that Barrier Kerbs are not used where traffic speeds are likely to be greater than 50 km/h;

Expressway & Other Interchanges:

Check:

- that interchanges are appropriately located (e.g. at the important roads), properly spaced and suit a logical traffic management strategy for the region.
- for situations/problems associated with the incompatibility of mixing at-grade intersections and interchanges on the same route
- that appropriate and consistent standards of layout geometry exits at Exit and Entry Ramps

- Identify locations where the provision of auxiliary lanes is inadequate or otherwise inappropriate, e.g. where 2 lane exits are not preceded by at least 300m of auxiliary lane and 2 lane entry ramps are not followed be at least 500m of auxiliary lanes.

- the 'start' and 'end' tapers of auxiliary lanes and note any instance where 'through' traffic may lead inadvertently into auxiliary lanes.

- for any location where the ramp alignment and length is inconsistent with the speed of traffic entering the ramp, bearing in mind deceleration requirements, and likely queuing of vehicles at the ramp intersection;

- for any deficiency in Sight Distance requirements at Entry and Exit points.

Traffic Signal Installations:

Check:

- that traffic signals are provided only where warranted for safe, efficient and equatable management of traffic flow along and across arterial roads and for the safe crossing of pedestrians

- that the provision, location and spacing of traffic signals suites a sensible traffic management strategy along the route.

- that any signal installed are operating effectively and efficiently.

- for any location where there is inadequate signal hardware (signal faces etc.) to safely control the various traffic movements, bearing in mind the need for some redundancy to cater for failed light globes etc.

- that the signal hardware and phasing provides adequately for pedestrian. Specific signal faces and phasing should always be provided for pedestrians in urban and other 'built-up' areas.

- the positioning and visibility of signal faces and record instances where visibility of signals is obstructed by tree foliage, traffic signs etc. or, where approach roadways are more than 3 lanes wide, overhead signal faces are not provided.

Street Lighting:

Check:

- that street lighting is provided on arterial roads and highways in cities, towns and other 'built-up' areas, particularly where there are pedestrians and parking along the road;

- that where lighting is installed, it is of an appropriate standard, consistent with the needs of the location, pedestrians and other factors;

- Identify locations where the street lighting poles constitute a hazard to traffic, e.g. on small islands, noses of medians, on the outside of sharp curves, etc;

- for situations where street lighting poles could be eliminated by joint sharing of traffic signal pedestals and electric power poles;

- that the arrangement of street lights enchances 'route guidance', rather than confuse the drivers ability to "seen the direction of the route ahead".

Traffic Signing:

General aspects:

Check:

- for any cases of unauthorised traffic signs and use of non-standard signs, (Colour and Shape);
- the location and spacing of signs and note locations where there are too many signs, or the signs are too close together;
- that all traffic signs are clearly visible and are prominently displayed to the intended road users;
- for any instances where the legibility of the information on traffic signs is inadequate, bearing in mind the speed of vehicles and the amount of information displayed;
- for any instances where signs contain too much Information to be capable of being read by drivers traveling at normal operating speed;
- the effectiveness of traffic signs by observing them at night and identify any lack of reflectorisation;
- the type of sign posts used and record situations where sign posts constitute a fixed roadside hazard or where the use of frangible sign posts should be considered;
- for any cases where there is a lack of clearance to traffic signs;
- for aany situations where traffic Signs themselves are obstructing essential 'Lines Of Sight' for drivers and pedestrian;

Regulatory And warning Signs:

Chek:

- that the appropriate Regulatory Signs are provided where necessary;
- that Warning Signs have been used only where they are warranted.

Guide And Direction Signs:

Check:

- that Guide and Direction Signing has been done on a systematic route or regional strategy, that it is logical and meets needs of unfamiliar drivers;
- that all important intersections are provided with:
  - Advance Direction Signs,
  - Intersection Direction Signs
  - Re-assurance (Distance) Signs.
- that these signs aare correctly positioned to allow the rquired action to be taken by the intended drivers;
- for instances where there are inconsistencies in Destination Names on consecutive signs, e.g. on 'advance direction signs' followed by 'intersection direction signs', followed by 're-assurance direction signs;

- for any lack of providing 'Road Names' on Direction Signs, particularly in urban areas, and 'Route Numbers';

- for instances of poor legiblity and poor arrangement of information on signs.

Pavement Marking:

Check:

- the general adequacy and visibility of pavement marking, both at night and in wet weather;

- that the correct type of line marking has been used in the various situations, e.g. 'Continuity Lines' at merge and diverge sections, 'Double (barrier) Lines where overtaking is to be prohibited, etc;

- for any discontinuities in 'through traffic lane' marking and the existence of any 'Trap' Lanes;

- for any deficiency in the delineation of Merge and Diverge areas, including situations where 'through' traffic may inadvertently lead into auxiliary and turn lanes;

- for locations where is a lack of 'Hazard Marking' at approach ends of islands and medians etc;

- for locations where auxiliary 'turn lanes' have been designated with the appropriate pavement arrows and locations where the wrong type of arrow has been used;

- for locations where pavement arrows and other markings are confusing to drivers, particularly where 'old incorrect' marking have not been properly removed;

- that the positioning of 'Stop' Lines and 'Holding' Lines are appropriate;

- the justification for any 'Yellow Bar' marking and record locations where it is inappropriately used. (Such markings should be rarely used).

- the effectiveness of road markings at night and in wet weather, consider the need for Retro-reflective Pavement Markers (Road Studs) to supplement line and hazard markings, Identify inadequate provision of these devices and in the use of non-standard arrangements of them.

Roadside Safety & Landscaping:

Check:

- the 'Clear Zone Width' (CZW) generally available along both sides of the road, and comment on this aspect in the RSA report;

- the 'Fixed Roadside Objects' which occur within the CZW and comment on the need to treat them in the interests of road safety.

- the provision of Guardrail along the road, consider whether it is really justified and identify locations where it is not justified and locations where it has not been provided where it is warranted;

- that the correct treatment has been applied to the ends of Guardrail sections. This includes 'soft' end treatments, end anchorage and approach end flaring;

- for the adequacy of 'Bridge Railing' systems on all bridges. Take particualar note of inadequate railings which will not restrain an impacting vehicle. This is often the case of old bridges;

- the treatment of 'Approach Guardrail' to bridges. Record situations where there is no 'strong' anchorage of the approach guardrail to the bridge railing system and/or no proper transition of the rigidity of flexible or semi-rigid approach guardrail as it approaches and meets the rigid bridge railing;

- that the ends of Median Barriers are properly treated to reduce the severity of possible end collisions. Identify the need for 'crash cushions' or other 'impact attenuation' devices;

- the extent to which trees and other vegetation obstructs driver and pedestrian sight lines which are essential for safe traffic operation.

- the existence of poles of various kinds along the road and comment on whether some or many of them can be removed, relocated to less hazardous positions, or (in the case of street lighting poles) made 'frangible';

- the degree of hazard associated with large trees, boulders etc, and whether these can be treated to improve roadside safety.

General Traffic Manaagement Items:

Check:

- to see what, if any, special provisions have been made for Motorcycles and comment on the need for the provision of such improvements as 'paved shoulders', 'segregated motorcycle lanes' or 'separated motorcycle roadways' in accordance with any adopted warrants, guides and practices;

- the degree of safety afforded to pedestrians, particularly school children and record instances where there is a need for special provisions to be made;

- the adequacy and credibility of existing Speed Limits and comment if they are not appropriate to the traffic situation and the nature of abutting development or are otherwise unrealistic in the view of most motorists;

- the effectiveness of Speed Limit signing: consider the need for more prominent signing of the start of 'restricted' speed zones and for 'reminder signs' within the speed zone, particularly near intersections where large numbers of vehicles enter the road in question from side roads;

- sub-standard curves and low speed curved sections of the road, consider the need for 'positive' advice to motorists about the safe travel speed and consider the need for 'Advisory Curve Speed' signing;

- the need at sub-standard curves, for other delineation improvements such as the provision of 'guide post' delineation, the placement of 'Chevron Alignment' signs and the use of retro-reflective road studs;

- the degree of safety afforded to all road users in town centres, particularly where highways pass through shopping centres or near schools. Record the need for 'Traffic Calming' techniques to improve safety in these sensitive locations;

- the availability of Overtaking opportunities along the route as a whole and comment on the need of specific 'overtaking lanes' at regular intervals along 2 lane undivided roads, particularly where traffic flows are high in hilly terrain;

- Consider the need for Rest Areas and other Roadside Stopping Places e.g. truck stops, scenic viewpoints, wayside picnic areas etc. and note any current 'unofficial' places where vehicles stop and the degree of hazard that this involves;

- the existence of roadside stalls and other roadside business activity within the 'Right of Way' of the road, comment on the relative safety of this and the possible need for formal parking arrangements, and other regulatory controls;

- the Safety of Bus Stop locations and the provisions for buses to stand clear of traffic lanes. Also the need for a street light at these locations for the security and safety of bus patrons;

- for any special problems and requirements that may be necessary to improve safety during 'Festive Season' and Holiday Periods, when traffic demands are heavy, and most drivers are relatively unfamiliar with the road.

8.1 Introduction

The operation of roads involves the interaction of three key elements: the ***driver***, the ***vehicle*** and the ***environment***. The consequence of this is that the physical shape of the 'road', (which is part of the environment) depends very much on attributes of the driver and the vehicle and their interaction in a dynamic sense. It needs to also be understood here that 'environment' not only includes the physical road, roadside, atmospherics etc. but also the regulatory, social and political environment within which the general traffic system operates.

Designing safe and efficient roads therefore requires a basic understanding of certain human factors and vehicle characteristics and their interaction with the road and its environment. These matters are key elements of Traffic Engineering Science and Practice.

A short discussion follows on Human and Vehicle Characteristics relevant to road safety, traffic management and the design of roads generally. Readers are encouraged to seek a much greater understanding of these matters by referring to some of the references listed at the end of this paper.

8.2 Human Factors

As stated in the introduction to this manual, human performance (or its failure) is known to be involved in more than 90% of Road accidents, but this statistic overstates the 'blame' on the 'road users' as in many cases vehicle drivers and pedestrians etc. are often faced with unnecessarily complex situations where the 'driving' task exceeds reasonable human capabilities. The above quoted reference indicates that about 25% of accidents involve a combination of road environment and human factors as contributory causes, (Austroads 1989) but this may be a low estimate for Malaysia.

The human performance characteristics which are important in traffic engineering and road safety may be discussed under the following headings:

* Vision
* Information Needs
* Information Processing.

Designers need to understand these characteristics and their implications in the design and operation of road and traffic facilities in order to achieve the highest standard of road safety for all road users.

8.2.1 Vision

It has been estimated (Lay 1990) that 90% of the information that a driver requires when operating a vehicle on a road is visual information. Thus it is not surprising that vision is such an important factor.

Characteristics of human vision such as depth and breadth of the visual field, eye movement, perception of colour, the effects of brightness and glare, perception of movement and judgement of speed etc., are important factors in the design of roads and the development of associated standards and practices. They are fundamental to the design and layout of various road and intersection features, traffic signals, signs, roadway delineation and street lighting.

For the human eye, the area of the visual field, in which things are in perfect focus (as necessary for reading), is quite small - a cone of about 3° to 10°. (See Figure 8.1). Objects can be detected outside of this field, in the peripheral vision, which for a stationary observer extends up to 90° left and right, and 60° above and 70° below the line of sight. In fact this peripheral vision area detects movement better than the central vision area, but at speed this field reduces to about 100° total angle at 30 Km/h and only 40° total angle at 100 Km/h. (Ogden & Bennett (1989) These factors need to be taken into account in the positioning of traffic signals and signs. Other characteristics, such as recognition of the fact that a proportion of the population has defective colour vision and that overall visual acuity/ sensitivity decreases markedly with age, are also important considerations in the development of various traffic engineering standards and practices.

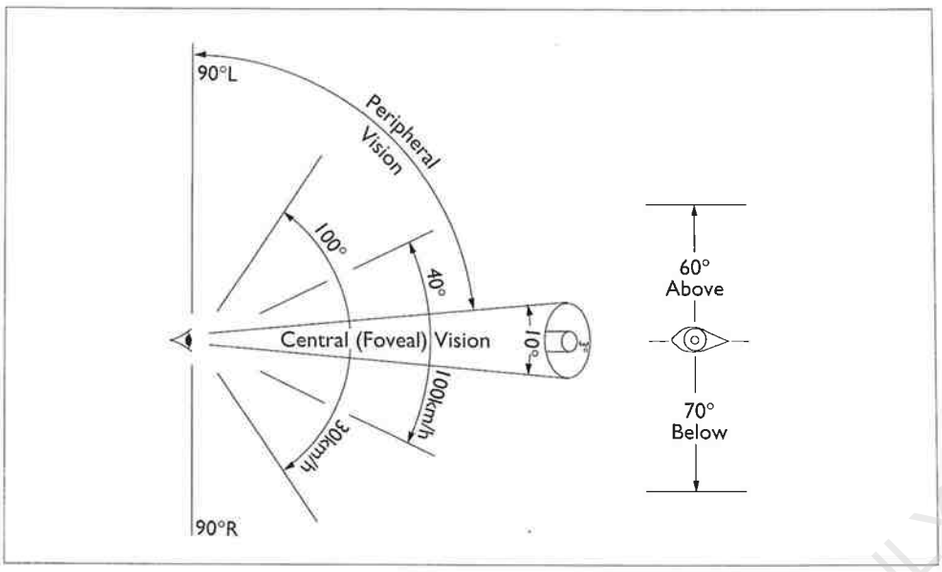


Figure 8.1 : Human Vision Characteristics
Source: Ogden & Bennett (1989)

8.2.2 Information Needs

In addition to recognising the visual capabilities and limitations of road users, an understanding of the information that they need in order to operate safely on the road safely is essential.

As nearly all of the information required is visually transmitted to the road user, the following matters are important:

* ***Conspicuity,*** - the signal (or sign etc) must be easily seen against its background. Size, brightness, boldness, edge, edge sharpness, contrast, simplicity of background and position relative to the normal line of sight are the major factors which influence conspicuity of traffic devices.

* ***Comprehensibility,*** - the message must be able to be quickly understood and its importance recognised. (note that many commonly used symbols, particularly abstract symbols, are not well understood by road users).

* ***Credibility,*** - the message or signal must be believed to be true and relevant to the particular road users to which it applies. The strict adherence to well established standards and proven practices and their consistent use and application is vitally important to achieve and maintain credibility.

* ***Delineation,*** - the road user must have the information necessary to maintain the vehicle's position on the roadway relative to other vehicles, and to make navigational, guidance and control decisions. This requires both short range (vehicle positioning) and long range(route guidance) information.

8.2.3 Information Processing

The driving task involves three essential tasks: navigation, guidance and control, in which the driver receives information, processes it, makes decisions about alternative actions, carries out the chosen action and observes the result by repeating the process, (Lay 1990). This process is complicated because of the limits of human performance and the difficulties imposed by the interface between the driver, the vehicle and the road environment.

For example:

- inadequate information may be available for the task, such as lack of sight distance to a sharp curve ahead.

- the driver may select inappropriate information from a display of competing or confusing alternatives or the information may be processed too slowly for safe or effective action.

- When drivers are overloaded with information and decision making, they 'shed' (ignore) some information and this information may be important to safe operation.

- The driver who is tired, stressed or is inexperienced may misjudge or fail to react to critical situations.

- Some drivers, particularly inexperienced drivers, have difficulty in dealing with unusual events or extreme actions.

It is important therefore that the traffic engineering and the road system allows all road users to deal with the tasks required for safe operation well within their human capability. This is assisted by:

- wherever possible providing 'trend' information which helps the driver anticipate the situation ahead.

- avoiding extraneous demands and the rapid introduction of heavy demands on the driver.

- allowing the driver/pedestrian to make a series of simple decisions rather than a single complex decision.

- providing the driver with 'quantitative' rather than 'qualitative' information.

- controlling the rate at which drivers/ pedestrians are required to make decisions.

- controlling the rate at which information is fed to the driver/pedestrian.

8.2.4 Other important human factors:

- *Expectancy:*

Most vehicle driving behaviour is governed by habit, experience and expectation. When information is presented to the driver in an expected form and a logical sequence of events or commonly found situations follow, drivers are less likely to make errors. Conversely, if information provided does not match a drivers expectation, or if events occur which do not accord with the information provided or what the driver expects, then accidents are likely to occur. Expectancy is enhanced by experience, thus treating similar situations in a consistent manner helps develop driver expectancy and results in less driver errors and misjudgements.

- *Reaction Time:*

Reaction time involves ***Perception*** - actually seeing (say) the signal or sign etc' ***Identification*** of the signal and understanding its meaning, ***Emotion*** - deciding what action to take, and ***Volition***, - carrying out the action.

Reaction time varies amongst the population and is effected by individual characteristics such as, skill, experience, alertness, risk taking, effect of drugs and alcohol etc. Most of these factors are not under the control of the road/traffic engineer, however reaction time can be improved by always providing the drivers with familiar situations (ie. developing expectancy), minimising the number of alternative courses of action available, providing positive information about what the driver needs to do and providing prior warning of a situation or event.

Studies have been made of the population of road users to establish values of reaction time to be used in various design situations. See Arahan Teknik (Jalan) 8/ 86.

- *Short Term Memory:*

It is well known that people have both a short term memory and a long term memory. In the short term memory, which has very limited capacity, information fades after about 30 seconds unless it is reinforced by repetition (Lay 1990). Most information involved in the driving task, eg. aspects of the visual scene around the driver such as traffic signs, road markings, signals, pedestrians and other vehicles etc. is held only in the short term memory. This information fades when that relevant to the task is used, or is replaced when another task is

imposed which requires different information.

The implications of this for traffic and road safety engineers is as follows:

- information presented to a driver must be immediately applicable and result in some action. Eg. a warning of a hazard ahead is likely to be not acted on if it is too far in advance of the hazard,

drivers need to be continually reminded about controls (or continuous situations) such as speed limits, parking bans etc. along a route.

the rate of presentation of different information to a driver needs to be controlled so that one item can be dealt with at a time.

8.3 Vehicle Characteristics:

Although vehicle factors have been shown to be a significant factor in only a relatively small proportion of accidents, there are many aspects of vehicle design and operation which are important in the design of safe roads. Their contribution to accident causation generally goes unrecognised because such information is rarely encoded or otherwise recorded on traffic accident reports compiled by the Police.

The most obvious vehicle characteristics which effect road design and traffic engineering are vehicle dimensions, e.g. width, height, length and mass, number of axles and points of articulation, power/ weight ratio etc. The less obvious characteristics such as driver visibility, braking, manoeuvrability and cornering characteristics also have a significant effect on traffic safety.

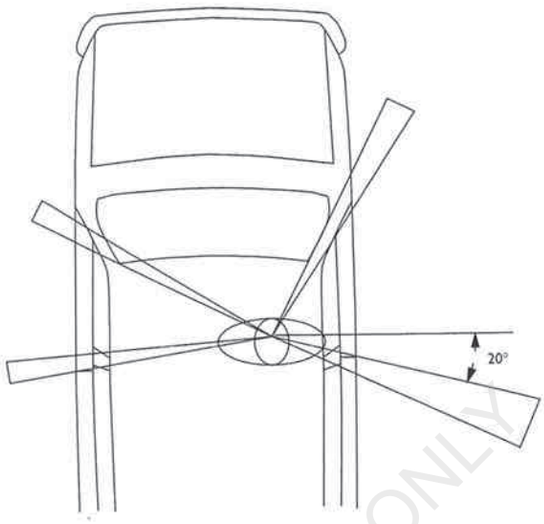
8.3.1 Visibility (For The Driver)

The height of the drivers eye above the road surface is a vital element in determining the requirements of sight distance. It varies significantly between trucks and buses on the one hand and cars and motor cycles on the other. The implications of this are not only important in the design of horizontal and vertical alignment, but also needs to be considered in the positioning of traffic signs and signals and designing roadside landscaping etc.

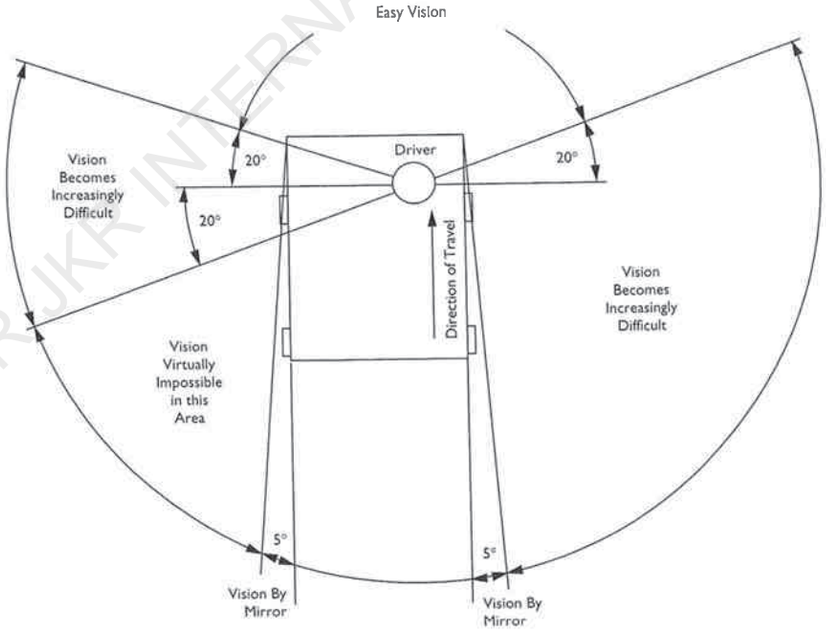
Also of importance is the restrictions on a drivers visibility imposed by the pillars each side of the vehicle's windscreen and the side pillars between the front and back seats of the vehicle. The type of load on trucks and the characteristics of the rear view mirrors effect the ability of drivers to see objects and other road users to the side and rear of their vehicle. The limitations of such visibility need to be taken into account when designing intersection layouts, merging lanes and lane-changing situations. (See Figure 8.2).

8.3.2 Braking Characteristics

Braking characteristics are of fundamental importance to the a vehicle's ability to stop in an emergency in all types of conditions. Vehicle stopping distance is effected by the drivers reaction time, vehicle speed, the type of brakes on the vehicle, road surface conditions and the type and condition of the tyres. The effect of these items are taken into account in the development of 'Stopping Distances' used for road design purposes. These distances, coupled with assumed 'driver eye height' and 'object' height, define the 'Stopping Sight Distance' which is tabulated for given vehicle operating speeds, in design guides and manuals.



Passenger Cars



Vans and Light Trucks

Figure 8.2 : In-Vehicle DriverVisibility
Source: Odgen & Bennett (1989)

8.3.3 Manoeuvrability

A vehicle's manoeuvrability involves the combined effect of a number of vehicle characteristics such as: steering capabilities, length, width, number and arrangement of axles and articulation points etc. These factors effect the space the vehicle requires when turning and thus are important in the layout of intersections, driveways, parking and loading bays etc. The 'swept path' or space used by various types of vehicles designated as 'Design Vehicles' have been determined for a range of turning radii and angles of turn and are essential design tools for road and traffic design. (See example in Figure 8.3).

8.3.4 Cornering

Cornering involves complex relationships between vehicle suspension, tyres, wheel base, wheel track and centre of gravity height. The combined effect of these factors determines the ability of the vehicle to resist overturning and to utilise all of the available side friction between the tyres and the road surface. The desirable objective in road design is to ensure that if a vehicle exceeds the design limits of the road, it will generally slide (skid sideways) rather than overturn. These factors are important in the design of turning roadways at intersections and interchanges and for curve superelevation and is particularly critical where there is a combination of sharp or high speed turning on steep down grades, especially if they are likely to be used by vehicles with a high centre of gravity such as some bulk liquid tankers and trucks carrying live stock.

8.4 General Attributes Of Safe Roads

Recognition of the above human factors and vehicle characteristics in the design of road and traffic facilities is fundamental to designing safe and efficient roads. Such roads will have the following attributes:

* Standards of horizontal and vertical alignment which are appropriate to the environment through which they pass, consistent with the function of the road and with driver expectations.
* Road cross-sections with appropriate lane and shoulder provisions, catering for the various traffic movements along and across the roadway, and meeting the needs of all road user groups.
* Access control or provisions consistent with the function of the road in the overall road network.
* Clearly visible and un-complicated intersections/interchanges, at which the various traffic movements are well defined and segregated where speed differentials occur, with appropriate traffic control providing safe movement for all road user groups.
* Well thought out traffic signing which provides the 'stranger' driver with clear advice, positive warning and unambiguous directional information, in advance of and at decision and manoeuvre points, and confirmatory information beyond the point.
* Adequate and consistent delineation of the roadway and the route ahead with advance warning of width and alignment changes not otherwise obvious to a driver.
* High standard of skid resistant pavement with good drainage, with particular attention given to locations where vehicles may need to brake heavily or turn on adverse grading.
* Appropriate street lighting, particularly where severe traffic conflicts occur and where pedestrians and other vulnerable road users come into conflict with heavy or fast moving vehicular traffic.
* A "forgiving" roadside, with a clear 'recovery' area, or 'Clear Zone' (see Figure 8.4) along it, free of unnecessary and unprotected hazards.
* Overall traffic management which properly considers the needs of all road users.

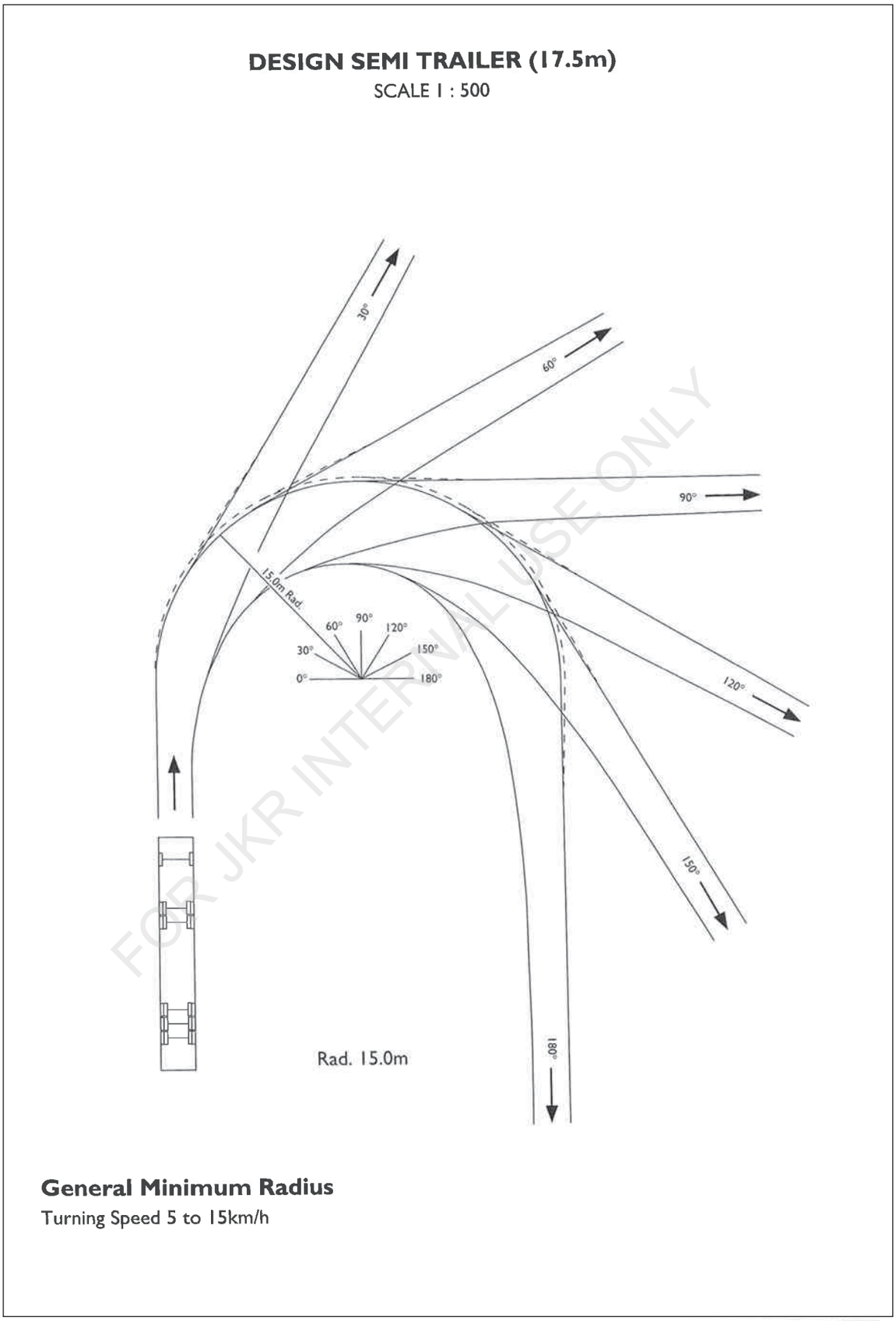
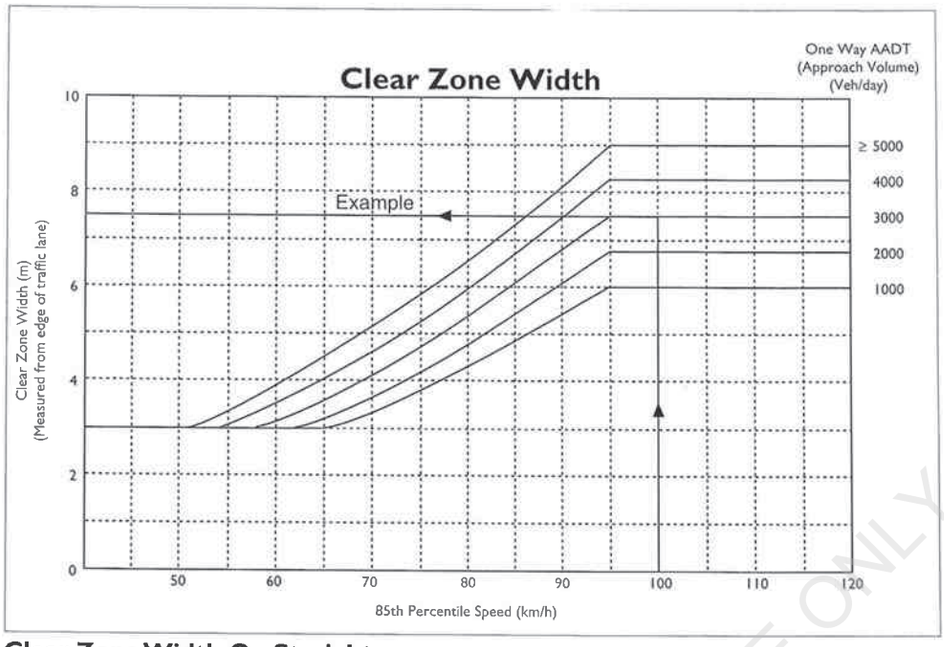
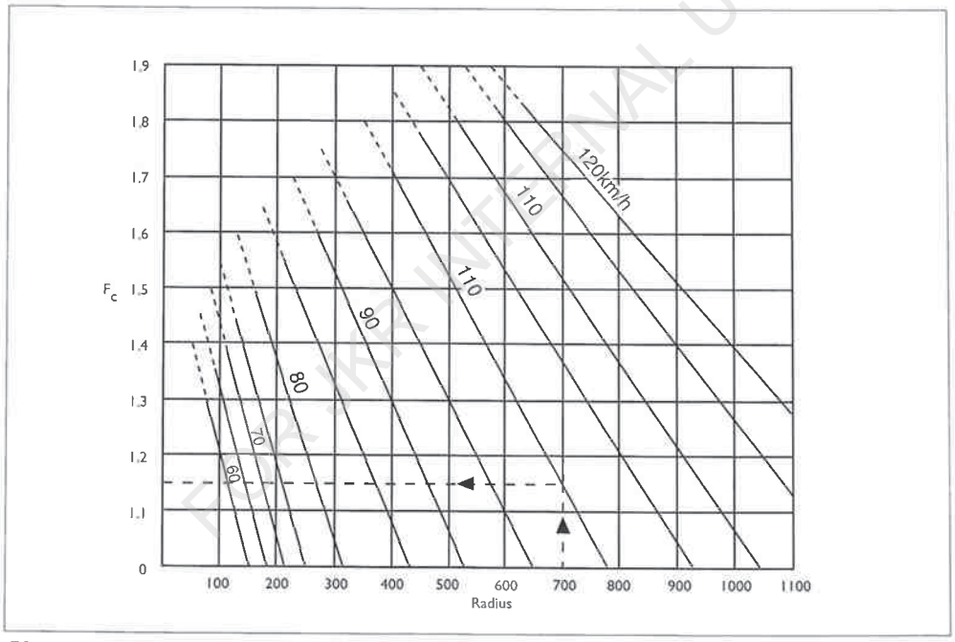


Figure 8.3 : Typical Design Vehicle 'Swept Path'
Source: Austroads (1987)



Clear Zone Width On Straights



Clear Zone Width on curve = Clear Zone Width on Straights x Fc

Figure 8.4 : Roadside 'Clear-Zone' Requirements
Source: Vicroads (1995)

8.5 Some Principles Of 'Design For Safety'

8.5.1 Intersection Locations

The following principles are important in designing safe intersections:

* Minimise the number of conflict points;
* Provide adequate spatial separation of conflict zones, so that drivers can deal with them one at a time;
* Reduce the area of the conflict zone;
* Minimise the angle of conflict and thus reduce the relative speed of any collisions;
* Ensure that locations of conflict points and conflict zones are clearly defined and visible to road users well in advance;* Delineate desired vehicle paths and provide adequate direction, guidance, warning and regulatory signing;
* Separate 'slowing' or 'waiting' vehicles from 'through' and fast moving traffic streams and avoid 'trap' lanes;
* Segregate 'un-protected'(vulnerable) road users (eg motorcyclists) from other vehicular traffic if practicable;
* Provide unambiguous allocation of "right -of-way";
* Ensure adequate sight distances:
* Simplify the decision making and the task of driving;
* Minimise delays to all road users;
* Minimise roadside hazards and provide safe recovery areas.

8.5.2 Road Links Between Intersections

Similarly the following principles are important when designing road sections between intersections:

* Adopt appropriate geometric standards for horizontal and vertical alignment;
* Ensure that the cross-section is suitable for the function of the road, provides adequate capacity for the expected traffic volume and caters for all road users;
* Develop access control appropriate for the functional class of road and the type of abutting development;
* Provide adequate delineation of the roadway for both long distance (route guidance) and for short distance (vehicle positioning) requirements of the driver in the most adverse weather and lighting conditions;
* Ensure adequate direction guidance and warning signing;
* Provide a "forgiving" roadside environment;
* Ensure that the speed limit is realistic and appropriately sign posted.

8.6 Safety Hints In Geometric Design

While the "Geometric Design Criteria" in Arahan Teknik (Jalan) 8-86, sets some general aspects of cross-section for the particular class of road, these may need to be varied to meet individual site requirements. The following guides are provided to assist designers in achieving the optimum level of safety in the detailed design.

8.6.1 Cross-section

(a) Right-of-Way width:

* At the planning stage, always provide sufficient width to allow for flexibility in the layout design, including landscaping, drainage, grading, services etc. Safety is often prejudiced where design widths of elements such as lanes, shoulders, medians and clearances have to be reduced in order to fit within a set R.O.W. width.

(b) Lane Width:

* Lane widths of as low as 2.5m may be acceptable for auxiliary (turn Lanes) on straights in low speed 'urban' areas, 'through lane' widths should rarely be less than 3.0m, and 3.5m where speeds are expected to be above 60km/h.

* Extra wide lane widths (>3.65m), or wide unmarked roadways encourage poor lane discipline by drivers and should be avoided.

* Consider the needs of particular road user groups such as Motorcycles and bicycles. In some situations where the width available is restricted, it may be better to provide narrower traffic lanes on a multi-lane carriageway in order to generate sufficient width to provide a separate marked lane or a paved shoulder for these vulnerable road users. The 'segregation' afforded will reduce motorcycle conflicts and the narrow lanes will discourage motorcycle riders driving up between lines of other vehicles.

  (Research has shown that providing paved shoulders significantly enhances road safety for all vehicles and for pedestrians where there are no separate footpaths).

* Widen traffic lanes on curves as required by Table 4.5 of Arahan Teknik (Jalan) 8/86. This is necessary to account for the "off-tracking" effects of long vehicles and for the inaccuracy of drivers steering on a curved path and thus it is particularly important where there is a high percentage of trucks, and where traffic flows are expected to be high. The lack of lane widening on sharp curves can result in motorcyclists being 'squeezed' between lines of vehicles and may well be a factor in some motorcycle accidents.

* Ensure that medians and dividers are of sufficient width to allow for 'sheltered' auxiliary lanes for right and left turning traffic. Also for the proper protection of pedestrians crossing the road and for road furniture items such as traffic signals, traffic signs, street lighting or other poles, drains etc.

* Avoid 'squeeze' points such as narrow bridges or unexpected pavement narrowing, etc. as far as practical, and where it is unavoidable provide adequate transitions and appropriate traffic signing.

* Ensure, as far as practical, that adequate clearances are maintained to roadside structures such as barriers and guardrail, sign posts, bridge piers & abutments, etc.

(c) Footpaths and Verge:

* Footpaths, adequately separated from the traffic lanes, should be provided wherever there is expected to be significant pedestrian movements along the road. This will generally be the case in all "built-up" areas. A footpath, well separated from the roadway, is essential in the vicinity of schools, and often where sporting, recreation, social, religious and/or other community facilities may generate significant pedestrian demand (even for short periods) on a regular basis.

  Footpaths should be provided with appropriate ramps between the roadway and footpath levels at all locations where pedestrians are expected to cross vehicular roadways. Where driveways into abutting properties cross a footpath,

it is better (from a safety viewpoint) to ramp the vehicular driveway up to footpath level rather than ramping the footpath down to the driveway level.

* Verge areas are within the 'Clear Zone' and therefore should be designed to provide a safe and forgiving roadside to minimise the severity of 'run-off' accidents.

8.6.2 Grading and Drainage

* Where the height/depth of embankment or cutting or otherwise construction economics allow, provide batter slopes of 4:1 or flatter as these can be traversed by an errant vehicle without overturning. In grading design, (and in construction) if excess fill material is available which would otherwise need to be 'wasted', use it to flatten batter slopes and reduce or eliminate the need for guardrail.

* Provide guardrail, only after careful consideration of the warranting criteria at the location in question. Do not provide guardrail where it is not absolutely necessary, remember that guardrail is itself a significant roadside hazard and it is always better to eliminate the need for guard rail if possible.

* Ensure that drains within the errant vehicle 'run-off' area (or clear zone) are traversable and otherwise safe for all types of vehicles and road users.

* Ensure that pavement drainage is fully adequate to avoid ponding of water on the traffic lanes, particularly where vehicles are expected to braking, such as on the approaches to intersections and pedestrian crossings etc.

8.6.3 Horizontal And Vertical Alignment

Highway curves tend to be locations of increased hazard for motor vehicles and the occurrence of accidents tends to increase as the curve radius decreases. The hazard is particularly acute for a curve at the end of a long straight section of road.

* It is important to ensure that the first curve at the end of a straight section is designed to well above the minimum standard. The design speed for such a curve should never be more than 10 km/h below the likely 85th percentile operating speed of traffic on the straight approaching the curve. In assessing this, disregard any speed limit that may be applicable at the site.

* Avoid abrupt changes in the standard of horizontal alignment, and also large variations in curve radius from one curve to the next. Try to achieve general consistency along the route.

* In flat/rolling country aim more for 'curvilinear' alignment rather than a series of curves joined by long straights. This tends to counteract the onset of driver tiredness and fatigue.

* On 2 lane 2 way roads, design to try to maximise overtaking opportunity. In vertical alignment design this sometimes means adopting shorter vertical curves which need to be 'barrier (double) lined' between longer grades rather than by using long vertical curves just equivalent to or less than overtaking sight distance.

* Avoid 'roller coaster' arrangements of vertical alignment. Avoid particularly, situations where the drivers view of the pavement ahead is only momentarily hidden. Likewise, combinations of horizontal and vertical alignment which result in unexpected areas of hidden pavement which may mislead the drivers understanding of the direction of the route ahead, should be avoided, These aspects are best identified by perspective drawings or 3 D computer modeling at the critical locations.

* On steep down grades and at intersections avoid using 'minimum standard' horizontal curves and avoid using high rates of superelevation. This combination is likely to increase hazard for vehicles 'turning' (due to reduced or adverse superelevation) particularly for vehicles with a high centre of gravity.

8.6.4 General Roadway Layout

* Ensure that the roadway layout provides an adequate and consistent capacity (and level of service) along the route. In this regard never consider a single location in isolation from other critical locations nearby and along the route as a whole.

* On high class routes such as expressways and other arterial roads, ensure that there is clear 'through lane' and 'route' continuity and also the proper lane balance at intersections and interchanges. This will avoid unnecessary lane changing and merging and erratic driver behavior which inevitably leads to accident situations, and will delay the onset of serious congestion at periods of high traffic demand.

  This will involve a detailed analysis of capacity and 'level of service' at each critical location in order to set the required number of traffic lanes and the arrangement of exit, entry and auxiliary lanes along the route.

* Carefully select the appropriate sight distance criteria applicable to each critical location and ensure that the design achieves the desirable standard or that other consequential actions are taken where lower standards may be unavoidable.

* Consider the individual safety requirements of all road user groups, especially the vulnerable road users such as pedestrians, motorcyclists and bicyclists. Consider also the special needs of public transport vehicles and passengers, eg. Provision of bus stops clear of traffic lanes, and provisions for bus passengers to cross busy and/or high speed carriageways in getting to and from bus stops.

8.6.5 Intersections

* Pay particular attention to sight distance requirements (refer to Figure 7.4):

'Approach Sight Distance' which is equivalent to 'Stopping Sight Distance' except that the object height should be taken as zero rather than 150mm to ensure that approaching drivers can always see the pavement surface, lane markings, arrows and stop lines etc. in time to make the necessary maneouvres.

'Crossing' or 'Entering' Sight Distance at unsignalised intersections. This is required to ensure that side road vehicle drivers can see main stream traffic approaching and select safe gaps for crossing or entering. This sight distance cannot always be achieved.

'Safe Intersection Sight Distance' which is applied where crossing or entering sight distance is not able to be achieved. It is an intermediate value which enables a main stream driver to take evasive action and avoid a collision if a side road driver enters the intersection without an adequate gap in main stream traffic.

* At intersections, ensure that large vehicles can efficiently make the necessary turning maneouvres without encroaching unexpectedly into adjacent traffic lanes or without traveling over kerbs, traffic islands etc unless this is specifically designed for. This requires the use of 'Design Vehicle' turning path templates or computer plots of vehicle swept path in traversing the intersection. (See section 3.3 of Arahan Teknik (Jalan) 8/86)

* Ensure that median and traffic islands are large enough to be clearly seen by drivers approaching the intersection under all conditions, and large enough to cater for such items as traffic signals (where applicable), traffic signs and pedestrian refuge.

* Ensure that 'speed change' and 'queuing' lanes are of adequate length to allow safe operation. Avoid 'trap lanes' and kerb alignments in which 'through vehicles' can be inadvertently lead into auxiliary lanes or turning roadways.

* Try to achieve angles of intersection and vehicle conflict angles of not less than 50° minimum (the preferable angle is 70°) and generally have the angle favoring the major traffic flow.

* Avoid "Seagull" type layouts at 'T' junctions, particularly in 'built-up' areas where pedestrians need to cross the roadway. This type of layout does not adequately provide for the safe movement of pedestrians across the 'free flow' traffic movement and also involves high risk right hand merges which are particularly difficult for drivers, especially truck and bus drivers. If this type of layout cannot be avoided, then ensure that the (right hand) acceleration/merge length is at least 20% greater than the equivalent design for left hand acceleration/merge situations.

* If practical, avoid intersections on steep grades or just over the crest of vertical curves.

* At signalised intersections always provide signal aspects and phasing for pedestrians.

* Carefully consider the justification and cost effectiveness of providing 'acceleration/merge lanes', particularly at signalised intersections in urban areas where such 'free-flow' movements may disadvantage safe pedestrian movements.

* Generally try to avoid a series of closely space conflicts. Wherever possible conflict points or zones should either be concentrated within the smallest area or be separated by a clear decision time (say 3s to 5s of travel time).

8.6.6 Interchanges

* Avoid unusual interchange layouts which may be confusing to drivers. Particularly try to achieve a consistent arrangement of entry and exit ramps at a series of interchanges along a route. This maintains driver expectations and enhances uniform and error free traffic operation. In general, exits and entry's should always be on the left hand side of the carriageway (for driving on the left), except that at some major Expressway to Expressway interchanges, where the volume of exiting traffic may be similar or greater than the volume of 'through' traffic, equal consideration may be given by providing a symmetrical 'bifurcation' arrangement, subject to this meeting lane balance and route continuity requirements.

* Strenuously avoid 'trap lane' situations. This will require careful consideration of the need for auxiliary lanes and also care in setting the pavement edge and lane alignments to avoid unintentionally leading 'through' traffic into auxiliary lanes and exit ramps.

* Minimise the use of weaving situations and where weaving is required, aim for simple (single lane change) arrangements rather than complex weaving involving multi-lane changes.

* Ensure that interchange ramps are long enough to provide for queuing space (at ramp intersections), plus appropriate deceleration distance from the 'exit nose' to the expected back of the queue. In design, assume that at least 80% of the deceleration required by vehicles exiting takes place after they pass the exit ramp nose as this ensures that 'through' vehicles on the main carriageway are not unduly slowed down by exiting traffic.

* Ensure adequate sight distance to 'exit' and 'entry' nose/gore areas. For exit ramps, at least 40m of the ramp beyond the nose should be visible to an approaching driver at the start of the exit taper. For entry ramps, at least 200m of the near side lane of the expressway should be visible to a driver on the entry ramp at a point 60m in advance of the nose.

* Strictly maintain standard 'exit' and 'entry' ramp layout geometry. This helps develop predictable driver behavior and enhances operational safety and efficiency.

* do not start curves on exit ramps, or end curves on entry ramps, too near the ramp nose. A straight of at least 40m should be provided on the ramp in the vicinity of the nose and the grading on this length should be closely similar to that of the main carriageways in this vicinity.

* Where interchanges involve signalised ramp intersections, ensure that the form and layout details allow flexibility

to run a range of signal phasing to cater for possible fluctuations in traffic demand at various times. It is important to carry out a full capacity analysis of the interchange including the ramp intersections for each peak period using the 'design year' traffic demands, Check particularly the lane requirements, e.g. at signals, and the extent of likely queuing along the exit ramps.

* Do not allow direct access from abutting property to interchange ramps.

8.6.7 Traffic Signals

* Provide traffic signals only where warranted.

* Design the phasing to adequately cater for all required vehicle and pedestrian movements, with no unexpected conflict situations. Provide fully controlled right turn movements where there is a high volume of right turn traffic or where the opposing carriageway has 3 or more lanes or in high speed areas or where sight distance is restricted. Always provide clearance intervals (yellow plus all-red periods) appropriate to the speed environment. In this respect , generally keep a constant yellow time, providing any additional clearance as an 'all-red' interval.

* Provide the correct number and arrangement of signal faces. Each separate vehicle movement should be controlled by at least 3 and preferably 4 signal faces (as this allows for possible lamp failures). Ensure that each signal head is properly positioned and aimed to be clearly visible to its relevant vehicle/pedestrian movement. Provide overhead mounted signal heads on carriageways with more than 3 lanes standing at the 'Stop' line, and otherwise where the speed environment is greater than 70 Km/h or where sight distance to the signals is restricted.

* Provide the correct size and brightness of signal face, providing 'backplates' where necessary to improve signal visability. Ensure that adequate clearance is provided between the signal face and traffic lanes to avoid damage to signal equipment by large vehicles.

8.6.8 Traffic Signs

The purpose of these devices is to Control, Warn, Advise, Guide and Inform. They therefore have a major influence on driver actions and behavior and are thus very important from a road safety viewpoint. The following are some safety related hints to achieve safe traffic operation.

* Plan and design the traffic signing scheme assuming that drivers will not be familiar with the area. In particular in planning the direction signing, do not consider a specific site in isolation to the intersections nearby and the route and region as a whole. Destination names must be carefully chosen as only the 'key destinations' can be displayed and always provide route names in urban areas and (where applicable) route numbers in rural areas.

* Ensure that the necessary 'Regulatory' signs are properly located to give effect to the necessary traffic controls at intersections and along the route.

* Provide 'Warning' signs only where the subject hazard is not obvious to approaching drivers. Carefully select the size of the warning sign appropriate to the speed environment, and position the sign so that it is prominent to drivers and gives them sufficient time to take any necessary action to avoid the hazard.

* All sub-standard curves, (curves with a speed value more than 10km/h below the vehicle approach speed), must be provided with the appropriate warning signs, including a supplementary plate indicating the recommended 'Safe Speed' for the curve.

* In respect to Direction and Guide signs, careful attention needs to be given to the presentation of information on the sign face. Limit the amount of information displayed to preferably not more than 8 words or symbols and provide a legend (Letter) height (which corresponds to a legibility distance) appropriate to the

number of words /symbols and the traffic speed. (Note that the average driver reads traffic sign information at a rate of not more than 4 words per second)

* At important intersections on arterial roads and at interchanges, always provide at least 2 'Advance Direction' signs in addition to the 'Position' sign (at the point of maneouvre). The destination names on these signs should be essentially the same, ie do not add or delete information on subsequent advance direction signs (however additional information may be added as an additional sign providing sign spacing requirements can be met.

* In addition to providing destination names on 'Position' signs, always include road name and route number information.

* Provide 'Reassurance' direction signs beyond intersections/interchanges to allow drivers to confirm their direction choices.

* Where specific traffic lanes are allocated to particular traffic movements or destinations, the information is best displayed on overhead signs. In this case, it is generally preferable to use 'upward pointing' arrows rather than 'downward pointing' arrows, as the latter can be confusing on curved alignment and does not adequately cater for 'optional-use' lanes.

* Ensure that sign information is equally legible at night as by day. This will require the use of retro-reflective sheeting on the sign face and/or external or internal illumination of the sign.

* Provide adequate sight distance to the sign and ensure that sufficient distance is provided between successive signs for a driver to observe and comprehend the message on each sign under normal traffic conditions.

* Ensure that sign posts and gantries etc. do not themselves create undue hazard by specifying the use of 'frangible' type sign posts or by the provision of guard rail protection where necessary.

8.6.9 Pavement Marking And Delineation

* Longitudinal line markings should accurately reflect the geometric design of the roadway, in terms of alignment, width and lane arrangement. Use the correct line marking pattern to define merge and diverge areas, auxiliary lane arrangements, shoulders and parking controls, pavement areas not intended to be traveled, hazard areas, lane drops and road narrowing etc.

* Ensure that the necessary hazard (chevron) markings are placed at expressway exit gore areas and the approach to the nose of traffic islands, medians and other dividers.

* Provide pavement arrows, at appropriate spacing, to designate any traffic lane in which traffic movement is restricted to a particular maneouvre e.g. left turn only or right turn only or 'through' only etc. or to confirm the desired traffic flow direction, e.g. to designate a one-way flow or a 'do not enter' situation. As with most other traffic control devices, use of pavement arrows where they are not necessary is not only wasting financial resources but also undermines the integrity of such markings where they are really essential for safe traffic operation.

* Provide retro-reflective pavement markers (Road Studs) to supplement painted or 'thermoplastic' markings to enhance their effectiveness at night and in wet or foggy weather. These are particularly beneficial for delineating the approaches to hazard areas such as interchange ramp gore areas, approach ends of traffic islands, medians etc.

* Provide supplementary 'Guide Post' delineation on all rural routes, paying careful attention to the spacing of these over crests and on horizontal curves. Note that to provide effective forward route guidance, three delineators must always be visible to the driver.

* At sub-standard curves, where the alignment of the road may be difficult for drivers to 'read', provide extra delineation in the form of post mounted 'Chevron Alignment' markers.

8.6.10 Roadside Safety Features

* Remember that collisions with guardrail or any roadside barrier can be serious, therefore provide guardrail only where the proper criteria is met. In general it should not be used where the consequence of a vehicle hitting the subject hazard is less than that of hitting the guardrail itself.

* Ensure that the terminals of barriers and guardrail are properly treated to avoid these items being a serious hazard to errant vehicles. Approach end terminals of guardrailing needs to be 'flared' away from the direction of oncoming traffic, properly anchored with proven 'break-away' features or other approved treatments. Where concrete (New Jersey) barrier is terminated in narrow medians or separators or exit ramp gore areas, 'Impact Attenuation' (crash Cushions) need to be installed to reduce the severity of vehicle collisions with these items.

* Guardrail is almost always required on the approaches to bridges. It is essential that where semi-rigid barriers, such as Armco'W' Beam, are used on bridge approaches, the proper transitions (of rigidity) must be provided between the approach guardrail and the bridge railing system. It is also essential to strongly anchor and otherwise connect the approach guardrailing to the bridge railing. This is always best done by incorporating a substantial 'End Post' into the bridge railing system, into which the approach 'W'Beam can be set and anchored.

* Particular care needs to be taken in the design of all types of roadside barriers to ensure that they function as required and retain and re-direct vehicles which run off the roadway. This may require higher than normal barriers where elevated roadways have little horizontal separation from adjacent lower level roadways. The danger here is that a vehicle or part of a vehicles load may fall over the top of a barrier onto vehicles on the roadway below. The probability of this occurring needs to be carefully assessed and high barriers should be used where necessary to reduce this risk.

* Kerbs, one of the most common roadside features, can be a significant hazard to traffic particularly for motorcycles and light cars. The functions of a kerb are: to define the edge of the pavement and discourage vehicles from indiscriminantly leaving the roadway, e.g at channelised intersections, to collect and direct water draining off the roadway, to strengthen the edge of the pavement, or to provide delineation. Kerbs are classified as mountable, semi-mountable or barrier types depending on the height and the shape/slope of the face of the kerb. Barrier kerbs, which may need to be up to 150mm high with an almost vertical face, should only be used in low speed, urban shopping areas, to give a greater sense of security to pedestrians and to discourage unlawful parking on the footpath. The other (above) functions are adequately achieved by 'semi-mountable' type kerbs of 100mm to 125mm height and with a sloping face of less than 45°. This kerb type allows the driver of a vehicle and motorcycle riders to maintain steering control in an accidental collision with the kerb. Thus semi-mountable kerbs should be used in all other situations, except that 'fully mountable' type kerbs are necessary where the road design allows for vehicles to traverse the kerbline, or where kerbs may be required to be located in front of guard railing or roadside barriers. (This is to avoid the 'dynamic jump' effect which is likely if semi- mountable or barrier kerbs are used in this situation).

8.6.11 Street lighting

The major objective of installing street lighting is to enhance traffic safety. It is therefore essential that its benefits in reducing night time accidents are not reduced by the lighting poles themselves being involved in accidents.

The following points need to be considered when designing street lighting installations:

* Design the lighting layout to minimise the number of additional poles to be placed beside the roadway. In some cases it may

be better to mount lights on existing power line poles if they are in appropriate locations rather than placing additional poles just for the street lights.

* For 'dual carriageway' roads with a median of sufficient width to allow poles to be installed within it, is better to utilise a 'central' median mounted arrangement rather than having to install a row of poles along both sides of the road. (It is easier to protect median mounted poles, there is less cabling involved and there is more flexibility in respect to choosing an optimum mounting height.

* Use 'frangible type poles where the lighting poles are to be located close to the roadway, e.g. within 3m to 5m of the nearest traffic lane in urban areas, or within 6m to 9m in rural areas, except where the poles are located behind guard rail installed for other reasons.

* Always locate the lighting pole as far from the traffic lanes as possible, consistent with the maximum length of 'outreach bracket' and with achieving the desired 'level of lighting' across the roadway.

* Avoid placing lighting poles in positions where vehicles are known to, or are likely to, run off the roadway.

* Always provide better than the minimum lighting level (standard) at places where the risk of collisions is greatest, eg within the conflict area at intersections, at merge and diverge areas, on the approach noses of traffic islands etc. Also ensure a high standard of lighting where pedestrians cross or walk along the roadway, or wait at bus stops.

* The highest standards of lighting should be applied to urban 'shopping' and 'commercial' environments where there is a high concentration of pedestrian movements combined with vehicle parking maneouvres, turning traffic and vehicles stopping. On the other hand it is difficult to justify even minimum levels of lighting on expressways and rural roads , where there is generally little or none of the above characteristics. However minimum lighting levels may be justified at critical locations such as entry and exit ramp 'gore' areas and ramp intersections on expressways, complex channelised intersections, roundabouts and at some isolated rural intersections.

* Avoid sections of lighting with short gaps of unlit road in between.

* Carefully consider the level of lighting required at the ends of long tunnels or in other situations where a drivers eyes need to re-adapt from a high lighting level to a low lighting level. Remember this process can take many seconds to accomplish and a gradual transition in the lighting level should be provided.

8.6.12 Landscaping

Landscaping can have a significant influence on the safety performance of a project and its planning, design and maintenance need to recognise its safety implications. The following are some points to consider:

* Ensure that landscaping effects do not obstruct sight distance at critical locations. This includes sight distance requirements for traffic signs and signals and sight lines between vehicle drivers and pedestrians at intersections and other crossing points. In assessing sight distance implications, take particular account of the effect of trees, shrubs and other vegetation when they are fully matured.

* Where trees are to be planted within the 'Clear Zone' choose species which do not develop, in their maturity, to have large trunk size (greater than 100mm diameter), which could be a danger to vehicles which may run off the roadway. Try to arrange to have the smaller shrubs and bushes closest to the edge of the roadway.

* Where road medians are wide enough for plantations, arrange the plantations to provide an effective barrier to headlight glare from opposing traffic. This is particularly relevant on horizontal curves in high speed rural areas where drivers at night are most likely to be using the 'High Beam' of their headlights.

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