ROAD SAFETY AUDIT AND A CASE STUDY

ON AKYURT – KALECİK ROAD

A THESIS SUBMITTED TO

THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

OF

ATILIM UNIVERSITY

BY

OKAN UZUN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

IN

THE DEPARTMENT OF CIVIL ENGINEERING

OCTOBER 2010

Approval of the Graduate School of Natural and Applied Sciences, Atılım University

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ABSTRACT

ROAD SAFETY AUDIT AND A CASE STUDY ON AKYURT – KALECİK ROAD

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October 2010, 125 pages

Road accidents are serious problems throughout the world considering social, health and economic terms. The number of road accidents in Turkey tends to increase every year.

In this thesis, the studies were performed to summarize actual practices of road safety auditing on existing roads in different countries. By taking account these different opinions and auditing procedures into account a strategy for road safety auditing on existing roads that fits to Turkish road conditions is proposed.

For an evaluation, a case study was conducted in order to determine whether the proposed methodology adds a value to the highway network follow up and improvements. Based on this study, the audit report was prepared to summarize findings with possible countermeasures.

Keywords: Road Safety, Road Safety Audit

ÖZ

KARAYOLU TRAFİK GÜVENLİĞİ KONTROLÜ VE AKYURT – KALECİK YOLUNUN İNCELEMESİ

Uzun, Okan

Yüksek Lisans, İnşaat Mühendisliği Bölümü

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Ekim 2010, 125 sayfa

Trafik kazaları bütün dünya için sosyal, sağlık ve ekonomik açılardan ciddi bir tehlike oluşturmaktadır. Türkiye'de trafik kazaları her yıl artmaktadır.

Bu tezde, mevcut yolların karayolu güvenlik kontrolleriyle ilgili olarak farklı ülkelerin mevcut deneyimlerini ortaya koymak amacıyla çalışmalar yürütülmüştür. Etüdün uygulanmasına ilişkin değişik yaklaşımlar dikkate alarak Türkiye şartlarına uyum sağlayan mevcut yolların karayolu trafik güvenliği kontrolleri yol güvenlik etütlerinin uygulanmasına yönelik bir yöntem önerilmiştir.

Önerilen yöntemin, karayolu ağına, izlenmesine ve iyileştirilmesine katkılarını değerlendirmek amacıyla örnek bir çalışma uygulanmıştır. Çalışmaya dayanarak, sonuçları ve olası iyileştirme önerilerini özetleyen bir etüt raporu hazırlanmıştır.

Anahtar Kelimeler: Yol Güvenliği, Yol Güvenlik Etüdü.

To My Wife

ACKNOWLEDGMENTS

I would like to express my sincere gratitude to my thesis supervisor, Assist. Prof. Dr. Cumhur AYDIN for his valuable guidance, continuous support and inspiration that he provided throughout all preparation stages of this thesis.

I also offer my sincere thanks to Mr. Veysel Akkuş and Mr. Orhan Yüce from the Traffic Department, Mr. Serkan Yılmaz from Strategy Planning Department of General Directorate of Highways, for their technical support. I also offer my sincere thanks are also gone to my friend Murat Özel for his technical support during the field survey.

Very special thanks are extended to my lovely wife, Nisan Bengi Uzun for her never ending valuable supports and help during my studies.

Finally I would like to thank to my family members for their continuous supports and encouragement.

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LIST OF ABBREVIATIONS

AADT	- Annual Average Daily Traffic
AASHTO	- American Association of State Highways and Transportation Officials
ADT	- Average Daily Traffic
AUSTROADS	- National Association of Road Transport and Traffic - Authorities in Australia
ETSC	- European Transport Safety Council
FHWA	- The Federal Highway Administration
GNP	- Gross National Product
IHT	- Institution of Highways & Transportation
KİTGİ	- Karayolu İyileştirmesi ve Trafik Güvenliği
NHCRP	- National Cooperative Highway Research
NRSC	- National Road Service Commission
PIARC	- International Association of Road Congresses
RIPCORD-ISEREST	-Road Infrastructure Safety Protection – Core Research and Development for Road Safety in Europe; Increasing Safety and Reliability of Secondary Roads for a Sustainable Surface Transport.
RCA	- Road Controlling Authority
RIA	- Road Safety Impact Assessment
RSA	- Road Safety Audit
RSI	- Road Safety Inspection
RTA	- Roads and Traffic Authority
RTI	- Road traffic deaths and injuries
TAC	- Transportation Association of Canada
TNZ	- Transit New Zealand
TRB	- Transportation Research Board
VIC	- Victoria Roads Corporation

CHAPTER 1

INTRODUCTION

Over 1.2 million people die each year on the world's roads, and between 20 and 50 million suffer from non-fatal injuries. In most regions of the world, this epidemic of road traffic injuries increases. In the past five years, most countries have endorsed the recommendations of the World report on road traffic injury prevention which give guidance on how countries can implement a comprehensive approach to improving road safety and reducing the death toll on their roads. [1]

1.1. The Trend in the Traffic Accidents and Casualties

More than eighty five per cent of all road traffic deaths and injuries occur in low income and middle income countries. The injury/mortality rates per 100,000 population differ by region (Figure 1.1), (Table1.1) with Africa enduring the world's highest rates per population and most dangerous roads, but South East Asia experiencing the highest number of actual fatalities and injuries and the highest predicted growth in road traffic injuries.[8]

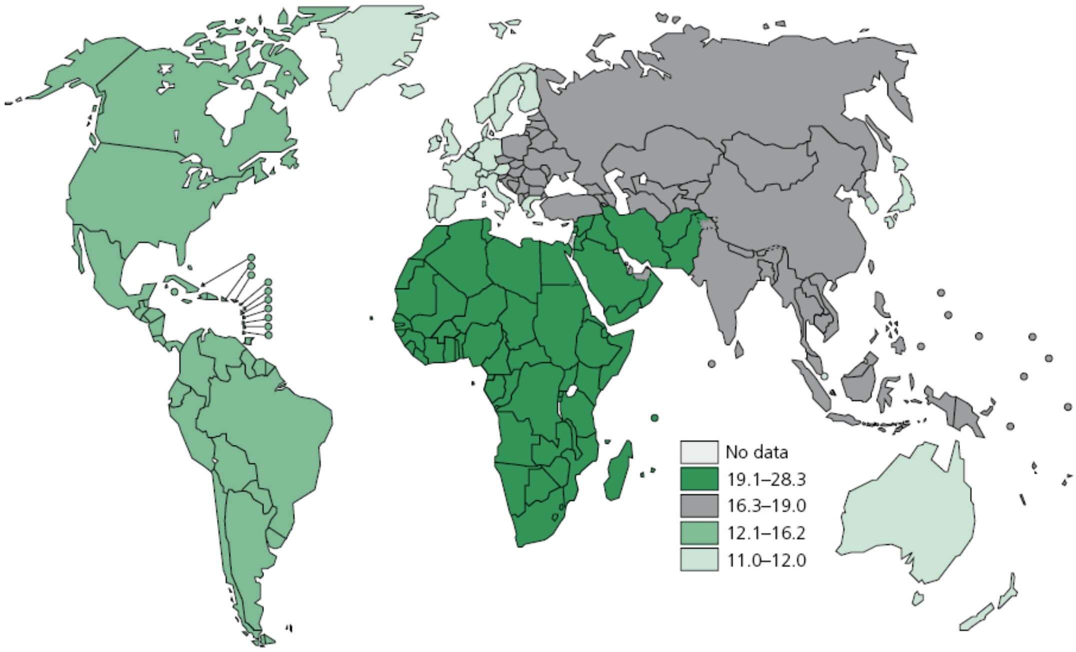

Figure 1.1 Road Traffic Injury Mortality Rates (Per 100 000 Population), 2002 [8]

WHO REGION	LOW INCOME AND MIDDLE INCOME COUNTRIES	HIGH INCOME COUNTRIES
African region	28.30	---
Region of the Americas	16.20	14.80
South-East Asia Region	18.60	---
European Region	17.40	11.00
East Mediterranean Region	26.40	19.00
Western Pacific Region	18.15	12.00

Table 1.1 World Report on road traffic injury prevention [8]

Road traffic deaths and injuries (RTIs) impose a huge economic burden on developing economies, amounting to 1-2% of Gross National Product (GNP) in most countries (Table 1.2). These costs, some $64.5 billion - $100 billion, are comparable with the total bilateral overseas aid contributed by the industrialized countries, which amounted to $106.5 billion in 2005. These estimates take only of the direct economic costs – mainly lost productivity – into account rather than the full social costs often recognized by industrialized countries. [8]

REGION	GNP	ESTIMATED ANNUAL CRASH COSTS $ BILLION	
	1997 $ BILLION	GNP%	COSTS
Africa	370	1	3.7
Asia	2454	1	24.5
Latin America and Caribbean	1890	1	18.9
Middle East	495	1.5	7.4
Central and Eastern Europe	659	1.5	9.9
Sub-total	**5615**		**64.5**
Highly motorized countries	22665	2	453.3
Total			**517.8**

Table 1.2 Estimated Annual Crash Costs [8]

Indeed, unless there is concerted action, the World Bank expects global road fatalities will increase by more than 65% between 2000 and 2020, with different trends across the different regions of the world. Fatalities are predicted to be increased by more than 80% in low and middle income countries, but be decreased by nearly 30% in high income countries (Table 1.3), thus revealing a widening gap between the road safety in rich and the road safety poor. [8]

WORLD BANK REGION	% CHANGE 2000 - 2020
South Asia	144%
East Asia & Pacific	80%
Sub-Saharan Africa	80%
Middle East & North Africa	68%
Latin America & Caribbean	48%
Europe & Central Asia	18%
Sub-total	**83%**
High income countries	-28%
Global total	66%

Table 1.3 Predicted Road Traffic Fatalities [8]

1.2. Actions for Improving Road Safety

Through out the efforts for increasing highway safety, some transportation agencies have introduced safety programs specifically designed to study and improve some important geometric elements contributing to highway accidents. At the same time, engineering design has greatly been improved in terms of increasing safety into road structure and environment. In earlier years, engineers designed and built highways, which provides a minor of protection to vehicles colliding with infrastructure or roadside elements outside travel lanes. In 1960s and 1970s, engineers have started to built more “forgiving highways” which incorporated critical design elements that mitigated the consequence of colliding with elements beyond the travel lanes. More recently, engineers have begun to develop “caring highways” by emphasizing the need to prevent (rather than mitigate) collisions. [3]

Although practiced elsewhere for nearly two decades, the concept of Road Safety Audits has only recently gained acceptance in North America. Originally developed in the United Kingdom in the 1980s as part of Accident Investigation and Prevention techniques, they have evolved to the point where they are now an integral component of the road safety process. Road safety audits help to ensure that issues associated with road safety are specifically addressed and are given equal importance as the other factors in a design project. [3]

With this intent, many countries such as United Kingdom, Australia, New Zealand, Canada and United States have adapted Road Safety Audits as a part of their national road safety strategies.

The road safety audit (RSA) has been defined as a formal examination of an existing or future road or traffic project, or any project which interacts with road users, in which an independent, qualified examiner reports on the project’s crash potential and safety performance. [2]

On the other hand, Road Safety Impact Assessment (RIA) is just come into the Road Authorities Agendas through the proposed applications and obligations that have been set by the European Parliament and The Council of The European Union. The Road Safety Impact Assessment’ means a strategic comparative analysis of the impact of a new road or a substantial modification to the existing network on the safety performance of the road network. The Commission expressed the need to carry out safety impact assessments and road safety audits, in order to identify and improve high accident concentration sections within the Community. It also sets the target of halving the number of deaths on the roads within the European Union between 2001 and 2010. [22]

The setting up of appropriate procedures is an essential tool for improving the safety of road infrastructure within the trans-European road network. Road safety impact assessments should demonstrate, on a strategic level, the implications on road safety of different planning alternatives of an infrastructure project and they should play an important role when routes are being selected. The results of road safety impact assessments may be set out in a number of documents. Moreover, road safety audits should identify, in a detailed way, unsafe features of a road infrastructure project. It therefore makes sense to develop procedures to be followed in those two fields with the aim of increasing safety of road infrastructures on the trans-European road network. [10]

Establishment and implementation of procedures are required by the directive that is relating to road safety impact assessments, road safety audits moreover the management of road network safety and safety inspections by the Member States. Also directive shall apply to roads which are part of the trans-European road network, whether they are at the design stage, under construction or in operation.[10]

Member States may also apply the provisions of this Directive, as a set of good practices, to national road transport infrastructure, not included in the trans-European road network that was constructed using Community funding in whole or in part. [10]

1.3. Thesis' Scope

The aim of this thesis is to evaluate different road safety auditing techniques and implement a case study on an existing road section in Turkey. Through out the implementation and reporting at this case study; the present safety situation of Turkey's roads and available techniques are tried to be evaluated.

The thesis is divided into five chapters as follows:

Chapter 2 provides an international overview on the historical evolution of road safety audits. This chapter also describes the principles underlying road safety audits. It provides a synthesis of concepts, stages and implementation of road safety audits. It presents also the Turkish road safety audit process of existing roads.

Chapter 3 describes the basic structure and explanations of road safety audit and it's reporting

Chapter 4 presents illustrative examples of road safety audits which are conducted in Turkey in road number of 140-06 between station km 27+000 and km 59+200. Proposal of specific countermeasures about the safety, safety improvement techniques and the cost analysis of these techniques are represented in this chapter.

Chapter 5 presents conclusion and recommendations.

CHAPTER 2

WORLDWIDE AND TURKISH EXPERIENCES OF ROAD SAFETY AUDITING

In this chapter, the general principles of road safety audits are discussed. Beside this, definition of road safety inspection, which is a new approach analyzing for road construction projects, is going to be evaluated.

The road safety audit process has progressively been more widely known over the last 15 years. So, it is useful to briefly evaluate the importance and the need of the road safety audit concept as a discrete element of a road safety program. A review of existing practices regarding road safety audits in the United States, United Kingdom, New Zealand, Australia, Canada and also other countries are involved in conducting RSAs, are going to be summarized in the following paragraphs.

Finally, monitoring and evaluation of road safety audit results and also feasibility parameters associated with road safety audits are presented in the last part of the chapter.

2.1. Road Safety Audit and Road Safety Inspection

Road authorities must guarantee adequate levels of safety on existing roads. To reach this goal, advanced road safety management considers not only traditional corrective measures due to analyses of high risk sites but also the whole infrastructure life cycle itself. This includes interventions to reduce the influence of hazards using general quantitative knowledge on factors affecting the safety of road facilities. [12]

Whenever road authorities plan new roads or whenever existing roads have to be redesigned due to changes of local conditions, the road designers have to consider a number of different aspects and interests in their schemes which have an effect on the design itself. [13]

For several reasons, the Project costs, environmental restrictions, and political restraints force the designer to make compromises which do not always lead to a design with the highest level of safety. Road safety aspects are mostly implicitly considered in the design standards and existing approval procedures usually check for compliance with design standards only. [13]

As a result also new roads can have a comparably low road safety level which forces the road authorities initiate costly remedial measures afterwards. To avoid unsafe new roads, road safety audits have been developed in the UK and adopted by many countries. [13] The figure 2.1 shows current use of road safety audits in Europe.

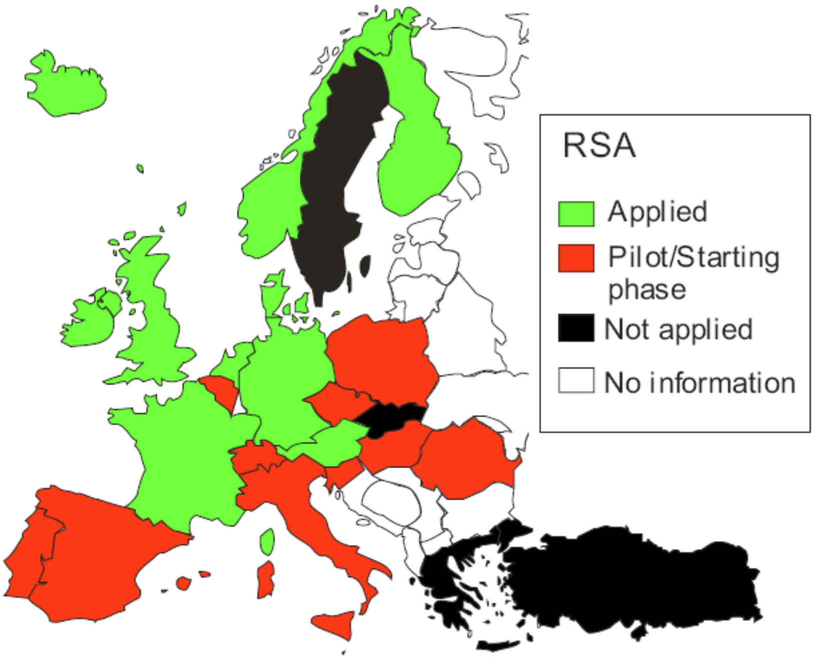

Figure 2.1 Current use of road safety audits in Europe [14]

There is a common consideration in many countries that is concern about road safety management is road safety inspection. Road safety inspections are increasingly used as a part of road safety management. A road safety inspection is a systematic assessment of the safety standard of an existing road, in particular with respect to hazards related to traffic signs, roadside features, environmental risk factors and road surface condition. The objective of a road safety inspection is to identify traffic hazards and suggest measures to correct these hazards. Road safety inspections are, to a large extent, based on similar checklists and procedures as those applied in road safety audits. Road safety audits are applied during the planning of new roads, whereas road safety inspections are carried out on existing roads. [9]

The figure given below (Figure 2.2) explains the application area of Road Safety Inspection in European Countries.

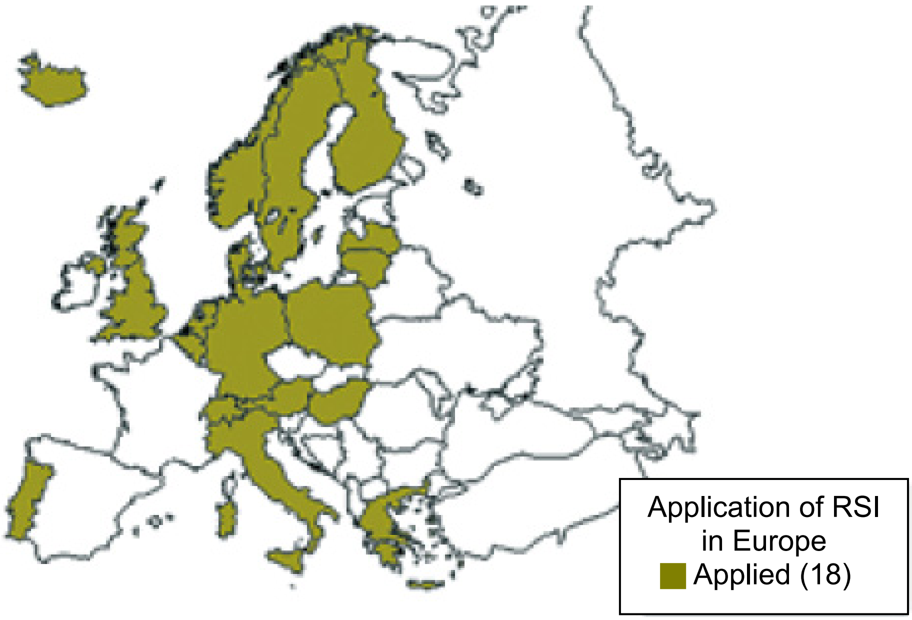

Figure 2.2 Current use of road safety inspection in Europe [14]

An international research project called Ripcord-Iserest about road safety issues' including audits was implemented between years 2005-2007 through the European Union 6th Framework Research Program.

The one of the main objectives of Ripcord-Iserest was to formulate best practice guidelines for RSI. To meet this objective, a questionnaire was sent to 14 European countries in order to obtain an appropriate description of the current European practice of RSI (Lutschounig, S., et al, 2005). A common understanding of the RSI concept was thereafter defined, as agreed by the participants (Mocsari, T., et al, 2006), and compared with the responses obtained in the questionnaire. The results are shown in Figure 2.3 (Nadler, H. *et al*, 2006). [12]

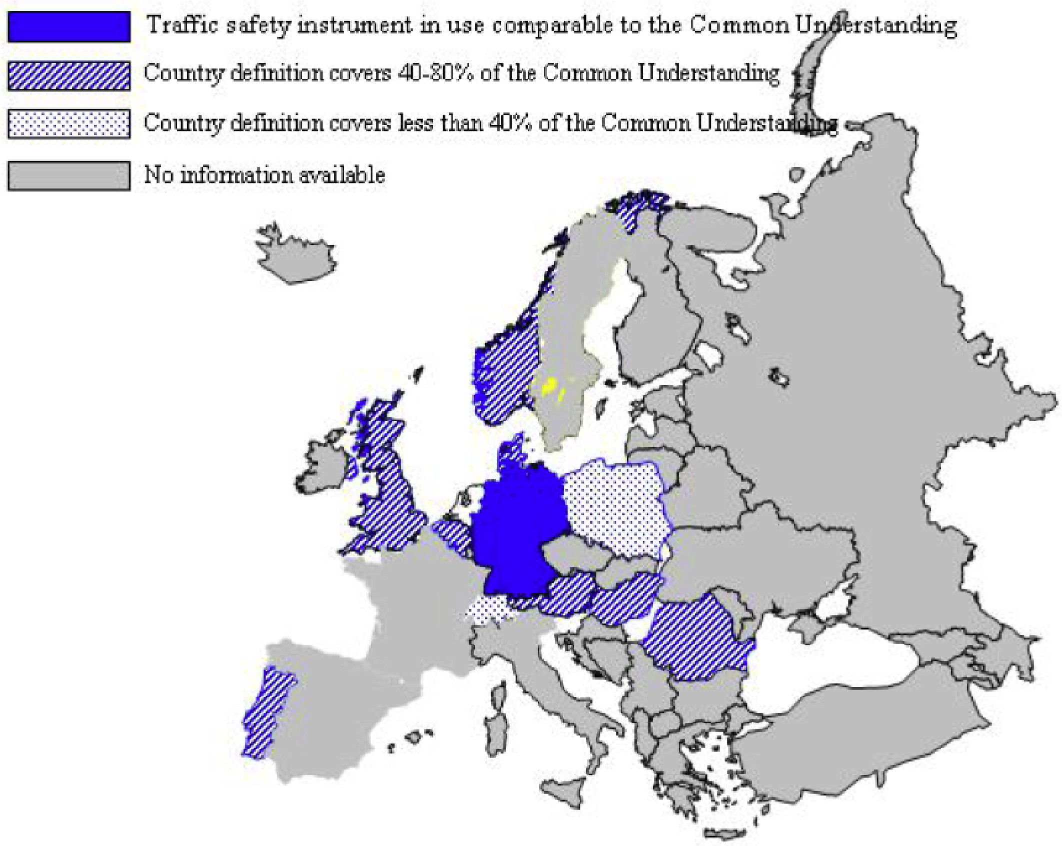

Figure 2.3 Compatibility between RSI Common Understanding and current practice [12]

According to the common understanding [Mocsari, T. et al, 2006], Road Safety Inspection is defined as: [12]

- a preventive tool,
- consisting of a regular, systematic, on-site inspection of existing roads, covering the whole road network,
- carried out by trained safety expert teams,
- resulting in a formal report on detected road hazards and safety issues,
- Requiring a formal response by the relevant road authority.

RSI are considered as a preventive tool because its application to an itinerary or road section is not dependent on knowledge concerning its specific safety level. In fact, neither the decision for the initiation of a RSI nor the procedures for its execution require knowledge on the registered safety record of the relevant itinerary.

To carry out a RSI, only general knowledge on road hazards, on safety issues related to the road environment and effective infrastructure interventions are needed. [12]

Nevertheless, in some EU countries accident data are used either as an inspection triggering criteria or as complementary information used for setting suitable interventions. Most probably this deviance from the mentioned common understanding does not seriously affect the application of the RSI concept, provided that the required accident data is readily available and meets quality requirements; however, caution should be taken, to ensure that RSI does not become too similar to other safety management tools, such as "Network Safety Management" and "Black Spot Management" (as defined in Ripcord-Iserest Work-package 6) [Ripcord-Iserest, 2007]. [12]

One important feature of RSI is that this activity should cover the whole network. Furthermore, to be fully effective, some regularity in RSI should be defined, to ensure that there is a periodic systematic evaluation of safety hazards throughout the entire road network. [12]

There are four stages of road safety inspections and their intended effects on road safety are;

- Road safety inspections should be targeted at hazards known to be risk factors for accidents or injuries
- Reports from road safety inspections should identify treatable traffic hazards and propose corrective measures
- There should be a check that the measures proposed by road safety inspectors are actually implemented
- Measures implemented as a result of road safety inspection should not elicit behavioral adaptations that offset the intended effects of the measures. [9]

There is no standardized procedure throughout Europe how RSI should actually be carried out. Although the objective of RSI is the same in many countries, i.e. to improve infrastructure safety on the already existing road network, there is also a wide range of definitions and methodologies used. This is one of the reasons why

RSI has not gained the same standing international safety work as the more popular road safety audits. Procedures and methods are still vague and just a few countries can offer guidance for those who want to incorporate this instrument in their network. [13]

Road safety inspection costs in the European countries were also surveyed by RIPCORDISEREST. Where inspections are carried out on a regular basis, costs range between 600 and 1.000 € per km of motorway. Considering the roads where the Directive will be mandatory (the EU25 trans-European road network, having an overall length of approximately 85.000 km in 2005), one can estimate that the overall cost of the inspection of the whole network will range between 50 and 85 millions of €. For a large sized country, having about 5.000 km of TERN on its territory, this means costs for inspections ranging between 3 and 5 millions of €. [7]

A recent European study (Lutschounig et al., 2005) studied the present application of RSIs in the EU. Countries apparently use different definitions of an RSI: mostly a mix of RSA, RSI, and black spot analysis. It is often decided to carry out an RSI if a road section has a high crash rate. In Germany, Hungary, Norway, and Portugal the national road authorities often carry out an RSI during maintenance inspections. RSIs have no legal basis, meaning that there is no large necessity of carrying out. That is why the EU project Ripcord-Iserest is attempting to come to a standardized approach of RSIs in Europe, to develop an implementation plan and checklists, and will carry out a number of trial projects. [5]

In contrast to road safety inspections, road safety audits are intended to increase road safety by avoiding accidents before a road is (re-)opened to traffic.

2.2. Review of Existing Practices Regarding Road Safety Audits in Different Countries

The number of countries worldwide using the tools of road safety audits and road safety audit reviews are growing rapidly. The most advanced countries have been involved in applying these techniques since the middle of 1980s. The United

Kingdom, Australia, and New Zealand are leaders in refining and advancing the state of the practice. [11]

This chapter presents the existing road safety audit practices in some countries that are United States, United Kingdom, New Zealand, Australia and Canada. Worldwide, the RSA concept has proven to be highly effective in identifying and reducing the crash potential of roadway projects. Globally it is estimated that one million fatalities result from motor vehicle crashes each year. The potential savings in lives, serious injuries, and property damage is measureless.

Moreover in many countries all over the world road safety audit application areas are widely increased since it is considered an important element of a road safety program. In some of the countries, manuals have been developed and Road Safety Audit carried out for years. The application concept is not exactly the same for applying countries but the general idea of RSA is of course same.

2.2.1. United States

The Federal Highway Administration (FHWA) sponsored an international technology scanning review that focused on Australia, and New Zealand. Its purpose was to review the application of safety management systems in 1996. One of the primary findings was that safety audits were effective in improving highway safety in the countries where they are implemented. The program participants recommended that a United States pilot study be conducted. [14]

In the United States, first pilot studies regarding road safety audits have been carried out by thirteen states and two local governments in 1997. Fourteen states are currently involved in the pilot project. This program has resulted in significant improvements and savings in road program technologies and practices throughout the United States, particularly, in the areas of safety and road maintenance. An inquiry carried out by the Transportation Research Board (TRB 2004) revealed that in 2003, eleven states were using RSA procedures although the practice in the states widely differs. [14]

2.2.2. United Kingdom

The road safety audit concept was originated in the United Kingdom in 1980s beside this the first documented use of RSA practices was in the United Kingdom. In 1987, the Transportation department of United Kingdom improved strategies objected at reducing road casualties by one-third by the year 2000. Based upon the Road Traffic Act 1974 and its revision 1988 which obligated road authorities to reduce the chance for road accidents on new roads, the first road safety audit standards were published in 1990. Since 1991 road safety audits are mandatory for the construction and re-development of national motorways and trunk roads. Beside this obligation, many local highway authorities voluntarily apply road safety audits also within their area of responsibility. For these organizations "Guidelines for the safety audits of highways" were developed by the Institution of Highways & Transportation (IHT 1996). [14]

In the mid 1990's both, the standards and the guidelines for road safety audits were revised. The road safety audit present version was broadcasted in 2003. [14]

2.2.3. New Zealand

A road safety audit in New Zealand was embraced in the early 1990's. The new guideline replaces that published by Transit New Zealand (Transit) in 1993. It retains the philosophy of the Transit guideline and includes more advice, for example, on the skills and experience of audit team members. It does not apply to existing road audits. [35]

Road safety audit guidelines were published in New Zealand by Transit New Zealand (TNZ) (succeeded in 1996 by Transfund New Zealand) after several pilot audits, because of the national road agency responsible for the maintenance and improvements of the highway network is Transit New Zealand (TNZ) Having revised the practices and procedures of road safety audits in the UK and Australia. After that "Safety Audit Policy and Procedures" was announced by Transit New Zealand. After RSA procedures were established, 20% of all national road projects had to be audited. Since July 2004 road safety audits are preconditions for the funding of new projects (Alkema 2004). [14]

2.2.4. Australia

In Australia, the national association of road and traffic agencies, Austroads is responsible for road safety. Austroads is the association of Australian and New Zealand road transport and traffic authorities whose purpose is to contribute to the achievement of improved transport outcomes. Like in New Zealand, road safety audits in Australia started in the early 1990's. In Australia, the states of New South Wales and Victoria started to establish Road Safety Audit procedures in 1991. Due to organizational differences in the Australian States the audit procedures partly differ between these states. [14]

In Victoria, Victoria Roads Corporation, known as VicRoads considered audits to be a critical element in the quality management process and a chance to improve quality with little increase in cost. All projects that cost more than US$4 million at all stages were subjected to safety audits. Twenty percent of all other projects were audited randomly at one or more of the project stages. [3]

In New South Wales, the Roads and Traffic Authority (RTA) who has executive responsibility for road safety commenced audits in 1990 and developed a road safety audit manual by the middle of 1991. In this manual, road safety audits were declared as part of the overall quality management approach the emphasis was on safety in all aspects of a project. Each year 20 percent of the existing roadways in each region were audited, and approximately 20 other design audits were conducted. While almost all state authorities have established road safety audits, local governments have not accepted RSA insofar as to apply RSA on a regular basis. [3]

2.2.5. Canada

Canada has been a leader in North America in the implementation of RSA concepts. The first formal audit was completed in Vancouver, British Columbia, in

1997. Since that initial audit, several provinces and local governments have conducted audits. One impetus for their use was the support of the Insurance Corporation of British Columbia in the development and application of audit techniques as a tool to reduce the number and severity of traffic crashes. The Transportation Association of Canada (TAC) has developed *The Road Safety Audit Guide* to aid safety professionals in the application of the audit process. [11]

2.2.6. Other Countries

A number of other countries are involved in conducting RSAs. Using of RSAs has been supported by The World Bank, providing funding for consultants, performance of audits, and training. The following list is not intended to be all inclusive, but is provided to indicate global acceptance of the practice. Other RSA participants include: [11]

- India, Thailand, and others in Southeast Asia;
- South Africa;
- Eritrea in Northeast Africa; and
- Denmark, Finland, Germany, Italy, Norway, the Netherlands, and Switzerland in Europe.

2.3. Road Safety Audit Principles

2.3.1. Definition and Purpose of Road Safety Audit

The Road Safety Audit (RSA) is a systematic procedure that brings traffic safety knowledge into the road planning and design process to prevent traffic crashes. The RSA is a formal systematic road safety assessment or “checking” of a road or a road scheme. This is usually carried out by an independent qualified auditor or a team of auditors who report on ways of minimizing risks to road users. These auditors can be in-house safety experts of the road authority or external specialist consultants. [2]

Also the national association of road transport and traffic authorities in Australia that is called as Austroads defines a road safety audit as *"....a formal examination of an existing or future road or traffic project, or any project which interacts with road users, in which an independent, qualified examiner looks at the project's accident potential and safety performance."*[3]

Another definition is according to PIARC (Permanent International Association of Road Congresses) (PIARC 2001) a Road Safety Audit is a "formal systematic road safety assessment of the road or road scheme carried out by an independent, qualified auditor or team of auditors who reports on the project's accident potential for all kinds of road users". Although the given definition also includes reviews of existing roads, the current international understanding of road safety audits refers to examinations conducted in the planning and the design stages of road projects (which include new projects but also re-design projects) before or shortly after a road is opened to traffic or the measure is completed. [14]

Moreover 'road safety audit' means an independent detailed systematic and technical safety check relating to the design characteristics of a road infrastructure project and covering all stages from planning to early operation; [10]

Lastly although many other definitions exist, most include the concept that a RSA is a formal examination, which applies safety principles from a multi-disciplinary perspective. [3]

The scope of safety audit is usually confined to an individual road scheme, which may be a new road or modification to an existing road. The basis for safety audit is the application of safety principles to the design of a new or a modified road section to prevent future accidents occurring or to reduce their severity. [22]

Another purpose of road safety audit is to identify potential safety disability for all road users and others affected by the road project and eliminate those safety problems also to ensure that measures to eliminate and reduce the problems are fully considered. Beside these the scope of safety audit is to minimize number of accident and severity. In safety audits the main purpose is to ensure that all new highway schemes operate as safely as is applicable. It is clear that consideration is given to enhance the safety of all road users rather than vehicles only. There are other secondary purposes too, including; [36]

- To reduce the long-term costs of a scheme unsatisfactory design can be expensive to correct at a later stages after they are built.
- To recognize the importance of safety in highway design to meet the needs and perceptions of all types of road users; and to achieve a balance between needs where they may be in conflict;
- To minimize the remedial works after construction.
- To minimize the risk of accidents on the adjacent road network as well as on the new road scheme.
- To improve the awareness of safe design practices by all involved in the planning and design of the project. [2]

When the risk of accidents are minimized at the design stage during the lifetime of a road project, there is less probability of having to take accident remedial measures later, and the project's life costs can be reduced. [22]

2.3.2. Benefits of Road Safety Audit

Some of the benefits of conducting a road safety audit are as follows;

- Can help produce designs that reduce the number and severity of crashes
- May reduce costs by identifying safety issues and correcting them before projects are built
- Promote awareness of safe design practices
- Integrate multimodal safety concerns
- Consider human factors in all facets of design [41]

Austroads identifies five benefits of the RSA project;

- Reduce the likelihood of accidents,

- Reduce the severity of accidents,
- Elevate road safety "in the minds of road designers and traffic engineers,"
- Reduce the need for "costly remedial work," and
- Reduce the "total cost of a project to the community, including accidents, disruption, and trauma. [3]

At any or all stages of the projects RSAs can be conducted. In general audits carried out in earlier stages get more potential benefits. That is why it is easier to change a line on a plan than to remove the problem by reconstruction once the road is opened.

2.3.3. Monitoring and Evaluation

All highway organizations involved with safety audits should monitor and evaluate their road safety audit procedures. This may be accomplished by maintaining a complete record of the safety Audit projects conducted by the organization. The record would contain a list of common deficiencies identified during all stages of road safety audits. This, in turn, provides feedback for designers and auditors performing future projects. The intent is to prevent recurring deficiencies from being designed into road projects. Otherwise, designers will continue to “build blackspots” into the road system. [3]

When a scheme has been completed, it is important to monitor its performance in terms of the number and severity of road accidents and casualties. A suggested working method for monitoring is outlined below:

- Identify accident locations;
- Identify accident types;
- Identify which items highlighted in the Safety Audit Report were amended on site;
- Prepare a monitoring report for the client (with a copy to the original Audit Team);

- It may also be useful to examine maintenance records as these could highlight where damage-only accidents have occurred. [6]

2.3.4. Road Safety Audit Management

Road safety audit management has a variation of methods, that are provide satisfactory results. There is no single “right” method of managing an audit. There is a number of key factors which are described below. The successful management of a Road Safety Audit can ensure by these factors; [36]

- Scope and organization of the audit should be clearly specified in the terms of reference The safety team should be independent of the design team
- The safety team must have specialist up-to-date knowledge of safety engineering
- The findings of the audit should be formally documented and reported
- The roles and responsibilities of owner, design team and audit team should be clearly understood by all parties
- The reasons for various actions resulting from the audit recommendations should be formally documented. [36]

2.3.5. Financial Considerations

The main immediate benefits of the procedures will be accident savings. In principle however, there are other longer term and more broadly based potential benefits; these include not just the immediate accident savings on the schemes subjected to the procedures, but more generally, improvements to the management of design and construction, reduced whole-life cost of road schemes, the development of good safety engineering practice, the explicit recognition of the safety needs of road users, and the improvement of design standards for safety. [6]

The benefits of an RSA are mainly the costs saved on crashes that have been prevented by following the audit's recommendations. In addition, Gadd (1997) mentions a series of qualitative benefits: after completion a diminished risk of crashes and the repair works resulting from them, a reduction of the total project costs, a greater awareness of road safety and quality in design processes, better facilities for vulnerable road users, and a contribution towards achieving road safety targets, better standards, and design guidelines. [5]

The costs of an RSA can vary greatly depending on the size of the project and the phase in which the audit takes place. A distinction can be made between direct and indirect costs. The direct costs are the time spent by auditors and the extra time that designers need to include the recommendations in the design. Experiences in Denmark estimate the direct costs to be an average of 1% of the total project costs. In Australia they vary between €600 and €6,000 an average of only 0.2% of the total project costs (Van Hout & Kemperman, 2004). In the Netherlands the direct costs during the trial audits were between €3,200 and €4,600 (Van Schagen, 2000). The earlier in the process an initial RSA is carried out, the lower the relative costs. [5]

A study in Great Britain that compared before and after crash statistics for a sample of audited schemes and non-audited schemes found that audited schemes achieved an average casualty saving per year of 1,25, compared to a saving of 0,26 for non-audited schemes.[4]

Another study in Great Britain found that the average saving from implementing changes at the design stage rather than after the project was constructed was approximately USD 15,000. [4]

An evaluation study which involved a cost benefit analysis of 13 projects in Denmark that had been subject to road safety audit gave a first year rate of return of 146 %. [4]

A study in the Middle East which considered a number of projects that were not subject to road safety audit, but developed problems soon after construction concluded that road safety audit would have provided a first year rate of return of 120 %. [4]

Moreover Directive of the European Parliament is estimated to reduce the number of EU citizens dying on the TERN by more than 600 fatalities per year and the injury accidents by about 7000 per year. According to the monetary estimations of the White Paper, the welfare benefit of these reductions corresponds to more than 2,4 billions € per year. If the Directive will be applied on motorways and main roads, the reduction of fatalities is estimated around 1.300 every year; this corresponds to more than 5 billions € per year. [7]

According to the Commission of the European Communities safety audits are performed in parallel with the design and construction process of the road, and are therefore not expected to cause any delay. The thematic network RIPCORDISEREST made a survey on audits costs estimations in the countries, where audits are already performed. The results of this study show that in the European countries audit costs range between 600 and 6.000 € per stage. In general, the estimations in the different countries indicate that audit costs, related to the time spent to complete it, are far less than 1% of the construction cost of the whole project. A recent Australian evaluation of safety audits21 in several countries found that benefit-cost ratios of audits reviewed ranged between 2.4:1 and 84:1. About half of all audits had benefit-cost ratios higher than 5 and about half had a cost of less than AUS $ 5,000 (3.000 €). [7]

The indirect costs are the extra costs of construction and reconstruction activities recommended by the auditors. Estimates of experiences abroad are between 1% and 2% of the total project costs. [7]

In smaller projects the direct and indirect costs of an RSA are relatively greater than in large projects.

2.4. Turkish Road Safety Auditing

In Turkey, in the recent years, rapid increase in trips demands and rapid changes in technology have resulted in high number of motor vehicles and high traveling speeds. On the other hand investigations have revealed that excessive speeds are the major causes of many traffic accidents. Since traffic accidents have became one of the primary concern of Turkish Road Authority, accidents prone locations and accident black spot concepts are developed and applied.

In the period “1997-2002” with the financial support of the World Bank, the Highway Improvement and Traffic Safety Project (KİTGİ) was launches by Turkish National Organizations through the assistance of the foreign specialists. It was the opportunity to start Safety Auditing Concept in Turkey Road Authority. For the last ten years, this topic has still been evaluated in Turkish General Directorate of Highways and will be implemented soon.

During this period, the Highway Traffic Safety Audit Handbook was prepared in 2007 among high traffic safety levels on existing roads and planned projects in Turkey. When handbook will be put into the practice;

- it can be applicable to; remove the high potential accidents locations and accident black spots before these points are appeared and/or become more problematic
- reevaluate the existing standards for having more safer roads

There are many methods to improve roads design safer that including black spot treatment, periodic inspection, adaptation of higher safety status road design practice and road safety audits of existing roads. It is for highway authorities to decide which of these techniques should be followed at certain time intervals.

For achieving safer roads; road safety audit technique can play an important role. To improve roadway traffic safety, many highway authorities have introduced road safety audits as an element of their road management. The Turkish Road Authority has intended to introduce safety auditing at project stage and after road opening to the traffic. At present; almost all highway design projects are being evaluated from safety point of view by Traffic Division.

Currently, audits are carried out unsystematically in the preliminary design stage and after the detailed design stage. There are also road safety inspections which are carried out on problematic existing roads sections. When audits are started to be carried out, more systematically will decide which road sections have to be audited in a short time. At present the auditors are members of the Directorate of Traffic Division who are also involved in the project (internal auditors). It will be more appropriate to use external auditors in order to have more objective evaluations and criticisms of the road design projects.

CHAPTER 3

BASIC STRUCTURE AND EXPLANATIONS OF ROAD SAFETY AUDIT AND SAFETY REPORTING

3.1. Inputs

The Road Safety Audit can be applied to specific operating and maintenance activities on existing roads as well as for systematic assessment of road safety aspects on existing roads and road networks. There are some important inputs, when applying an audit.

Some of the inputs for road safety audits are road function, traffic data, speed data and accident data. These data support auditors for better performing the audit of the road. By the help of these data auditors can clarify the road function, have idea about the typical accident types, volume of traffic, speed levels of different vehicles and etc. After getting these data they can immediately determine the potential problematic sections and focus on them.

3.1.1. General Project Data

Functional classification is the process by which streets and highways are grouped into classes, or systems, according to the character of traffic service that they are intended to provide. This classification recognizes that individual highways do-not serve travel independently. Rather, most travel involves movement through networks of highways and can be categorized relative to such networks in a logical and efficient manner. Thus, functional classification of highways is consistent with the categorization of travel. [42]

The roads making up the functional systems differ for urban and rural areas. The hierarchy of the functional systems consists of principal arterials (for main movement), minor arterials (distributors), collectors, and local roads and streets; however, in urban areas there are relatively more arterials with further functional subdivisions of the arterial category whereas in rural areas there are relatively more collectors with further functional subdivisions of the collector category. [18]

Rural roads consist of facilities outside of urban areas. The names provided for the recognizable systems are principal arterials (roads), minor arterials (roads), major and minor collectors (roads), and local roads.

The rural principal arterial system consists of a network of routes with the following service characteristics:

- Corridor movement with trip length and density suitable for substantial statewide or interstate travel.
- Movements between all, or virtually all, urban areas with populations over 50,000 and a large majority of those with populations over 25,000.
- Integrated movement without stub connections except where unusual geographic or traffic flow conditions dictate otherwise. [18]

The rural minor arterial road system, in conjunction with the rural principal arterial system, forms a network with the following service characteristics:

- Linkage of cities, larger towns, and other traffic generators are capable of attracting travel over similarly long distances.
- Integrated interstate and inter county service.
- Internal spacing consistent with population density, so that all developed areas of the state are within reasonable distances of arterial highways.
- Corridor movements consistent with items through with trip lengths and travel densities greater than those predominantly served by rural collector or local systems. [18]

The rural collector routes generally serve travel of primarily between counties rather than statewide importance and constitute those routes on which predominant travel distances are shorter than on arterial routes. Consequently, more moderate speeds may be typical. [18]

The rural local road system, in comparison to collectors and arterial systems, primarily provides access to land adjacent to the collector network and serves travel over relatively short distances. The local road system constitutes all rural roads not classified as principal arterials, minor arterials, or collector roads. [18]

Road function is important input for road safety audit. When starting an audit the auditors should have information about the character of the traffic that is based on the road function. All roads should be evaluated in their own function because different types of roads include different types of safety situations. For example the prevailing risk of having fatal accidents is bigger in rural areas compared to urban areas thus the safety solutions of these areas are also different. The function of a road should be clear to all road users, and a well planned and defined road hierarchy can assist road users in providing a safe road network.

3.1.2. Traffic Data

Highway Transportation Surveys are performed to establish a basis for transportation planning process and they contribute to the highway design, construction, maintenance and management facilities. Transportation surveys are accomplished according to the Annual Transportation Survey Program carried out by the Planning Departments of Road Authorities. They are achieved in order to determine traffic characteristics of highways by using modern counting devices and techniques.

All pertinent information such as volume, speed and accident data is formed by these surveys. The subsequent paragraphs represent the definitions of these data and explain relationship of the data and the road safety audits.

3.1.2.1. Volume Data

Traffic volume studies are conducted to determine the number, movements, and classifications of roadway vehicles at a given location. These data can help to identify critical flow time periods, to determine the influence of large vehicles or pedestrians on vehicular traffic flow and to document traffic volume trends. The length of the sampling period depends on the type of count being taken and the intended use of the data recorded. For example, an intersection count may be conducted during the peak flow period. If so, manual count with 15-minute intervals could be used to obtain the traffic volume data.

Generally the two methods are available for conducting traffic volume counts. One of them is manual method the other is automatic. Most applications of manual counts require small samples of data at any given location. Manual counts are sometimes used when the effort and expense of automated equipment are not justified. Manual counts are necessary when automatic equipment is not available.

The automatic count method provides a means for gathering large amounts of traffic data. Automatic counts are usually taken in 1-hour intervals for each 24-hour period. The counts may extend for a week, month, or year. When the counts are recorded for each 24-hour time period, the peak flow period can be identified. [26]

Volume data is an important input for road safety audit. Especially the data should be correct and reliable. Reliable and accurate data are needed to raise awareness about the magnitude of road traffic injuries. Reliable and accurate data are also needed to correctly identify problems, risk factors and priority areas, and to formulate strategy, set targets and monitor performance. Ongoing, data-led diagnosis and management of the leading road tragic injury problems enables appropriate action and resource allocation. Without this, there will be no significant, sustainable reductions in exposure to crash risk or in the severity of crashes.

3.1.2.2. Speed Data

Design speed is a selected speed used to determine the various design features of the roadway. Geometric design features should be consistent with a specific design speed selected as appropriate for environmental and terrain conditions. Low design speeds are generally applicable to roads with winding alignment in rolling or mountainous terrain or where environmental conditions dictate. High design speeds are generally applicable to roads in level terrain or where other environmental conditions are favorable. Intermediate design speeds would be appropriate where terrain and other environmental conditions are a combination of those described for low and high speed. [18]

All geometric design elements of the highway are affected in some way by the selected design speed. Some roadway design elements are related directly to and vary appreciably with design speed. These include horizontal curvature; superelevation, sight distance, and gradient. Other elements are less related to design speed, such as pavement and shoulder width and clearances to walls and traffic barriers. The design of these features can, however, affect vehicle operating speeds significantly. As a result, more stringent criteria for these features are generally recommended for highways with higher design speeds. Conversely, less stringent criteria for these features may be more appropriate on roadways with lower design speeds. [43]

The selection of a particular design speed is influenced by the following:

- The functional classification of the highway
- The character of the terrain
- The density and character of adjacent land uses
- The traffic volumes expected to use the highway
- The economic and environmental considerations.

Typically, an arterial highway warrants a higher design speed than a local road; a highway located in level terrain warrants a higher design speed than one in mountainous terrain; a highway in a rural area warrants a higher design speed than one in an urban area. [18]

Another important input for road safety audit study is the speed data. When conducting audit on acceleration, deceleration lanes, barrier design, exit and entrance parts of the roadside facilities, desired clear zone width, stopping and passing side distance, all these features, design are based on the speed data. On the other hand, prevailing speed surveys may reveal speeding related casualties.

3.1.2.3. Accident Data

An accident database is needed for accurate assessment of the road safety situation. In order to be useful, the file needs to cover data on deaths and casualties and the circumstances of the accidents. This will help organizations that are able to contribute for safety improvements and implement appropriate measures designed to solve specific problems. [37]

The main processes of producing an accident database include an accident reporting and recording system, storage and retrieval system, an analysis system, and an effective dissemination system. [37]

The data collected for all recorded accidents need to answer the following questions:

- Where accidents occur;
- When accidents occur;
- What type of car involved;
- What was the result of the collision?
- What were the environmental conditions?
- How did the collision occur?

Having introduced an effective database system, it is important to ensure that the data is utilized as effectively and widely as possible. Police annual accident statistics reports should be circulated widely and national decision makers should use the data. They should also be made readily accessible to relevant organizations for designing appropriate countermeasures, producing plans, monitoring effectiveness, and carrying out research. [37]

Accident data is one of the primary inputs for road safety audit. If the audit is being conducted on existing road, the team should analyze all of the accident reports for the last year. Preferably the analysis period should be 3 to 5 years.

3.2. Safety Auditing in General

The road safety audit (RSA) has been defined as a formal examination of an existing or future road or traffic project, or any project which interacts with road users, in which an independent, qualified examiner reports on the project's crash potential and safety performance. [2]

There are four types of road safety audit phases. It's shown in table below that illustrates a method of grouping RSA's by phase and by stage.

<table>
<tr><td rowspan="11">More major issues addressed by audit</td><td>RSA Phases</td><td>RSA Stages</td><td rowspan="11">Less opportunity for design changes</td></tr>
<tr><td rowspan="3">Pre-Construction Road Safety Audits</td><td>Planning</td></tr>
<tr><td>Preliminary Design</td></tr>
<tr><td>Detailed Design</td></tr>
<tr><td rowspan="3">Construction Road Safety Audits</td><td>Work Zone Stage</td></tr>
<tr><td>Construction Stage</td></tr>
<tr><td>Pre-Opening</td></tr>
<tr><td>Post-Construction Road Safety Audits</td><td>Existing Roads</td></tr>
<tr><td rowspan="2">Development Projects Road Safety Audits</td><td>Land Use</td></tr>
<tr><td>Development</td></tr>
</table>

Table 3.1 Types of RSA grouped by phase and stage [15]

Road safety audits have been conducted on a wide range of projects varying in size, location, type, and classification. The types of projects that can be audited are categorized under the following headings:

- Major Highway Projects
- Existing Facilities

- Minor Improvement Projects
- Traffic Management Schemes (construction)
- Development Schemes
- Maintenance Works
- Municipal Streets [3]

After the audit route is determined, all necessary information and data about the route should be provided. Before going to the site all background information are gathered out and checked. Following information is provided;

- Route map
- Traffic volumes (AADT) for all road users types of vehicles for last five years
- Collision information history for at least the last year (last three years information is necessary but five years provide more clear results)
- Speed data
- Road inventory (lanes width, surface types, shoulder, median width road characteristics)

3.3. Safety Auditing on Existing Roads

All information is collected before the field survey. Audit on existing roads can start afterwards. Highway section should be audited for both traffic directions. Nevertheless one site study is never enough to collect auditing information and its evaluation. In many cases two or more auditing studies have to be implemented. At least one survey must be conducted at night.

In this manner the audit of the route is realized by traveling at appropriate driving speeds in order to attention to the potential problematic locations and crash features on the existing alignment. Photographs and video record are also used to make later discussions and evaluations.

One of the benefits of the RSA process is the synergy created by the members of the audit team. The knowledge and experience of the team as a whole are greater than the sum of these attributes as vested in the individual members, so the process benefits from being conducted by a team. While three members in a team may be adequate for some project types, that number may not be sufficient for larger, more complex projects or those requiring specific expertise. The best practice is to have the smallest team that brings all of the necessary knowledge and experience to the process. [15]

All of the observations achieved during the audit are recorded on the checklists and forms.
During the field survey, the following aspects of route are identified;

- Locations in which shoulder widths are inadequate
- Markings that are non exist or in a complex condition (old and new markings mix each other)
- Problematic road side zones that include dangerous features which can create specific "fixed roadside objects" that can be eliminated individually occur within the "clear zone width". (Tress, Utility Poles)
- The existence of various kinds of trees and other vegetation which obstruct the sight distance of the drivers
- Improper location of the bus stops
- Non guard-rail sections
- Concrete structures and dangerous wall endings
- Information signs
- Intersections
- Drainage structures

The safety checklist should be filled during the site investigation. By taking photographs and video records along the route, observations along the route are also illustrated at different stages of reporting for better describing the dangerous section.

The recommended structure of checklist is illustrated below. Some of checklist safety measures are described in the subsequent paragraphs.

SAFETY AUDIT CHECKLIST ON EXISTING ROAD

Date: **Conducted By:**
Weather:

Control Station Number (CSN)	KM	Distance (m)	Type of Hazard	Comments

Road Design
1) Shoulder missing
2) Shoulders too narrow
3) Shoulders unpaved
4) Improper junction design (3 arms)
5) Improper junction design (4 arms)
6) Improper connection to shop, petrol station or other commercial activity
7) Improper connection to small access road
8) Improper connection to roadway
9) Improper median opening (only divided roads)
10) Limited sight distance
11) Improper or dangerous pedestrian crossing
12) Too small radius of horizontal curve
13) Too small radius length of vertical curve
14) Speed limit too high
15) Speed limit too low
16) Improper vertical sign
17) Improper horizontal sign

Road Side Area
18) Dangerous fixed object in roadway
19) Dangerous fixed object in roadside or the median
20) Dangerous fixed object in road island
21) Temporary road narrowing (e.g. bridge)
22) Fixed massive poles near road or in the median (lighting, electricity, etc.)
23) Big tree or trees so close to road
24) Dangerous bridge piers
25) Dangerous hedge
26) Dangerous cut form
27) Dangerous free stones or rocks
28) Dangerous supports for signs (advertisement or road information signs)
29) House or other building so close to road
30) Steep edge slope without guard-rail
31) Dangerous guard-rail start and end
32) Improper culvert design on the roadside
99) Others

Table 3.2 Road Safety Audit Checklist [23]

3.4. Roadside Safety

The roadside safety is the prior concept of the road safety audit (RSA) on existing roads. Roadside safety concept includes information about the clear zone area and hazardous obstacles locations for both at project level and for analysis for existing road sections.

Run off road is (leaving carriageway / loss of control) an accident type that accident can be further changed into fatal accident if crash with dangerous objects on the roadside is applicable. The severity of this type of accident may also be influenced by the physical characteristics of the roadside environment (side slopes, etc.). The Highway Project Engineers have to give attention to minimize the number and severity of accidents by designing roads with more gentile side slopes and by arranging safe zones along the road sides. Flat, traversable, stable slopes can minimize further overturning if vehicle leaves the carriageway. Roadsides, in which obstacles cannot be removed with a reasonable cost, should be controlled by installing guardrails. Up to the time guardrail application is finished, consideration should be given to delineating the feature so it is readily visible to motorists. [17]

It was found that one out of four drivers and passengers were killed in road accidents in which the vehicle hits a road side obstacle in Sweden in 2001. These obstacles were:

- 50 % trees
- 20 % guardrails
- 10 % lighting columns
- 10 % other posts
- 10 % other objects [16]

In this study, it was found that at about one third of observed problematic sections road equipment (guardrails, lighting columns and some other posts) was needed the safe traffic operation of the road. As an example road lighting, is supposed to save three to four times more life than the persons killed in collisions with lighting columns. However, those objects could probably have been placed or designed safer. [16]

3.4.1 Safety Zone

Along both road sides; there should be a recovery area, a clear zone, permitting the driver to regain control of a vehicle which for some reason has left the roadway. The recovery area should have a gentle design with flat slopes to prevent the vehicle from rolling over. It should also be clear from hazardous objects which can inflict injuries to the driver or passengers. [16]

The typical design of the clear zone is shown in figure below.

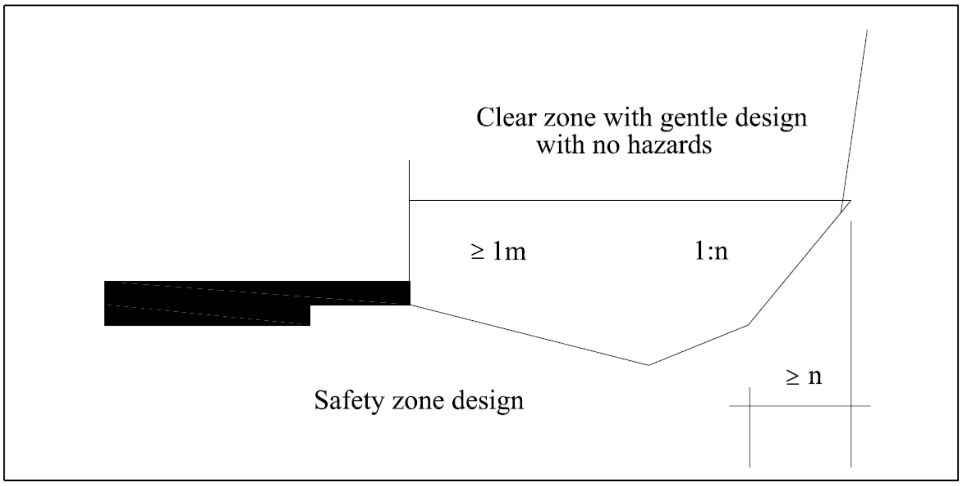

Figure 3.1 Roadside safety zone design [23]

Some of the hazardous objects are described below; [17]

- Bridge piers, abutments, railing ends
- Rocks with diameters > 0,2 m
- Trees with diameters > 0,1 m
- Cross (transverse) pipe opening widths larger than (750 mm)
- Box culverts and cattle passes
- Approach (parallel) pipe height larger than (600 mm)
- Cut slopes (rough)
- Steep inslopes

- Approach slopes steeper than 6:1
- Signs/luminaries/traffic signals with non-breakaway supports
- Utility poles (lighting)
- Walls (unless crashworthy)
- Other obvious unforgiving obstacles. [17]

Adequate clear zone distance between the edges of traffic lanes and roadside obstructions has been shown to be a very important safety factor. Out of control vehicles leaving the roadway should have a reasonable opportunity to recover control and return to the roadway without overturning or colliding with roadside obstacles. The combination of a relatively flat slope and an obstacle-free roadside within the prescribed clear zone distance helps this situation. [17]

To prevent casualty accidents in the clear zone the hazards that are located in the safety zone should be;

- Taken away or removed
- Replace it with a non-hazardous equipment
- Redesigned or shielded by traffic barriers or crash cushion

The Turkish Highway Traffic Safety Control Handbook uses AASHTO standards. According to the design speeds, cut, fill slopes, and annual average daily traffic (AADT) values there is a calculation way of clear zone widths (Figure 3.2). The width of clear zone is found out by evaluating the annual average daily traffic (AADT), the design speed and cut or fill slope section of roadside slope. According to the data, the required widths of safety zone are given in Table (3.4).

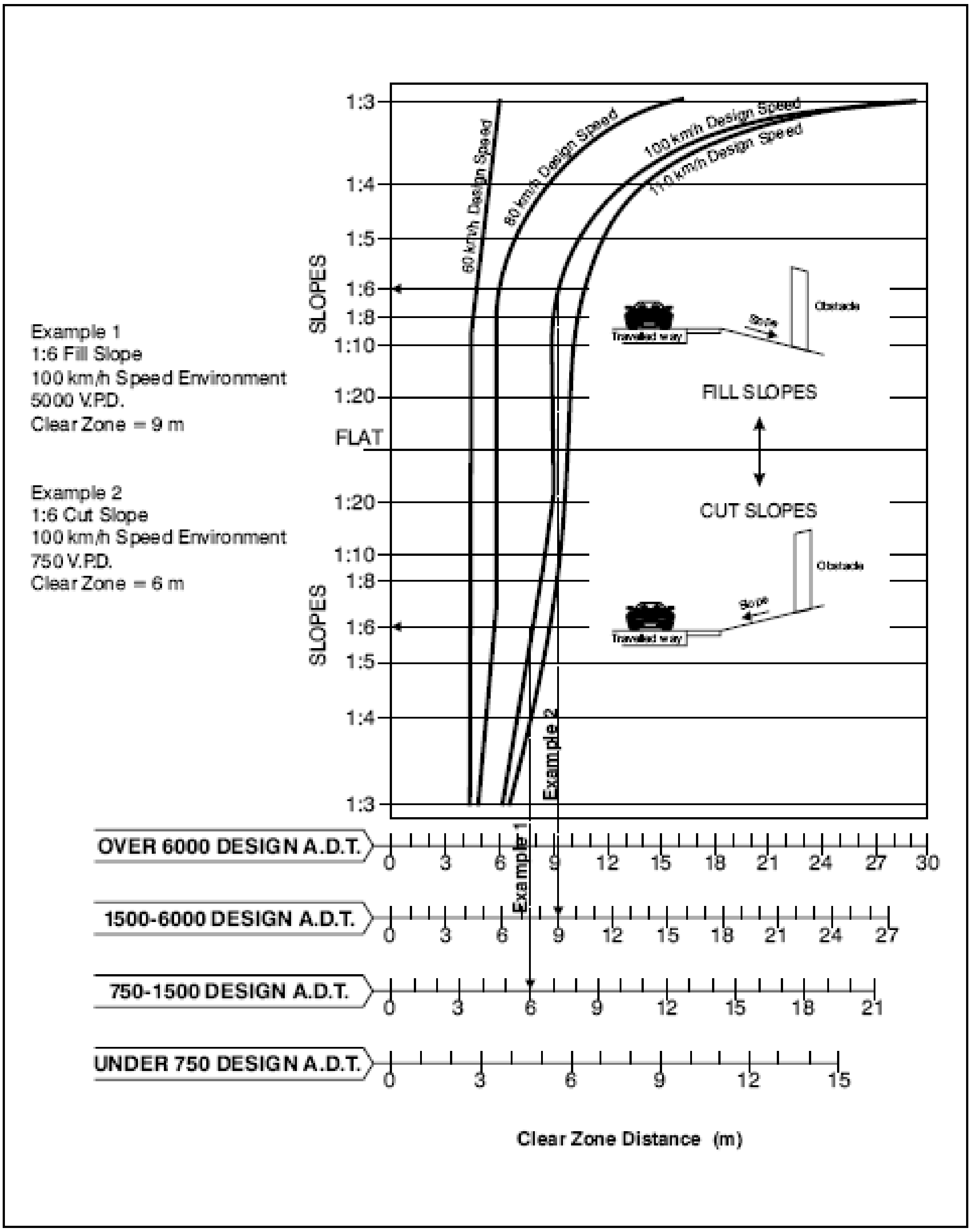

Figure 3.2 Clear Zone Distance Curves for Straight Roads [27]

Design Speed	Design Year ADT	Fill Slopes			Cut Slopes		
		1V:6H or Flatter	1V:5H to 1V:4H	1V:3H	1V:3H	1V:5H to 1V:4H	1V:6H or Flatter
60 km/hr or less	Under 750	2.0 - 3.0	2.0 - 3.0	**	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
	750 - 1500	3.0 - 3.5	3.5 - 4.5	**	3.0 - 3.5	3.0 - 3.5	3.0 - 3.5
	1500 - 6000	3.5 - 4.5	4.5 - 5.0	**	3.5 - 4.5	3.5 - 4.5	3.5 - 4.5
	Over 6000	4.5 - 5.0	5.0 - 5.5	**	4.5 - 5.0	4.5 - 5.0	4.5 - 5.0
70 - 80 km/hr	Under 750	3.0 - 3.5	3.5 - 4.5	**	2.5 - 3.0	2.5 - 3.0	3.0 - 3.5
	750 - 1500	4.5 - 5.0	5.0 - 6.0	**	3.0 - 3.5	3.5 - 4.5	4.5 - 5.0
	1500 - 6000	5.0 - 5.5	6.0 - 8.0	**	3.5 - 4.5	4.5 - 5.0	5.0 - 5.5
	Over 6000	6.0 - 6.5	7.5 - 8.5	**	4.5 - 5.0	5.5 - 6.0	6.0 - 6.5
90 km/hr	Under 750	3.5 - 4.5	4.5 - 5.5	**	2.5 - 3.0	3.0 - 3.5	3.0 - 3.5
	750 - 1500	5.0 - 5.5	6.0 - 7.5	**	3.0 - 3.5	4.5 - 5.0	5.0 - 5.5
	1500 - 6000	6.0 - 6.5	7.5 - 9.0	**	4.5 - 5.0	5.0 - 5.5	6.0 - 6.5
	Over 6000	6.5 - 7.5	8.0 - 10.0*	**	5.0 - 5.5	6.0 - 6.5	6.5 -7.5
100 km/hr	Under 750	5.0 - 5.5	6.0 - 7.5	**	3.0 - 3.5	3.5 - 4.5	4.5 - 5.0
	750 - 1500	6.0 - 7.5	8.0 - 10.0*	**	3.5 - 4.5	5.0 - 5.5	6.0 - 6.5
	1500 - 6000	8.0 - 9.0	10.0 -12.0*	**	4.5 - 5.5	5.5 - 6.5	7.5 - 8.0
	Over 6000	9.0 - 10.0*	11.0 -13.5*	**	6.0 - 6.5	7.5 - 8.0	8.0 - 8.5
110 km/hr	Under 750	5.5 - 6.0	6.0 - 8.0	**	3.0 - 3.5	4.5 - 5.0	4.5 - 5.0
	750 - 1500	7.5 - 8.0	8.5 - 11.0*	**	3.5 - 5.5	5.5 - 6.0	6.0 - 6.5
	1500 - 6000	8.5 - 10.0*	10.5 -13.0*	**	5.0 - 6.0	6.5 - 7.5	8.0 - 8.5
	Over 6000	9.0 - 10.5*	11.5 -14.0*	**	6.5 - 7.5	8.0 - 9.0	8.5 - 9.5

Table 3.3 Width of Safety Zone in Roadside Design Guide [34]

The Turkish General Directorate of Highways (KGM) prepared a handbook for traffic safety in 2006. After that year the standards given in the handbook has been applied to the road design projects. The handbook includes the width of safety zone in roadside design guide (Table 3.4).

3.5. Typical Hazards

During conducted road safety audits, one of the important decisions is to determine the type of hazards which cause accidents. Some of the typical hazards are explained in the following pages.

a) Utility Poles

Utility pole crashes are fixed-object crashes that involve vehicles leaving the travel lane, encroaching on the roadside, and striking a utility pole.

Utility poles can also contribute to the severity of other crash types. Many crashes are not classified as run of roadway or fixed-object crashes where one or more vehicles strike a utility pole. Crashes are often classified by "first harmful event." In some cases, striking the utility pole is a secondary event that may be as severe as, or more severe than, the first harmful event. Crashes involving utility poles as secondary events easily go unnoticed when examining the total magnitude of the utility pole crash problem. [19]

Utility poles are one of the most substantial objects that are intentionally placed on roadsides. They are substantial both in sheer number and in structural strength. Because of the structural strength of utility poles, these crashes tend to be severe.

b) Trees

Beside the utility pole crashes, another higher crash rates and fatalities are also associated with roadside trees. One of the most common causes of fatal and severe injury accidents, on rural roads in particular, are fixed objects. Trees are the objects most commonly struck in run-off-road (ROR) collisions, and tree impacts are generally quite severe.

Collisions between vehicles and trees are a major type of traffic fatality. Fatal tree crashes were most prevalent on local rural roads, followed by major rural collectors. All fatal tree crashes, 90 percent occurred on two-lane roads and 5 percent on four-lane roads. [20]

The crash effects of nearby trees along high-speed, rural roadways are indisputable. County and township roads that generally have restrictive geometric designs and narrow, off-road recovery areas account for a large percentage of the annual tree-related fatal crashes, followed by state and U.S. numbered highways having curved alignments (AASHTO 2002). Existing trees often pose greater risk than trees that have been placed along new or reconstructed roads. [20]

c) Walls and Concrete Structures

Walls and concrete structures located in critical positions are not consistent with a forgiving roadside. Most of the highway sections there are concrete structures that are walls and wall endings in the roadside area. Walls and concrete structures are made by high structural strength of materials so these types of roadside structures cause more serious injury and damage accidents. Because of the energy absorption of the materials are so low for this type of accident.

3.6. Typical Improper Design Features

a) Improper Signing and Marking

Driving is mainly based on visual information input. There are many types of visual information, but road signs and road markings are important because they can provide relevant information for the driver to execute his or her task. Therefore, road signing may constitute an important road safety factor. The characteristics of road signing may have negative effects on traffic safety in the following cases: [28]

- The driver does not detect the sign/marking;
- The driver is not able to identify the sign/marking properly;
- The driver does not understand the sign/marking;
- The driver does not have enough time to (a) decide and (b) take the action(s) needed;
- The sign/marking does not meet the driver's expectations;
- The sign's message is not heeded by the driver;
- The information on the sign is wrong / inappropriate;
- The driver does not remember the sign for the necessary time. [28]

b) Intersections

A large proportion of accidents on rural highways occur at intersections. Intersections are locations where two or more roads join or cross each other. The crossing and turning maneuvers that occur at intersections create risks for vehicle-vehicle, vehicle-pedestrian, and vehicle-bicycle conflicts, which may result in crashes. Thus, intersections are likely points for concentrations of traffic crashes. [18]

c) Improper Access Management

Regulating access is called “access control.” It is achieved through the regulation of public access rights to and from properties abutting the highway facilities. These regulations generally are categorized as full control of access, partial control of access, access management, and driveway/entrance regulations. The principal advantages of controlling access are the preservation or improvement of service and safety. [18]

Access control, which is defined as regulating public access to and from properties abutting highway facilities, is one of the most significant factors in the safe, efficient operation of a highway. Full control of access is the most important single safety factor that may be designed into new highways. The principle of full control of access is invaluable as a means for preserving the capacity of arterial highways and of minimizing accident potential. On the other hand, improper access control may create great potential for the traffic accidents. [18]

d) Improper Bus Stop Design

Improving facilities for public transportation is one of the main concerns of the urban network improvements. In this concept there must be safe areas for busses to stop and take passengers without interrupting the traffic stream. In some cases, bus stop designs are improper thus create danger for public transportation users and the other drivers. At some other cases there are not any safe areas for bus stops.

e) Improper Drainage Structure Design

Drainage is one of the most critical elements in the design of a highway. Highway drainage facilities carry water across the road body and remove storm water from the roadway itself. Drainage structures include bridges, culverts, channels, curbs, gutters, concrete pipes and various types of drains. These elements should be designed, constructed, and maintained considering both hydraulic efficiency and roadside safety. In out of control, the driver probably no longer has the ability to later control the vehicle. Any object in or near the path of the vehicle becomes a potential contributing factor to crash severity. This object could be an end of culvert or any drainage structure. [18]

The ends of large drainage structures, which are safety problems for errant vehicles, can be shielded with guardrails or other barriers. Culvert openings should be covered with traversable grates, where practical, to prevent trapping a vehicle.

National Cooperative Highway Research Program (NHCRP) is stated that:

- The improper design of roadside (and of wide medians, which is equivalent to roadside) drainage elements can increase accident severity.
- The improper placement of drainage inlets / outlets may cause improper drainage resulting in a reduced friction hazard and thus contributing to the occurrence of an accident. [36]

f) Improper Medians and Median Openings

A median is the portion of a highway separating opposing directions of the traveled way. Medians are highly desirable on arterials carrying four or more lanes. Median width is expressed as the dimension between the edges of traveled way and includes the left shoulders, if any. The principal functions of a median regarding safety are to separate opposing traffic, provide a recovery area for out of- control vehicles, provide a stopping area in case of emergencies, allow space for speed changes and storage of left-turning and U-turning vehicles, minimize headlight glare, and provide width for future lanes. [18]

In an urban area there are some additional benefits of median that it may offer an open green space, also provide a safe area for pedestrians crossing the street, and may control the location of intersection traffic conflicts. For maximum efficiency, a median should be highly visible both night and day and should contrast with the traveled way. Medians may be depressed, raised, or flush with the traveled way surface. [18]

Properly designed median barriers minimize vehicle damage and lessen the accident likelihood of traffic moving in the same direction. A narrow median also does not allow for emergency departure from the lane.

g) Improper Selection of Lane and Shoulder Widths

Total roadway width is among the most important cross-section considerations in the safety performance of a highway. Wider lanes and shoulders normally result in fewer crashes. NCHRP Report is stated that:

- Although the highway design elements such as lane width, shoulder width, and sight distance restriction are related to accidents, they do not ordinarily serve as good predictors of accidents. Generally speaking, wider lanes, wider shoulders, and unimpaired sight distance result in a safer highway. [36]

The capacity of a highway is affected by the lane width. Narrow lanes force drivers to operate their vehicles closer to each other laterally than they would normally desire. Restricted clearances have much the same effect. In a capacity sense the effective width of traveled way is reduced when adjacent obstructions such as retaining walls, bridge trusses or headwalls, and parked cars restrict the lateral clearance. In addition to the capacity effect, the resultant erratic operation has an undesirable effect on driver comfort and crash rates. [18]

A shoulder is the portion of the roadway platform that accommodates stopped vehicles, emergency use, and lateral support of sub-base, base, and surface courses. In some cases, the shoulder can accommodate bicyclists. Regardless of the width, a shoulder should be continuous. With a continuous shoulder, almost all drivers making emergency stops will leave the traveled way; but with intermittent sections of shoulder, some drivers will find it necessary to stop on the traveled way, creating a hazardous condition.

h) Improper Selection of Speed Limit

Speed is often a contributing factor in accidents, but it must be related to conditions. It is improper to conclude that any given speed is safer than another for all combinations of different kinds of drivers, vehicles, highways, and local conditions. For a highway with particularly adverse roadway conditions, a relatively low speed may result in fewer crashes than a high speed, but this does not necessarily mean that all potential crashes can be eliminated by low speeds. Likewise, vehicles traveling on good roads at relatively high speed may have lower crash involvement rates than vehicles traveling at lower speeds, but it does not necessarily follow that yet a higher speed would be even safer.

The safest speed for any highway depends on design features, road conditions, traffic volumes, weather conditions, roadside development, spacing of intersecting roads, cross-traffic volumes, and other factors. Crashes are not related as much to speed as to the range in speeds from the highest to the lowest. [18]

ı) Improper Fill and Cut Slopes

Fill slopes can present a risk to an errant vehicle with the degree of severity dependent upon the slope and height of the fill. Providing fill slopes that are 4H:1V or flatter can mitigate this condition. According to the critical surface condition the fill slopes can be reduced 3H:1V or more steep but if the fill slope height is high some of the safety conditions should be thought by designer for road users safety. Also 3H:1V or more steep side slopes the surface stability analysis should be considered.

A cut slope is usually less of a risk than a traffic barrier. The exception is a rock cut with a rough face that might cause vehicle snagging rather than providing relatively smooth redirection. Analyze the potential motorist risk and the benefits of treatment of rough rock cuts located within the Design Clear Zone. Conduct an individual investigation for each rock cut or group of rock cuts. A cost-effectiveness analysis that considers the consequences of doing nothing, removal, smoothing of the cut slope, and other viable options to reduce the severity of the condition can be used to determine the appropriate treatment. [18]

In general according to the Turkish Highway Design Manual maximum cut slope is 1H:4V but this slope is just used within the high strength characteristics of rock formations. In slope-wash type of cut slope the minimum slope value is 3H:2V. Cut slopes can be changed by the material type and the topographical conditions of the road alignment. In high cut slopes; safety for road users and pedestrians along the cut slope area can be provided by establishing guardrails.

j) Barriers

Roadside barriers are important components in road and bridge project designs when a hazard is perceived alongside the roadway. Hazards include fixed objects such as non- breakaway light and sign posts, telephone poles, bridge piers and abutments, retaining walls and culverts, trees, rough rock cuts, boulders, embankments, streams and permanent water bodies. Roadside barriers are also used to separate roadways from pedestrians, bicycle paths and steep grades, to separate opposing traffic lanes, and to define medians. They are typically set in the roadway's “clear zone” or “recovery zone”, the area beyond the travel lane that needs to be kept clear of potential fixed-object hazards. This area’s depth varies with traffic volume and design speed. [38]

Safety barriers include guard fences (traffic barriers on the edge of a carriageway; if used in a median they may be referred to as median barriers) and impact attenuators (devices installed at fixed installations, such as bridge piers; they are also referred to as crash cushions).

Guardrails not only decrease the accident casualty, but also cause increase severity of accidents, with wrong design and loss of functionality.

k) Pavement

The selection of pavement type is determined based on the traffic volume and composition, soil characteristics, weather, performance of pavements in the area, availability of materials, energy conservation, initial cost, and the overall annual maintenance and service-life cost.

Important pavement characteristics that are related to geometric design are the effect on driver behavior and the ability of a surface to retain its shape and dimensions, to drain, and to retain adequate skid resistance.

Nevertheless, when eliminating crashes is not possible, reducing the severity of a crash is an important goal. In this sense, more attention is required to other elements of the roadway system that could be a contributing factor in traffic crashes. One such contributing factor that has been discussed and evaluated over the years is road surface characteristics, specifically skid resistance (friction) of roadway pavements under various weather and aging conditions. [24]

Skid resistance of pavements is the friction force developed at the tire-pavement contact area. In other words, skid resistance is the force that resists sliding on pavement surfaces. This force is an essential component of traffic safety because it provides the grip that a tire needs to maintain vehicle control and for stopping in emergency situations. Skid resistance is critical in preventing excessive skidding and reducing the stopping distance in emergency braking situations. [24]

l) Temporary Work Zones

The driving conditions of work zones differ from normal driving conditions. In addition, the driving conditions of each type of work zone (short-term, long-term, etc.) may differ from those of another type of work zone. These factors can result in violations of road user expectancy, which in turn can lead to congestion, erratic maneuvers, and ultimately crashes. [25]

Federal Highway Administration (2002) also reviewed the factors found to have contributed to crashes at work zones. These included:

- some aspect of the work zone
- traffic congestion
- lane changing
- vehicles entering and leaving the work zone
- unexpected presence of flag-person [39]

3.7. Road Safety Evaluation

Evaluation of completed highway safety projects and programs are essential for safety professionals to identify the improvements that are working, the ones that are producing nominal benefit and the ones not working. [29]

In order for a safety improvement to be effective, one must first identify that there is a crash/injury problem. This function is often performed by analyzing historical crash data. The next step should be to identify causes of the predominance of some specific type of crashes and injuries. This step requires many engineering studies and driver behavioral studies. In many instances, practitioners avoid performing such detailed studies, thus increasing the chance of selecting and implementing inappropriate countermeasures. Such incidences are discovered when an evaluation of effectiveness is performed and the situation may get corrected. [29]

Evaluation of effectiveness of safety projects and programs can lead to continuing safety improvements at the same level, increasing resource allocations due to success achieved, or even discontinuing some safety initiatives due to their observed inability to alleviate traffic crash problems. [29]

3.7.1 Countermeasure Selection

Having identified the elements of the road and traffic environment or driver behavior, which may have contributed to the crashes, it is now time to consider countermeasures. There are no ‘general’ road safety solutions; for a solution to be effective, it must be applied to a particular problem, which it is known to affect. It must be an effective countermeasure. Although a large proportion of crashes are deemed to be a result of driver error, with engineering measures, it is possible to [21]:

- modify driver behavior
- modify the road and environment that led to the error
- make the environment more accepting of human error

The most important aspect of developing solutions is to link the specific countermeasures to the specific problems identified. The countermeasures could include engineering, enforcement and education. Enforcement and education recommendations need to be forwarded to the appropriate agencies for program development and implementation. [21]

Typically, a Crash Reduction Study (CRS) has focused on low to medium cost engineering solutions and these have proven to be very effective with excellent economic returns. However, in some cases a significant crash reduction may only be achieved through larger scale, more substantial improvements. If this is the case, the CRS team would generally recommend a more detailed study be carried out to investigate these more substantive options rather than to delay the overall study pending more detailed analysis. [21]

The degree to which these more substantive solutions are developed is dependent upon the CRS brief. The Road Controlling Authority (RCA) may widen the study brief to include consideration of medium to high cost options. The expertise of the team members may need to be broadened to accommodate this and other aspects such as traffic flow, environmental impact, mobility, accessibility and sustainability.

There are number of general countermeasures for hazards and problems that can be applied in order to achieve safe traffic operation for the roads, were proposed at the following pages.

Intersections

- Check sight distance available and where practical, clear obstructions to provide the appropriate standard of sight distance. Where installation of traffic controls such as stop signs standards can not be achieved consider or speed controls.
- Check day and night visibility of traffic control devices
- Consider the installation of appropriate warning signs and devices
- Consider installation of canalization such as median islands in side road approaches, wide median treatments (where appropriate) and staggered intersections treatments in rural areas
- Consider installation of traffic signals where warrants are met
- If there is a high involvement of wet weather crashes, check skid resistance and pavement drainage
- Provide protected right left turn auxiliary lanes. [39]

Side Collisions

- In a rural area provide or check adequacy of centre and edge lines. Where relevant, lane lay delineation and supplement with retro-reflective pavement markers (RRPMs) if warranted.
- Consider provision of wider lanes.
- On the approach to an intersection, consider improving direction signing including overhead lane use signs where relevant. Also consider adequacy or provision of auxiliary lanes for turning traffic. [39]

Head on Collision

- In a rural area check adequacy of centre line marking and consider supplementing this with RRPMS.
- If at locations where visibility is restricted, consider barrier lining

- Where justified, consider separation of opposing without rumble strips or by means of a raised flows by means of a painted median with or median where economically justifiable
- If occurring on a divided roadway, consider improving delineation, widening of the median or provision of a median barrier. [39]

Run-off Road Collision

- Consider improved delineation including post mounted delineators, RRPMs, edge lines and alignment markers etc.
- If at an isolated curve, consider adequacy of alignment design and superelevation.
- If at critical curves, consider warning signs and advisory curve speed signing.
- If there is a high incidence of wet weather crashes, check surface texture, skid resistance and pavement drainage. [39]

Collision to Obstacle

- Remove the obstacle
- Make the obstacle traversable
- Relocate the obstacle beyond the clear zone
- Reduce impact severity by using an appropriate breakaway system
- Shield the obstacle with a longitudinal barrier or crash cushion (only if obstacle cannot be removed, relocated, or redesigned)
- Delineate the obstacle (only if all above options are not appropriate) [39]

3.7.2 Economic Analysis of Traffic Safety Improvements

In order to effectively assign priorities to potential improvements, comparable benefits and costs must be determined for the improvement alternatives. Most of the investments are made because it has been estimated that these improvements will yield larger benefits than costs or larger benefits than other candidate investments. Economic analysis is the comparison of the economic costs of a candidate countermeasure or set of candidate countermeasures with the economic benefits, and indicates not only whether the countermeasure is worthwhile, but also indicates which is the best countermeasure or set of countermeasures to implement. [32]

Once the problem or problems and their sources are identified, then the second step is the selection of the correct and adequate countermeasures to implement. Before finalizing of the treatment decision, all the cost and accident reduction factors of the different improvement as benefits scenarios should be analyzed. The most cost-effective countermeasure has to be applied. The word cost-effectiveness generally stands for the net resource cost of a measure per year of life saved. [31]

Development of Accident Reduction Factors

Estimating the reduction in number of accidents is a key element in estimating the benefits that result from a particular improvement or set of improvements on a black spot. When the effectiveness of given countermeasures are known or can be quantified from Accident Reduction Factors (ARF), these estimates will be incorporated into the economic analysis for selection of appropriate countermeasures to get the highest benefit. [32]

Several nations have developed ARFs for various road improvements based on information from previous safety studies. Also a wide range of improvement types have been included in various research reports with sufficient detail to apply ARFs. On the other hand applicability of these estimates to Turkey is not certain. Since no past studies were carried out in Turkey on this subject, the use of other nations' estimates on ARFs is inevitable.

When several types of improvements are included in a specific project, the factors for these improvements must be combined. A key issue to be addressed is the determination of appropriate ARFs for the combinations of countermeasures. It is well established that accident reduction percentages should not be combined in additive fashion. If one countermeasure reduces accidents by 40 percent and another by 20 percent, their combined effect will not be 40 percent, but would be expected to be less than 60 percent and higher than 40 percent. [32]

ARFC = 1 – [(1-ARF1) (1-ARF2) (1-ARF3)]

Where; ARFC is the combined accident reduction factor and

ARF1, ARF2, ARF3 are the individual reduction factors

Evaluation of Improvement Projects

The management techniques available to evaluate highway projects in terms of project costs and safety impacts can be grouped into two broad categories. The basic difference between the two categories is the method of measurement of safety impact. In the first approach, the safety impact is represented by the monetary amount of accident cost savings called Benefit-Cost Analysis, while the second approach considers the cost per expected number of accidents reduced as the measure of safety effectiveness called Cost-Effectiveness Analysis. [32]

Benefit = (Accident Cost without Improvement) - (Accident Cost with Improvement)

BCR= Benefits / Cost

Cost effectiveness= Total Cost / Expected Number of Accidents Reduced

3.7.3 Implementation

As road safety audits have been implemented by agencies across the country, transportation professionals have realized that they are an effective tool for proactively improving the future safety performance of a roadway during the planning and design stages and for identifying safety issues in existing transportation facilities. However, there has been limited study of the implementation of road safety audit recommendations on existing roadways. [40]

The European Transport Safety Council (ETSC) is an international nongovernmental organization which was formed in 1993 in response to the persistent and unacceptably high European road casualty toll and public concern about individual transport tragedies. Cutting across national and sector interests, ETSC provides an impartial source of advice on transport safety matters to the European Commission, the European Parliament and, where appropriate, to national governments and organizations concerned with safety throughout Europe. [22]

3.8. Follow-Up

A follow-up meeting provides an opportunity to discuss the findings of road safety audit. Discussion can be made between the auditor(s), a representative from region municipality in which the audit process implemented for and a representative from National Road Service Commission (NRSC). Documenting the safety actions and project scope including programming and scheduling are recommended. If there is uncertainty about the existence of a safety problem exists or about the most appropriate corrective action to improve the situation, it is desirable to consult with qualified highway and safety engineer. [3]

The follow up process is lead by the designer/project manager. The designer/project manager reviews the audit report and prepares a written response to each concern cited. Each remedial measure suggested in the audit report can be accepted or rejected. For each accepted suggestion, logical remedial measures should be identified and adopted by the designer/project manager. The redesign should then advance to diminish the safety hazard. All project redesigns should be submitted to the audit team for consideration or re-auditing. The designer/project manager must make sure that modifications are made to the project which results from agreed improvements described in the audit report. [3]

3.9. Reporting

Having identified all potential safety issues, the audit report should be prepared. The outcome of an audit should be a written report, which contains a list of concerns about road safety matters and recommendations on how these identified potential safety problems in the existing road will be addressed. The report should clearly and succinctly identify the process, issues and recommendations. It is important to note that the recommendations should focus on safety issues, rather than specify the details of a solution. Also the photographs should be included in to the report to help readers visualize the problems. Also while writing a report the video and photographs help to make certain decisions about the safety problems and good level of recommendations. [36]

CHAPTER 4

CASE STUDY

4.1. Introduction

Although the concept of road safety audits (RSA) is relatively new in Turkey, the road safety audit has been applied at the plan stage of the projects for the last ten years. On the other hand RSA of existing roads has not regularly been implemented yet.

The Case Study of this thesis is an application of a RSA on Akyurt - Kalecik State Road of Turkey. The case study was conducted on control section of Road 140-06 on June, 2010. The 33 kilometer section extends from control section 140-06 station km: 27+000 (exit part of the Akyurt) to station km: 59+200, which is the junction part of the Çankırı-Kalecik State Road.

The control section 140-06 is divided into four parts. First section (1) of the route has 9 km length, second section (2) has 14 km length, third section (3) has 28 km length, last and the fourth section has 6 km length. Case study covers third (3) and fourth (4) sections of the control section.

General layout of the Case Study area is show in figure 4.1.

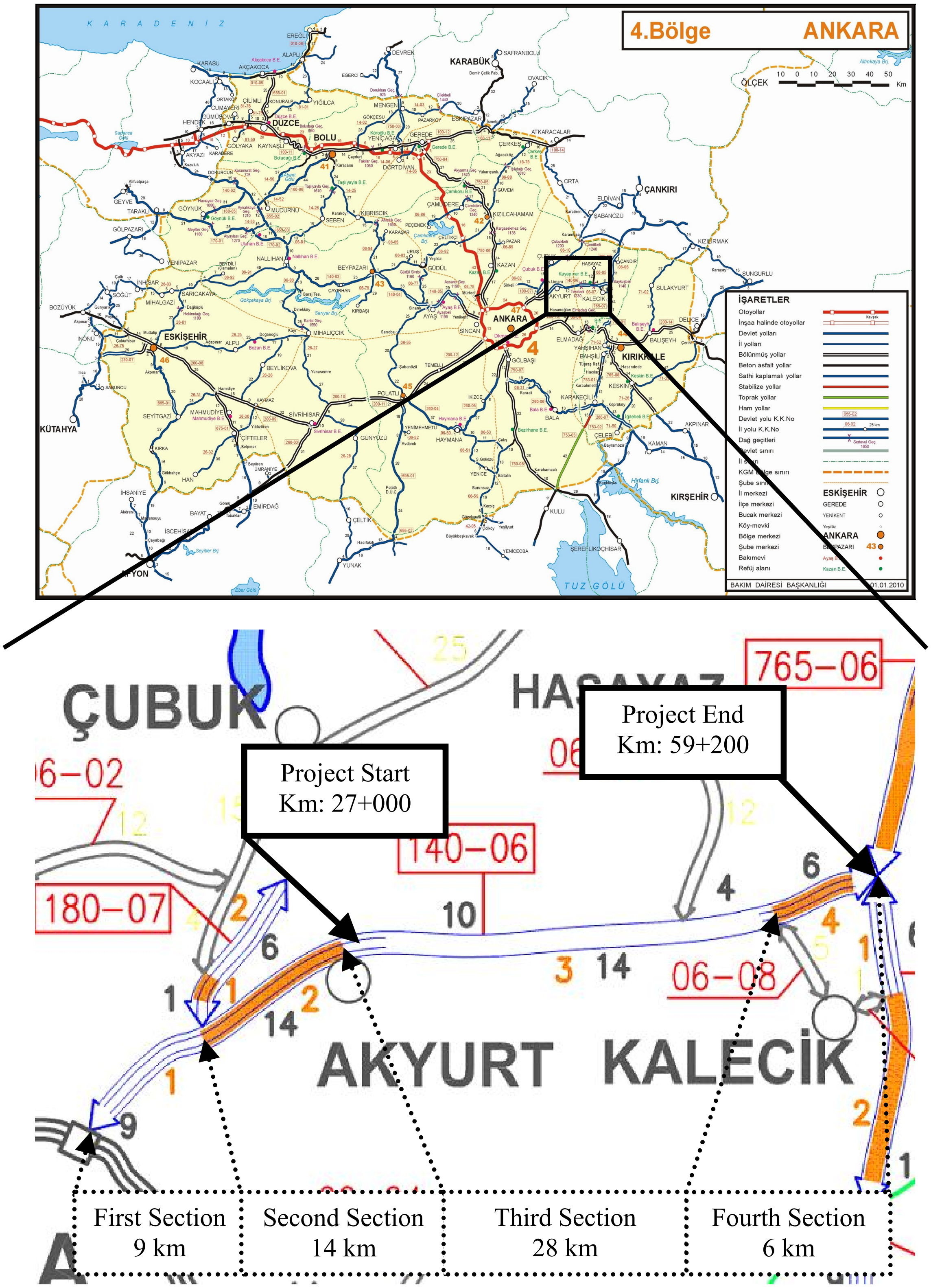

Figure 4.1 General Layout of the Audit Route [30]

The objective of the case study can be explained as follows;

- Show safety consciousness among route 140-06 state road.
- Identify potential safety problems for road users.
- Application of RSAs through practical training on selected route.
- Carry out RSAs along selected sections of state road to identify typical recurring problems and possible solutions.

4.2. Preconditions

4.2.1 General Project Data

a) Function of the Road

Traditionally, existing paved road which is the control station number of 140-06 was constructed to improve the accessibility of Ankara. The route is an important artery which connects the Middle Anatolia to the Blacksea Region. In addition to this, the surrounding counties position's, are as follows; Polatlı and Sivrihisar at the west side, Konya is at the south, Kırıkkale and Kırşehir are at the east side of the audit route. All of these cities are connected to the Blacksea Region by the help of this route. The route is a state road and the main function is to facilitate regional distribution of traffic (intercity movement).

The audit route control section number is 140-06 and covers station km: 27+000 between km: 59+200. This road is a ring road for Ankara. The route connects the Ankara and Kalecik Area. Kastamonu and Çankırı Cities are connected to Ankara by the help of this route so the route is an important link road between these cities.

The two lane divided highway project was under construction when audit has been conducted. After the project is finished there is a strong interest about the increasing the volume of traffic and development of new industrial facilities. There are not industrial developments or factories along the mentioned sections of the route.

It should be realized that economic development needs the efficient use of land resources thus accessibility which is created by the route 140-06 is essential for the future development.

b) Traffic Volumes

The traffic volume records that belong to the audit route were taken from the Traffic and Transportation Survey of Highways Handbook. 2006, 2007, 2008 and 2009 year's traffic volume data are illustrated as table below. (KGM Publications)

Type Of Vehicle	Years			
	2006	2007	2008	2009
Car	4837	4965	4774	5190
Medium Goods Vehicle	446	441	461	452
Bus	207	222	240	237
Truck	933	857	724	843
Trailer	85	95	104	131
Total AADT	6508	6580	6303	6853

Table 4.1 Four Years Traffic Volumes of the Route 140-06 [30]

Car represents passenger car, average loaded commercial vehicle represents the pick-up lorry and minibus which have capacity between 8-14 people.

The figure given below explains the percentage use of the route by the vehicles.

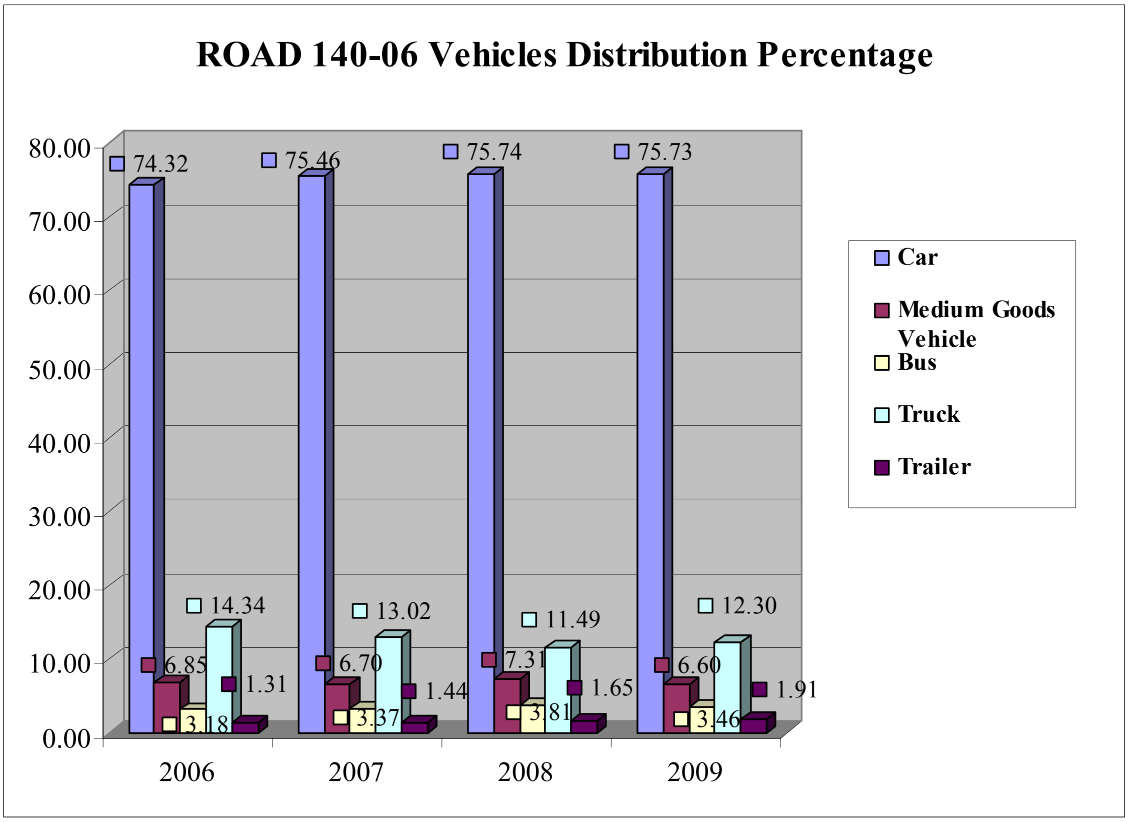

Figure 4.2 Distribution Volumes of the Types of Vehicles

The bar chart given above shows the Annual Average Daily Traffic (AADT) percentage of the route 140-06. The cars in AADT volumes constitute the highest percentage value. The medium goods vehicle, bus, truck and trailer which were constitute 25% of AADT volume. When compared the total AADT volume of 2006 and 2007, the traffic growth in 2007 was 0.011%. Between 2007 and 2008 AADT volumes decrease. This indicates the new divided road construction. After the construction was moved ahead, the traffic growth in 2009 was 0.087% when compared with 2008.

Finally according to the values this section of the route serves basically the local and long distance traffic. The high growth was in the year 2009. This increase can be defined as the improving the standardization of the road.

c) Accident Data

Traffic accident data which were taken from the Akyurt and Kalecik Gendarme is shown in table below. There are more specific traffic accidents data information are given in appendices part of he report.

Akyurt – Kalecik Road Accident Statistics				
Years	2006	2007	2008	2009
Injury Accident	40	29	32	55
Fatal Accident	1	7	0	2
Total Injured	72	98	57	152
Total Dead	1	16	0	3
Total Vehicle	58	52	36	76

Table 4.2 Control Section Number 140-06 four year accident data [Akyurt, Kalecik Gendarme, KGM Traffic Department]

d) Road Standards

The audit route was constructed in 1980; it serves as two lane road. The new two lane divided road project was completed in 2007. Construction of the route was started in 2008.

Existing road platform width is 10 m. The existing road pavement surface is surface dressing and generally passing through from flat, rolling and partially mountainous areas. Some section of the route's horizontal and vertical geometry can be accepted as in good standards. Along the route there are unpaved and narrow shoulders sections, also some sections there are not any shoulders at all.

Between km 27+000 and km 32+300 the route serves as divided highway. Between km 32+300 and km 53+600 the route is two lane highway. Between these kilometers the road construction works is going on. The last section of the route serves as a divided highway the station km 53+600 to station km 59+200. The table given below shows the existing standards of the route.

Kilometer	27+000 - 32+300	32+300 - 53+600	53+600 - 59+200
Road Class	2x2 Divided Road	2x1 Two Lane Road	2x2 Divided Road
Platform Width (m)	22.00	10.00	22.00
Number of Lane	2x2	2x1	2x2
Lane Width (m)	3.50	3.50	3.50
Median Width (m)	2.00	----	2.00
Interior Shoulder Width (m)	1.00	----	1.00
Exterior Shoulder Width (m)	2.00	Look at note	2.00

Table 4.3 Standards of The Route

Note: Some sections of the route the shoulders are unpaved, some sections both unpaved and narrow, some sections just narrow finally some of the sections there are shoulders missing. For detailed information please look safety audit checklist.

e) Speed Limits

The audit route speed limit is mostly 50 km/hr. But at some sections of the route it is increased to 70 km/hr. However the audit route serves as a state road, because of the low geometric standards at some sections, operated speed limit is not adequate for rapid movement.

When audit was conducting by video camera, a general observation was achieved about the speed limits. When audit operating speed limit was 50 km/hr, most of the other vehicles operated above the posted speed limit. At divided sections also speed limit is improper. The starting point of the audit route is a divided road. Inspite of the section has good geometric standards; the posted speed limit is low for rapid movement. Some section of the audit route is under construction so the speed limit is also 50 km/hr at these sections.

In addition to these posted speed limit values, Traffic and Transportation Survey of Highways Handbook speed information on state roads for four years period are given in table below.

	2006		2007		2008		2009	
Segment Number	3	4	3	4	3	4	3	4
Car	83	-	83	96	80	99	78	100
Medium Good Vehicles	78	-	78	93	75	93	74	94
Bus	81	-	80	86	76	88	75	86
Truck	73	-	71	78	68	81	63	80
Articulated Truck	63	-	66	76	63	76	61	77
Percentage of Heavy Vehicles	16	-	15	13	12	14	13	15

Table 4.4 Control Station Number 140-06 Average Speed (km/hr) Specifications [30]

Although the posted speed limits are generally 50 and 70 km/hr for the audit route sections, for all type of vehicles as we can see form the table the speed values are higher than the posted speed limits. Because one of the important accident reasons is speed, these values can increase the accident rate on the route.

4.2.2 Surroundings

Although Central Anatolia Region generally has poor vegetation, the audit route covers more wealthy green belts. Beginning of the audit route there are gardens, the centre of the route there are oak forests areas attract attention. End of the route again the typical Central Anatolia Region areas can be seen.

There are also mainly woodland areas dominant on the audit route. Types of the trees on the route are generally poplar and pine. The route passes through mountainous area at highest elevations. Beside this at lowest elevation, the route passes through farms and meadow places.

First 23 kilometer section of the road, the route generally passes through woodland areas. At these sections of audit route there are short plate trees, poplar trees and pine trees exist. Approximately after the km 50+000 the route is passing through meadow places and farms lands.

There are not any important establishment areas on the audit route. Generally the site areas are founded far from the route. Some section of the route there are some built-up areas as houses on both sides. There are two recreational areas, which are restaurants, and there are also petrol stations. There are not any constructed commercial activity and industrial areas such as factories and companies on this section of the route.

There are lots of villages and also counties cover environments of the route and their approximate are given below.

Km	**Direction**	**Name**
32+900	Right	Çamköy Village Road
33+700	Right	Karayatak Vilage Road
39+700	Left	Karacakaya Village Road
41+400	Right	Kozayağı Village Road
42+600	Left-Right	Haydar Village - Kozayağı Village Road
44+800	Right	Eskiköy Road
53+100	Left-Right	Kızılkaya Village - Kalecik County Road
59+200	Left-Right	Çankırı City-Kalecik County Junction Part

Table 4.5 Kilometers of Villages and Counties of the Route

4.3. Methodolgy

After the audit route was determined, all necessary information and data about the route were provided. Before going to the site all background information were gathered out and checked. Following informations were provided;

- Route map

- Traffic volumes (AADT) for all road users types of vehicles for last five years
- Collision information history for the last five years (also last three years information is enough but five years provide more clear results)
- Speed data
- Road inventory (lanes width, surface types, shoulder, median width road characteristics)

All of these background informations were collected; the data were evaluated and analyzed. The details about the proposed project, details of plans and background information on a section were also examined. All pertinent information such as accident reports and all other relevant information were analyzed before conduct the audit. Accident records were gathered from General Police Directorate (EGM), General Directorate of Highways (KGM), also Akyurt and Kalecik County Gendarme Commandership.

In this manner the audit of the route was realized by traveling at appropriate driving speeds in order to observe potential problematic locations and crash features on the existing alignment. Photographs and video record were also used to make later discussions and evaluations.

Both sections of the route were driven at a proper speed, 50 km/hr and all of the section has been recorded for further evaluation. Photos were taken for subsequent comments and discussions on observed hazards during the field survey.

During the field survey, the following aspects of route were identified;

- Locations in which shoulder widths are inadequate
- Markings that are non exist or in a complex condition (old and new markings mix each other)
- Problematic road side zones that include dangerous features which can create specific "fixed roadside objects" that can be eliminated individually occur within the "clear zone width". (Tress, Utility Poles, Concrete Structures)

- The existence of various kinds of trees and other vegetation which obstruct the sight distance of the drivers
- Improper location of the bus stops
- Non guard-rail sections
- Concrete structures and dangerous wall endings
- Information signs
- Intersections
- Drainage structures

According to the observations the safety checklist was filled during the field survey. Observations along the route and photos were also illustrated at observation part of the report.

The important role of the safety zone criteria was examined during the field study. The Turkish Highway Traffic Safety Control Handbook uses AASHTO standards for fortification of a clear zone width. There is a calculation method of clear zone width according to the design speeds, cut, fill slopes, and annual average daily traffic (AADT) values that is shown in table 4.1.

The audit route average design speed is mainly 50 km/hr and 70 km/hr, in addition to this AADT is over 6000. According to the General Directorate of Turkish Highways (KGM) standards at 50 km/hr and 70 km/hr speed and also AADT data, the required safety zone widths for fill slope and cut slope area, are given below. During the field survey, the safety zone width verification was done according to these values.

	Fill Slope		Cut Slope	
Design Speed (km/hr)	50	70	50	70
Safety Zone Width (m)	5	7	5	5

Table 4.6 Safety Zone Width Dependent on the Design Speed (AASHTO standards)

4.4. Observations Performed During Audit

Potential safety problems and hazards were observed along the route during the field survey. All of the problems and deficiencies were recorded to the checklists.

Checklist is categorized under two main headings. One of them is road design another one is the road side area. When conducting the audit, the safety problems can categorize under these main headings and recorded to the opinion part of the checklist.

The checklist table consists of five columns. The first column defines the road number that is the control station number. Kilometer and distance are located at the second and third column of the checklist respectively. Kilometer and distance define the location of hazard and potential safety areas. Fourth column explains the type of the hazards which arise from the road design or road side area. The fifth and the last column of the checklist give the auditor comments and short suggestions to the problems and hazards.

Most of the connection roads have inappropriate design. Especially the markings were complicated, old and new markings were got into each other. Also at some sections markings were completely worn. This signs were improper at some sections of the road.

Moreover the road pavement was not suitable for the design speed. Some sections of the audit route pavement were patched and these were out of date and weathered.

Along the audit route one of the important observations was the inadequate safety zone area. The concrete structures, big trees, buildings, fixed objects were in the road island also free stones and rocks, fixed massive electricity poles were near to the roadside and also drainage structures constitute hazard within the safety zone. The provided safety zone area was inadequate at many sections of the route.

The safety checklist of the route which belongs to right side is given with recorded observations during the field survey. The checklists are given at the following pages. Opposite direction safety checklist is given in appendices part of the thesis.

During the site investigation the hazardous objects within the safety zone, also factors which affect to road safety were photographed and reported in detail at the following sections.

SAFETY AUDIT CHECKLIST OF EXISTING ROAD

Date: 05/06/2010
Weather: Partly Cloudy

Conducted By: Okan Uzun

Right Side of The Audit Route

CSN	KM	Distance (m)	Type of Hazard	Comments
140-06	27	0	17	start station of the audit
140-06	27	100-200	30	high steep side slope
140-06	27	150	30,19	concrete heap location create dangerous situation
140-06	27	400	8	Improper connection to small access road
140-06	27	400	17	improper markings
140-06	27	500-700	30	high steep side slope zone, without guardrail
140-06	28	0-200	30	dangerous retaining wall section
140-06	28	100	22	wooden telephone poles in the safety zone
140-06	28	100	29	house so close to the roadside area
140-06	28	600	8	improper connection to roadway
140-06	28	700	23	big trees within the safety zone
140-06	29	600	7	improper connection to roadway
140-06	31	600	7	improper connection to roadway
140-06	32	100	21	temporary road narrowing because of the working zone
140-06	32	400	21	temporary road narrowing because of the working zone
140-06	32	600	17	confusing markings (old and new)
140-06	32	900	7	improper connection to çamköy village road
140-06	33	0	21	bridge on the alignment
140-06	33	200	27	stones within the safety zone
140-06	33	500-600	31	dangerous guardrail start - end
140-06	33	700		karayatak town entrance
140-06	34	400	17	confusing markings
140-06	34	500-600	1	shoulder missing
140-06	35	100	1.3	uncertain shoulders, shoulder missing
140-06	35	300	1	shoulder missing
140-06	35	300	2	shoulders too narrow
140-06	37	0	3.17	unpaved shoulders and missing horizontal markings
140-06	37	200-300	17	improper sign
140-06	37	400-600	2.3	unpaved and narrow shoulders

Table 4.7 Safety Audit Checklist of Road 140-06 (Right Side)

CSN	KM	Distance (m)	Type of Hazard	Comments
140-06	37	500	10	limited sight distance
140-06	38	0	2.3	unpaved and narrow shoulders
140-06	38	100	12,17	small radius of horizontal curve, missing sign
140-06	38	200	8	improper connection
140-06	38	200	32	dangerous culvert design
140-06	38	300-600	2.3	unpaved and narrow shoulders
140-06	38	800	12	small radius of horizontal curve
140-06	39	0	3,17	unpaved shoulders, improper marking
140-06	39	300-500	3,17	unpaved shoulders, missing markings
140-06	39	400	19	dangerous wall ending
140-06	39	500-700	17	old sign
140-06	39	600	3	unpaved shoulders
140-06	39	650	30	dangerous culvert section
140-06	40	0		divided road construction, work zone
140-06	40	500-700	17	confusing markings
140-06	41	100-400	17	confusing markings
140-06	41	400		kozayağı town entrance
140-06	42	100-400	17	confusing markings
140-06	42	400	17	Improper warning sign usage
140-06	42	600	8	narrow opening and improper connection to roadway
140-06	42	600-800	30	steep side slope
140-06	43	100	16	missing sign
140-06	43	100-900	17	confusing markings
140-06	44	0-400	30	steep side slope
140-06	44	500	16	improper sign
140-06	44	800	8	improper connection to Eskiköy village road
140-06	44	600	19	fixed object in the roadside area
140-06	44	900		divided road construction work zone
140-06	45	0-300	17	confusing markings
140-06	45	700-900	17	confusing markings
140-06	46	750	16	improper sign (vertical sign in the shoulder)
140-06	47	0	10	limited sight distance
140-06	47	100-300	1	shoulder missing
140-06	49	100-200	2	narrow shoulders

Table 4.7 (Cont.) Safety Audit Checklist of Road 140-06 (Right Side)

CSN	KM	Distance (m)	Type of Hazard	Comments
140-06	49	200-400	17	confusing markings
140-06	49	400	1	shoulder missing
140-06	49	800	2	narrow shoulders
140-06	49	800	10	limited sight distance, small radius of horizontal curve
140-06	49	800	19	dangerous wall section
140-06	49	900	3	shoulders unpaved
140-06	50	0	3	shoulders unpaved
140-06	50	0	10	limited sight distance
140-06	50	0	19	dangerous wall ending
140-06	50	100	2,23	narrow shoulders are covered with small bushes
140-06	50	0-100	2	narrow shoulders
140-06	50	0-100	2	narrow shoulders
140-06	50	200-300	2,3	narrow and unpaved shoulders
140-06	50	400-700	17	missing horizontal markings
140-06	50	500	19	rock is so close to the road
140-06	50	600-700	2,3	unpaved and narrow shoulders
140-06	50	700-900	3	unpaved shoulders
140-06	51	0	2	narrow shoulders
140-06	51	600-700	1	shoulder missing
140-06	51	800	17	missing markings
140-06	52	200	17	missing markings
140-06	52	300	19	fixed concrete objects in the roadside area
140-06	52	500-600	1	shoulders missing
140-06	52	400-600	17	improper markings
140-06	52	900	32	the location of manhole structure is close to roadway
140-06	53	100	8,16	missing sign
140-06	53	200	16	bridge vertical signs are improper
140-06	53	200	30	dangerous gap between the bridges steep side slope
140-06	53	500	4	improper junction design (3 arms)
140-06	53	600		starting point divided road section
140-06	54	0-150	17	confusing markings
140-06	54	200	6	dangerous entrance petrol station
140-06	54	300-600	17	confusing markings
140-06	55	100-500	30	steep side slope
140-06	55	150	16	improper sign

Table 4.7 (Cont.) Safety Audit Checklist of Road 140-06 (Right Side)

CSN	KM	Distance (m)	Type of Hazard	Comments
140-06	55	800-900	30	steep side slope
140-06	56	400	99	dangerous median starting
140-06	56	600		return junction
140-06	56	700	17	confusing markings
140-06	57	0	17	confusing markings
140-06	58	600-900	17	confusing markings
140-06	59	0		information sign
140-06	59	0	99	dangerous green band starting point
140-06	59	200		Improper junction design
140-06	59	200	16	missing sign
140-06	59	200	17	missing markings at junction
140-06	59	200		end of the audit

Table 4.7 (Cont.) Safety Audit Checklist of Road 140-06 (Right Side)

a) Utility Poles

Utility pole causes severe roadside crashes. Along the audit route mostly there are telephone poles, which are made by wood, and also electricity poles are recorded in the safety zone area for both sides of the route. Because of the poles are located in the safety zone area, they involve high potential safety risks for road users.

Along the audit route the most noticeable pole type is the telephone poles which are made of wood. The telephone poles are located inside the safety zone at most places. They are located both sides of the route. These locations are found to be associated with frequent utility pole crashes due to run off the roadway accidents. (figure 4.3)

Figure 4.3 Wooden pole inside the safety zone

b) Trees

This section addresses crashes involving impacts with trees. Along the audit route trees can be thought as a major type of traffic fatality. Tree crashes are strongly correlated with traffic volume, roadway geometry, and overall roadside condition. There are lots of trees with varying size and type along the audit route. During the field survey the trees which involve the high potential safety risk are recorded. Most of the trees that are on the route can be considered as fixed objects. Also some of them prevent sight distances for road users.

Some of the trees are lined at the beginning section of the route and all of the trees are in the safety zone area. Between km 28+500 and km 28+800 trees so close to the road. Between km 41+300 and 41+500 the sight distance is prevented by trees. At station km 34+900 the tree is also in the safety zone area (figure 4.4). Some sections of the route the shoulders are covered by small bushes which are located at station km 50+200.

Figure 4.4 Tree is in the roadside safety zone

c) Walls and Concrete Structures

Formidable walls and concrete structures located in critical positions are not consistent with a forgiving roadside. Most of the section of the road the concrete structures are in the safety zone area so these structures can cause serious damage accidents.

Especially one of the most hazardous sections of the audit route is between km 28+000 and km 28+200. There is a concrete house is just under the roadway (figure 4.5).

At station km between 31+600 and 32+200 there is a retaining wall on the left side of the route. Retaining wall is built to resist lateral pressure (especially a wall built to support or prevent the advance of a mass of earth). The distance between wall and shoulder is 6 m so the wall location is proper and well designed for this section. Beside this there is a wall at station 39+400 of which is the ending part is not safe. This wall can be considered as a fixed object for road users when hitting it. At station km 45+700 there are some concrete pipes with big diameter, also which create high potential accident risks. Moreover in the safety zone area there is a concrete heap is just under high steep side slope of the road.

Figure 4.5 Location of house may create hazard for the drivers

d) Improper Signing and Marking

Some of the information signs are located at inappropriate locations. Nevertheless the passing sight distance is appropriate for the section of the route, which is station km 42+300, there is a overtaking prohibited sign (figure 4.6). Beside this the sign is also worn out. This section's old and new markings are mixed into each other. At station km 55+000 vertical sign is inside the shoulder area. Moreover there are missing markings sections on the audit route.

Figure 4.6 Improper sign usage

e) Intersections

There are two junctions on the route. One of them is (Kalecik-Kırıkkale) – Çankırı Junction that is located at station km 59+300. Second one is the returning junction on the route that is located at station km 56+600.

The junction at km 59+300 is a non-signalized junction (figure 4.7). The excessive speed of vehicles on the minor road approach to the junction might cause and increase accident risk. The width of the main road and connection road is proper. The junction is located on sag type of vertical curve.

At (Kalecik-Kırıkkale) – Çankırı Junction there are not enough warning signs and markings for both directions. Also for the vehicles that are coming from the Kalecik-Kırıkkale road there is a high fill slope when they enter the junction for turning to Ankara direction. This area is not safely designed.

There is a potentially hazardous situation, particularly for traffic traveling in Çankırı direction, at the intersection with sideway at station km 38+200. Because the sideway intersects the audit route at the apex of one of its horizontal curves, it results in optical confusion for drivers. It appears as if the audit route continues straight ahead (with no curve) but in fact, it is sideway which intersects the highway at this location. This would confuse drivers, especially at night, if there is a vehicle traveling towards the intersection on sideway.

Figure 4.7 Improper junction design

f) Improper Access Management

When conducting an audit along the route there are some roadside facilities. There are two types of facilities along the route. One of them is petrol stations the other one is recreation areas.

There is a gasoline station at station km 46+600. The entrance section of the petrol station is too close to the road. In addition to this, concrete wall endings and information signboard of the petrol station create high hazardous risk for road users.

There are trees at the exit section of the gasoline station so this also can cause a visibility problem (figure 4.8). The limited sight distance problem appears for leaving vehicles from petrol station. It is difficult for drivers to detect other vehicles coming from the roadway.

Another potential accident area is the Baykuşboğazı site. It is recorded that many accidents were happened at this location. Entrance section of the recreation area is just near the road. Lighting poles that are on the road island can increase the severity of the collisions. It is a potentially hazardous location because the facility area is just designed at the tangent section of the horizontal curve. If the vehicles, which are on the Çankırı direction, want to turn left to enter the Baykuşboğazı site they can threaten safety of vehicles which are on the Ankara direction.

At station km 54+500; there is another gasoline station, which is on the left way and the divided section of the route. Also a big information board is located within the safety zone. This information board can increase the severity of accidents.

Figure 4.8 Dangerous exit section of gas station

g) Improper Bus Stop Design

Along the audit route there are no safe areas for busses to stop and take passengers without interrupting the traffic stream. In some cases, bus stop designs are improper thus create danger for public transportation users and the other drivers.

Improper bus stops can be accepted as dangerous fixed objects which are located in the safety zone of the roadway. These bus stops can increase the risk of serious injury and damage accidents.

One of the bus stops is just located on the tangent section of the horizontal curve. This area also creates risk for vehicles. Because of the bus stop's high construction material might increase the severity of collisions. Another bus stop is almost out of the bus driver's sight area. The sight distance is obstructed by trees (figure 4.9). In addition to this, at station km 44+800 one of the bus stop sign is on the electricity pole. It is not visible for bus driver because of its improper design.

Figure 4.9 Invisible bus stop is in the roadside safety zone

h) Improper Drainage Structure Design

There are many culverts and concrete pipes along the road sides. There are also two bridges on the route.

At the station km 39+600 there is a box culvert is 3x(2x3). Concrete culvert is just located under the road. Because there is not any barrier, the wing walls of the culvert might increase the severity of accidents (figure 4.10). At km station 55+800 there is another culvert without guardrail protection.

There is a bridge on the audit route at the station km 33+100. The lane widths of the bridge are narrow, so this type of situations may increase the probability of a vehicle colliding with the bridge. Guardrail of the bridge is also old so this can be a problem when hitting it. Another bridge is located at station km 53+200. This is the new bridge of the alignment. The old bridge is located left side and there is 4 meter gap between two bridges so it was noted that could be a potential hazard for drivers. There are not any warning signs at both guardrail ends. Moreover the manholes at the road edges can be considered as hazardous objects, because there is no grid-type cover on the manholes. This improper design can increase the severity of accidents and it is also non-safe area for pedestrians.

Figure 4.10 Dangerous transition zone of culvert without guardrail

ı) Improper Median Designs

The route is a divided highway between km 27+000, which is the starting point of the audit, to km 32+300. Another section is located between km 53+600 and km 59+300, which is the end point of the audit route.

At the beginning section of the route the median width is 2 meters. There is no ditch structure in the median region. Because of unseen and worn horizontal sign the road is just divided with vertical warning signs. Because there is no ditch structure, it can become a potential contributing factor to crash severity (figure 4.11).

The end section of the route also serves as a divided road. There is a median width of 2 meters and there is also a ditch structure. Therefore, neither the widths nor the slopes of the medians are suitable from safety point of view. There is an opening on the route for turning movements. The return way island is provided at this section of the roadway. This design can be made safer for vehicles. Moreover at some sections the ending part of the ditch line is a vegetable band (green band) starting. The starting point of the green band's edges is so sharp, so this situation creates safety risk for vehicles.

Figure 4.11 There is no ditch structure in the median zone

j) Improper Shoulder Widths

Shoulders are generally designed with desirable widths within the divided sections of the route. The road has little or no shoulder widths throughout the undivided sections. In some parts of these undivided two lane sections of the route, shoulders are not only too narrow but they are also unpaved. There is no exact width of the shoulders that are observed on undivided sections. It varies from 1.00 m to 2.00 m at undivided sections. Narrowing shoulder widths or loss of shoulder may cause serious safety problems (figure 4.12). This is particularly important since the lanes are 3- 3.5 meters in width and there is an extra width for other purposes.

Left side of the audit route shoulders is covered by some dangerous loose stone and rocks which are at station km 49+500. These stones or rocks can be thought as fixed objects that are almost on the shoulders. This area can be considered as potential accident location for road users.

Figure 4.12 Shoulder missing

k) Improper Speed Limits

The audit route speed limit is mostly 50 km/hr. At some sections of the route it is increased to 70 km/hr. Although operated speed limit can be accepted as quite low; it is adequate with the existing geometric standards.

At divided sections speed limit is improper at some locations. The starting point of the audit route is a divided road. Because the section has good geometric standards;

the posted speed limit, which is 50 km/hr seems to be low (figure 4.13). Some section of the audit route is under construction so the speed limit selection is reasonable; it is 50 km/hr.

Figure 4.13 Improper sign usage in the shoulder zone

l) Improper Fill Slope Designs

There are many road sections where the side slopes are less than desirable. "General Directorate of Turkish Highways" uses AASHTO standards. AASHTO considers side slopes of 4H:1V to be the steepest slopes for permitting safe vehicle controls. The first section of the audit route, the fill slopes are 1H:1V, 3H:2V, 2H:1V. High steep side slope at this area can cause a vehicle to overturn at run off roadway accidents. At station km 27+150, between km 27+500 and 27+700, and also between km 28+000 and 28+200; there are high steep side slopes (Figure 4.14). For slope stability and expropriation areas, there is a retaining wall structure. If an errant vehicle leaves the highway at these locations, the severity of the collision can be increased considerably. There are also many other steep side slope areas were recorded during the audit.

Figure 4.14 High steep sideslope zone

m) Improper Cut Slope Designs

Along the route, there are many cut slopes recorded and noted at the checklist. Most critical cut slope zone is just located at the beginning part of the route. Between the stations km 29+200 and 29+300 and between 31+600 and 32+200, claystone formation is dominate (Figure 4.15). Claystone can easily be dispersed and also it has a lamellar structure. Because of the claystone characteristics; the cut slopes can be considered as hazardous for road users.

Figure 4.15 Dangerous cut slope area

n) Guardrails

Poorly designed or poorly positioned guardrails together with their improper terminations can become a roadside hazard. The guardrail was failed at station km 50+000. There is a dangerous gap at the middle section of the guardrail, because of this situation the guardrails end sections might increase the severity of accidents when hitting it.

Figure 4.16 Dangerous guardrail section

o) Pavement

Within the study area, the condition of pavement varies according to the road classification. Generally, road surfaces appear to be roughest in fill cross sections with cracks, bumps and potholes on them. The pavement condition is particularly poor where the edge of the pavement meets the shoulders.

There is considerable rutting, resulting in ponding of water on roadway and there is also considerable raveling of pavement edges. There are many patches on the road surface. Because of this situation, at some sections road surface is rugged (Figure 4.17). At some sections, the road surface was collapsed because of the probable bad pavement design and construction. Generally the condition of the road surface is poor throughout the section.

Figure 4.17 Improper pavement design

p) Temporary Work Zones

Road construction has been conducted at some sections through the audit route. At station km 42+400 the warning sign is under another warning sign. These signs can create confusion for road users. At station km 45+600 another warning sign is just inside the lane of the road and it is temporarily fixed with stones (Figure 4.18). Because the sign limits the existing lane, it can create danger especially for heavy vehicles. At another construction site; on the route between km 50+400 and 50+900, there are flagpersons for directing the traffic movement. On the other hand, the location of the flagpersons can also cause accidents.

Figure 4.18 Improper location of warning sign

4.5. Proposal of Countermeasures

The accident data was analyzed systematically to identify hazardous locations of route. Also specific site investigation was performed to observe the problems, types of hazard and deficiencies. There are number of countermeasures for specific hazards were proposed at the following pages.

a) Utility Poles

At a certain section on the route there are telephone poles, which are made of wooden, within the safety zone area. There are some applicable countermeasures. One of them is to install reflector on the poles, which is realized by drivers. This solution has low cost and short term implementation. The other one is, install guard rail or crash cushion for hazardous utility poles near curve locations, which has low/mid cost and mid term implementation. Another one is, removing or relocating utility poles from safety zone area, and it has the long term and mid/high cost implementation. In addition to this the poles cable can be buried underground this is also long term and mid/high cost implementation.,

b) Trees

In some circumstances it may be considered appropriate to remove a tree which clearly presents an unacceptable hazard to vehicles. In other cases it may be possible to erect a longitudinal barrier, to reduce the risk of a vehicle striking the tree because when striking the tree is greater then the barrier. To prevent the stopping sight distance problem, the trees must be removed from safety zone. However, the potential benefits of removing such obstacles should be weighed against the adverse environmental and aesthetic effects of their removal. Therefore, trees should be removed only when considered essential for safety. However, it may only be practical to remove those fixed objects in very vulnerable locations. Alternatively, trees which can not be removed should be protected by guardrails, ditches or retaining walls. Also foliage should be removed from the shoulder area, because they obstruct traffic flow and sight distance.

c) Walls and Concrete Structures

Removing or relocating a building from the safety zone can not be seen appropriate, because high amount of expropriation cost. Installing the guardrails along the building section can be a possible solution for reducing the accident risk. Walls on the audit route which was constructed for slope stability will increase the severity of accidents. Installing barriers can be a solution to prevent this problem.

d) Markings and Signs

To reduce the confusions on the route the following improvements should be implemented:

- Worn signs should be renewed
- Warning signs should be installed at required section's of the route (e.g. before dangerous horizontal curves, approaching area of intersections, overtaking prohibited sections, work zones, bridge abutments etc.)
- The markings should be renewed by repainting and widening centerlines and edge lines or re-stripping at nonexistent sections of the route

- Existing markings which cause confusion on the route should be removed and re-stripping should be considered.

e) Entrance to the Roadside Facilities

Entrance part of the Termo Gas Station should be re-designed in a way not to include any hazard risks. Widening the shoulders and traffic lanes can be a solution. At Baykuşboğazı site Boğaziçi rest area entrance and exit parts can be considered highly potentially accident area. So there should be some future improvements in their design. If possible construct a new lane should be constructed and the road at that section should be turned to a divided road. Also construct turning lanes at entrance and exit parts for the vehicles that come from Ankara direction. In addition to this there should be warning signs both sides of the route. Speed breakers are also considerable solution. If all of these solutions will not be effective on reducing the accident rates, the relocation of the Boğaziçi rest area can be a considerable solution.

f) Bus Stops

Along the audit route all of the bus stops should be relocated. Also bus stops can be visible for all road users. Beside this bus stop signs should be installed properly. Moreover the construction of the bus bays should be considered for solutions.

g) Drainage Structures

- Install guardrails on the culverts, where there is high steep sideslope
- Place grid-type covers on the manholes
- Bridge guardrails should be renewed and extended

h) Medians

At divided sections of the route, where there is no median, constructing a median should be considered. In urban areas medians should ideally be wide enough to protect turning or crossing vehicles.

ı) Shoulders

There are some countermeasures, which are concern about the shoulders, are listed below;

- Shoulders should be paved
- Shoulders should be wide
- Upgrading and re-surfacing of shoulders should be considered.

j) Speed Limits

The speed limits are improper at some sections. Especially at undivided sections of the route the speed limits should be increased from 50 km/hr to 90 km/hr. At mountainous sections of the route because of the low geometric standards the speed limits should not exceed the 50 km/hr. At work zone areas the speed limits should be reduced gradually from 70 km/hr to 50 km/hr and then to 30km/hr. Also at small radius of horizontal curves speed limit should be 30 km/hr.

k) Fill Slopes

At the fill sides, generally the side slope steeper than 3H:1V. Slopes steeper than 3H:1V are critical because the possibility to rollover of the vehicle increases substantially. When consider the high amount of construction costs, this value can be steeper than 3:1. Fill slopes steeper than 3:1 should be used with appropriate safety barriers.

l) Cut Slopes

Rock face cuttings are created for roads constructed through hard rock outcroppings or hills. This type of cuttings should be shielded by safety barriers. Retaining walls should be used with softer soil types to support or prevent the advance of a mass of earth.

m) Barriers

Barriers should be properly installed and placed at required locations. Safety barriers (guardrails) can be effective in reducing the severity of crashes. Also following countermeasures should be considered:

- Extend guardrails at bridge parapets
- Guardrails on the bridge should be renewed
- Install guardrails at all steeper sideslope areas
- Deformity guardrails should be renewed or repaired
- Missing guardrail sections should be completed

n) Pavement

Resurfacing the pavement should be considered in areas where road conditions are particularly poor and necessary.

p) Work zone

Road work zones can represent a particular hazard to road users. The following improvements should be considered:

- The work zone should be let in a safe condition when work is not in progress.
- Improving the work zone traffic control devices can be consider as an another solution.

Benefit-Cost Analysis of Alternative Improvements Proposals

In this part of the study, benefit and cost comparisons are discussed regarding the evaluation of different safety improvement alternatives. With the help of some values updated and collected every year by the Road Authorities, it can be possible to convert accident, death and injuries data into monetary values (for example; travel time cost, cost of accident, cost of injury, etc.) Later; decrease in number of accidents, reduction in number of fatalities have to be decided for the improvement alternatives in order to evaluate these decreases in monetary terms in benefit estimations. On the other hand, cost of improvements can directly be taken as cost items of the feasibility analysis.

On the case study, road alignment, benefit-cost analysis and net profit cost improvement proposals belonging to two problematic sections were made. Their feasibilities were checked regarding the results of the mentioned analysis.

a) Guardrail and Roadside Slope Improvement

By analyzing the safety audit results and accident reports, two improvement alternatives; i.e. “guardrail application” and “flattening the side slopes” have been considered to evaluate the safety situation on section km 27+000 and 29+000 km of the case study road. The benefits of these two improvement alternatives have been determined by the computer program used by Turkish General Directorate of Highways. Later the cost of applications was also inserted to the analysis program thus it can perform benefit-cost analysis and issue the benefit/cost (B/C) ratios of the alternatives.

Guardrail application and maintenance costs have been considered. When total cost is being compared to the benefits which come from the reduction in number of casualties and deaths through traffic accidents, it is seen that benefit/cost ratio becomes 4.74 and it brings about 4.866.500 TL benefit.

Costs and benefits were also evaluated for the second improvement alternative for the same road section that is flattening the side slopes (for example, from 1:3 1:4). This alternative gives total benefit value of 4.614.577 TL and benefit/cost ratio as 3.97.

Choosing “guardrail application” as an improvement proposal seems to be more feasible than “flattening the slopes” alternative.

b) Climbing Lane with Guardrail Improvement

Net profit cost and benefit cost ratios of climbing lane construction together with the application of one side guardrails which can be constructed on mountainous area of another section of the road which is 4 km long were also calculated as a further example of the evaluation study. Since two different improvement steps were introduced in the same proposal, a common accident reduction factor and corresponding benefit values were calculated. Moreover, traffic increase rates have also been inserted in calculating traffic operating costs belonging to this section of the road in order to evaluate vehicle operating cost and time cost values. Reduction in vehicle operating costs and time costs that are obtained through the application of the improvement works can also be accepted as benefits of the proposed improvements.

Construction and maintenance costs were also calculated in improvement studies. As a result, benefits which come from vehicle operating costs, time saving benefits and especially benefits which come from the decrease of accidents resulted in number of deaths and injuries have been evaluated. In conclusion, net present value and benefit cost ratio value of larger than 1.0 indicate that the project can be considered a feasible solution in terms of improvement.

The results of two evaluation studies are given on tables C-2, C-4, C-8 and the processes are also displayed in Appendix C.

4.6. Results of Case Study

a) It is recognized that the standards of the road sections investigated in the case study, except for that of divided roads, are far lower than a state road standards. Small radius curves are noticed especially going through the mountainous district reduce the road standards. It is also observed in this section that necessary precautions were not taken to prevent road settlements which might be resulted from landslide. It is seen that at these points of the road, which carry the highest potential of the risk of accident, the pavement between 33+000 km and 37+000 km is partially damaged.

b) Another important problem observed in this study is the researches that shoulders are very narrow and they are not paved on many parts of the roads. In addition, it is seen that there are almost no shoulders on some others. Considering the supportive characteristic of the shoulders and their usability in emergency situations, it can be concluded that most of the present shoulders might have adverse effect to road safety.
c) Another problem is that culverts which exist on the alignment are constructed in such a way that they might create additional danger to the overall safety of the road and its environment.
d) Another significant safety problem is recorded as steep fill slopes. It is considered that slopes were not designed regarding safety standards on the fill cross sections. Guardrail application can be considered as a solution for this problem
e) On the other hand, guardrails only exist on mountainous areas and road sections that are subjected to landslides. Especially on the retaining wall sections, which can be considered as dangerous because of the existence for culvert passing, there are almost no guardrails. There are not also any guardrail applications on the high fill slopes and dangerous cut sections. Moreover, on the parts which have guardrails it is observed that they may cause additional safety problems at endings because of out of standard applications.
f) In benefit-cost analysis study; benefit-cost ratios and net profits have been evaluated and studied for different road safety improvement alternatives.

4.7. Proposals for Improvements in the Case Study Area

a) Horizontal curves especially on the mountainous zones of the route need to be expanded. It is essential to take precautions against landslide and to place warning signs. Warnings should be given with vertical signs on the sections that have limited passing sight distance or vertical curve revision.
b) Shoulders which are generally in bad conditions on the roads should be rebuilt, i.e. should be paved and extended; moreover, worn and structurally settled pavement sections need to be removed and re-constructed.

c) In many parts of the audited route, road markings have to be renewed and replaced immediately.
d) Guardrails should be placed on the sections of high fill slope sections with no guardrails, and on the sections with retaining walls. They also have to be placed on dangerous cut sections.
e) Barrier (guardrail) applications have to be considered along the road sides where wooded areas, posts, bus stations, dangerous concrete structures, stones and rocks are available.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

In this thesis the real practices of road safety audit on existing roads in different countries were summarized. By taking account these different opinions and auditing procedures into account a case study has been performed for road safety auditing on existing roads. Following conclusions can be drawn from this study:

a) Some safety defects observed during the audit study that can be considered as typical for Turkish rural highway network can be mentioned as follows:

- guardrails are deficient or not in appropriate positions,
- slopes are steep and can not be considered as gentle regarding road safety,
- pavement damages are considerably remarkable,
- shoulders are insufficient, narrow and are not paved at most locations

b) Some basic have vital importance for a safety audit study. However, there may be some defects and errors in the context of such data in Turkey as traffic, accident etc. They have adversely influenced the reliability of the thesis' case study.

c) The realization of safety audits on existing roads bring great support and guidance for building road safety and improving existing or potential accident prone locations. With the performed case study and the evaluated results, it is tried to make some contributions to the importance of 'safety audit concept'.

d) The cost effectiveness study that has been applied to some of the improvement proposals can be accepted as guidance for evaluating safety audit results.

5.2. Recommendations

The following recommendations can be written for the case study:

a) The case study methodology as a safety audit should be followed and implemented on all present rural highway networks in Turkey for evaluating the overall safety rating of the country roads.

b) Road safety audit surveys should be done for 1-3 years intervals to observe changes in the road structure and equipment as well as the road environment.

c) Road Safety Audits are being considered as more and more important and widely used tools/applications to increase the road and the road environment safety. It is necessary to teach millions of junior highway engineers in many parts of the world about these techniques as quickly as possible thus different teaching techniques such as distant learning and distant workshop facilities should be applied.

d) Problems with the lack of dependable traffic and accident common database in Turkey have adversely influenced the road safety activities. Thus, implementing reliable and well designed traffic safety database including road and traffic statistics and records should be accepted as the first priority action in the recent future. This common database should be open to researchers with no restrictions.

e) Turkey should start to invest in the researches of accident reduction factors that are currently not available but adapted from international studies. These researches require long-term studies and should be implemented as soon as possible.

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APPENDICES

APPENDIX A

Safety Audit Checklist

The safety checklist of the route which belongs to left side is given with recorded observations during the field survey.

SAFETY AUDIT CHECKLIST OF EXISTING ROAD

Date: 12/06/2010
Weather: Sunny, Partly Cloudy

Conducted By: Okan Uzun

Left Side of The Audit Route

CSN	KM	Distance (m)	Type of Hazard	Comments
140-06	59	200		start station of the audit
140-06	58	300-500	25	dangerous hedge
140-06	58	100	30	steep side slope
140-06	58	0	30	steep side slope
140-06	57	900	30	steep side slope
140-06	56	900	30	steep side slope
140-06	56	100	30	steep side slope
140-06	55	900	30	steep side slope
140-06	55	800	30	steep side slope
140-06	55	300	30	steep side slope
140-06	54	800	25	dangerous hedges
140-06	54	400	28	dangerous advertisement sign
140-06	52	100-900	2,3	unpaved and narrow shoulders
140-06	51	500-600	1	shoulder missing
140-06	51	100-200	8	improper connection to the construction site
140-06	50	400-900	1,17	shoulder missing and improper horizontal markings
140-06	50	200-300	2.3	unpaved and narrow shoulders
140-06	50	100	31	dangerous guardrail start, end
140-06	50	0	31	guardrail missing
140-06	49	800	6	dangerous entrance and exit section of recreation area
140-06	49	600-700	1	shoulder missing
140-06	49	500	27	stones and rocks in the shoulder
140-06	49	500	26	dangerous cut slope
140-06	49	300-500	2	narrow shoulders
140-06	49	100-300	3	unpaved shoulders
140-06	49	0	18	dangerous fixed object in the roadside
140-06	49	0	8	improper road connection to Hasayaz Village
140-06	48	0-800	1	shoulder missing
140-06	48	0-900	25	improper hedge design
140-06	47	400-500	25	improper hedge design

Table A.1. Safety Audit Checklist of Road 140-06 (Left Side)

CSN	KM	Distance (m)	Type of Hazard	Comments
140-06	47	0	25	improper hedge design
140-06	46	600	6	entry of petrol station, limited sight distance exit
140-06	45	700-900	17	confusing old and new horizontal markings
140-06	45	700	19	concrete pipes in roadside
140-06	45	600	30	steep side slope at culvert section
140-06	45	600	22	wooden poles in the safety zone
140-06	45	400	12	small vertical radius
140-06	44	800	99	improper bus stop design
140-06	44	900	25,30	dangerous concrete hedges
140-06	44	800	8	improper connection to roadway
140-06	44	0-700	2	narrow shoulders
140-06	43	100-900	2	narrow shoulders
140-06	42	200	99	pavement material within the safety zone
140-06	41	500	8	improper connection to the roadway
140-06	41	300-500	23	big trees so close to road side, limited sight distance
140-06	41	350	18	invisible bus stop design, trees so close to roadside
140-06	41	0	30	steep side slope
140-06	40	100-150	16	missing vertical sign
140-06	40	0	18	bus stop so close to the roadway
140-06	39	650	30	high steep side slope at culvert section
140-06	39	700	8	improper connection to karacakaya town
140-06	39	700	18	dangerous bus stop location
140-06	38	300-600	3	unpaved shoulders
140-06	37	600-900	3	unpaved shoulders
140-06	37	400-500	30	high steep side slope
140-06	36	700-900	2.3	narrow and unpaved shoulders
140-06	36	400	10	limited sight distance
140-06	35	900	8	improper connection to roadway
140-06	35	800	1	missing shoulder
140-06	35	300	3	unpaved shoulders
140-06	35	0		erosion zone
140-06	35	0	23	trees in the safety zone
140-06	34	900	30	improper guardrail design
140-06	34	900	23	big trees within the safety zone
140-06	34	800		improper pavement design

Table A.1.(Cont.) Safety Audit Checklist of Road 140-06 (Left Side)

CSN	KM	Distance (m)	Type of Hazard	Comments
140-06	34	600		erosion zone
140-06	33	600-800	12	small radius of horizontal curve
140-06	33	200	25	dangerous concrete hedge
140-06	33	200	3	unpaved shoulders
140-06	33	200	23	trees close to the road
140-06	33	0-100	21	dangerous bridge section, temporary road narrowing
140-06	32	900	8	improper connection to çamköy village road
140-06	32	700	1	missing shoulder
140-06	32	500-900	1	missing shoulder
140-06	32	200		dangerous wall ending
140-06	32	100	32	dangerous culvert section
140-06	32	100-200	26	dangerous cut slope
140-06	31	600	26	dangerous cut slope
140-06	31	100	7	improper connection to small access road
140-06	30	0	7	improper connection to small access road
140-06	29	200-300	26	dangerous cut slope
140-06	29	100	32	improper manhole design on the roadside
140-06	29	0	8	improper connection to the roadway
140-06	28	700	8	improper connection to the roadway
140-06	28	400-500	23	trees so close to road
140-06	27	900	8	improper connection to the construction site
140-06	27	700-800	26	dangerous cut slope
140-06	27	400	8	improper connection to roadway
140-06	27	0		end of the audit

Table A.1.(Cont.) Safety Audit Checklist of Road 140-06 (Left Side)

APPENDIX B

Accident Information for the Case Study Route

Reasons of accidents (e.g. run off the road collision, head-on collision, etc.) are labeled by numbers for an easy use.

Number	Type of Accident
1	head on collision
2	rear end collision
3	side collision
4	collision to parked car
5	collision to obstacle
6	collision to pedestrian
7	collision to animal
8	turn over
9	run-off the roadway

Table B.1 Type of Accidents

Accident Data of Year 2006										
Road Number	Control Station	Date/Month/Year	Km	Meter	Reason of Accident	Injury Accident	Fatal Accident	Total Injured	Total Dead	Total Vehicle
140	06	01.12.2006	27	850	9	1	0	5	0	1
140	06	15.07.2006	28	400	9	1	0	5	0	1
140	06	04.05.2006	28	800	9	1	0	4	0	1
140	06	23.04.2006	31	000	8,9	1	0	5	0	1
140	06	30.01.2006	34	000	1	1	0	2	0	2
140	06	20.02.2006	34	100	1	1	0	2	0	2
140	06	11.11.2006	34	100	9,8	1	0	1	0	1
140	06	20.08.2006	34	500	8,9	1	0	1	0	1
140	06	01.02.2006	34	600	9,5	1	0	1	0	1
140	06	25.08.2006	35	000	1	1	0	2	0	2
140	06	26.12.2006	36	300	8,9	1	0	2	0	1
140	06	01.05.2006	36	800	9,8	1	0	1	0	1
140	06	02.08.2006	38	200	1,9	1	0	1	0	2
140	06	02.07.2006	39	100	4,8	1	0	3	0	4
140	06	19.06.2006	39	400	9,8	1	0	1	0	1
140	06	06.10.2006	40	100	8,9	1	0	1	0	1
140	06	16.06.2006	40	300	9	1	0	2	0	1
140	06	16.09.2006	41	700	2	1	0	2	0	2
140	06	06.01.2006	42	000	9,8	1	0	1	0	1
140	06	21.08.2006	44	175	6	1	0	1	0	1
140	06	24.03.2006	45	000	9	1	0	2	0	1

Table B.2 Accident Data of Year 2006

Road Number	Control Station	Date/Month/Year	Km	Meter	Reason of Accident	Injury Accident	Fatal Accident	Total Injured	Total Dead	Total Vehicle
140	06	15.01.2006	46	800	3	1	0	1	0	2
140	06	20.08.2006	47	400	2	1	0	1	0	2
140	06	20.08.2006	48	500	2	1	0	1	0	2
140	06	18.07.2006	50	700	9	1	0	1	0	1
140	06	02.06.2006	50	800	3	1	0	2	0	2
140	06	22.07.2006	50	900	9	1	0	1	0	1
140	06	13.11.2006	51	000	9,5	1	0	1	0	1
140	06	23.02.2006	51	750	1	1	0	1	0	2
140	06	14.10.2006	51	750	9,8	1	0	1	0	1
140	06	22.09.2006	52	000	8,9	1	0	1	0	1
140	06	29.06.2006	52	250	8,9	1	0	2	0	1
140	06	03.09.2006	53	200	3	1	0	1	0	2
140	06	14.03.2006	53	800	3	1	0	1	0	2
140	06	23.04.2006	53	800	3	1	0	3	0	2
140	06	21.07.2006	53	900	3	1	0	1	0	2
140	06	16.04.2006	55	600	8	1	0	1	0	1
140	06	20.04.2006	56	790	8,9	1	0	1	0	1
140	06	14.04.2006	56	800	9	0	1	3	1	1
140	06	02.06.2006	58	200	9	1	0	2	0	1
TOTAL						**40**	**1**	**72**	**1**	**58**
TOTAL ACCIDENT						**41**				

Table B.2 (Cont.) Accident Data of Year 2006

Accident Data of Year 2007										
Road Number	Control Station	Date/Month/Year	Km	Meter	Reason of Accident	Injury Accident	Fatal Accident	Total Injured	Total Dead	Total Vehicle
140	06	14.07.2007	27	450	1	1	0	7	0	2
140	06	22.07.2007	27	500	1	0	1	9	6	3
140	06	22.07.2007	27	500	1	1	0	6	0	2
140	06	03.01.2007	27	850	2	1	0	2	0	2
140	06	19.07.2007	30	700	9	1	0	1	0	1
140	06	31.03.2007	31	500	8	1	0	2	0	1
140	06	04.05.2007	34	000	9	1	0	2	0	1
140	06	04.01.2007	34	100	5	1	0	2	0	1
140	06	24.12.2007	34	900	5,9	1	0	2	0	1
140	06	02.02.2007	35	000	8,9	1	0	2	0	1
140	06	30.09.2007	38	200	8	1	0	1	0	1
140	06	26.08.2007	39	100	2	1	0	2	0	2
140	06	10.02.2007	39	975	1,2	1	0	4	0	2
140	06	25.10.2007	40	200	9	1	0	1	0	1
140	06	30.09.2007	42	100	8	1	0	1	0	1
140	06	22.02.2007	42	800	8	0	1	0	1	1
140	06	20.09.2007	42	800	9	1	0	1	0	1
140	06	16.09.2007	43	000	6	1	0	1	0	1
140	06	09.03.2007	43	200	8	1	0	4	0	1
140	06	21.03.2007	43	700	9,8	1	0	4	0	1
140	06	27.07.2007	44	700	3	1	0	1	0	2

Table B.3 Accident Data of Year 2007

Road Number	Control Station	Date/Month/Year	Km	Meter	Reason of Accident	Injury Accident	Fatal Accident	Total Injured	Total Dead	Total Vehicle
140	06	03.03.2007	44	800	8,9	1	0	2	0	1
140	06	10.09.2007	46	600	3,9	0	1	6	3	2
140	06	05.06.2007	48	600	9,3	1	0	2	0	2
140	06	17.08.2007	48	700	1	0	1	7	1	2
140	06	18.07.2007	48	800	3,8	1	0	4	0	2
140	06	19.12.2007	49	900	8,9	0	1	1	1	2
140	06	26.09.2007	50	900	9	1	0	1	0	1
140	06	25.07.2007	51	100	9	1	0	3	0	1
140	06	20.04.2007	51	400	2,9	1	0	1	0	2
140	06	29.08.2007	52	000	1,9	0	1	4	3	3
140	06	21.10.2007	52	300	8,9	1	0	4	0	1
140	06	31.08.2007	54	800	2	1	0	4	0	2
140	06	28.05.2007	57	000	9,8	0	1	2	1	1
140	06	19.12.2007	59	400	9,8	1	0	2	0	1

TOTAL	**28**	**7**	**98**	**16**	**52**
TOTAL ACCIDENT	**35**				

Table B.3 (Cont.) Accident Data of Year 2007

Accident Data of Year 2008										
Road Number	Control Station	Date/Month/Year	Km	Meter	Reason of Accident	Injury Accident	Fatal Accident	Total Injured	Total Dead	Total Vehicle
140	06	12.04.2008	28	000	9	1	0	1	0	1
140	06	10.05.2008	28	400	9	1	0	6	0	1
140	06	07.04.2008	28	600	9	1	0	2	0	1
140	06	10.02.2008	30	100	9	1	0	3	0	1
140	06	21.06.2008	31	000	9	1	0	2	0	1
140	06	25.10.2008	34	500	8,9	1	0	1	0	1
140	06	29.04.2008	34	750	8	1	0	1	0	1
140	06	08.09.2008	34	800	8	1	0	1	0	1
140	06	19.11.2008	34	800	5	1	0	1	0	1
140	06	22.12.2008	34	800	9	1	0	3	0	1
140	06	12.10.2010	34	800	9,8	1	0	2	0	1
140	06	27.10.2008	34	900	2	1	0	1	0	2
140	06	24.09.2008	36	500	1	1	0	2	0	2
140	06	22.04.2008	38	200	9	1	0	1	0	1
140	06	02.11.2008	38	700	9	1	0	1	0	1
140	06	05.02.2008	42	250	8,9	1	0	1	0	1
140	06	04.04.2008	45	900	8,9	1	0	1	0	1
140	06	09.02.2008	46	900	8,9	1	0	1	0	1
140	06	06.10.2008	50	000	3,9	1	0	1	0	2
140	06	24.05.2008	50	700	9	1	0	1	0	1
140	06	12.07.2008	50	800	8,9	1	0	1	0	1

Table B.4 Accident Data of Year 2008

Road Number	Control Station	Date/Month/Year	Km	Meter	Reason of Accident	Injury Accident	Fatal Accident	Total Injured	Total Dead	Total Vehicle
140	06	14.10.2008	51	000	8,9	1	0	1	0	1
140	06	14.12.2008	51	000	9,8	1	0	2	0	1
140	06	14.06.2008	51	400	1	1	0	1	0	2
140	06	10.03.2008	51	800	9,8	1	0	1	0	1
140	06	28.06.2008	52	300	8	1	0	1	0	1
140	06	06.11.2008	53	100	8,9	1	0	1	0	1
140	06	29.03.2008	53	460	9	1	0	2	0	1
140	06	11.08.2008	54	350	8	1	0	4	0	1
140	06	09.08.2008	55	500	9,8	1	0	1	0	1
140	06	31.01.2008	59	100	9,8	1	0	5	0	1
140	06	28.02.2008	59	300	9	1	0	4	0	1

TOTAL	**32**	**0**	**57**	**0**	**36**
TOTAL ACCIDENT	**32**				

Table B.4 (Cont.) Accident Data of Year 2008

2009 Year Accident Statistics										
Road Number	Control Station	Date/Month/Year	Km	Meter	Reason of Accident	Injury Accident	Fatal Accident	Total Injured	Total Dead	Total Vehicle
140	06	25.07.2009	27	150	3	1	0	3	0	2
140	06	14.10.2009	28	500	9	0	1	1	1	1
140	06	14.08.2009	30	300	9	1	0	1	1	1
140	06	28.05.2009	31	800	8	1	0	4	0	1
140	06	27.06.2009	33	850	1	1	0	4	0	2
140	06	02.07.2009	34	0	1	1	0	4	0	2
140	06	15.04.2009	34	0	9	1	0	3	0	1
140	06	02.08.2009	34	50	9	1	0	1	0	1
140	06	16.12.2009	34	50	3	1	0	2	0	2
140	06	11.12.2009	34	60	1	1	0	4	0	2
140	06	21.09.2009	34	600	3,9	1	0	2	0	2
140	06	10.01.2009	34	600	1	1	0	3	0	2
140	06	13.09.2009	34	800	9	1	0	4	0	1
140	06	02.09.2009	35	0	9	1	0	1	0	1
140	06	10.08.2009	35	450	3	1	0	1	0	2
140	06	07.03.2009	35	900	9,5	1	0	4	0	1
140	06	15.07.2009	37	800	8	1	0	2	0	1
140	06	09.12.2009	38	70	9	1	0	1	0	1
140	06	07.07.2009	38	400	1	1	0	3	0	2
140	06	23.08.2009	38	400	9,5	1	0	1	0	1
140	06	19.06.2009	38	950	9,5	1	0	3	0	1

Table B.5 Accident Data of Year 2009

Road Number	Control Station	Date/Month/Year	Km	Meter	Reason of Accident	Injury Accident	Fatal Accident	Total Injured	Total Dead	Total Vehicle
140	06	17.02.2009	39	500	8,9	1	0	1	0	1
140	06	10.06.2009	39	700	9,8	1	0	1	0	1
140	06	21.02.2009	41	0	1	1	0	4	0	2
140	06	09.10.2009	42	0	2	1	0	4	0	2
140	06	04.04.2009	42	500	9	1	0	2	0	1
140	06	10.11.2009	45	400	2,9	1	0	3	0	2
140	06	10.11.2009	45	400	5,9	1	0	4	0	1
140	06	22.04.2009	46	550	9,8	1	0	3	0	1
140	06	30.08.2009	47	950	3,8	1	0	3	0	3
140	06	18.09.2009	48	100	9,8	1	0	5	0	1
140	06	09.09.2009	48	500	8,9	1	0	2	0	1
140	06	08.11.2009	48	700	9,8	1	0	4	0	1
140	06	13.02.2009	49	900	8,9	1	0	1	0	1
140	06	20.02.2009	50	200	8,9	1	0	1	0	1
140	06	10.10.2009	50	300	3,8	1	0	4	0	1
140	06	14.10.2009	50	650	9	1	0	2	0	1
140	06	30.10.2009	50	750	9,8	1	0	2	0	1
140	06	24.09.2009	50	915	9,8	1	0	1	0	1
140	06	29.08.2009	51	0	9	1	0	2	0	1
140	06	07.05.2009	51	100	1	1	0	4	0	2
140	06	23.05.2009	51	200	2	1	0	3	0	2
140	06	14.10.2009	51	500	9,8	1	0	2	0	1

Table B.5 (Cont.) Accident Data of Year 2009

Road Number	Control Station	Date/Month/Year	Km	Meter	Reason of Accident	Injury Accident	Fatal Accident	Total Injured	Total Dead	Total Vehicle
140	06	21.05.2009	51	800	8,9	1	0	1	0	1
140	06	19.09.2009	51	900	2,3	1	0	8	0	3
140	06	06.08.2009	53	150	9,8	1	0	2	0	1
140	06	10.06.2009	54	0	3	1	0	1	0	2
140	06	21.12.2009	54	450	9,8	1	0	3	0	1
140	06	26.04.2009	55	600	9,8	0	1	6	1	1
140	06	22.10.2009	56	0	9,8	1	0	1	0	1
140	06	23.11.2009	56	500	9,8	1	0	2	0	1
140	06	23.07.2009	56	550	9	1	0	6	0	1
140	06	29.01.2009	56	950	9,8	1	0	1	0	1
140	06	15.05.2009	57	100	9,8	1	0	4	0	1
140	06	15.08.2009	57	300	9,8	1	0	2	0	1
140	06	13.07.2009	58	300	9,5	1	0	3	0	1
140	06	09.12.2009	59	600	9,8	1	0	2	0	1

TOTAL	**55**	**2**	**152**	**3**	**76**
TOTAL ACCIDENT	**57**				

Table B.5 (Cont.) Accident Data of Year 2009

APPENDIX C

Economical Analysis Output Tables

AKYURT - KALECİK ROAD ACCIDENT ANALYSIS (Guardrail Application)

Project Name	Akyurt - Kalecik Road
Project No	
Division	4
Section No	140-06
Location	

Analysis Date	10/6/2010
Analysis Period	20

No of Damaged Vehicles	0
No of Accidents	3
No of Fatality	2
No of Injuries(light)	6
No of Injuries(heavy)	6
A.A.D.T.	
Growth Rate of Traffic Accidents (%)	2
Traffic Data Year	

Control Station Number	KM	YEARS	Accident	Dead	Injury
140-06	**27+000 29+000**	**2006**	**3**	**0**	**14**
		2007	**4**	**6**	**24**
		2008	**3**	**0**	**9**
		2009	**2**	**1**	**4**
Length (KM)	**2**	**Average**	**3**	**2**	**13**

Cost of Injury (light) (TL)	8,959
Cost of Injury (heavy) (TL)	123,011
Cost of Person incase Fatality (TL)	1,162,377

Cost of repairment (TL/Accident)	1,420

Estimated Accident/Casualty Reductions

		Reductions (%)
Accidents		0
Fatalities		20
Injuries		20

Table C.1 Accident data and cost information (Guardrail Design) [33]

Akyurt - Kalecik Road Evaluation Table

(Guardrail Design)

YEARS	BENEFITS (Existing-New)				COSTS				Cost Difference Between Existing and New Project	Net Benefits of the New Project, According to Existing Project (TL)
					Existing		New			
	Accident	Vehicle Operating Cost	Time	TOTAL	Construction Cost	Others	Construction Cost	Others		
2010	0	0	0	0	0	0	282,983	0	282,983	-282,983
2011	586,596	0	0	586,596	0	0	0	70,000	70,000	516,596
2012	598,327	0	0	598,327	0	0	0	70,000	70,000	528,327
2013	610,294	0	0	610,294	0	0	0	70,000	70,000	540,294
2014	622,500	0	0	622,500	0	0	0	70,000	70,000	552,500
2015	634,950	0	0	634,950	0	0	282,983	46,146	329,129	305,821
2016	647,649	0	0	647,649	0	0	0	70,000	70,000	577,649
2017	660,602	0	0	660,602	0	0	0	70,000	70,000	590,602
2018	673,814	0	0	673,814	0	0	0	70,000	70,000	603,814
2019	687,290	0	0	687,290	0	0	0	70,000	70,000	617,290
2020	701,036	0	0	701,036	0	0	282,983	46,146	329,129	371,907
2021	715,057	0	0	715,057	0	0	0	70,000	70,000	645,057
2022	729,358	0	0	729,358	0	0	0	70,000	70,000	659,358
2023	743,945	0	0	743,945	0	0	0	70,000	70,000	673,945
2024	758,824	0	0	758,824	0	0	0	70,000	70,000	688,824
2025	774,000	0	0	774,000	0	0	282,983	46,146	329,129	444,871
2026	789,480	0	0	789,480	0	0	0	70,000	70,000	719,480
2027	805,270	0	0	805,270	0	0	0	70,000	70,000	735,270
2028	821,375	0	0	821,375	0	0	0	70,000	70,000	751,375
2029	837,803	0	0	837,803	0	0	0	70,000	70,000	767,803
2030	854,559	0	0	854,559	0	0	282,983	46,146	329,129	525,430

Economical Analysis Result

Discount Rate % :	**8.00**	
Internal Rate of Return :	**1.8391**	
NET Present Value (NPV):	**4,866,500**	TL
Benefit/Cost Ratio (B/C) :	**4.7437**	

Table C.2 Benefit Cost Analysis Result (Guardrail Design) [33]

AKYURT - KALECİK ROAD (Flattening Slope)

Project Name	Akyurt - Kalecik Road
Project No	
Division	4
Section No	140-06
Location	

Analysis Date	06.10.2010
Analysis Period	20

No of Damaged Vehicles	0
No of Accidents	3
No of Fatality	2
No of Injuries(light)	6
No of Injuries(heavy)	6
A.A.D.T.	
Growth Rate of Traffic Accidents (%)	2
Traffic Data Year	

Control Station Number	KM	YEARS	Accident	Dead	Injury
140-06	**27+000 29+000**	**2006**	**3**	**0**	**14**
		2007	**4**	**6**	**24**
		2008	**3**	**0**	**9**
		2009	**2**	**1**	**4**
Length (KM)	**2**	**Average**	**3**	**2**	**13**

Cost of Injury (light) (TL)	8,959
Cost of Injury (heavy) (TL)	123,011
Cost of Person incase Fatality (TL)	1,162,377
Cost of repairment (TL/Accident)	1,420

Estimated Accident/Casualty Reductions

		Reductions (%)
Accidents		0
Fatalities		20
Injuries		20

Table C.3 Accident data and cost information (Flattening Slope) [33]

Akyurt - Kalecik Road Evaluation Table

(Flattening Slope)

YEARS	BENEFITS (Existing-New)				COSTS				Cost Difference Between Existing and New Project	Net Benefits of the New Project, According to Existing Project
					Existing		New			
	Accident	Vehicle Operating Cost	Time	TOTAL	Construction Cost	Others	Construction Cost	Others		
2010	0	0	0	0	0	0	1,200,000	476000	1,676,000	-1,676,000
2011	586,596	0	0	586,596	0	0	0	0	0	586,596
2012	598,327	0	0	598,327	0	0	0	0	0	598,327
2013	610,294	0	0	610,294	0	0	0	0	0	610,294
2014	622,500	0	0	622,500	0	0	0	0	0	622,500
2015	634,950	0	0	634,950	0	0	0	0	0	634,950
2016	647,649	0	0	647,649	0	0	0	0	0	647,649
2017	660,602	0	0	660,602	0	0	0	0	0	660,602
2018	673,814	0	0	673,814	0	0	0	0	0	673,814
2019	687,290	0	0	687,290	0	0	0	0	0	687,290
2020	701,036	0	0	701,036	0	0	0	0	0	701,036
2021	715,057	0	0	715,057	0	0	0	0	0	715,057
2022	729,358	0	0	729,358	0	0	0	0	0	729,358
2023	743,945	0	0	743,945	0	0	0	0	0	743,945
2024	758,824	0	0	758,824	0	0	0	0	0	758,824
2025	774,000	0	0	774,000	0	0	0	0	0	774,000
2026	789,480	0	0	789,480	0	0	0	0	0	789,480
2027	805,270	0	0	805,270	0	0	0	0	0	805,270
2028	821,375	0	0	821,375	0	0	0	0	0	821,375
2029	837,803	0	0	837,803	0	0	0	0	0	837,803
2030	854,559	0	0	854,559	0	0	0	0	0	854,559

Economical Analysis Result

Discount Rate % :	**8.00**	
Internal Rate of Return :	**0.3690**	
NET Present Value (NPV):	**4,614,577**	TL
Benefit/Cost Ratio (B/C) :	**3.9736**	

Table C.4 Benefit Cost Analysis Result (Flattening Slope) [33]

AKYURT - KALECİK ROAD ACCIDENT ANALYSIS (Climbing Lane, Guardrail Design)

Project Name	Akyurt - Kalecik Road
Project No	
Division	4
Section No	140-06
Location	

Analysis Date	10/6/2010
Analysis Period	20

No of Damaged Vehicles	7
No of Accidents	8
No of Fatality	0
No of Injuries(light)	8
No of Injuries(heavy	8
A.A.D.T.	
Growth Rate of Traffic Accidents (%)	2
Traffic Data Year	

Control Station Number	KM	YEARS	Accident	Dead	Injury
140-06	33+000 37+000	2006	8	0	12
		2007	4	0	8
		2008	8	0	12
		2009	12	0	33
Length (KM)	4	Average	8	0	16

Cost of Injury (light) (TL)	8,959
Cost of Injury (heavy) (TL)	123,011
Cost of Person incase Fatality (TL)	1,162,377
Cost of repairment (TL/Accident)	1,420

Estimated Accident/Casualty Reductions

		Reductions (%)
Accidents		0
Fatalities		32
Injuries		36

Table C.5 Accident data and cost information (Climbing Lane, Guardrail) [33]

Akyurt - Kalecik Road Transit Traffic Vehicle Operating Cost (VOC) Value

VOC Data and Assumption

Alternative Route	Length	Surface Type	Avg. Vertical Slope	Avg. Horizontal Curve	Section Lengths	UNIT VOC VALUES (TL/VEHICLE- KM)				ROUTE'S VOC VALUES (TL/VEHICLE)			
			(%)	(deg/km)	(KM)	Car	Bus	Truck	Trailer	Car	Bus	Truck	Trailer
Control Station 140-06 Km 33+000 - Km 37+000	4	Surface	1	15	0	0.20671	0.91454	0.96508	1.08049	0.84216	4.73167	5.22712	7.31557
		Treatment	3	75	0	0.20735	0.96182	1.03100	1.31224				
		(R=3)	5	300	4	0.21054	1.18292	1.30678	1.82889				
Existing Road	4	Surface	1	15	0	0.20924	0.93244	0.98823	1.10921	0.85223	4.80559	5.32584	7.45286
		Treatment	3	75	0	0.20989	0.98008	1.05364	1.34183				
		(R=4)	5	300	4	0.21306	1.20140	1.33146	1.86321				

TRANSIT TRAFFIC						EXISTING ROUTE VOC VALUE (TL)					NEW ROUTE VOC VALUE (TL)					TOTAL VOC BENEFIT
YEARS	CAR	BUS	TRUCK	TRAILER	TOTAL	CAR	BUS	TRUCK	TRAILER	TOTAL	CAR	BUS	TRUCK	TRAILER	TOTAL	
Increase Rate (2009-2012)	1.07	1.02	1.02	1.2												
Increase Rate (2013-2015)	1.06	1.02	1.02	1.2												
Increase Rate (2015-2020)	1.06	1.02	1.02	1.11												
Increase Rate (2024-2035)	1.05	1.02	1.01	1.04												
2011	3290	209	657	101	4257	1,023,542	366,368	1,277,070	274,206	2,941,186	1,011,444	360,733	1,253,397	274,206	2,899,779	41,407
2012	3521	214	672	121	4528	1,095,190	375,169	1,306,422	329,047	3,105,829	1,082,245	369,399	1,282,205	329,047	3,062,896	42,933
2013	3732	219	688	139	4778	1,160,902	384,191	1,336,476	378,404	3,259,973	1,147,179	378,282	1,311,702	378,404	3,215,567	44,406
2014	3956	224	703	160	5044	1,230,556	393,438	1,367,249	435,164	3,426,407	1,216,010	387,387	1,341,904	435,164	3,380,466	45,942
2015	4193	230	720	184	5327	1,304,389	402,917	1,398,759	500,439	3,606,504	1,288,971	396,720	1,372,830	500,439	3,558,960	47,544
2016	4445	235	736	202	5619	1,382,652	412,635	1,431,023	550,483	3,776,793	1,366,309	406,288	1,404,496	550,483	3,727,576	49,217
2017	4712	241	753	223	5928	1,465,611	422,596	1,464,062	605,531	3,957,800	1,448,288	416,096	1,436,923	605,531	3,906,837	50,963
2018	4994	247	771	245	6256	1,553,548	432,808	1,497,894	666,084	4,150,334	1,535,185	426,151	1,470,127	666,084	4,097,547	52,787
2019	5294	253	788	269	6604	1,646,761	443,276	1,532,539	732,693	4,355,269	1,627,296	436,458	1,504,130	732,693	4,300,577	54,692
2020	5559	258	799	280	6895	1,729,099	452,142	1,552,692	762,000	4,495,934	1,708,661	445,188	1,523,910	762,000	4,439,759	56,175
2021	5837	263	809	291	7200	1,815,554	461,185	1,573,144	792,480	4,642,363	1,794,094	454,091	1,543,982	792,480	4,584,648	57,715
2022	6128	268	820	303	7519	1,906,332	470,408	1,593,898	824,180	4,794,818	1,883,798	463,173	1,564,352	824,180	4,735,503	59,315
2023	6435	274	831	315	7854	2,001,648	479,816	1,614,961	857,147	4,953,572	1,977,988	472,437	1,585,024	857,147	4,892,596	60,977
2024	6757	279	842	328	8205	2,101,731	489,413	1,636,336	891,433	5,118,912	2,076,888	481,885	1,606,003	891,433	5,056,209	62,703
2025	7094	285	853	341	8573	2,206,817	499,201	1,658,030	927,090	5,291,138	2,180,732	491,523	1,627,295	927,090	5,226,640	64,498
2026	7449	290	864	354	8958	2,317,158	509,185	1,680,047	964,173	5,470,564	2,289,769	501,354	1,648,904	964,173	5,404,200	66,364
2027	7822	296	876	369	9362	2,433,016	519,369	1,702,393	1,002,740	5,657,518	2,404,257	511,381	1,670,836	1,002,740	5,589,214	68,304
2028	8213	302	887	383	9785	2,554,667	529,756	1,725,074	1,042,850	5,852,347	2,524,470	521,608	1,693,096	1,042,850	5,782,024	70,323
2029	8623	308	899	399	10229	2,682,400	540,351	1,748,094	1,084,564	6,055,410	2,650,694	532,040	1,715,690	1,084,564	5,982,988	72,422
2030	9054	314	908	415	10692	2,816,520	551,158	1,765,575	1,127,947	6,261,200	2,783,228	542,681	1,732,846	1,127,947	6,186,702	74,498
2031	9507	321	917	431	11176	2,957,346	562,181	1,783,231	1,173,064	6,475,823	2,922,390	553,535	1,750,175	1,173,064	6,399,164	76,659

Table C.6 Vehicle Operating Cost Benefit (Climbing Lane, Guardrail) [33]

Akyurt - Kalecik Road Time Saving Values

Gross National Product (GNP) :	
(TÜIK_2009)	13,269 TL / Year
	1,106 TL / Month
Work period in 1 month (In 1 Month, 22 day and 8 hour in a day	176 Hour
Passenger Time Cost	**6.283 TL/Hour**

The Number of Passengers per Vehicle

CAR	BUS
3	32

Length (KM)	
Existing Road	4
New Road	4

Type of Vehicle	Passenger Time Cost per Vehicle (TL/KM)		
	Existing Road	New Road	Benefit
Car	0.2416	0.2217	0.0199
Bus	2.6806	2.6110	0.0696

Type of Vehicle	Speed (Km/Hour)	
	Existing Road	New Road
Car	78	85
Bus	75	77

Year	Traffic		New Route Passenger Time Cost (TL)			Existing Route Passenger Time Cost (TL)			Time Benefit (TL)
	Car	Bus	Car	Bus	Total	Car	Bus	Total	
2011	3075	204	995,566	777,563	1,773,129	1,084,912	798,298	1,883,209	110,081
2012	3290	209	1,065,255	796,224	1,861,479	1,160,855	817,456	1,978,312	116,832
2013	3521	214	1,139,823	815,351	1,955,175	1,242,115	837,094	2,079,209	124,035
2014	3732	219	1,208,213	834,957	2,043,170	1,316,642	857,223	2,173,865	130,695
2015	3956	224	1,280,706	855,055	2,135,760	1,395,641	877,856	2,273,497	137,737
2016	4193	230	1,357,548	875,656	2,233,203	1,479,379	899,006	2,378,386	145,182
2017	4445	235	1,439,001	896,774	2,335,774	1,568,142	920,688	2,488,830	153,055
2018	4712	241	1,525,341	918,422	2,443,763	1,662,230	942,914	2,605,144	161,381
2019	4994	247	1,616,861	940,615	2,557,477	1,761,964	965,698	2,727,663	170,186
2020	5294	253	1,713,873	963,367	2,677,240	1,867,682	989,057	2,856,739	179,499
2021	5559	258	1,799,567	982,634	2,782,201	1,961,066	1,008,838	2,969,904	187,703
2022	5837	263	1,889,545	1,002,287	2,891,832	2,059,119	1,029,015	3,088,134	196,302
2023	6128	268	1,984,022	1,022,333	3,006,355	2,162,075	1,049,595	3,211,670	205,315
2024	6435	274	2,083,223	1,042,779	3,126,003	2,270,179	1,070,587	3,340,766	214,763
2025	6757	279	2,187,384	1,063,635	3,251,019	2,383,688	1,091,998	3,475,687	224,667
2026	7094	285	2,296,754	1,084,908	3,381,661	2,502,873	1,113,838	3,616,711	235,050
2027	7449	290	2,411,591	1,106,606	3,518,197	2,628,016	1,136,115	3,764,131	245,934
2028	7822	296	2,532,171	1,128,738	3,660,909	2,759,417	1,158,838	3,918,255	257,346
2029	8213	302	2,658,779	1,151,313	3,810,092	2,897,388	1,182,014	4,079,402	269,310
2030	8623	308	2,791,718	1,174,339	3,966,057	3,042,257	1,205,655	4,247,912	281,855

Table C.7 Time Benefit (Climbing Lane, Guardrail) [33]

Akyurt - Kalecik Road Evaluation Table

(Climbing Lane, Guardrail Design)

YEARS	BENEFITS (Existing-New)					COSTS				Cost Difference Between Existing and New Project	Net Benefits of the New Project, According to Existing Project (TL)
						Existing		New			
	Accident	Vehicle Operating Cost	Time	Maintanance	TOPLAM	Construction Cost	Others	Construction Cost	Others		
2010	0	0	0	0	0	0	0	1,620,000	565966	2,185,966	-2,185,966
2011	393,732	41,407	110,081	-24,118	521,101	0	0	0	140,000	140,000	381,101
2012	401,607	42,933	116,832	-24,118	537,254	0	0	0	140,000	140,000	397,254
2013	409,639	44,406	124,035	112,014	690,093	0	0	0	140,000	140,000	550,093
2014	417,832	45,942	130,695	-24,118	570,350	0	0	0	140,000	140,000	430,350
2015	426,189	47,544	137,737	-24,118	587,351	0	0	565,966	92,294	658,260	-70,909
2016	434,712	49,217	145,182	-16,490	612,622	0	0	0	140,000	140,000	472,622
2017	443,407	50,963	153,055	-24,118	623,307	0	0	0	140,000	140,000	483,307
2018	452,275	52,787	161,381	-24,118	642,324	0	0	0	140,000	140,000	502,324
2019	461,320	54,692	170,186	112,014	798,212	0	0	0	140,000	140,000	658,212
2020	470,547	56,175	179,499	-24,118	682,102	0	0	565,966	92,294	658,260	23,842
2021	479,958	57,715	187,703	-152,622	572,754	0	0	0	140,000	140,000	432,754
2022	489,557	59,315	196,302	112,014	857,187	0	0	0	140,000	140,000	717,187
2023	499,348	60,977	205,315	-24,118	741,522	0	0	0	140,000	140,000	601,522
2024	509,335	62,703	214,763	-24,118	762,683	0	0	0	140,000	140,000	622,683
2025	519,522	64,498	224,667	112,014	920,701	0	0	565,966	92,294	658,260	262,441
2026	529,912	66,364	235,050	-152,622	678,704	0	0	0	140,000	140,000	538,704
2027	540,510	68,304	245,934	-24,118	830,631	0	0	0	140,000	140,000	690,631
2028	551,321	70,323	257,346	112,014	991,003	0	0	0	140,000	140,000	851,003
2029	562,347	72,422	269,310	-24,118	879,961	0	0	0	140,000	140,000	739,961
2030	573,594	74,498	281,855	-24,118	905,828	0	0	565,966	92,294	658,260	247,568

Economical Analysis Result

Discount Rate % :	**8.00**	
Internal Rate of Return :	**0.1840**	
NET Present Value (NPV):	**2,010,666**	TL
Benefit/Cost Ratio (B/C) :	**1.4904**	

Table C.8 Benefit Cost Analysis Result (Climbing Lane, Guardrail) [33]