Towards a Road Safety Development Index (RSDI)

Development of an International Index to Measure Road Safety Performance

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Norrköping, Sweden 2005
To my parents, my wife, and my sweet little boy Aghyad
with deep love and appreciation

“...Road safety is no accident, the theme for this year’s World Health Day, reminds us that road safety does not happen by chance. Achieving and sustaining safety on the roads requires deliberate action from many sectors of society...”.

Kofi Annan’s Secretary-General of the United Nations

Message on the World Health Day, observed 7 April/2004
The United Nations, News Centre- Press Releases- SG/SM/9224 OBV/415
(United Nations, 2004)
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Ghazwan Al Haji

ABSTRACT

**Aim.** This study suggests a set of methodologies to combine different indicators of road safety into a single index. The RSDI is a simple and quick composite index, which may become a significant measurement in comparing, ranking and determining road safety levels in different countries and regions worldwide. **Design.** One particular concern in designing a Road Safety Development Index (RSDI) is to come up with a comprehensive set of exposure and risk indicators which includes as far as possible the main parameters in road safety related to human-vehicle-road and country patterns instead of considering few and isolated indicators such as accident rates. The RSDI gives a broad picture compared to the traditional models in road safety. **Challenges.** The differences in definitions, non-collection of data, no reliability of data and underreporting are problems for the construction of RSDI. In addition, the index should be as relevant as possible for different countries of the world, especially in developing countries. **Empirical study.** This study empirically compares the road safety situation and trends between ten Southeast Asian countries and Sweden for the period 1994-2003. **Methodologies.** Eleven indicators are chosen in RSDI, which have been categorised in nine dimensions. Four main approaches (objective and subjective) are used to calculate RSDI and determine which one is the best. One approach uses equal weights for all indicators and countries, whereas the other approaches give different weights depending on the importance of indicators. **Findings.** The thesis examines the RSDI for the ten ASEAN countries and Sweden in 2003. The results from this study indicate a remarkable difference between ASEAN countries even at the same level of motorisation. Singapore and Brunei seem to have the best RSDI record among the ASEAN countries according to the indicators used, while Laos, Cambodia and Vietnam show lower RSDI records. **Conclusions.** The RSDI results seem very promising and worth testing further applications with bigger samples of countries and from different parts of the world.

Key Words: Road safety, RSDI, ASEAN, international comparisons, Human Development Index, ranking, principal components, composite indicators, macro-performance indicators, macro-models.

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Ghazwan Al Haji

Norrköping, Sweden
May 2005
### List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ADB</td>
<td>Asian Development Bank</td>
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<tr>
<td>ASEAN</td>
<td>Southern Asian Nations</td>
</tr>
<tr>
<td>ASNet</td>
<td>Regional Traffic Safety Network to Ten South East Asian Countries</td>
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<tr>
<td>DC</td>
<td>Developing Country</td>
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<td>EU</td>
<td>European Union</td>
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<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>Globesafe</td>
<td>Globe Road Safety Database</td>
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<td>GRSP</td>
<td>Global Road Safety Partnership</td>
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<tr>
<td>HDC</td>
<td>Highly Developed Country</td>
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<tr>
<td>HDI</td>
<td>Human Development Index</td>
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<td>HMC</td>
<td>Highly Motorised Country</td>
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<td>IRF</td>
<td>International Road Federation</td>
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<tr>
<td>LMC</td>
<td>Low Motorised Country</td>
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<tr>
<td>NGO</td>
<td>Non-Governmental Organisation</td>
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<tr>
<td>OECD</td>
<td>Organisation For Economic Cooperation and Development</td>
</tr>
<tr>
<td>RetsNet</td>
<td>Regional Traffic Safety Network to Five African Countries</td>
</tr>
<tr>
<td>RSDI</td>
<td>Road Safety Development Index</td>
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<tr>
<td>SIDA</td>
<td>The Swedish International Development Agency</td>
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<tr>
<td>SPIDER</td>
<td>The Swedish Program for ICT in Developing Regions</td>
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<tr>
<td>TechTrans</td>
<td>Developing E-learning Courses in Road Safety to Russian Universities</td>
</tr>
<tr>
<td>UNDP</td>
<td>United Nations (Development Program)</td>
</tr>
<tr>
<td>VRU</td>
<td>Vulnerable Road Users</td>
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<tr>
<td>WB</td>
<td>World Bank</td>
</tr>
<tr>
<td>WDI</td>
<td>World Development Indicators, World Bank</td>
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<td>WHO</td>
<td>World Health Organisation</td>
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Chapter 1

Introduction

The purpose of this chapter is to briefly present the outline of this thesis as well as explaining the reasons why this study is of interest. A brief description of the concept of ‘Road Safety Development Index’ (RSDI) is given and the aim of the study is highlighted. In addition, this chapter outlines the structure of the thesis.

1.1 Relation to previous work

During the last few years, I have worked on a variety of international projects focusing on road safety development in developing countries. One of the most important lessons I have learned is that the concept of Road Safety Development is broader and more complex than what I have learned in theory during my undergraduate years and master’s study. I now realise how much this development in road safety requires deeper processes, integrated programs and much more cooperation between all the key bodies, which are responsible for road safety in the country. Road safety concerns everyone and all aspects of life.

My master’s thesis (Al Haji, 2001) dealt with the extension of one project called RetsNet ‘Regional Traffic Safety Network’. At that time, the primary purpose of this project was to strengthen the cooperation and technology transfer in road safety between five south African1 countries and Sweden. The project was successful in bringing these countries together and sharing experience. More recently, I have been involved in several overseas projects; these are the ASNet project, TechTrans project, and SPIDER project. The ASNet project ‘The ASEAN Road Safety Network’ started in November 2003. It is designed as an Internet networking system and devoted to the Southern Asian Nations (ASEAN)2 professionals and institutions. The ASNet members can discuss issues affecting the road safety field and exchange expertise in the region as efficiently and widely as possible.

1 This refers to the countries: Botswana, Malawi, Namibia, South Africa and Zimbabwe
2 ASEAN countries are: Brunei, Cambodia, Indonesia, Laos, Malaysia, the Philippines, Singapore, Thailand, Vietnam and Myanmar
The TechTrans project started in December 2003. It aims to establish a sustainable virtual resource centre at the State Technical University (MADI) in Moscow, Russia. This project developed e-learning courses and applications in the field of road safety to Russian universities. The other project that I am currently working on is called the SPIDER project ‘The Swedish Program for ICT in Developing Countries’. This project aims to create programmes and applications for higher education adapted to the needs of developing countries. The project focuses on three developing countries for cooperation with: Burkina Faso, Sudan and Vietnam.

During these overseas experiences and our visits to different countries, I had the opportunity to discuss road safety development with local professionals and consultants. There I also had the opportunities to attend various conferences, seminars and workshops and to listen to experts from different countries. This was a rewarding learning experience, which was especially meaningful for me in terms of future contacts. There were always questions raised during this work, for instance, how do we define and measure road safety development in a country? How do we determine the progress this country has achieved? How do we establish targets for road safety improvement in a country? Until now, there is no simple answer to these questions. This has inspired me to develop sets of macro-indicators that can be used as appropriate benchmarks to compare the performance of different countries. I started to use previous results of the projects as a point of departure, in order to build a model from the conclusions drawn.

By keeping this goal, some two years ago. I, together with my advisor³, met representatives of many departments and organisations in Sweden, such as the Swedish International Development Agency (SIDA)⁴, World Health Organisation (WHO)⁵ and Karolinska Institute⁶ where we have introduced a new concept of road safety performance, which we called RSDI ‘Road Safety Development Index’. We emphasised the broader concept of road safety development more than the accident rates that are currently used.

To address national development in the area of road safety, it is desirable to view road safety level in a global context. Road safety is a complex issue and there is a high number of factors and indicators involved in the accidents. This situation leads me to examine several theories and models in order to compare the achievements in road safety between different countries and regions. The problem itself is underestimated in many countries, especially in developing countries where the issue is challenging. The progress in any country will be minimum unless the country has a good and standard measurement to rely on (e.g. RSDI), in comparisons and problem formulation.

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³ Kenneth Asp (Professor), Linköping University, Sweden. E-mail address: kenas@itn.liu.se; Tel: +46 11 363497
⁶ Karolinska Institute is a medical university in Sweden, website: http://www.ki.se (last accessed 2005-05-15)
1.2 Purpose of the study

The purpose of this study is to integrate and summarise much information and knowledge about road safety into measurable indicators, which will be then converted into a single value. The study develops methodologies and approaches for constructing RSDI. This will allow RSDI to make a direct comparison and will rank road safety progress internationally. Therefore, RSDI is capable of increasing the awareness of road safety problems among the public and policy makers. This information will help a country’s policy makers to take appropriate decisions, setting targets and priorities for the future. The RSDI is developed to be as simple and easily understandable by ordinary people as possible. I believe that over time, the RSDI index I am developing in this study will be useful for road safety research. It may become a significant index in ranking and determining road safety levels worldwide.

1.3 Target of the study

By constructing the RSDI, the road safety level of different countries can be compared directly. This will be useful for researchers who have an interest in working on international comparisons and analysis. It will also be of interest to governments and international organisations to refer to the RSDI index since it will show the scale of the problem that they were perhaps not aware of. Other targets of this research are the country policy makers and ordinary persons. This index will help them to understand the magnitude of the problem and to draw attention to this phenomenon.

1.4 Approach and thesis overview

There are several steps involved in this study in constructing the RSDI as illustrated in Figure 1.1 that are organised into six chapters, with the relations between different chapters and sections. I begin in chapter two by showing the scope of road safety problem worldwide and how it concerns every country. Then in chapter three I provide a theoretical background of all the factors that could contribute to road accidents by showing the relationship between each factor and the probability that road accidents may happen from the macro-level. Following this, the key macro-performance indicators will be identified. These indicators should be easy, available, measurable and comparable worldwide. This leads me to make a comparative review of macroscopic models and methodologies used in describing and comparing road safety development internationally. This will support the theoretical framework of the RSDI index. In chapter four, I gather data regarding the identified macro-indicators and apply some of the previous models to this data. The empirical (case) study comes from ten Southeast Asian countries (ASEAN region). Chapter five is a more practical part where I assess the importance of the chosen indicators and then I discuss different approaches in normalising (standardising) the variables and weighting them. I combine the weighted indicators into the index (RSDI) by using different techniques. This will include an application of RSDI to ASEAN countries and I perform an analysis of the results. In
Chapter six: the conclusions are drawn from the previous discussion and moreover an indication of future work is given. The appendix concluding the thesis gives the overall data of the case study and indicators used in calculating RSDI.

![Figure 1.1: Structure of the thesis.](image)

1.5 Terminology

There are several terms concerning road safety issues and their applications. It is not possible to give a precise definition of all the terms used in the following chapters. This would run to many pages and discussions. It may be useful for now to go briefly through the key terms that are frequently used and differences from one study to another. Readers should bear in mind that the meaning of each term depends on the context and the subject of discussion.

In this thesis, the term "Road Safety" is often used instead of "Traffic Safety" because this thesis focuses on road traffic safety only including road user safety and vehicle safety. The term “Traffic Safety” is a general term and could refer to the safety of all traffic modes: air traffic, sea, rail and road.

Some studies are not comfortable with the term "accidents" that describes road safety problems as accidents that happen by random chance. They prefer to use the term "crash" instead of accidents. In this thesis, as accidents is a popular term and widely
used, I prefer to keep it. Accidents can be simply classified as fatal, serious, slight and damage only. The term "casualties" means both deaths and injuries.

I used the term "aggregated data" to describe the group of data from a macro and national level e.g. number of injuries in the country, whereas "disaggregated data" refers to detailed information and smaller groups from a micro and local level e.g. number of injuries by age and transport mode.

The distinction between developed and developing countries is a hard matter. The term "developing countries" is rather misleading because all countries are developing today. Developing countries are officially classified on a human development index (according to the United Nations) or on an economic basis. Whether we call this group developing country, less developed countries, underdeveloped countries, third world, south, or other names; there is no precise definition of the term "developing countries". Some international studies, e.g. Jacobs et al. (2000), consider "vehicle ownership" as the most appropriate criteria to define developing countries e.g. "less motorised countries". This term again has no direct meaning; in particular many developing countries have high motorisation levels similar to those of developed countries. Also, the question of whether the number of vehicles can be considered as a sign of development in a country. In contrast, many European countries are currently discussing whether to stop or reduce the increasing level of motorisation. For the purpose of this study and because of the lack of something better, I use the term "Highly Developed Countries" (HDCs), e.g. North America, Western Europe and Japan, and "Less Developed Countries" (LDCs) are the remaining countries.

The term "composite index" is used throughout this thesis to mean the combination of several indicators. The "indicator" itself is a measure derived from variables. In this study the indicator is not any measure and it is normally used to show the level of performance in the country. The indicator can be presented as an average or accident rate. The term "risk" better emphasises the accident rate.

The term e-Learning refers to anything delivered, by electronic technology for the purpose of learning. Internet-based distance education (learning) is often called online learning or e-learning.
Chapter 2

Road Safety is a Global Issue

The purpose of this chapter is to give a brief overview of the scope of the road accident problem worldwide and how it is a serious problem almost everywhere. Also it aims to show a comparative summary of the road safety situation across different regions over the world.

As the use of motor vehicles is continuously increasing globally, road traffic accidents have become an increasing cause of deaths and injuries. The most recent World Health Organisation (WHO) statistics (Peden M et al., 2004) shows that almost 1.26 million people are killed in road accidents each year worldwide and an additional 50 million people are estimated injured. Nearly half of them are seriously injured or disabled. Due to the unreliability and under-reporting of data in most countries, these figures are still under-estimated. The road traffic injuries ranked currently as the ninth leading cause of the global burden of disease and injury. WHO estimates road accidents will become the world's third leading cause of death by the year 2020 (after heart disease and deaths linked to mental illnesses) if no effective actions and efficient measures are taken.

The road safety problem has seen in many countries as accidents that happen by chance. In the year 2004, road safety received a considerable attention at national and international levels. This was a result, among with other things, from the WHO health day on 17th April. WHO launched a global campaign titled “Road Safety is No Accident” to raise awareness about road traffic injuries and costs. The message of the campaign indicates that road injuries can be prevented by appropriate countermeasures and policy. However, many efforts still need to be taken to reduce the severity of this problem in the years to come.

Apart from these tragic injury losses, road accidents also lead to serious consequences for family social life and the economy. Annually, the cost of road accidents is between one and three percent of a country's Gross National Product (GNP). In a few developing countries, the cost probably is less than this (one per cent of GNP) but this is still a
major loss for these countries. Developing countries cannot afford such a considerable waste of resources because they need them for their development.

According to one study carried out by TRL (Jacobs *et al.*, 2000), the majority of road deaths and injuries occur in developing and transitional countries, with approximately half of all fatalities in Asia and Pacific. Highly developed countries (HDCs) have sixty percent of the total motor vehicle fleet but they contribute only to fourteen percent of the total global road accident deaths. Trends from these data show that the total number of road fatalities in HDCs has been declining or stabilising during recent decades, whereas the situation in developing countries is particularly severe and the total number of fatalities continues to increase.

Although Asia has the highest proportion of global road fatalities, Africa has the highest road death rate per number of vehicles. Al Haji (2001) performed a comparative study internationally for fatal accidents, motorisation (vehicles per person), personal risk (deaths per person), and traffic risk (deaths per vehicle). Results (Figure 2.1) show that developed countries have the lowest risk records with high motorisation, while Africa has the lowest motorisation with high traffic risk. The South East Asia countries together with Africa and the Middle East have the highest risk of being killed in terms of personal safety. This comparison should not be taken too seriously, since there are differences within the same region concerning motorisation, population, education, health, welfare, GDP, etc. Most recent international comparisons look within similar countries in the same situation of development.

![Figure 2.1: Motorisation, personal risk and traffic risk in different regions in 1995 (Al Haji, 2001)](image)

Notes: Motorisation is taken in this figure as the number of vehicles per 100 persons.  
Personal Risk is fatalities per 100,000 inhabitants.  
Traffic Risk is fatalities per 10,000 vehicles.  
( ) = Number of selected countries.
It should be emphasised that the majority of road accident victims (injuries and fatalities) in developing countries are the vulnerable road users (pedestrians, cyclists, motorcyclists and non-motorised vehicle (NMV) occupants), whereas car occupants account for most of the victims in high-income countries since there are many people who own cars (Asp et al., 1998). Pedestrians are mostly the main victims anywhere in developing countries, throughout Asia, Africa and the Middle East. In Southeast Asia, a substantial percentage of the victims are cyclists and motorbike riders. Globally, road accidents are the main cause of death in the 15- to 35-year-old age group, which represents a major loss of human resources and productivity in society.

Because of the rapid economic growth, motorisation and urbanisation in developing nations are growing very fast. These create a pressure on the transport infrastructure, which is not sufficient or ready to meet such an increase in the number of vehicles and people. The lack of institutional framework, appropriate engineering, education, and law enforcement are important explanations for the severity of the safety problem in these countries. There is a need to bring together all the key departments, agencies and professionals in an effort to improve road safety in the country.

Nevertheless, there is also a need for a transfer of information and experience between countries for accident prevention and reduction. E-learning techniques are good examples of such a technology transfer and cooperation between countries. Linköping University in Sweden is one of the international institutes, which has taken part in several road safety activities and projects in developing countries (i.e. the ASNet project). Additionally, the Global Road Safety Partnership (GRSP)\(^7\), among others, is an active international agency that facilitates knowledge sharing and delivers several road safety projects to less developed countries.

The Theoretical Framework of Macro-Indicators and Models in Road Safety

The purpose of this chapter is to give a literature survey of the most important macro factors and concepts in road accidents. It describes the road safety problem as a function of three dimensions (exposure, risk and consequences). The chapter discusses the relationship between different factors and accident risk. This will be useful to choose the most important performance indicators that could be used as benchmarks in international comparisons. I also give a brief literature review of the most important and/or recent macroscopic models in road safety that are used for describing the development in road safety in a country and internationally. Finally, I conclude this chapter with important notes regarding under-reporting of data and the correction factor.

There is a growing interest globally in macroscopic indicators and models in road safety due to the importance they can play in describing the road safety situation in a country, comparing the development and assessing the effect of different measures. This chapter is divided into three main parts. The first part describes the relationship between risk, exposure and safety. The second part identifies the key macro-performance indicators, which will help later in constructing the RSDI index (Chapter 5). The third part provides a review of macro-models that are usually used for comparing the development in road safety in a country and internationally.

3.1 The quantitative relationship between risk, exposure and safety

As young road users represent a high risk in accidents all over the world, we might say that a developing country, which has high proportion of young people of the total population, should have more casualties than those of the developed countries where they have low birth rates as well as an older age group. Similarly, countries with a high proportion of motorcycles or vulnerable road users on roads should have more casualties than those countries where most road users are well protected inside vehicles. In the same context, as rich people are healthier than poor people because they have
better access to hospitals and health services, so we might say that rich countries are healthier (safer) than poor countries. In the same way, one can try to assess the differences between countries in relation to other types of factors such as: weather differences between countries, age of vehicles in a country, the expenditure rate on road safety measures, etc.

Although there are many attempts have been made to describe road accident problem, I used to describe the problem as a disease where the causes of road accidents are symptoms as (illness). The road safety problem is a sign of illness in society. To diagnose the problem, there are direct and indirect symptoms (causes). The direct symptoms in road safety can be easily seen in society from simple observation and data such as: speed problems, alcohol and driving, vehicle conditions, road user behaviour, etc. The indirect symptoms in road safety are not simply obvious and they need more checking and examination such as: the traffic management, education, traffic police enforcement, legislations, etc.

It is generally known that the amount of road safety problems in a country can be observed by the large number of accidents, large number of casualties, high severity level of accident consequences, high risks in travel, and high cost. There are many studies and much research in road safety that have attempted to formulate a theory or model that can explain why accidents happen. Hauer (1982) defined the road safety problem as the product of Exposure and Risk. Rumar (1999) illustrated the road safety problem as a function of three dimensions: exposure, accident risk for a certain exposure and injury consequences.

3.1.1 What are the Exposure, Risk and Consequences?

*Exposure* is an important dimension in road traffic that refers to the amount of travel in which accidents may occur. The more we travel on roads, the higher the probability of an accident to occur. Without traffic or mobility, there will be no accidents and no road safety problems. Many studies show that there is a correlation between vehicle traffic volume and the total number of accidents. Moreover, traffic volume (mobility) is one of key issues, which is needed to promote the sustainability of transport in any country.

At present, there are many ways of measuring exposure. In international comparisons as well as for national statistics, the population size, urban population, the number of vehicles, length of road network and number of driving licenses are possible and available indicators of exposure. However, these indicators, as found in many studies, do not always work as good measures of exposure. This is due to the differences in socio-economic conditions between countries, population density, vehicles per citizen, and transport mode split.

The number of kilometres vehicles travelled is generally considered as a relevant exposure measure and is defined as the sum of the distance travelled by all motor
vehicles in the country over a year (the distance travelled per vehicle multiplied by the number of vehicles). Unfortunately this measure is not often available in most countries. Many countries do not have any national system/scale for counting travel volume on the basis of this measure, where they estimate the kilometres driven by either the total fuel sales (consumption) in the country or they give an estimated equal average distance for each car driven (amount of kilometres per year). In fact, these assumptions are not fully accurate because of the differences in fuel consumption and the distances travelled by each type of car and vehicle. Also one should remember that the amount of kilometres is gathered more on urban roads, which are busier than those in rural areas.

The lack of detailed and quality exposure data is a challenging issue and therefore, international comparisons are often conducted on the basis of a per-capita population or per-vehicle. There is a need for detailed exposure information on a specific population (e.g. children or elderly road users), non-motorised modes (e.g. cyclists and pedestrians), motorcycles, and driver information. This information is often less known and available in many developing countries than in highly developed countries. The classifications of roads also differ in their standards from one country to another (e.g. national/regional/motorways). There is a need for special counts of traffic volume by type of vehicle and type of roads.

Calculation and gathering of annual exposure traffic data is not a simple issue and it needs to be conducted in a regular and systematic manner for each group of road user, type of roads, time, etc. Besides travel, surveys are increasingly expensive in many countries especially in developing countries. Fortunately, more advanced technologies have now become more available in most countries. They are cheap and effective in calculating exposure of travel (e.g. widespread use of mobile telephones, telecommunications technologies inside vehicles and along roads) that it hopes will provide better and more accurate exposure variables that can be used in international comparisons.

**Risk:** is determined as the probability of an accident to happen per units of exposure or it is valuated as the size of consequences (severity) of this accident. The higher the accident risk, the higher is the probability of an accident to occur for a given road user in one particular place and time. Sometimes the term risk of accident is named as accident rate.

When comparing different countries, the indicators of fatality per population and fatality per vehicle are widely used and they vary from country to country and over time. Both measures do not take into consideration the characteristics of the type of transport modes or the road users. The risk per exposure unit has generally shown a clear decrease over time in most countries. This is an indication of an improvement in the overall accident situation in most countries where they produce lower accident rates for each unit of exposure. However, the exposure unit itself (i.e. number of vehicle or vehicle kilometres travelled) has continued to increase and more casualties occur on
roads in many countries. It is internationally found that the risks for accidents are higher in the countries with low motorisation (vehicle fleet) level and in countries that have experienced very rapid and quick motorisation.

Consequences: The third dimension in describing the road safety situation is the risk of injury severity (consequence variable) in an accident, which refers to the outcome of accidents in terms of injuries. The severity of the consequences of an accident ranges from fatalities and serious injuries down to slightest and damage only.

By multiplying the three dimensions (Exposure, Risk, and Consequences) we get the total number of killed or injured persons or accidents in road traffic. Rumar (1999) described the road safety problem as a function of three dimensions, which are ‘exposure’ (E), ‘accident risk’ (A/E) for a certain exposure and ‘injury risk’ (I/A). This is illustrated in Figure 3.1 where the volume of the cube determines the size of the road safety problem. Any change in any one of these three dimensions will change the whole safety situation in a country.

The shaded area indicates the number of accidents (A). The total number of deaths or injured persons (I) = Exposure (E) * Accident risk (A/E) * Injury severity (I/A).

Figure 3.1: Road safety problem described by three-dimensional cube (Rumar, 1999)

This formula can be transformed to the fatality rate. An example of this expression is:

\[
\frac{\text{fatalities}}{\text{inhabitants}} = \frac{\text{exposure}}{\text{inhabitants}} \times \frac{\text{accidents}}{\text{exposure}} \times \frac{\text{fatalities}}{\text{accidents}}
\]

If we take the number of vehicles as an exposure measure, we find:

Personal Risk = Motorisation * Traffic Risk
These formulas would allow us to compare and illustrate the road safety situation among countries. Thulin & Nilsson (1994) have shown how exposure, risk and consequences vary for different transport modes and age groups in Sweden.

In principle there are three main ways for reducing this size of safety problem in response to any change in the three dimensions:

- **Reducing Exposure Factors**: by reducing the amount of travel per person or vehicle and the total reduction in traffic volume.
- **Reducing Risk Factors**: by reducing the accident rate for a given unit of exposure (travel). It is possible to reduce this by improving driver skills, road user education, vehicle performance, road standards, legislation and enforcement.
- **Reducing accident severity**: by protecting people better in vehicles from injury severity. Protecting pedestrians and other vulnerable road users by vehicle design, and protecting two wheelers by using appropriate helmets.

Shifting travel from means of transport with high exposure and risk (e.g. motorcyclists) to means that have a low level such as public transport can influence the level of the safety situation in the country.

### 3.1.2 Correlation between the quantified macro factors and road accidents

Many studies have shown that there are many factors that can be chosen as risk factors that increase the probability of accidents to occur and their severity. The correlation between any factor and road accidents means that they both increase and decrease simultaneously. For example, if an increase in speed causes an increase in road accidents it means both are correlated. The degree of such a correlation differs from factor to factor and is usually measured by using different statistical techniques and it ranges from zero to one. If one, it means the factor is highly correlated to road accidents and if zero there is no correlation at all. In this section I will not discuss these techniques in detail, but instead I focus on the results from several sources have been reviewed. I have tried to select recent studies demonstrating long international experience in this field. For example, the *Handbook of Road Safety Measures* (Elvik & Vaa, 2004) provides a wide literature survey and meta-analysis of different road safety measures made in relation to accidents in different countries. I will provide a summary of the most important factors in relation to risk, exposure and consequences at the end of this section. However, I know that it is hard to identify all those macro-factors that have the potential to contribute to accident occurrence and consequences. In all approaches, the chosen factors should be relevant to the concept of road safety that one is seeking to measure.

#### I. Risk and Road User Behaviour

Different studies indicate that the human factor (road users) is the major contributory factor to accidents. At the same time, any error in the system and on roads will lead to unsafe road user behaviour:
Speed and risk of crash involvement: Speed has been identified as a highly important influencing factor concerning road safety risk and consequences. An increase in average speed results in a higher risk of involvement in an accident and greater severity. In many countries, speed contributes to a significant percentage of all deaths on the roads. Leaf & Preusser (1999), for example, concluded that reducing vehicle speeds could have a highly significant influence on pedestrian accidents and injuries. Garber & Gadiraju (1988) determined that accident rates increased with increasing variance of speed.

Alcohol and risk of crash involvement: Drivers with high BAC (Blood Alcohol Content) in their blood have more chance of being killed than those with zero BAC (sober drivers). Hakkert & Braimaister (2002) provided a review of many studies and reported that the risk in traffic will increase rapidly with BAC. Such results have given the basis for setting BAC limits in many countries (e.g. .08 g/dl). Thoresen et al. (1992) have shown a positive correlation between the total number of fatalities in Victoria state in Australia with alcohol sales and inverse relationship with random BAC breath testing.

Age of drivers and risk of crash involvement: Road accidents are the leading cause of death for young drivers and motorbike riders. The risk by age group per kilometre travelled and per hour exposed to traffic is higher among young people (15-24) and old (65+). However the exposure for young is higher than old people. Evans (1991) reported that young male drivers are overrepresented in accidents in the US. Page (2001) concluded from a survey in OECD countries that the higher the proportion of young people in the population, the higher the number of road accident fatalities.

Use of helmets: Motorcycle helmets have been shown to have a clear impact on reducing fatal and serious injuries by between 20% and 45% (WHO, 2004). The same study shows that bicycle helmets reduce the risk of head and brain injuries between 60% and 80%. Wearing helmets reduces the probability of being injured by around 25% (Elvik & Vaa, 2004). Many countries have legislated mandatory helmets use, which has been effective in preventing, or reducing the severity of two-wheeler riders (motorcyclists and cyclists). The use of helmets varies from country to country. In high-income countries, the usage rate tends to be high.

Use of seat belts: Road accident research has found that seat belts reduce the fatal injuries significantly and it can reduce the risk of fatal injury to front-seat passengers. The use of seatbelts varies from country to country. In high-income countries, the usage rate tends to be high. In Sweden for instance, seatbelt usage exceeds 90% (Koornstra et al., 2002). The use of seat belts reduces the probability of being killed by 40-50% for drivers and front-seat passengers and by 25% for passengers in the back seats as shown in (Elvik & Vaa, 2004). Regarding the use of safety seats for children and infants, studies (e.g. WHO, 2004) have shown that reduce infant deaths in cars by 70% and deaths of small children by 50%. Mandatory seat belt use proves to provide strong
protection against fatalities in accidents in different countries according to various studies.

II. Risk and Road Conditions: Motorways have the lowest risk on injury accidents compared to other types of roads because of the separation between vehicle movements according to their speed (no high speed variance). (Elvik & Vaa, 2004) show that the rate of injury accidents per million vehicle kilometres of travel on motorways is about 25% of the average for all the public roads. Road surface conditions, poor road surface, defects in road design and maintenance contribute to an increase in the risk of accidents. Bester (2001) reported that countries with more paved roads will lead to lower fatality rates.

III. Risk and vehicle related factors: New cars tend to have more safety and protection features, such as air bags, anti-brake system (ABS), etc. There is relation between vehicle age and risk of a car crash. One study (in WHO, 2004) showed that occupants in cars manufactured before 1984 have almost three times the risk of new cars. Many developed countries improved vehicle crashworthiness and safety, which means the protection that a vehicle gives its passengers (and to the VRUs) from a crash. Many countries in the European Union (EU) as well as USA have set out legislation for safety standards in motor vehicles, for instance the New Car Assessment Program (NCAP), where vehicle crash performance is evaluated by rating the vehicles models according to their safety level for occupant protection, child protection and pedestrian protection. Vehicle defects increase the risk of accident. The size of vehicle is crucial; the greater the mass of the vehicle (e.g. heavy trucks), the more protection people have inside the vehicle (their occupants) and the more involved in fatal accidents to others. It is known that poor vehicle maintenance and technical conditions can also contribute to accidents. In terms of periodic vehicle inspection, different research shows different results. (Elvik & Vaa, 2004) concluded in the review of macro-studies that there is no clear evidence that periodic vehicle inspection has an effect on the number of accidents, while (Hakim et al. 1991) presented in another review of macro-studies that the periodic inspection of motor vehicles reduces the number of road fatalities.

IV. Risk and post-crash injury outcome: Different studies have shown that fatality rates are correlated with the level of medical facilities available in the country expressed in terms of population per physician and population per hospital bed, see (Jacobs & Fouracre, 1977) and (Mekky, 1985). A review of a European study, in (WHO, 2004), showed that about half of deaths from road accidents occurred at the spot of the accident or on the way to the hospital. Noland (2003) concludes that medical care has led to reductions in traffic-related fatalities in developed countries over time (1970-1996). The variables used are: infant mortality rates, physicians per capita, and average acute care days in hospital.

V. Risk by different transport modes: The ETSC report (1999) has compared the risk of different transport modes in EU countries and it shows that the risk for cars (expressed
in terms of fatality per hundred million passenger hours or kilometres travelled) is 10
times greater than buses. The risk for the vulnerable modes (foot, cycle and motor-
cycle/moped) is 80-200 times more than buses. Motorised two-wheelers are the highest
risk among all other modes. The study gave a rough assumption of travel speed by the
transport modes.

VI. Socio-Economic Factors and Risk: There are many socioeconomic factors that
contribute to the causes of accidents. Some of the major factors are the following:

Gross National Product GNP: It is widely known that the motorisation rate (vehicle per
population) increases with income (GNP per capita). This may affect both exposure and
the risk of fatal accidents. Many studies (e.g. World Bank, 2003) have shown that the
fatalities per vehicle appear to decline rapidly with income. Maybe this reflects the shift
from vehicles with high risk (motorbikes, foot) to safer and protected vehicles (e.g.
four-wheelers) or it may show more funds and expenditure being spent by the country
on its road safety measures. There is a negative relationship between income growth and
the number of road accidents in the long term (Hakim et al. 1991). The increase in
income leads to safer vehicles and more investment in road infrastructure, that leads to
fewer road accidents and casualties. However, it should be clear that the improvement
of income could also increase the travel distance (higher exposure) and more alcohol
consumption (higher risk).

Unemployment: Few studies have used the unemployment factor as a risk factor for
accidents. It appears to be negatively related to accidents and casualties. Hakim et al.
(1991) has shown in the literature review he made that an increased unemployment rate
in country might reflect on the ability to pay for a single journey and a reduced exposure
to the whole journey. Page (2001) included employment (percentage of population in
employment) into his model in the study conducted for the OECD countries (1980-
1994). The higher employment figures showed an increase in the number of fatalities.

Urban population: Urban roads will have more accidents and fewer fatalities or severity
per kilometre travelled than rural roads, because of the density of vehicles and the lower
speeds of travel. Hakkert and Braimaister (2002) have shown in one macro-study that
countries with a high level of urbanisation will have higher population densities and
they may experience lower levels of fatalities and serious injuries. Page (2001) has
found that the population who live in urban areas have fewer road accident fatalities
than other places. Bester (2001) also reported similar results that countries with higher
road densities will have fewer fatality rates. Shorter distances to medical services can
explain this.

Illiteracy: Bester (2001) has analysed socio-economic factors in different countries and
he found that the illiteracy percentage has a statistically significant effect on the national
fatality rate. He explained that a country that can read and write is expected to influence
the ability of road users to understand the rules of the road and road signs.
Technology level: Few studies have described the decline in the number of fatalities in all industrialised countries as a result of the increase of technology use in vehicle and road infrastructure (i.e. Evans, 1991).

VII. Risk and other factors: Different macro studies have shown that the risk of crash will increase by other factors such as: poor visibility, using hand-held mobile telephones, dark conditions, wet roads and roads that are covered with snow or ice (Elvik & Vaa, 2004), (Evans, 1991). There is an inverse relationship between accidents and the average gasoline prices (Hakim et al., 1991). It seems that an increase in the price of gasoline reduces the number of trips and the exposure. Similarly, there is an inverse relationship between number of accidents and the number of driving licenses delivered (Van and Wets, 2003). Moreover, the road safety audit process is shown to have a clear impact on the number of accidents (Proctor et al., 2001). However, there is lack of data concerning all these factors and they are not available in many countries.

To sum up, what I have now of the main points discussed, is a classification of the most important of factors into three categories of exposure, risk and consequences as shown in the following table:

Table 3.1: Factors influencing exposure, risk and consequences

<table>
<thead>
<tr>
<th>Factors influencing exposure to traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Economic factors and GNP per capita</td>
</tr>
<tr>
<td>- Urban population density, and other demographic factors</td>
</tr>
<tr>
<td>- Type of travel mode choice</td>
</tr>
<tr>
<td>- Travel route</td>
</tr>
<tr>
<td>- Length of trip</td>
</tr>
<tr>
<td>- Mix of traffic</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Factors influencing risk of accident</th>
</tr>
</thead>
<tbody>
<tr>
<td>- To driver: speed, alcohol and driving, being young, etc.</td>
</tr>
<tr>
<td>- To groups of road users: unprotected road users</td>
</tr>
<tr>
<td>- To vehicles: Motorcyclists, heavy trucks, non-motorised traffic, defects, age of car, etc.</td>
</tr>
<tr>
<td>- To roads: intersections, unpaved, defects in road design, poor maintenance, etc.</td>
</tr>
<tr>
<td>- To environment: darkness, fog, ice, etc.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Factors influencing accident severity (Consequences)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Human factors: speed, alcohol</td>
</tr>
<tr>
<td>- Vehicle: active and passive safety (e.g. seatbelts, airbags, child safety seat, vehicle safety and protection standards)</td>
</tr>
<tr>
<td>- Helmets worn by users of motorcyclists and cyclists</td>
</tr>
<tr>
<td>- Crash-protective road sides, guardrails, barriers</td>
</tr>
<tr>
<td>- Poor rescue and pre-hospital emergency care</td>
</tr>
<tr>
<td>- Poor country health care system</td>
</tr>
</tbody>
</table>

I believe this summary will be useful in obtaining a picture of the whole safety situation in a country. It will contribute to the selection of macro-indicators in more detail, as will be discussed in the next section. These performance indicators can be checked and determined whether if they can be used as benchmarks in international comparisons.
3.2 Macro-indicators of performance in road safety

In road safety, there are a large number of variables (causal factors) contributing to road accidents and their severity. The weight of each variable depends on the conditions of the accident, place and time. According to the studies and evaluations shown in the last section, there is no single cause of accidents and it is hard to pick up one factor (or even a few of them) as being more important than the others. From this, removing any factor that contributes to or causes the accidents will not provide a fully and quick satisfactory solution to road accident problems. However, in many studies and theories it is shown that accidents are caused by a combination of five main dimensions (human-vehicle-environment-road-system). These dimensions are not fully independent of each other and each dimension is influenced by many factors. I can express this function as: \( Y = F(X) \), where \( Y \) is the number of accidents or the accident rate, and \( X \) is a vector matrix of the explanatory variables in each of (human-vehicle-environment-road-system). The safety situation can also be quantified by a combination of risks in traffic as probabilities (e.g. speed risk, alcohol and driving risk, etc.). For instance this can be indicated by the following formula (Koornstra, 1996):

\[
SAFETY = \sum (w_1 R_1 + w_2 R_2 + \ldots + w_n R_n) \times \text{kilometres}
\]

Where
- \( R \) is the risk of particular factor
- \( \text{kilometres} \) is the exposure in traffic, and
- \( w \) is the weight of the risk factor in a particular country

One of the major contributory factors in road accidents is human error (for example violation of speed limits). The type, size and frequency of these human errors depend on the whole road system and traffic regulations, which must be designed in a way to be safe and protective of such human errors.

The indicator itself is a value derived from variables. The choice of each indicator is crucial, which depends on the type of data being collected, what we want to measure, and for whom this indicator will be used (target group). Indicators can be used at the highest national levels to measure or assess the progress being made towards a certain goal, such as reducing the number of accidents and injuries in the whole society. At the local level, indicators can be used to measure the daily/monthly activities through which measures can reduce the number of accident in a certain place and time (e.g. young pedestrians involved in an accident at particular intersection). The ordinary road user (at micro- or individual level) is more concerned with his/her danger or what is meant by the probability of accident on the way from his home to work or to school. This is associated with the type of his/her behaviour on a particular road and the use of a particular mode of transport, while policy decision makers (at top level) are often interested in the number of total accidents, deaths and injuries in the whole of society and in the way to reduce them and the cost.
3.2.1 The macro-performance indicators in road safety and their purposes

Macroscopic road safety performance indicators refer to all national measurements that could indicate the country’s progress over time in road safety, to monitor this progress or any changes in countries’ efforts, and to allow international comparisons. The macro-indicator is a value that quantifies something that affects the national road safety level and it can be measured as a number (e.g. number of fatalities), a percentage (e.g. percentage of front-seat belt usage), a rate (e.g. number of fatalities per population), or as qualitative information (e.g. level of national data collection and reporting: Very Good, Good, Fair, Unsatisfactory). The number of accidents, deaths and injuries tells us nothing about the safety level or the process that produces accidents. Not all indicators and data used at a local and provincial level can be used nor are available at a national level. Most of the detailed data is available only at a local level. The need for macroscopic performance indicators in road safety becomes more important and necessary to every country so that they can measure and monitor the progress they made against other countries.

Data can be converted into different forms; some common forms include percentages, rates, and indices. The national multidimensional index integrates and summarises much information and knowledge about road safety into measurable indicators that will be then converted into a single value. In this section, I will discuss the overall concept of criteria and macro-performance indicators. This will also be useful in designing a multidimensional index Road Safety Development Index (RSDI) (this will be discussed in Chapter five). Figure 3.2 shows hierarchical development of the data and availability from local to national level. I focus in this part of the study on the indicators that are used in national and international levels.

Figure 3.2: The pyramid of road safety indicators and levels of performance
3.2.2 Criteria for selecting macro-performance indicators in road safety

The value of each chosen indicator is expected to correlate with the road safety outcome, which means it is related to the probability of accidents to occur under different conditions. It is possible to find multiple indicators relating to a single meaning. This needs a clear selection especially of which ones to choose and why. For instance, if I take the health level in a country as an example (road safety is a health matter), possible indicators could measure this: the proportion of the total health care expenditure as a percentage of GDP, life expectancy at birth (years), physicians per population, hospital beds per population, etc. However, a higher number of ‘hospital beds’ in a country does not necessarily lead to better health. In addition ‘Life expectancy at birth’ which is being used by HDI, is not enough to measure the health level in a country. The focus should be first on more comprehensive and efficient indicators and second on the outcomes (outputs)\(^8\) not on the mere numbers. In terms of road safety, I might add the severity index (proportion of deaths per total accident casualties) as a good indicator of health, which severity index decreases with better medical facilities and rescue services.

Consider, for instance, the indicators that can be used to measure the change of the number of drivers above the legal BAC limits or driving exceeding speeds limits checked by police in one particular country over a year. This change could indicate a higher real traffic violation rate, but at the same time it can be sign of an increased level of reporting and checking by police.

On the way to develop a complete set of macroscopic performance indicators that can be used for international comparisons, one needs to remember that such a choice is restricted by certain conditions and requirements for both the indicators and data:

First, the indicators should have effect on road safety if any change in indicator occurred (relevant to the concept). They should represent the improvement in the situation and be reasonably accepted from different studies and literature surveys.

Second, one should care about the quality of each indicator and data. There are usually several data sources available from which we can find data to measure. But the data should come from one or more reliable sources (national and international).

Third, the indicators chosen should be clear and with a precise definition. For example, an indicator of ‘safer vehicles or urban roads standards’ without a clear and precise definition of what we mean by the words safe or standards could easily lead to an unclear collection of data. This will likely lead to a misunderstanding of what results are being achieved.

\(^8\) An example of the outcome indicators (in health sector) that have been developed in recent years are: the number of specific surgical operations are made in the country annually, and the level and spread of infectious diseases in the country.
Fourth, the reliability of any indicator means that there is no real, major and sudden change in the indicator for a country being measured between different sources and over time.

Fifth, indicators should be simplified, to various degrees, in order to make it possible to measure and to be easily understood by the widest possible audience. Some indicators are simple, have a relatively direct meaning and can be expressed in units which most people are comfortable with (e.g. motorcycles as a percentage of total fleet vehicles). Other indicators are more complicated but have a long experience in the field and are supported by research (e.g. fatalities per vehicle kilometres travelled).

Sixth, we should always use a group of indicators relating to the desired objective we want to describe. But at the same time, we should not allow the set of indicators to become too many because that will take too much time to interpret and analyse (also it is a matter of cost). There is no exact number of indicators; rather the number should at least capture the results sufficiently for what we want to obtain. The chosen indicators should be as minimal as possible. For instance, road user behaviour in the country may require many indicators to capture the major aspects. However, we should remember that if we have identified a large number of indicators for single aspect, this might mean that the aspect is too complex or more data is being collected than necessary. In brief, it needs a well-balanced set of indicators as possible.

Last, as is known, the data collection process should be available year-to-year. This will make the indicators available and accessible whenever data is needed. The data and indicators should be updated more frequently.

3.2.3 Sample of survey and the multidimensional index

It is not possible to collect data from all countries to examine the chosen indicators. This needs work from international organisations. A sample of countries might well be enough to select at this stage. For the purpose of this study, data has been obtained from ASEAN countries as will be shown in the next chapter.

3.2.4 Quantitative versus qualitative indicators

Not everything in road safety that is known and is important can be counted. Many of the measurements (indicators) of development involve subjective judgments. For example, the degree of development of the ‘National Road Safety Program (NRSP)’ in a country cannot be easily quantified into numbers. Often these judgments can be measured, using questionnaires or opinions of expert panels, and be translated into rating systems. But here we need to assume that the expert panels are recognised as full experts in this area of interest. Also we will assume that the combined information they have is good enough to judge on this issue we seek for. Moreover, it would be difficult to obtain the opinions of experts regularly whenever they are desired. The point here is
not to decide on which measurement techniques to use or to say quantitative indicators are meaningful measures or better than qualitative indicators. Rather this requires that the indicator should be clearly defined, measured, regularly available and be comparable over time.

3.2.5 IT supports the macro-performance indicators

Computer databases can facilitate the accessibility to a large road safety data, indicators and other information from different countries. This will allow a quick analysis of the data with regular updating. Then the databases could provide this information to the country policy makers and to the public, which will help them in drawing attention to these phenomena. The Globesafe database (Asp, 2004) in Sweden is one good example of such an advanced database. It is an Internet-based tool that collects, harmonises and analyses the accident and exposure data for the purpose of global comparisons. The Globesafe database is regularly maintained to ensure the accuracy of information.

3.2.6 Several types of indicators

The first step in doing international comparisons is to come up with a comprehensive set of macro-indicators that includes all possible main valuable parameters in road safety of human-vehicle-road-environment-regulation instead of considering a few factors such as accident rates per population or per kilometre driven. Selecting a set of macro-performance indicators is a complex issue where the importance of each indicator depends on its type, availability and quality. Many previous studies and models (discussed in detail in the next section) have presented few indicators on the national level. The reasons can be given briefly here as follows: (i) the lack of availability and reliability of data; (ii) the need for simplification in the study (model) to avoid any possible errors; (iii) to reduce the costs of the study.

The ETSC report (ETSC, 2001) can serve as a good example in developing a comprehensive set of performance indicators as the most valuable measures in road safety in the European Union. The study has outlined four performance themes which are first in behaviour: speed, alcohol, seat belts; second vehicles: passive safety, third roads: percentage of roads meeting design standards; and fourth on trauma management: arrival time and quality of medical treatment. However, the chosen indicators in this study are more general, and they are in progress (as mentioned in the report) as is the question of how these indicators should be applied between European union countries in an example of real data.

I have identified eight groups of indicators (see Figure 3.3) of which each corresponds to a special area of road safety. The groups listed are: traffic risk, personal risk, socio-economic indicators, road safety organisational structure, traffic police and enforcement, vehicle safety, roads situation and road user behaviour. The groups measure road safety development in terms of output or input classes. The output
indicators are derived measures (outcomes or direct symptoms), for example fatalities rates (traffic risk and personal risk) and they are considered as good measures for explaining national road safety development in a direct way. The input indicators are individual means (processes or indirect symptoms) in the way they could describe the development in a particular theme to road safety.

I have attempted to identify a set of performance macro-indicators from a literature review, either in how they illustrate road safety level and development in a country or how they offer a significant affect on accident rates. The quantitative relationship between the indicators and risk was discussed in the previous section. The indicators should be selected on the basis of the discussed criteria for selecting macro-performance indicators. Special attention has to be paid to indicators covered by data, which is already available. The chosen categories and indicators will not provide a complete picture of road safety issues in a country, rather they will give summary information on the national performance in the country, which can help in comparing its progress and experience with other countries.

The full summary list of the possible macro-indicators in each category is shown in Table 3.2. The indicators have been classified into three classes according to their data availability, quality and type. When dealing with data availability, as with quality, it is necessary to have clear description of what is meant by ‘data quality’ or ‘data availability’. For instance, one acceptable indicator is ‘fatalities per vehicle kilometre’ and it is an important element in road safety, but this measure is still not available in most developing countries. On the other hand, the indicator ‘percentage of motorways per road network’ has poor quality of data and there is difference of definitions of road standards across countries. In fact, there are several indicators that may play an essential role in the development of RSDI, but unfortunately these indicators are hard to measure for now and they will be kept for further and future development.
The indicators may either be quantitative/objective or qualitative/subjective. In some indicators, there is lack of quantitative information and it will be better if I include subjective indicators. Subjective indicators can be considered as complementary indicators. Both ‘ organisational structure’ and ‘enforcement measures’ are based purely on subjective assessments and at this stage it is a major problem to gather experts’ assessment regarding both dimensions and to measure subjective indicators. However, I believe that both dimensions can be developed and become more concrete indicators for the future.

A high availability of data means that enough data is available to access at all times. Medium means that data is under development (work in progress) and there is a call for data collection in these indicators. A low rating means that data is currently not available and they require further development and collection of data in the future for a large number of countries, especially from developing countries.

A high quality of data means that data comes from reliable sources without errors and the results are accurate. Acceptable data means that it is fairly reliable and accurate. Poor quality means that we have a data quality problem and the results are questionable and should not be fully trusted. Not rated means indicators are not identified for now and there is no indication what the quality could be in future.

The increase in availability of data will improve the quality of data. In other words, the quality of indicators is good when data is available. I attempted to estimate the size of quality and availability of the indicators as be given in (Table 3.2), although it is often hard to estimate that. However, any such future attempt would require especial techniques (done directly with computer) used to assess the availability and quality of data in different countries worldwide. The selection of the key macro-indicators is not final. The indicators will continue to be developed and refined. Further, efforts will be made to enable high quality data delivery.

In Chapter 5, I will try to select a list of the quantitative macro-indicators from (Table 3.2) and they will be used in the construction of RSDI. It is not possible to gather all sets of macro-indicators are shown in the table into the RSDI index. This is because they are many and they will take too much time to interpret and analyse. Besides, some of the indicators require further development, which involves availability and definitions. The most appropriate indicators with high data availability and acceptable quality will be selected and linked together in the RSDI index. The number and type of indicators depend on the development level of the country, motorisation level (vehicles per population), and availability of data. In the long term it might be possible to use more dimensions and indicators. Further, it is possible to split up the indicators into two separated groups, one group is devoted to developing countries and the one other group is relevant for developed countries where they have better and more data collection.
Table 3.2: The sets of macro road safety indicators and characteristics

<table>
<thead>
<tr>
<th>Core Dimensions and Indicators</th>
<th>Availability</th>
<th>Quality</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Road User Behaviour:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of seat belt use</td>
<td>Medium</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td>Percentage of crash helmet use</td>
<td>Medium</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td>Percentage of drivers above the legal BAC limit in police checks</td>
<td>Low</td>
<td>Poor</td>
<td>Objective</td>
</tr>
<tr>
<td>Percentage of all drivers exceeding speed limits</td>
<td>Low</td>
<td>Poor</td>
<td>Objective</td>
</tr>
<tr>
<td>Consumption of alcohol per capita (litres)</td>
<td>Medium</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td>Minimum age for driving</td>
<td>Medium</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td><strong>Vehicle Safety:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Index of national crashworthiness (vehicle crash performance)</td>
<td>Low</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td>Distribution of vehicles by age: Percentage of new cars</td>
<td>Low</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td>Mass classes of car fleet (%)</td>
<td>Low</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td>Percentage of buses and coaches in total vehicle fleet</td>
<td>High</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td>Percentage of vehicles not motorcycles</td>
<td>High</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td><strong>Rods Safety:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of roads paved</td>
<td>High</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td>Total paved roads (km) per capita/vehicles</td>
<td>High</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td>Total motorways/freeways (km) per capita/vehicles</td>
<td>Low</td>
<td>Poor</td>
<td>Objective</td>
</tr>
<tr>
<td>Km of motorway per km of paved road</td>
<td>Low</td>
<td>Poor</td>
<td>Objective</td>
</tr>
<tr>
<td>National expenditure in road (engineering/maintenance) % GDP</td>
<td>Low</td>
<td>Poor</td>
<td>Objective</td>
</tr>
<tr>
<td>National expenditure in road (safety measures) % of GDP</td>
<td>Low</td>
<td>Poor</td>
<td>Objective</td>
</tr>
<tr>
<td>National expenditure in road per total vehicles</td>
<td>Low</td>
<td>Poor</td>
<td>Objective</td>
</tr>
<tr>
<td>Road density (km/1000 km2)</td>
<td>High</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td><strong>Socioeconomic indicators:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of urban population</td>
<td>High</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td>Population density (people per km2).</td>
<td>Medium</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td>Life expectancy (years)</td>
<td>Medium</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td>Population per physician</td>
<td>Medium</td>
<td>Poor</td>
<td>Objective</td>
</tr>
<tr>
<td>Population per hospital beds</td>
<td>Medium</td>
<td>Poor</td>
<td>Objective</td>
</tr>
<tr>
<td>Average acute care days related road accidents in hospital</td>
<td>Low</td>
<td>Poor</td>
<td>Objective</td>
</tr>
<tr>
<td>Severity index (number of fatalities per total casualties)</td>
<td>Medium</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td>Illiteracy: percentage of persons over 15 years unable to read</td>
<td>Medium</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td>Gross National Product (GNP) per capita</td>
<td>High</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td>Percentage of people in unemployment</td>
<td>Medium</td>
<td>Poor</td>
<td>Objective</td>
</tr>
<tr>
<td><strong>Traffic Risk:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fatality rate (per vehicles-km)</td>
<td>Low</td>
<td>Good</td>
<td>Objective</td>
</tr>
<tr>
<td>Fatality rate (per person-km)</td>
<td>Low</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td>Fatality per vehicles</td>
<td>High</td>
<td>Good</td>
<td>Objective</td>
</tr>
<tr>
<td>Fatality per paved road</td>
<td>Medium</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td>Percentage of fatalities trend (increase or reduction) over time</td>
<td>Medium</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td><strong>Personal Risk:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fatality rate per population</td>
<td>High</td>
<td>Good</td>
<td>Objective</td>
</tr>
<tr>
<td>Fatality rate per population age</td>
<td>Medium</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td><strong>Traffic Police and Enforcement:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The annual number of random breath tests (per vehicles)</td>
<td>Low</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
<tr>
<td>The technical means/equipments are available to the traffic police</td>
<td>Low</td>
<td>Not Rated</td>
<td>Subjective</td>
</tr>
<tr>
<td><strong>Organisational structure:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How far the cooperation between the key bodies</td>
<td>Low</td>
<td>Not Rated</td>
<td>Subjective</td>
</tr>
<tr>
<td>The development of the ‘National Road Safety Council’ and NGO’s</td>
<td>Low</td>
<td>Not Rated</td>
<td>Subjective</td>
</tr>
<tr>
<td>The funds level are spent on road safety measures</td>
<td>Low</td>
<td>Not Rated</td>
<td>Subjective</td>
</tr>
<tr>
<td>Legislations level, data collection level and statistics</td>
<td>Low</td>
<td>Not Rated</td>
<td>Subjective</td>
</tr>
<tr>
<td>Inspection of vehicles</td>
<td>Medium</td>
<td>Not Rated</td>
<td>Subjective</td>
</tr>
<tr>
<td>Number of driving licenses delivered per total vehicles fleet</td>
<td>Low</td>
<td>Acceptable</td>
<td>Objective</td>
</tr>
</tbody>
</table>

Objective indicators mean data obtained from international sources, while subjective indicators are complementary indicators and obtained from a survey of experts. A high availability of data means enough data are available to access at all times; medium means data is under development (work in progress); while a low rating means that data is currently not available and they require further development. A high quality of data means data comes from reliable sources without errors and the results are accurate; acceptable means data are fairly reliable; poor quality means that we have a data quality problem and the results are questionable; while not rated means indicators are not identified for now and there is no indication what the results could be in future.
3.3 Macro-models for describing, comparing and forecasting the road safety development internationally

Research on aggregated road accidents data has already progressed nationally and internationally. The characteristics between factors and road safety (e.g. exposure versus risk) have been studied at microscopic and macroscopic levels in several articles and models (i.e. OECD, 1997). The focus of this section is on the macroscopic models that are usually used for describing the development in road safety in a country and internationally. The road safety situation is a complex issue and there is a need to examine and develop new models, especially with the highly involved number of accidents factors and indicators. The model is a representation of the actual data and formulas. The models help us to compare countries’ road safety performance between each other by means of risk and exposure indicators. Several attempts have been made to use vehicle, population and fatalities together in the models in describing the development of road safety over time. The models can help in predicting and monitoring the number of fatalities in the country. The question raised is how fatalities can be explained by a few explanatory variables and how the models will fit the result data? Special cases of comparisons in these models consider few indicators together and describe how they interact with each other. In this section, I divide the models into cross-sectional models (time-independent models) and time-dependent models. The cross-sectional models are used in the regression analysis and they are observed at one point in time (e.g. for the same year). The time-dependent models are observed over time and the data is called time series data.

3.3.1 Linking motorisation, traffic risk and personal risk

In 1949, R. J. Smeed compared twenty countries, mostly European for the year 1938, where he developed a regression model (log-linear model) and he found an inverse (or negative) relationship between the traffic risk (fatality per motor vehicle) and the level of motorisation (number of vehicles per inhabitant). This regression represented the best estimates of the mean values of traffic risk for each given value of motorisation (what is called least square). This shows that with annually increasing traffic volume, fatalities per vehicle decrease (see Figure 3.4). Smeed concluded that fatalities (F) in any country in a given year are related to the number of registered vehicles (V) and population (P) of that country by the following equation:

\[
\frac{F}{V} = \alpha \left(\frac{V}{P}\right)^{-\beta}
\]  

(3.1)

Where

- \( F \) = number of fatalities in road accidents in the country
- \( V \) = number of vehicles in the country
- \( P \) = population
- \( \alpha = 0.003, \beta = 2/3 \)
This formula became popular and has been used in many studies. It is often called as Smeed's formula or equation despite some authors preferring to call it a law.

This nonlinear relationship can be translated to a linear one by taking the logarithms of the two sides: \( \log Y = \log \alpha + \beta \log X \), where \( Y = F/V \) and \( X = V/P \).

The number of fatalities can be derived from Smeed’s formula as: \( F = c.V^{\alpha}P^{\beta} \), where \( c, \alpha, \beta \) are parameters and they are estimated from data by using the least square method.

For the Smeed data (year 1938) the formula was: \( F = 0.0003 P^{2/3} V^{1/3} \)

Personal Risk (fatalities per population) is obtained by multiplying both sides of Smeed’s equation (3.1) by \( V/P \) as follows: \( F/P = a(V/P)^{1-b} \) or \( F/P = 0.0003(V/P)^{1/3} \)

Since 1949, many studies have been discussed on the basis of Smeed’s equation (3.1) or they made a reference to this formula. Some authors followed the equation of estimating the regression parameters (\( \alpha, \beta \)) of the data by calculating the country road safety performance in comparison to other countries; see Jacobs and Hutchinson (1973), Jacobs (1982), Mekky (1985). They found that Smeed’s formula can give a close estimation of the actual data and it can be applied to different sample sizes of countries and years with the use of different values of \( \alpha \) and \( \beta \). Jacob and Fouracre (1977) applied this formula to the same sample of countries used by Smeed for the years 1968-1971 and they found that the formula remains stable. Jacobs and Hutchinson (1973) examined the data for 32 developing and developed countries from the year 1968. Mekky (1985) found that the equation significantly captures the relationship between motorisation and traffic risk; he used cross sectional data for the Rich Developing Countries (RCDs). Al Haji (2001) compared 26 countries around the world with different levels of development. The results from this study support Smeed’s view of the relation between motorisation and fatality rates. The correlation was high, 96% of the variations are explained for the low motorised countries and 93% for the highly motorised countries.
Some authors have tried to develop Smeed’s formula and its accuracy further by including several socio-economic variables in the model. Fieldwick (1987) has included speed limits in the same model. The number of registered vehicles has been replaced by the total vehicle kilometre driven in many late studies (e.g. Silvak, 1983). This measure (vehicle kilometre driven) was not available at the time of Smeed’s study.

Nevertheless, some other studies have tried to explain why the curve of development (fatality rates) declines downwards as been noted in many countries and shown in Smeed’s formula. The studies have analysed the factors and measures that influence the development of the curve of road safety. A review of these studies is reported by (Elvik & Vaa, 2004) and (Hakim, 1991). Besides, Minter (1987) and Oppe (1991b) showed that Smeed’s law is a result of a national learning process over time. The development in society at the national level is the result from the developments at the local level. In other words, the individuals (road users) can learn by experience in traffic where they improve their driving skills and knowledge, while the whole society can learn by better national policy and action plans. The Figure shown here illustrates these factors on the development curve of road safety.

![Figure 3.5: The influencing factors on the development curve of road safety](image)

At the same time, many studies have criticised Smeed’s model because it only concentrates on the motorisation level of country and ignores the impact of other variables, see (Broughton, 1988), (Andreassen, 1985), (Adam, 1987), where according to Smeed’s model, population and vehicles are the only country values, that influence the number of fatalities. This means that road safety measures have no meaning because road fatalities can simply be predicted from population and vehicle numbers in any country and any year. Andreassen (1985) criticised the model’s accuracy because there would always be a decline in traffic risk for any increase in the number of vehicles, but generally in non-linear way. Andreassen proposed relating fatalities to \((V)^{B_4}\) where \(B_4\) is a parameter highly related to each particular country, even to countries with a similar degree of motorisation. Furthermore, Smeed’s study analysed data for one year, it was a
cross-sectional analysis with no time series analysis (Adam, 1987). Smeed’s formula expected the downtrend in fatalities rate but not the number of absolute fatalities, which has occurred in almost most western countries in the seventies (Broughton, 1988). In other words, the trend failed to fit and predict the same as the real figures in HDCs. Broughton has concluded that: “Smeed’s formula has no generally validity”

In later years Smeed (in Oppe, 1991a) has commented on some of these remarks that: “...We must be guided by the data and not by our preconceived ideas...The number of fatalities in any country is the number that the country is prepared to tolerate...”

Also, Haight (in Andreassen, 1985) has referred to Smeed’s equation that: “…When the formula disagrees with the observations we tend to assume that the particular area under investigation is safer or less safe than it ought to be…”

Regardless of whether one agrees or disagrees with Smeed’s model, the fact remains that the model gave a simplified and fairly good representation between traffic risk and motorisation of different parts of the world during the earlier stages of road safety development.

At the same time, there are many other curves developed and presented in different studies in a simple way and with a small number of indicators (motorisation, personal risk and traffic risk), which can describe the development of road safety in different countries. For instance, Koornstra & Oppe (1992) have suggested the model shown in (figure 3.6) to describe the long-term development of the number of fatalities over time in highly developed countries (HDCs). There is an increasing S-shaped curve with regard to the development of motorisation (referring to the number of vehicle kilometres per year). There is a decreasing curve for the development of the fatality rates per year (traffic risk). Together, by multiplication the values of motorisations and fatality rates, they result in the increase and decline of the number of fatalities that have been noticed in HDCs in recent decades.

Figure 3.6: Road safety development in HDCs (Koornstra & Oppe, 1992)

Haight (1983) illustrated the development of road safety in developing countries as shown below. The total number of fatalities increases, the fatalities per unit of travel
decreases, and the fatality per population remains almost stable or with some decline over time.

Figure 3.7: Road safety development over time for developing countries (Haight, 1983)

The long-run trends which are shown in (Figure 3.6) and (Figure 3.7) based mainly on repeated cross-section surveys from different countries for different years. The objective is to show whether the change (development) of data varies over time.

The Timo model (1998) shows curves of number of fatalities and total national mileage by time in many eastern and western Europe countries according to the development levels of mobility (Figure 3.8). At the beginning of the growth of motorisation, total fatalities are very high, but decline continuously at a declining rate when mobility increases. When the mobility reaches the saturation level, the decrease in the number of fatalities has slightly stopped or fluctuated.

Figure 3.8: Total fatalities based on the development of mobility (Timo, 1998)

The correlation between traffic risk (fatalities per number of vehicle kilometres) and personal risk (fatalities per number of population) is shown in Figure 3.9. With a growing number of vehicles per population, countries move from the right to the left across the curve (Fred, 2001). An early level of motorisation, first leads to a growing
number of traffic-related deaths, but not necessarily with the same high growth in the number of population-related deaths. However, later at a medium level of motorisation, traffic and personal risks increase and both values are high. At the third higher stage of motorisation, when a country is completely motorised, traffic and personal risks decrease. The change between the three stages is due to better engineering of vehicles and roads and greater understanding of the system by the road users.

As we discussed earlier, the personal risk is a function of traffic risk and motorisation. Navin (1994) has converted this function into the following equation (see also Figure 3.10):

$$ T = T_f e^{-M} $$

Where

- $M_0$ is the value of motorisation at maximum personal risk,
- $T_f$ is the point where the exponential curve meets the $T$-axis,
- $T$ is the traffic risk, fatalities per number of vehicles, and
- $M$ is the motorisation, vehicles per population

Figure 3.9: Traffic risk and personal risk in different countries where countries move from the right to the left across the curve (Adapted from work by Fred, 2001)

Figure 3.10: Three-dimension model of motorisation and fatality rates (Navin, 1994)
The models previously mentioned are in some way based on regression models or multiple regression models or quadratic regression models. They employ more than variables to check the goodness of fit to data from different countries and to find the appropriate related equation(s). On the other hand, many macro-models have been developed to describe and predict safety development in developing countries on the basis of time series models and theories. They relate the variables to a function of time to determine the long run change in safety level over time either in a monthly form or annually. These models attempt to find the smoothed curves to the time series data. This is discussed in the section below.

3.3.2 Linking traffic risk, motorisation and personal risk with time

(Koornstra, 1992) has shown that motorisation is considered to be dependent on time, and the relationship between deaths and population should include time. To measure the correlation between the output and input variables, one should take into account the trends in the model. He found the following formula for approximating the number of fatalities for a country in a particular year:

\[ F_t = cF_t^{(V_{t-k})} \left( \frac{V_{t-k}}{V_{t-k}} - 1 \right)^y \]

Where 
- \( F_t \) is the number of fatalities for a country in a year \( t \),
- \( V_t \) is the number of vehicle kilometres travelled in the year \( t \),
- \( V_{\text{max}} \) is the maximum number of vehicle kilometres,
- \( k \) is the time lag in years, and
- \( x, w, z, y, \) and \( c \) are constants.

Oppe (1989) assumes that fatality rates follow a negative exponential learning function in relation to the number of vehicle kilometres and time. This method has been found to be most effective when the components describing the time series behave slowly over time as follows:

\[ \ln \left( \frac{F_t}{V_t} \right) = \ln (R_t) = \alpha t + \beta \]

Or, equivalently:

\[ R_t = e^{\alpha t + \beta} \quad (3.2) \]

Where 
- the \( \ln \) function is the natural logarithm,
- \( F_t \) is the number of fatalities for some country in a year \( t \),
- \( V_t \) is the number of vehicle kilometres travelled in that year,
- \( R_t \) is \( F_t/V_t \) and
- \( \alpha, \beta \) are constants.

This means that the logarithm of the fatality rate decreases (sign of improvement) if \( \alpha \) is negative proportional with time. This model is called the negative exponential learning model, where \( \alpha \) is supposed to be less than zero. Both \( \alpha \) and \( \beta \) are the parameters to fit.
Oppe (1991a) assumes that the amount of vehicle kilometres per year is related to time and it is assumed that traffic volume will develop over time by a logistic function of a saturation model. This assumption indicates that the growth rate of traffic volume is a percentage of the ratio between the traffic already existing and the remaining percentage of $V_m$ as follows:

$$\ln\left(\frac{V_t}{V_m-V_t}\right) = \alpha t + \beta$$

Or, equivalently:

$$V_t = \frac{V_m}{1 + e^{-(\alpha + \beta)t}} \quad (3.3)$$

Where $V_t$ is the number of vehicle kilometres travelled in that year, and $V_m$ is the maximum number of vehicle kilometres.

This formula shows that countries with a large $\alpha$ should have a fast growth in traffic. The traffic volume will increase quickly first and at the end it will reach its saturation level, which differs from country to country.

Oppe has applied the two formulas (3.2 and 3.3) to data from six highly motorised countries over the time period 1950-1985. He found that both models describe the data fairly well. He concluded that the development in road safety is a result of the development (learning) of the traffic system in the country, which is more or less similar to Smeed’s conclusions. However, Oppe’s theory in estimating the remaining growth of traffic is questionable, particularly when we know that many European countries are currently discussing the possibility to stop or reduce the increase rate of motorisation. It is uncertain whether the number of fatalities can be predicted simply from the fitted curves or from the number of vehicle-kilometres. The question is therefore whether this decreasing equation (3.2) assumes that the fatality rate reduces to zero in the end or not, and in this case what is the predicted year for one particular country according to its current level of mobility? Besides, what will happen to the expected number of fatalities if the country’s trend becomes fully motorised to 100%.

Adams (1987) has stated a similar relation between fatalities (F) and vehicle kilometres (V), which was presented: $\log(F/V) = a + b\cdot y$ where $y =$ year – 1985. Broughton (1988) has tested this logarithmic model on data from Britain between 1950 and 1985 and the results fitted well. In the same study Broughton applied the same model to data from four western countries: U.S.A (1943-85), West Germany (1965-85), Norway (1947-85) and New Zealand (1948-83). He found that this model describes the data pretty well.

(Broughton 1991) and (Oppe, 2001a) they developed another technique, the ‘singular value decomposition method’, in comparing road safety trends between different countries. This technique investigates the similarities and dissimilarities between
different groups of countries regarding fatality trend. They compared various time series of data of countries jointly to investigate the correlation between these series. This technique is useful in classifying the countries that are similar (accidents patterns) to each other.

The more detailed time series data have led to advanced and sophisticated ways of fitting a curve to data, especially with the current use of computer packages. For example, auto-regressive integrated moving average (ARIMA) techniques are used to fit and forecast the time series that are changing fairly quickly. ARIMA models should be stationary; otherwise we need to transform the data to make them stationary. The first part of the model is the auto-regressive (AR). This means that the Y factor is a relation of past values of Y. The second part is the moving average (MA). This means that the Y factor is a function of past values of the errors; see Frits et al. (2001). For instance Scott (1986) has applied this method to model the accidents in England (seasonal and annual data). Oppe (2001b) has applied this method to a model that predicts the accident data from Poland (1980-2010).

3.3.3 Other macro-models for international comparisons with many other variables involved

Page (2001) has compared safety situations and trends in the OECD countries from 1980 to 1994. He developed a statistical model using pooling cross-sectional time series. The model gives a rough estimate of the safety performance of a country regarding some variables such as: population levels, vehicle fleet per capita, percentage of young people, and alcohol consumption. Based on this model, countries that are showing the best levels are Sweden, the Netherlands and Norway.

Bester (2001) has developed a model by means of stepwise regression analysis. The criteria will indicate the variables that should be added or removed in the model. The study used collected data from different international sources and the variables used are: national infrastructure and socio-economic factors (e.g. GDP per capita).

Many of the previous models have investigated the trend of accidents or fatalities based on the input factors and some on the causes to the accidents. (Elvik & Vaa, 2004) has developed techniques for evaluating the effectiveness of various road safety measures (output) in different countries by using what is called the “before and after study” evaluation technique. Similar techniques might be used to show the effectiveness of road safety measures that countries have taken.

(Asp & Rumar, 2001) developed a unique model called ‘Road Safety Profile (RSP)’ it includes all possible quantitative and qualitative variables that may have been important in describing, explaining and comparing road safety situations in different countries. This technique illustrates the development in a country over time in a quick and easy illustration. RSP uses both types of quantitative and qualitative indicators. The
quantitative data obtained from international sources. The qualitative indicators are derived from a survey of questionnaires to experts in each country. Respondents’ countries were asked to answer questions regarding key road safety issues. The answers are used to measure the RSP level for each country.

The countries were divided into three different groups of motorisation (low, medium and high). The RSP technique includes more than 20 direct and indirect road safety indicators. Each indicator is normalised on a scale from +2 to –2. Then the results are illustrated as a profile (see Figure 3.11). This made the comparisons between countries simpler and easier. The Road Safety Profile was seen as a successful tool for identifying the problems in the country where actions are needed.

Figure 3.11: Illustration of Road Safety Profiles (Asp & Rumar, 2001)

The Globesafe database (Asp, 2004) is presently being constructed by means of IT and Internet. It includes accident data and indicators from different countries. The Globesafe system will facilitate the illustration of Road Safety Profile across countries.

### 3.3.4 Summary

Although road accident fatalities are affected by many variables, only a few of these variables are generally included in the modelling process and are population, vehicles and fatalities. There are several reasons for reducing the number of input variables in the model. These include the simplification needs in the model, avoiding or reducing the errors, and also reducing the cost and time of the data collection and analysis. However, road safety development in a country is not only measured by the parameters just given,
it is more effective where there are a large number of factors involved in the model. The road safety level in a country is a result of the whole society system development. Today computers are developing rapidly, which simplifies the work and analysis of cross-sectional data and time series data, which was not available before (e.g. to Smeed in 1949). Models have shown that making linear function between the log-traffic risk and the log-traffic volume rates could be a reasonable representation for data development. It is necessary to add time to any future model. Making predictions for traffic volume, fatality risk, and the number of fatalities are other interesting in the future. The question always remains whether those models and the indicators used are enough to explain the differences in road safety between countries and the development ahead. In Chapter 5, I propose a new model (composite index: RSDI), which could allow more indicators to be grouped together in one single value.

3.4 Accident data under-reporting and correction factor

Accident data gives a good indication about the severity of the situation. Many developing countries have definition problems, non-collection of data and no reliability of data, which are important for international comparisons. In most countries there is under-reporting of road accident deaths and injuries. The magnitude of under-reporting level varies from country to another and from year to year. In some developing countries it is difficult to obtain data on road accidents occurring in places other than urban areas or on major highways. This is probably due to the lack of and difficulties in communication. The damage-only accidents (non-injury accidents) are not always reported. For deaths and serious injuries, the reporting level is higher and they are mostly registered in most countries. (Elvik & Vaa, 2004) concluded in the review of macro-studies he made that the reporting of road accidents is incomplete and inaccurate in official statistics in most countries worldwide.

Under recording is another important problem. The basis of accident data in developing countries is data recorded by the police in each country. The police do not often record detailed information of the accident. This is because of inadequate reporting and untrained personnel. Tessmer (1999) has compared crash statistics in OECD countries and it has shown that there is a problem of under-recording by the police in most OECD countries. Some injuries recorded by the police papers are not shown in the computer files. Police have no medical or engineering background, so there is no accurate information. In addition, there is lack of information and reliable data that recorded by the police.

The number of fatalities in accidents cannot be directly compared internationally since the individual definitions of road accident fatality differ widely. Most European countries use the standard of dead within 30 days of the accident occurred. The international fatality data should all be adjusted to the 30-days definition. Most developing countries use the definition of deaths as on the spot or within 24 hours. A correction factor has to be developed to adapt these data to the 30-days definition.
Therefore the number of recorded deaths should be multiplied by a factor of more than one. This correction factor is based on the overall country conditions and system, such as the level of medical treatment and rescue services. In other words the correction factor is not based only on the number of days but it is also a country-specific.

Under reporting of injuries is known to be even worse than with fatalities. According to a global study by Jacobs et al., (2000) only approximately 50 percent of road injuries are reported from road accidents. There was an estimation of 100 injuries for every fatality in the HDCs and 30 injuries in the LDCs.

The total number of registered vehicles varies from country to country. Some international studies exclude the category of motorcycles from the total of vehicles in the country. This makes a significant difference in the actual vehicle fleet when comparing both the developing and developed countries. Some countries have a high rate of motorcycles (in some cases more than 50%) like Malaysia, Thailand, India and Japan. If we exclude these commonly used vehicles, this will eliminate an essential percentage of the total vehicle fleet. At the same time, there is difference in risks between the types of vehicles, for instance motorcyclists are generally associated with a high involvement of casualties. The amount of two-wheeled travel is probably underestimated in most countries, as many of these vehicles are not registered. Developed countries have a high percentage of vehicles per family, and many families have more than one car and less vehicle-passengers per trip compared to developing countries. Additionally, there are a limited number of kilometres driven by some types of use vehicles, for instance the motorised three-wheelers in some Asian countries.

Accurate and comprehensive accident data is essential in improving traffic safety. The existing statistics gave a good indication about the severance of the situation. There is a need to standardize the international traffic statistics between all the countries for traffic definitions. This includes the methods in collecting the accident data (from police, hospital and insurance companies), registrations, and the definitions of accident data. Good data enables a country to diagnose its road safety problems and to select appropriate measures to apply.
This chapter aims to determine whether the varieties in road safety between ASEAN countries can be explained by differences in some indicators and socio-economic patterns. This chapter analyses the trends and levels of road safety among the region between 1994 till 2003. The indicators used here are traffic risk as number killed per vehicle, motorisation measured as vehicle per person, and personal risk as killed per person. Special cases of comparisons are presented when both indicators are considered together and when they interact with other indicators such as urbanisation and severity index (killed per casualties). This empirical study is supported by tables and graphs based on data gathered on our visits to the ASEAN region. This data will also be useful in testing the multidimensional index, RSDI, in the next chapter.

4.1 BACKGROUND OF THE ADB-ASEAN-ASNET PROJECT

ASEAN countries have identified road safety as an urgent and priority issue to be addressed across the region due to high rate of road accidents that is resulting a huge social and economic loss. From November 2003, the ADB-ASEAN-ASNet program has started in collaboration with the Asian Development Bank (ADB)\(^9\), Association of Southeast Asian Nations (ASEAN)\(^10\) and Linköping University\(^11\) in Sweden. This program has been set up to strengthen the regional cooperation in road safety between ASEAN countries through sharing of information, experience, best practices and communication. The first part of the program is the ADB-ASEAN project, which aims to identify the main problem in the region and gives the possible national and regional action plans to tackle the road safety problems.

\(^10\) The ASEAN website: http://www.aseansec.org (last accessed 2005-05-15)
The second part is the ASNet project ‘ASEAN Road Safety Network’. It is an Internet-based regional network established with funding from (SIDA)\textsuperscript{12} ‘The Swedish International Development Agency’. The ASNet networking system was designed with the support of e-learning inputs from Linköping University in Sweden. It aims to provide a common Internet platform for ASEAN members/institutions for discussing issues affecting or related to the road safety field. To this purpose, ASNet coordinators\textsuperscript{13} from Linköping University have carried out the implementation of the ASNet programme through a series of national training seminars and regional workshops. During our visits to the region (one-week visit to each country) we have had the opportunity to discuss road safety problems with local professional colleagues. We realised, among other things, that government officers and NGOs in the region are highly concerned about road safety and the necessity to improve it.

4.2 Data sources

Most of the data presented and analysed in this chapter has been collected from the ten participating countries during the period of our project within the ADB-ASEAN-ASNet program and visits to the region (in 2004). The ASNet database, we improved, is one important source of accident data and information from the region. It includes accident statistics from the region, country reports, external links to other international reports (e.g. ADB reports), and much more\textsuperscript{14}. But some other data remains to be collected from other international sources such as the World Bank, the United Nations, and the IRF International Road Federation Database.

4.3 Nature and characteristics of road safety situation in ASEAN countries

The ASEAN countries have a combined population of about 530 million (approx. 8.6% of the total world population of 6.2 billion in 2002) and ranges from a small country of 0.34 million (Brunei) to one of the largest populations in the world at 224 millions (Indonesia). According to the Human Development Report of the United Nations (UNDP, 2004) ASEAN countries have shown different levels of the human development index (HDI) out of a field of 175 countries worldwide. Two ASEAN countries ranked higher up the scale in development, which are Singapore (25) and Brunei (33). Others are categorised in the medium development, such as Malaysia (59), Thailand (76), the Philippines (83), Indonesia (111) and Vietnam (112), whereas Cambodia (130), Myanmar (132) and Laos (135) are categorised at a lower level in human development compared to other countries in the region.

\textsuperscript{13} Prof. Kenneth Asp, PhD, Per Lindskog, MSc (Eng), Ing-Marie Eriksson, and PhD student. Ghazwan Al Haji.
\textsuperscript{14} The ASNet platform is hosted by Linköping university and consists of three main parts: 1) ASEAN Road Safety Database includes different materials from ASEAN countries such as: road safety statistics, consultant presentations, country reports, ADB reports, and external links to international materials. 2) Communication system and networking tools include: e-mails, online discussion board between regional professionals in road safety, chat rooms, sharing files, etc. 3) Web based information and newsletters that shows the updated information from the region, what’s new coming, good practices and ongoing activities. See: http://www.asnet.org/ (last accessed 2005-05-15).
Recent data from the United Nations shows that population density varies widely from one ASEAN country to another, from a high of 6,700 people/km² in Singapore to only 2 people/km² in Lao PDR. There is a growth rate of urban population across the ASEAN region and the countries are urbanised to varying degrees. Singapore is fully urbanised while other countries like Cambodia and Laos have only 20% urbanisation of population. There are three mega-cities situated in the ASEAN region (or cities that of a population of more than 10 million). These cities are Jakarta, Bangkok and Manila. This makes the sustainable transport development (mobility, environment and safety) in these areas a real challenge.

The ASEAN region is among the fastest growing parts of the world economy, especially during the last decade. This has resulted in an annual increase in GDP ‘Gross Domestic Product’ per capita. The rate of annual increases in GDP in some ASEAN countries such as Singapore, Malaysia and Thailand is higher than the average global rates (World Bank, 2005). This trend is expected to continue in the future. By this increase in income the number of vehicles is expected to increase and will likely increase the number of deaths in traffic.

The quick growth in urbanisation, number of vehicles and GDP are causing a demand for road transport networks to expand. However, in many ASEAN countries, the road infrastructure, legislation and education have not often followed this quick and sudden growth.

In addition, tourist traffic to the ASEAN region has also been increasing, which has led to increased traffic volumes and congestions on some roads. This has led to an increase in the number of traffic accidents.

Sadly, the amount of money allocated to road safety countermeasures is inadequate in several ASEAN countries. To further complicate this matter, many ASEAN countries bordering on the Indian Ocean were hard hit by the Tsunami earthquake in December 2004, especially Indonesia and Thailand. This exhausted the funds (temporarily) and most of the regional governments and donors have turned their attention to the Tsunami and its aftermath.

ASEAN countries have a serious road accident problem and the problem itself is underestimated. The ADB-ASEAN project conducted a study (ADB, 2004) to estimate the total road injuries as well as the cost of road accidents in the ASEAN region. It was found that nearly 70,000 deaths and over 4.6 million injuries occur annually in the region. The annual cost of road deaths in ASEAN countries is about $14 billion or 2.1 percent of their gross national product. The total number of vehicles in the region in 2003 is also estimated to about 40 million vehicles.

From these estimated results, I estimated the proportion of the number of vehicles, population and deaths in the region from the total world data. It is found that the region
accounted for about 5 percent of vehicle, 8.6 percent of the population of the world and 6 percent of deaths of the total 1.2 million people killed annually in the road accidents worldwide. These results seem compatible with those obtained by Jacobs *et al.*, (2000) for the Asia/Pacific region.

Half of the ASEAN countries drive on the left side of the road (right-hand-drive vehicles), which are: Brunei, Indonesia, Malaysia, Singapore and Thailand. Others drive on the right: Cambodia, Laos, Vietnam, the Philippines and Myanmar. At the same time, thousands of vehicles on roads in Cambodia and Laos are right-hand drive and they are smuggled or imported from neighbouring countries like Thailand where vehicles are right-hand drive. However, there is now legislation to ban this type of vehicle in Cambodia but the law has not been strictly enforced (ASNet database, 2004). This is a real challenge for drivers when they drive between two countries that drive on opposite sides of the road. Many ASEAN countries have accommodated special transfer zones on the border, what allows changing sides from the left side to right and vice versa. In Sweden 1967 was the year when traffic switched from the left side of the road to the right and there were fewer accidents during that transition period.

Although several ASEAN countries have a law requiring the use of a seatbelt for passengers and drivers in the front seat, in several of them do not wear it and many vehicles do not even have seatbelts at all (e.g. Indonesia, Cambodia and Laos).

ASEAN countries are found to be quite dissimilar. This is explained further in the following sections. The characteristics of road accidents are different from one country to another and they differ from these in highly developed countries (HDCs). Therefore the priorities for action are also likely to differ nationally and regionally.

It is useful to know before proceeding that in several Asian countries there are other important health problems to be addressed as well. For instance, in Thailand (year 2001), AIDS has been acknowledged as the leading cause of death, before road accidents, heart disease and cancer (AEGIS, 2001).

### 4.4 Motorcycle safety in ASEAN countries

Motorcycles are a major component of the traffic fleet in several ASEAN countries, whereas these are a minority in HDCs. In year 2003 (see Table 4.1) motorcycles accounted for 95% of the total number of vehicles in Vietnam, 80% in the Laos, 75% in Cambodia, 75% in Indonesia and 48% in Malaysia. These figures are still increasing because of the cheaper models appearing on the roads (e.g. from China and Malaysia).

A high proportion of trips are made by non-motorised modes of traffic (NMT) in ASEAN countries. The casualties in respect of motorcycles constitute the majority of road users in accidents, nearly 90% in Cambodia, 70% in Vietnam and 60% in Malaysia. This group of road users together with pedestrians and cyclists is referred to
as vulnerable road users (VRUs) and they are forced to share road space with motor vehicles because either there are no separate lanes to be used or the designed space is not enough or convenient.

Table 4.1: Motorcycles and other socioeconomic variables in ASEAN countries 2002

<table>
<thead>
<tr>
<th>Country</th>
<th>Motorcycles (% of total vehicles)</th>
<th>Urban population (% of total population)</th>
<th>GDP per capita (ppp US$)</th>
<th>Human Development Index (HDI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunei</td>
<td>3.0</td>
<td>75.5</td>
<td>19,210</td>
<td>0.867</td>
</tr>
<tr>
<td>Cambodia</td>
<td>75.21</td>
<td>18</td>
<td>2,060</td>
<td>0.568</td>
</tr>
<tr>
<td>Indonesia</td>
<td>75.22</td>
<td>44.5</td>
<td>3,230</td>
<td>0.692</td>
</tr>
<tr>
<td>Laos</td>
<td>80.14</td>
<td>20.2</td>
<td>1,720</td>
<td>0.534</td>
</tr>
<tr>
<td>Malaysia</td>
<td>48.18</td>
<td>63.3</td>
<td>9,120</td>
<td>0.793</td>
</tr>
<tr>
<td>Myanmar</td>
<td>36.92</td>
<td>28.9</td>
<td>1,027</td>
<td>0.551</td>
</tr>
<tr>
<td>Philippines</td>
<td>37.67</td>
<td>60.2</td>
<td>4,170</td>
<td>0.753</td>
</tr>
<tr>
<td>Singapore</td>
<td>18.95</td>
<td>100</td>
<td>24,040</td>
<td>0.902</td>
</tr>
<tr>
<td>Thailand</td>
<td>70.92</td>
<td>31.6</td>
<td>7,010</td>
<td>0.768</td>
</tr>
<tr>
<td>Vietnam</td>
<td>94.40</td>
<td>25.2</td>
<td>2,300</td>
<td>0.691</td>
</tr>
</tbody>
</table>

Notes:
Sources of data are: C2 is ASNet Database, while C3, C4 and C5: Human Development Report 2004
Purchasing Power Parity (PPP) is a theoretical exchange rate between different currencies to US$

Motorcycles do not offer enough protection to the riders and they face a higher risk of head injuries in accidents, hence helmets are required for people riding motorcycles. This is not efficiently enforced in many ASEAN countries despite a law making the wearing of helmets compulsory across the region. It is found in several ASEAN countries (e.g. Malaysia and Singapore) that the introduction of helmet use has led to a significant reduction in motorcycle deaths. According to the ASNet database fewer than 3% of riders who use helmets in Vietnam and 60% of road deaths were caused by head injuries. In Indonesia, motorcycle passengers rarely wear helmets in rural areas, while in Malaysia and Singapore they have shown a high percentage of motorbike riders wear helmets (more than 70%). In the Appendix 1, the ADB consultants through the ASNet database have estimated the percentage of seatbelts and helmets in ASEAN countries. In highly developed countries, the usage rate tends to be high. For instance, Sweden estimated helmet usage at about 90% (Koornstra et al., 2005).

One of the issues discussed during the ADB-ASEAN-ASNet program is how to make helmets compulsory for motorcycle riders. This includes education, legislation and enforcements measures. There has been also concern regarding helmet quality. They should be more standardised, convenient to wear, lighter in weight, less expensive, and suit the weather in this region (e.g. tropical weather). In addition riders should wear helmets properly.
It is also recommended that governments in the region, especially those that have a high proportion of motorbikes, should start to develop bus networks in the main cities and encourage people to shift from using motorbikes to more sustainable (safer) modes such as public transport (Lindskog & Al Haji, 2005). According to the discussions with consultants in the region, this recommendation remained unsuccessful due to the influence from the local motorbikes makers and the high production they offered due to low prices in the country (for instance in Vietnam).

4.5 The importance of good data and reporting in ASEAN countries

Not all accidents and exposure variables are available in ASEAN countries, especially for what is considered necessary for meaningful comparisons like: (fatalities, km. veh, fatalities by type of road user, by age distribution, by time, driving experience, types of vehicles, types of travel, etc.).

The basis of the accident data in the ASEAN countries is data reported by police in each country. Unfortunately police records don’t always cover all the aspects of the accident due to inadequate reporting and untrained personnel. There is a difference between ‘official’ road accident statistics registered in police records and those held by hospitals, in almost all ASEAN countries. According to (ADB, 2004) Malaysia and Singapore were the only countries in the ASEAN region with a reasonably good national accident data system and it is still improving. All other countries had very inadequate systems that need significant improvements in this area.

Under the ADB-ASEAN project, local consultants and researchers have compared police data with other data available from hospitals, the Ministry of Health and insurance companies. They estimated the true number of deaths and injuries occurring in each ASEAN country (Table 4.2). It was found that police-reported deaths are underestimated in a few countries but in most countries the reported deaths seemed to be reasonably accurate. In the case of injuries there were often very significant underestimated figures between the numbers of injuries that reported by the police and the numbers obtained from hospital or Ministry of Health records (ADB, 2004).

Table 4.2 shows the size of the problem of data reliability and under-reporting. The accident deaths and injuries are estimated to be higher than officially reported. In most ASEAN countries there is under-reporting of road accident deaths and injuries. The magnitude of under-reporting level varies from country to country and from year to year. It is shown that underreporting problem is more severe in Indonesia and the Philippines.
In this study, I use the estimated figures from ADB than the official police reported fatalities and injuries for the year 2003. I have applied the adjustment factors to the data given in other years.

The number of people killed in accidents cannot be directly compared since the individual definition of road accident deaths differ or is underestimated. As defined by the United Nations Economic Commission for Europe, a road death is a victim of a traffic accident who dies at the scene or within 30 days from the date of the accident. However, not all ASEAN countries apply this 30-days definition; for instance in Laos, Thailand and the Philippines, died on the spot; in Vietnam, within 24 hours of an accident, while other ASEAN countries follow the European criteria of 30 days (see Table 4.2). The fatality figures from Laos, the Philippines, Thailand and Vietnam should be all adjusted to the 30-days definition and multiplied by a factor of more than one. If this is not done, then such non-uniform definitions can considerably affect the level of accident statistics. However, this 30-days correction factor is not used in this study since I already performed the estimated figures from ADB to the data. It is unnecessary to apply more than one correction factor to the data.

The two-wheeled number is underestimated in some ASEAN countries as many of these vehicles are not registered. Their percentage of the total vehicle fleet in the country may be even higher than is shown in the data. According to the same study from ADB (2004), it found that an additional 465,783 motorcycles were identified and unregistered in Myanmar, which almost doubled the official registered motorbike vehicle fleet.

There are different classifications of road accidents in the region. The police report the personal injury accidents but minor collisions (property damage only) are not always reported. The data in most ASEAN countries are collected and kept manually. This

Table 4.2: The estimated numbers of deaths and injuries in ASEAN (year 2003)

<table>
<thead>
<tr>
<th>Country</th>
<th>Deaths</th>
<th>Definition of deaths in accident</th>
<th>Deaths (estimated by ADB)</th>
<th>Under Reporting adjustment factor</th>
<th>Injuries</th>
<th>Injuries (estimated by ADB)</th>
<th>Under Reporting adjustment factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunei</td>
<td>28</td>
<td>30 days</td>
<td>28</td>
<td>0</td>
<td>645</td>
<td>1 273</td>
<td>97</td>
</tr>
<tr>
<td>Cambodia</td>
<td>824</td>
<td>30 days</td>
<td>1 017</td>
<td>23</td>
<td>6 329</td>
<td>20 340</td>
<td>221</td>
</tr>
<tr>
<td>Indonesia</td>
<td>8,761</td>
<td>30 days</td>
<td>30,464</td>
<td>248</td>
<td>13 941</td>
<td>2 550 000</td>
<td>18 191</td>
</tr>
<tr>
<td>Laos</td>
<td>415</td>
<td>on the spot</td>
<td>581</td>
<td>40</td>
<td>6 231</td>
<td>18 690</td>
<td>200</td>
</tr>
<tr>
<td>Malaysia</td>
<td>6,282</td>
<td>30 days</td>
<td>6 282</td>
<td>0</td>
<td>46 420</td>
<td>46 420</td>
<td>0</td>
</tr>
<tr>
<td>Myanmar</td>
<td>1,308</td>
<td>30 days</td>
<td>1,308</td>
<td>0</td>
<td>9 299</td>
<td>45 780</td>
<td>392</td>
</tr>
<tr>
<td>Philippines</td>
<td>995</td>
<td>on the spot</td>
<td>4 200</td>
<td>322</td>
<td>6 793</td>
<td>361 200</td>
<td>5 217</td>
</tr>
<tr>
<td>Singapore</td>
<td>211</td>
<td>30 days</td>
<td>211</td>
<td>0</td>
<td>7 975</td>
<td>9 072</td>
<td>14</td>
</tr>
<tr>
<td>Thailand</td>
<td>13 116</td>
<td>on the spot</td>
<td>13 116</td>
<td>0</td>
<td>69 313</td>
<td>1 529 034</td>
<td>2 106</td>
</tr>
<tr>
<td>Vietnam</td>
<td>11 853</td>
<td>24 hours</td>
<td>13 186</td>
<td>11</td>
<td>20 694</td>
<td>30 999</td>
<td>50</td>
</tr>
</tbody>
</table>

Source: ADB-ASEAN-ASNET Regional Road Safety program
requires an effective computer-based accident data system to enable a good analysis and it might reduce the underestimated level of the data in future time.

Most published data from international sources exclude the category of motorcycles when they report the number of registered motor vehicles in different countries. This in fact will make little difference for HDCs where motorcycles account for only a small percent of all vehicles on the roads, but in countries such as Vietnam, Laos, Indonesia, Cambodia, Thailand and Malaysia where they have a high rate of motorcycles (more than 50%), this exclusion makes the internationally published accident rates less accurate. In this study, the total number of vehicles in use was taken as the sum of cars, buses, lorries and motorbikes.

It is strongly recommended for each individual ASEAN country to establish a national integrated road accident database that should follow the international standards of definitions. This database must include all country data, traffic police data, hospital accident data and insurance company data as well.

Despite the fact that the mentioned points on the differences in definitions, non-collection data, and under-reporting would affect the level of reliability of comparisons, a great advantage still exists in such comparisons. It enables a judgment of safety situations between countries and it can detect the progress ahead.

The data period in this study is from 1994 to 2003. In a few cases it was necessary to combine data from different years to make a calculation of accident rates. The basic collected variables were population, vehicles in use, road casualties, and some main socio-economic factors and, from these, other statistics were derived to determine underlying patterns. The main source of data, as mentioned before, is the ASNet accident database for the ASEAN region that we developed.

4.6 Accident rates in ASEAN countries

The degree of motorisation is associated with the level of income of the country. A strong relationship exists between average per capita income in an ASEAN country and the number of vehicles per population. The fatality rates are related to vehicle ownership levels: The lower the vehicle ownership level, the higher the fatality rate per vehicle. The number of vehicles has increased rapidly in ASEAN countries during recent decades as it happened in the HDCs countries after the Second World War. In HDCs, the number of persons killed decreased after 1970. By contrast, the number in the ASEAN region keeps increasing. Many ASEAN nations are in the period of a rising number of deaths and there is no guarantee that the development of road safety in ASEAN will follow the same patterns in HCDs. One main factor that may lead to these variations is that developed countries have never experienced road traffic conditions in ASEAN countries, which include a high proportion of motorcycles in many of Asian countries.
It can be noted from (Table 4.3) that for all ASEAN countries the number of fatalities increased from 1994 to 2003 with the exception of Brunei, Thailand and Singapore (data from Indonesia is questionable). Some countries have shown a high increase trend in the number of fatalities from 1994 to 2003 such as Cambodia (767 percent), Vietnam (161 percent) and Laos (108 Percent). The number of fatalities in 2003 is highest in Indonesia (30,464 fatalities), Vietnam (13,186) and Thailand (13,116), and lowest in Brunei (28) and Singapore (211).

Table 4.3: Accident rates over a period 1994-2003 in ASEAN countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Year of data</th>
<th>Deaths</th>
<th>Injuries</th>
<th>Vehicles</th>
<th>Population (000's)</th>
<th>Motorisation (vehicles per 1,000 person)</th>
<th>Personal Risk (Deaths per 100,000 person)</th>
<th>Traffic Risk (Deaths per 10,000 vehicles)</th>
<th>Severity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunei</td>
<td>1994</td>
<td>56</td>
<td>977</td>
<td>160 000</td>
<td>289</td>
<td>553.63</td>
<td>19.38</td>
<td>3.50</td>
<td>5.42</td>
</tr>
<tr>
<td></td>
<td>2003</td>
<td>28</td>
<td>1 273</td>
<td>244 727</td>
<td>358</td>
<td>683.59</td>
<td>7.82</td>
<td>1.14</td>
<td>2.15</td>
</tr>
<tr>
<td>Cambodia</td>
<td>1994</td>
<td>117</td>
<td>791</td>
<td>164 750</td>
<td>10 367</td>
<td>15.89</td>
<td>1.13</td>
<td>7.12</td>
<td>12.92</td>
</tr>
<tr>
<td></td>
<td>2003</td>
<td>1 017</td>
<td>20 340</td>
<td>447 428</td>
<td>13 487</td>
<td>33.17</td>
<td>7.54</td>
<td>22.73</td>
<td>4.76</td>
</tr>
<tr>
<td>Indonesia</td>
<td>1994</td>
<td>38 263</td>
<td>N.A</td>
<td>11 929 000</td>
<td>190 043</td>
<td>62.77</td>
<td>20.13</td>
<td>32.08</td>
<td>N.A</td>
</tr>
<tr>
<td></td>
<td>2003</td>
<td>30 464</td>
<td>2 550 000</td>
<td>24 994 890</td>
<td>234 893</td>
<td>106.41</td>
<td>12.97</td>
<td>12.19</td>
<td>1.18</td>
</tr>
<tr>
<td></td>
<td>2003</td>
<td>581</td>
<td>18 690</td>
<td>278 384</td>
<td>5 921</td>
<td>47.02</td>
<td>9.81</td>
<td>20.87</td>
<td>3.01</td>
</tr>
<tr>
<td>Malaysia</td>
<td>1994</td>
<td>5 159</td>
<td>43 344</td>
<td>6 166 432</td>
<td>20 103</td>
<td>306.74</td>
<td>25.66</td>
<td>8.37</td>
<td>10.64</td>
</tr>
<tr>
<td></td>
<td>2003</td>
<td>6 282</td>
<td>46 420</td>
<td>12 868 930</td>
<td>24 500</td>
<td>525.26</td>
<td>25.64</td>
<td>4.88</td>
<td>11.92</td>
</tr>
<tr>
<td>Myanmar</td>
<td>1994</td>
<td>938</td>
<td>34 161</td>
<td>265 253</td>
<td>43 519</td>
<td>6.10</td>
<td>2.16</td>
<td>35.36</td>
<td>2.67</td>
</tr>
<tr>
<td></td>
<td>2003</td>
<td>1 308</td>
<td>45 780</td>
<td>467 350</td>
<td>48 895</td>
<td>9.56</td>
<td>2.68</td>
<td>27.99</td>
<td>2.78</td>
</tr>
<tr>
<td>Philippines</td>
<td>1994</td>
<td>2 723</td>
<td>211 732</td>
<td>2 500 000</td>
<td>66 814</td>
<td>37.42</td>
<td>4.07</td>
<td>10.89</td>
<td>1.27</td>
</tr>
<tr>
<td></td>
<td>2003</td>
<td>4 200</td>
<td>361 200</td>
<td>4 292 000</td>
<td>84 620</td>
<td>50.72</td>
<td>4.96</td>
<td>9.79</td>
<td>1.15</td>
</tr>
<tr>
<td>Singapore</td>
<td>1994</td>
<td>254</td>
<td>7 680</td>
<td>611 611</td>
<td>3 421</td>
<td>178.78</td>
<td>7.42</td>
<td>4.15</td>
<td>3.20</td>
</tr>
<tr>
<td></td>
<td>2003</td>
<td>211</td>
<td>9 072</td>
<td>711 043</td>
<td>4 608</td>
<td>154.31</td>
<td>4.58</td>
<td>2.97</td>
<td>2.27</td>
</tr>
<tr>
<td>Thailand</td>
<td>1994</td>
<td>15 176</td>
<td>960 508</td>
<td>12 939 954</td>
<td>58 272</td>
<td>222.06</td>
<td>26.04</td>
<td>11.73</td>
<td>1.56</td>
</tr>
<tr>
<td></td>
<td>2003</td>
<td>13 116</td>
<td>1 529 034</td>
<td>25 100 000</td>
<td>64 265</td>
<td>390.57</td>
<td>20.41</td>
<td>5.23</td>
<td>0.85</td>
</tr>
<tr>
<td>Vietnam</td>
<td>1994</td>
<td>5 043</td>
<td>19 558</td>
<td>3 360 555</td>
<td>71 679</td>
<td>46.88</td>
<td>7.04</td>
<td>15.01</td>
<td>20.50</td>
</tr>
<tr>
<td></td>
<td>2003</td>
<td>13 186</td>
<td>30 999</td>
<td>12 054 000</td>
<td>81 624</td>
<td>147.68</td>
<td>16.15</td>
<td>10.94</td>
<td>29.84</td>
</tr>
</tbody>
</table>

Notes: Source of data is ASNet “ASEAN Road Safety Regional Network and Database”
Correction factor for deaths and injuries (2003) were estimated by ADB experts and the same were applied to year 1994
Number of vehicles is taken as the sum of all registered cars, buses and coaches, lorries, motorcycles and motorised three-wheelers.

4.6.1 How to compare traffic safety in ASEAN countries

There is no meaning to use the total number of fatalities or injuries to compare the safety problem in ASEAN countries, due to wide differences in population and motorisation in these countries. Measures of risk are essential in comparing different countries and studying the development of the road safety situation. Therefore, numbers of deaths have to be translated into measurable indicators that take road usage and exposure to accidents into account. The two general indicators of death rates relevant to our comparisons are traffic risk (fatalities per vehicles) and personal risk (fatalities per
population). The most important is to combine these two common types of rates with motorisation (vehicles per population).

Comparisons are still less accurate as a result of the difference in risks between the types of vehicle, where motorcycles have a higher risk of crash and injury. In addition some type of vehicles on roads (e.g. motorised three wheelers for instance in Indonesia and Cambodia) have a limited number of kilometres driven compared to other vehicles. Moreover, Brunei for instance has a high percentage of vehicles per family, and many families have more than one car and fewer vehicle-passengers per trip compared to other ASEAN countries.

In order to achieve good results in comparisons, we must compare countries at a similar level of motorisation and with a similar type of transport system. Comparing Laos with Singapore is less useful than comparing Laos with Cambodia where they have similar levels of motorcyclists and more in common with transport patterns. This conclusion was also reached by the study we made concerning the road safety perspective in Arab countries (Al Haji & Asp, 2001).

4.6.2 Motorisation

The number of motor vehicles in relation to population largely depends on the standard of living or GDP per capita income (the gross domestic product) in most countries. Motorisation is highest in Brunei, Malaysia and Thailand (over 300 motor vehicles/1,000 inhabitants), and lowest in Myanmar, Cambodia and Laos (less than 50 motor vehicles/1,000 inhabitants). It can be seen that in all ASEAN countries (except Singapore) there was an increase in the number of vehicles per population over the studied period (1994-2003). In year 2003, the average of motorisation in ASEAN countries was 215 vehicles per 1,000 persons, which was 145 vehicles per 1,000 persons in 1994. This means that motorisation in the ASEAN countries over the period 1994 to 2003 has increased by 47.5 percent over the region. In particular, motorisation has grown very quickly in some ASEAN countries such as Cambodia (109%), Vietnam (215%) and Thailand (76%). Many countries of South-East Asia have shown signs of an emerging and new economic during recent decades and this can explain this high increase of motorisation.

4.6.3 Traffic risk

Traffic risk is measured in terms of deaths per 10,000 registered motor vehicles or per 100 million vehicle-kilometres travelled. The latter is the most relevant risk measure in road transport but unfortunately the total number of kilometres covered by vehicles is not normally available in most ASEAN countries. If the traffic risk is defined as the number of fatalities per 10,000 vehicles, several investigations show that this indicator is not enough to explain the real situation of traffic safety. This measure does not
directly consider the population density or vehicles per citizen or other socio-economic factors in the country.

The difference in traffic risk between ASEAN countries is very large. An indication of these differences and the changes of road accident deaths per 10,000 vehicles for the years 1994 and 2003 can be seen in Figure 4.1. Firstly it can be seen that fatality rates are extremely high in low-motorised ASEAN countries such as Myanmar, Laos and Cambodia, and low in high-motorised ASEAN countries such as Brunei, Malaysia and Singapore. In 1994 the traffic risk rates ranged between 3.50 in Brunei to 35.36 in Myanmar (data was suspect for Indonesia). Correspondingly in 2003, whilst traffic risk in high-motorised ASEAN countries is often less than 3, like in Brunei and Singapore, some other ASEAN countries have a rate exceeding 25, like Myanmar. The average traffic risk in the selected ASEAN countries over the period 1994 to 2003 had decreased by 27 percent. Although all ASEAN countries showed a decrease in traffic risk with time, there is a high increase rate in Cambodia of 219 percent (from 7.12 to 22.73) over the period 94 till 03.

It would seem that ASEAN countries fall into three levels of traffic risks. Countries with the lowest levels, less than 5 killed per 10,000 vehicles, include Brunei, Singapore and Malaysia. Countries with a medium level, less than 20 and more than 5, include Thailand, the Philippines, Vietnam and Indonesia. The other ASEAN countries have a very high level of traffic risk, more than 20, including Myanmar, Cambodia and Laos.

Figure 4.1: Progression of the ASEAN countries according to the traffic risk indicator (fatalities per 10,000 vehicles) 1994-2003
These results seem to correspond with the level of motorisation as already been discussed in the previous chapter (Figure 3.5). Most ASEAN countries are still at the lower level of the motorisation curve and a few are now starting to enter the phase of rapid motorisation (medium level) as Malaysia. The death figures rise until quite a high level of motorisation is reached and, subsequently, it falls. Perhaps this explains the low figure in traffic risk in Brunei, which is comparatively similar to that in HDCs.

The HDCs have shown low figures in traffic risk despite the fact that they have a large growth in the number of vehicles, population and kilometres travelled by vehicles. For instance, the current traffic risk in Sweden and United Kingdom is less than 2. In countries like the Philippines and Vietnam the comparable rate is something like four to six times higher.

A further comparison can be made here if the useful life of a motor vehicle is about ten years, an average of about one vehicle in about eight hundred will be involved in a fatal accident in Brunei during the vehicle as life (ten years in this example). In a country such as Malaysia, one motor vehicle in two hundred is likely to be involved in a fatal crash; in the Philippines, about one in hundred; and in Myanmar one in thirty five.

### 4.6.4 Personal risk

Personal risk is the risk of a person being killed in an accident, or the death rate per 100,000 people. Almost half of the selected ASEAN countries showed an increase of personal risk over the period 1994-2003 (Table 4.3). There is no clear relationship between personal risk with the vehicle ownership growth or the urbanisation or population density. Personal risk does not show the level of development of the transport system or traffic safety but it may illustrate the social problem of traffic accident deaths among population. It can be seen that there is no clear sign for the personal risk to decrease with time, like the traffic risk made in most countries. It shows also that the country with a high level of traffic risk tends to have a lower level of personal risk, such as Myanmar. When we move to the countries with a low level of traffic risk, it is seen that the personal risk level increases in Brunei and Malaysia, while in Singapore it shows a good performance in both traffic risk and personal risk indicators. These findings agree well with (Figure 3.9) that illustrated in previous chapter.

### 4.6.5 Traffic risk, personal risk and motorisation

In the process of clarifying the relationship between traffic risk and the level of motorisation in the same model, Figure 4.2 shows that as motorisation level (number of vehicles per population) increases, the traffic risk (fatalities per vehicle) decreases. This negative correlation can probably be explained by the fact that the more vehicles in a country led to more improvement in safety and the learning process by experiences in traffic (Jacobs and Hutchinson 1973), (Oppe, 1991b).
Figure 4.2: Traffic risk and motorisation for ASEAN countries in 2003

I have tested different regression models (linear and non-linear) to fit the data. It is found that the transformation log 10 for motorisation values seems to work pretty well in presenting the data. The parameters of the formula (shown in Figure 4.2) are estimated from data by using the least square method. The resulting line of best-fit gives R-Sq=85.8% goodness of fit, which seems a good model. This means that nearly 86% of the traffic risk has been explained by motorisation variables. The remaining 14% of variations in this data remain unexplained. The confidence limits were calculated at a 95% level. At 0.05 significance level, the above relation is significant (p <0.001).

Models discussed in the previous chapter have shown that making linear function between the log-traffic risk and the log-traffic volume rates could be a reasonable representation for data development. However, this function did not demonstrate a better fitting for the ASEAN data (R-sq =75.1%) than the obtained model in this study (Figure 4.2). The transformation log 10 for motorisation seems better fit to represent the pattern of the data plot since R-sq value is slightly higher than other functions. At this stage of study, it was not possible to test the negative exponential learning curve that developed by Oppe (see equation 3.2 and 3.3 in previous chapter) for the reason that there is no adequate time series data available in these countries, besides the number of vehicle kilometres travelled is not also available in most ASEAN countries.

In Figure 4.2 there is a clear deviation from all data points around the fitted regression line. The points of the Philippines and Singapore lie down at the bottom limit suggesting that it has a low traffic risk comparing to other countries group. In some countries (e.g. Cambodia and Laos) the points lie over the line, which means that there are many persons may have been killed on roads than it should be in these countries. In Singapore many persons have been saved on roads comparing to the average line of ASEAN countries.
This model can also be used for estimating or predicting the data from the equation, i.e., by predicting what will happen to traffic fatalities if the same trends of motorisation continue with the same rates. We will leave this work for further analysis in future work. Besides, better curves could be obtained here if the analyses in the ASEAN countries had been divided into two categories of motorisation, one line devoted for high-motorised ASEAN countries for each of (Brunei, Malaysia, Singapore and Thailand) and one line for lower motorised countries for each (Vietnam, Indonesia, Cambodia, the Philippines, Myanmar and Laos). In like manner, we leave this work for future work.

It is interesting to compare the present motorisation in the ASEAN countries with the same vehicle ownership in the HDCs in earlier periods. Data is obtained for Sweden over the period 1950 to 2000, which is illustrated in Figure 4.2. It can be seen that all points of Sweden lie on or below the fitted regression line. This indicates that for a given vehicle density, the level the traffic risk was less in Sweden during these years than in most ASEAN countries in 2003. Most ASEAN countries lie over the line (except the Philippines and Singapore). Laos had in 2003 the same motorisation as Sweden in 1950, but the traffic risk was clearly higher than in Sweden at that time. Similarly, Malaysia in 2003 has the same motorisation as Sweden in 2000, but the traffic risk was clearly higher than in Sweden. However, one has to take into account that vehicles have become faster in recent decades, and therefore more fatal accidents occur. On the other hand, road systems and vehicle safety have considerably improved.

Concerning personal risk with motorisation, Figure 4.3 shows that there is no clear relationship between personal risk and motorisation. When motorisation increases, it leads to a decrease in the traffic risk but not necessarily to a decrease in personal risk. The quadratic curve indicates that the pattern is non-linear. The resulting line of best-fit gives $R^2=65.4$ goodness of fit. This means 65% of the traffic risk has been explained by motorisation variables.

![Estimated regression line for ASEAN region](image)

**Figure 4.3: Personal Risk and Motorisation for ASEAN countries 2003**
4.6.6 Traffic risk and urbanisation

The rapid increase of population in ASEAN countries has caused economic and social problems. The changes in urbanisation in recent decades have also led to increased traffic congestion in urban centres. This leads to an increase in traffic accidents on road networks that are not designed for the current volumes and types of traffic. The irregular increase of the population in urban areas with limited facilities has affected the balance between the supply and demand of transport in the ASEAN countries. Figure 4.4 shows that as urbanisation increases, the traffic risk (fatalities per vehicle) in most countries decreases. This can be probably explained by the fact that the increase in urbanisation has also led to improved road safety facilities in urban areas, better medical recovery, lower speeds, and better communications.

Figure 4.4: Traffic risk and urbanisation for ASEAN countries in 2003

4.6.7 Severity Index

Severity index is another factor of interest in international comparisons. It was calculated for each ASEAN country in 2003 as the percentage of fatalities per casualty (fatal, serious and slightly injured). Table 4.3 shows that severity index varies with a low percentage of almost 0.85 in Thailand and a high percentage of 29.84 in Vietnam and 11.92 in Malaysia. The severity index decreases with the better medical facilities and rescue services (number of hospital beds per person or the number of physicians).

4.7 Final comments and summary

The results from this study indicate a remarkable difference between ASEAN countries of road safety even at the same level of motorisation. The study has shown that there is a continuing increase in the number of road deaths in all ASEAN countries except
Brunei, Singapore and Thailand (data from Indonesia is questionable). The trend in traffic risk (fatality rates per vehicle) is decreasing with time (1994 to 2003) in all selected ASEAN countries except Cambodia. This means that the road safety situation in ASEAN countries has improved from 1994 to 2003. Motorisation has increased about 50% in the ASEAN countries over the period 1994-2003. Traffic risk in ASEAN countries was found to be related with motorisation as was explained in Chapter 2 by Smeed and Oppe models. An increase of motorisation and urbanisation may lead to better road safety system in these countries. There is no clear sign for the personal risk to decrease over a time period like the traffic risk does in most ASEAN countries. Comparisons are limited to the indicators used because these are less complete and less reliable data in many ASEAN countries. If one is searching for the safest country in the ASEAN region, the answer cannot be given easily. It depends on which indicators that have been used and on what one wants to compare. Singapore and Brunei seem to have the safest record among the ASEAN countries according to the indicators (traffic risk and personal risk) used, while Laos, Cambodia and Vietnam show lower road safety records.

Identification of safety plans either in each single ASEAN country or regionally needs a more in-depth analysis of the accidents data, patterns and causes before coming to any conclusions or detailed explanations to the situation and problems in the region. Without further in-depth data, it is impossible to find more detailed explanations to the road safety problem in the ASEAN region. This comparison remains insufficient because other important factors are not taken into consideration. However, this study can be considered as a warning sign and a starting point. The next step is to explain why ASEAN countries differ and why a particular country had such serious road accident problem than another. One of the benefits from designing RSDI in the next chapter is to combine together more factors that influence road safety level in ASEAN countries and to compare the RSDI results with those are obtained in this chapter.
Chapter 5

Road Safety Development Index (RSDI)

The purpose of this chapter is to describe the methodologies and approaches that are used in the construction of RSDI. The idea is to integrate several aspects of road safety together in one simple and summary index. The dimensions and macro-level indicators that are used in building this index will be outlined in this chapter. This index is likely to become one major measure in comparing road safety progress internationally. Ten Southeast Asian countries are chosen as an empirical study. Sweden is additionally considered. At this stage and based on the availability and quality of data, eleven indicators are chosen in RSDI which have been categorised in nine dimensions. Four main approaches are used to calculate RSDI and determine which one is the best if possible.

Many composite (multidimensional) indices have been developed internationally and used in different aspects of life to indicate a progress or achievements between countries. They cover environmental issues, sustainable development, globalisation issues, agriculture, economy, information technology, and more. A large number of these indices are being developed and presented with the cooperation of international organisations and bodies. For instance Human Development Index (HDI), which was developed by the United Nations; Environmental Sustainability Index by the World Economic Forum; Composite of Leading Indicators by OECD; and Overall Health System Index by the World Health Organisation. Some other international indices were developed at universities and research institutes, for example The Growth Competitiveness Index by Harvard University in the US. A review of these studies is reported by John et al., (2001), Saisana and Tarantola (2002) and Andrew (2004). Moreover, different calculation techniques and treatment of indicators were applied to measure these summary indices.

Multi-national discipline and experts were involved in constructing and assessing the international composite indices. A.K. Sen, for instance, is a Nobel Prize holder and he is one of the key developers of the Human Development Index (HDI) in terms of his theory on poverty and welfare on a global scale (Andrew, 2004). Since 1990 the "Human Development Reports" (UNDP, 2004) have measured the country's
achievements annually by using HDI, according to: ‘life expectancy index’, ‘standard living index’, and ‘education index’. Since then several other supplementary indices to HDI have been developed such as the Human Poverty Index (HPI), Gender-Related Development Index (GDI) and Gender Empowerment Measure (GEM).

Until now, no similar index has been developed and used in road safety issues. Most previous work in international road safety assessment has focused on one or a few indicators (as outlined in the previous chapters). Most of the macro-models compare countries road safety performance by means of risk indicators (accident rates), which are few and isolated. However, road safety represents complex phenomena, where a high number of accident factors and indicators of human, vehicle, road, environment, regulation are involved. A systematic way to add up all the potential indicators combined with weights into one index is required. This will directly compare the road safety level and progress across a large number of countries and regions worldwide.

The proposed index in this study is the development of Road Safety Development Index (RSDI), which has been initiated from a desire to create a benchmark of national performance and development in road safety and to rank country’s level on a global scale and over a time period. The first outline of the RSDI is shown in (Al Haji & Asp, 2003).

As I move forward with this proposal, the concept of human development that is used by HDI does not end there and it is much more broader. The discussion in Chapter two has shown that there is a relationship between road accidents and each of the HDI components such as the level of income of the country, education and health level. Therefore, RSDI could be developed further to become a supplementary index to the HDI.

Nevertheless, the Human Development Index as many of other multidimensional indices has been criticised for its methodology and lack of accuracy. Frederik (2002) for instance has criticised HDI due to excluding several essential indicators on the quality of life, which drives the decision makers in the country to concentrate their efforts on education and health only. However, despite these shortcomings, HDI gets widespread media coverage, is widely accepted and is the most successful index worldwide.

5.1 The expected benefits of using RSDI

Many countries need to compare their own achievements and progress in road safety with other countries, where the awareness of the problem by public and policy makers is not enough. The problem itself is underestimated in many countries, especially in developing countries where the issue is challenging. The progress in any country will be minimum unless the country has good and standard measurement to rely on comparisons and problem formulation. Briefly, the main purposes of this new approach are as follows:
• RSDI integrates and summarises a lot of information and knowledge about road safety into measurable indicators, which will be then converted into a single value.
• RSDI describes the contributions of various indicators to the overall size of safety.
• RSDI is a simple format that allows direct comparison and ranks road safety progress internationally in a better way and more easily understandable form for ordinary people.
• RSDI can identify the performance in the country, which can increase the awareness of the problem among public and policy makers. This will help policy makers to take appropriate decisions, setting targets and priorities for the future.
• RSDI re-evaluates the results over time and may be used to monitor the trends in road safety in a country and indicates the direction of progress ahead.

5.2 Sources of data

The sources of data have been obtained from international organisations, including World Bank, United Nations agencies, World Health Organisation (WHO), International Road Federation (IRF). At this stage of study, much of the newly collected data comes from ASEAN countries together with ASNet database. Our intention here is to measure and test RSDI for a set of countries, which will then be developed for more study and used in other countries. The Globesafe\textsuperscript{13} in Sweden is one additional database for accident and exposure data in many countries. World Development Indicators (WDI)\textsuperscript{14} is an extensive database from the World Bank that groups different development indicators for most countries. For this purpose, it is important that data source is always available, reliable and everyone can check its accuracy.

5.3 RSDI quality criteria

The quality of RSDI or any composite index depends on the quality of the indicators and data that are used in the index. The major obstacle in constructing any international index is the lack of data. The index should be based on the selected criteria of macro-performance indicators that I discussed earlier (see Section 3.2.2). This means that these indicators must be reliable, valid and available. The composite index in general depends on what it is designed for? How is it designed? What is the agenda of such construction? Here come the strengths and weaknesses of any index. Concerning the criteria of RSDI, a number of issues can be addressed here:

• RSDI must be drawn from annual and national accounts;
• RSDI should be valid and regularly updated based on comparable and available indicators and data;

\textsuperscript{13} The Globesafe available online: \url{http://www.globesafe.org/}
\textsuperscript{14} The WDI is available in a print or online: \url{http://www.worldbank.org/data/}
• RSDI should provide a clear description of the selected indicators and the theories behind what already discussed in this thesis; and finally
• RSDI should provide a simple and clear selection of methodologies.

This set of criteria aims to improve the transparency and accuracy of the RSDI index. Missing of data is another issue that should be taken into account. It leads to less reliability on indicators and creating less reliability on the derived index. This problem differs from one country to country and it seems to have more severe affects in developing countries. In fact, there are some possibilities to solve or reduce this problem, for instance by estimating the values from nearest data/year with similar characteristics; by taking an average value (before and after if available); by using time series regression models to predict the missing value, or by using another year or mixing of years in case of cross-sectional data. In some countries where there is lack of data for one or more indicators, the RSDI will be hard to calculate or estimate. In this case, it would be better if we ignore the value of the country for this particular year (Not Available). Alternatively, we may give less-weight to the indicators with less availability.

The RSDI has the capability to be comparable over time series, and predicts the future. It shows the progress already made in a country by comparing the best and worst performance over the studied period. On the other hand, any change in the measurement criteria of RSDI will change the country’s ranking over time. This change of criteria includes: data improvements, differences in the weights, more variables included, and change in the methodologies. The change in calculation of the RSDI will change the final results of the country’s ranking as well.

5.4 Methodologies used in RSDI construction

In the previous work of this study, I presented a theoretical background to all the factors that could contribute in road accidents. I have identified the key macro-performance indicators, which has the potential for international comparisons and development. These selected indicators might be included in the RSDI index. Besides, I have made a comparative review of the main macroscopic models and methodologies are used in describing and comparing road safety development internationally. In addition to that, in the last chapter I gathered data from ASEAN countries, regarded as a case study. I am now moving ahead to develop this index RSDI in the remainder of this thesis and to test it on the data gathered from ASEAN countries.

RSDI is the sum of many dimensions where each dimension is a sum of indicators. There will be as balanced and important indicators within each dimension as available of data as possible. Both indicators and dimensions will give a broad picture of road safety and not focus on one particular aspect.
The major steps used in the process of constructing RSDI are the following and perhaps in some cases of process, the steps are interrelated:

- Finding the key indicators and dimension (group of indicators) that will be used in the long term of RSDI and in the purpose of the case study,
- Normalising (standardising) the variables,
- Weighting the variables,
- Combining the chosen indicators into (RSDI) by using different techniques,
- Applying RSDI for the ASEAN countries and performing an analysis of the results, and finally
- Testing the uncertainty and comparing the methods used with the obtained results.

Most composite indices follow the linear functional form. (Frederik, 2002) reported that the additive regression means that we can measure apples and oranges individually and then aggregate them into one index. The typical (standard) composite index of RSDI will take the form:

\[
\text{RSDI} = \frac{\sum_{i=1}^{n} w_i X_i}{\sum_{i=1}^{n} w_i}
\]

Where: \( w_i \): the weights of the \( X_i \)
\( X_i \): normalised indicators for country \( i \)

In most approaches \( \sum_{i=1}^{n} w_i = 1 \) and ranged from 0 to 1

5.4.1 Finding the best indicators to be added in RSDI

The first step in designing a road safety development index (RSDI) is to come up with a comprehensive set of indicators, which includes as far as possible all the main parameters in road safety of human-vehicle-road-environment-regulation, instead of considering a few factors such as accident rates per population or per kilometre driven. In addition, this index should be as relevant as possible for different countries, especially in developing countries. The choice of accident risk and exposure variables is necessary to what is available in international data and what is considered necessary for meaningful comparisons. Commonly, frequencies of annual numbers of vehicles, accidents, injured and killed people are some kind quantification and relatively easy to define and to measure in different countries. But differences in definitions, non-collection of data, non-reliability of data and under-reporting are problems for effective measurements of road safety.
Selecting macro-indicators for a multidimensional index is a complex issue, especially in which ones to choose and why? The indicators should make a valuable contribution to the area of road safety development in a country, whether the indicator provides any progress or not. In the early stage of this thesis, I tried to explain the relationship between the indicators and the risk of accidents as a whole as it would be possible to identify a set of performance macro-indicators (see Table 3.2) from literature review either in how they illustrate road safety level and development in a country (direct measures) or how they offer a significant affect on accident rates (indirect measures).

It is not possible to gather all sets of macro-indicators that are shown in Table 3.2 into the RSDI index, not only because they are many and they will take too much time to interpret and analyse, but because some of the indicators are requiring further development, which means availability and definitions. The number and type of indicators depend on the development level of a country, motorisation level (vehicles per population), and availability of data. The response of any indicator varies from one country to another. For instance, one acceptable indicator is ‘deaths per vehicle kilometre’ and it is an important element to be added to RSDI, but this measure is still not available in most developing countries. Hence this indicator is excluded from the selected indicators in the current study. For a similar argument, the indicator ‘percentage of motorways per road network’ was dropped because it has a low quality and reliability of data and there is a difference of definition of road standards across the countries. In fact, there are several indicators that may play an essential role in the development of RSDI, but unfortunately it is hard to obtain at this stage and they will be kept for further and future development. The selection of set of core indicators for RSDI is not final. The indicators will continue to be developed and refined.

The indicators covered in Table 3.2 have been classified into three classes according to their data availability and quality. The RSDI index reflects the availability and quality of indicators. Here I have to make first a distinction between RSDI in the short term, near term and long term. In the short term, RSDI will include indicators with high availability and acceptable quality. In the near term (in progress), RSDI will include the indicators with medium availability and acceptable quality. While the indicators that have no available information at the moment (availability low) where they require further development and collection of data will be used in the long term of RSDI development. For these reasons, RSDI in the long term will include more dimensions and indicators for a large number of countries, especially from the developing world. It is possible to develop two RSDI indices, one devoted to developing countries and one relevant for developed countries where they have well data collection. As an example Human Poverty Index (HPI) developed two indices HPI-1 and HPI-2 for developing and developed countries respectively. But I will leave this work for more analysis in future work.

In principle, eight general themes have been selected in the construction of RSDI, which are: traffic risk, personal risk, vehicle safety, roads situation, road user behaviour, socio-
economic index, road safety organisational index, and enforcement index. Each dimension has been broken up into indicators or sub-indices. For instance the socio-economic is the sum of four sub-indices, which are: health index, education index, urban population level, and income level (see Figure 5.1). The dimensions and indicators are illustrated briefly as follows:

The first chosen dimension is the level of traffic risk in a country, which deals with the fatalities rates. The fatality rate per vehicle is currently used, while fatality rate per vehicle-km or per person-km or per type of road user (pedestrians, cyclists, motorcyclists and drivers) are all other indicators of this dimension and they can be used on the long term of RSDI.

The second dimension is the personal risk, which is defined as fatalities per total population. An additional indicator that might be added in the long term is the fatalities per age of population.

The vehicle safety dimension is currently based on the percentage of the vehicles (not motorcycles) in the total vehicle fleet. Additional indicators that may be added in the long term include percentage of vehicles by age of car, and index of national crashworthiness (percentage of vehicles by crash performance and the protection given to its occupants against injury crash).

The road level is currently based on the percentage of the paved roads per total network. Additional indicators that might be added here in the long term include proportion of the motorways per capita/vehicles, and the national expenditure in roads as percentage of GDP.

The dimension of road user behaviour is currently based on the percentage of seat belt use, and helmet use. Additional indicators that might be added, include the percentage of drivers above BAC (Blood Alcohol Concentration), and percentage of all drivers exceeding the speed limits.

In the socioeconomic index the sub-indices are: urban population, health level, education level, and income level.

The urban population is based on the percentage of population in urban areas. Data on annual population growth rate, population age (with high risk in traffic) between 15-29, aged 65 and above might be added.

In the health sub-index, the currently used indicators are life expectancy, and severity index (number of fatalities per total population). Additional indicators that might be added in this sub-index in the long term of RSDI are the proportion of the physicians per capita, number of hospital beds per capita, and health care expenditures.
The currently used indicator in the education sub-index is the literacy rate (the percentage of people over 15 years able to read and write in their home language). Data on public expenditure on education may be added in the long term to RSDI.

In the income sub-index, the indicator currently used is Gross Domestic Product (GDP) per capita. An additional indicator that might be added in the long term is the unemployment of the labour force in the country.

The enforcement index measures traffic enforcement effectiveness levels in the country. It can be based on the objective indicators such as the annual number of random breath tests (per vehicles) and the annual number of speed-violation tickets (per vehicle). Additional subjective indicators that may be added include the technical means and equipments that are available to the traffic police in the country. One study (Cameron & Diamantopoulos, 2000), of the few studies in this area, has developed a combination of objective and subjective indicators to measure an enforcement index for the State of Victoria in Australia. This enforcement index cannot be used at this stage due to the lack of data from most countries.

The last proposed dimension of RSDI is the road safety organisational index that measures how much is the cooperation between the key bodies responsible for road safety actions in the country, how much funding is spent on road safety measures. It shows the level of development of national road safety council and NGOs. It shows how far each country is from the goal of national road safety programs (if there is any). This index can be developed further and benefit from other available indices especially those used to assess the management development and organisational culture between countries. This index is not used here because of lack of data.

The indicators included in RSDI measure road safety development in terms of direct (output or ends) and indirect (means or input). The direct indicators are derived measures e.g. fatalities rates (traffic risk and personal risk) and they are considered as good measures for explaining national road safety development. The indirect indicators are individual means in the way they can describe the development in a particular relevant theme to road safety. Many international indices include both terms in the same index. For example, the Composite Health Index includes ‘infant mortality rates’ as an output (direct) indicator of health index.

It is also possible to include qualitative information from expert reviews into any dimension of RSDI after translating the expert’s answers and opinions into the rating system of RSDI (the methodology will be discussed further in section 5.6.2). In many cases, there is a lack of quantitative information and it would be better if RSDI could include subjective indicators in the long run. Both organisation and enforcement measures are based purely on subjective assessments and at this stage it is a major problem to gather expert assessments regarding both measures and to measure
subjective indicators. However, I believe that both dimensions can be developed further and become essential elements of RSDI in the future.

The following figure shows the main components involved in RSDI where each component comprises a number of indicators:

![Diagram of RSDI components](image)

Figure 5.1: Components of RSDI

At this stage of the study and based on the previous discussion, we are left with eleven indicators in nine themes (see Table 5.1). They do not fully address the development, but still they give a broad picture of road safety rather than just focusing on individual aspects. I tried to find balanced and important indicators within each dimension as available as possible. I identified the maximum and minimum values in the table for each of the selected indicators based on a wide-ranging sample of countries. The sample was taken from different countries in different years with different levels of development and motorisations. The aim of this survey was to observe the differences across the countries worldwide in terms of the selected indicators. It can be seen from the table that huge differences exist between the countries in all indicators. In addition, the range of values is different from indicator to another, which means that the change percentage (increase or decrease) between indicators is different. For example a decrease 10% of roads paved in a country from a level of 90% is probably more significant than the same decrease of GDP per capita from 30,000 U.S. dollars level. In
like discussion, the percentage change of value at low level of indicator maybe is
different than the same change at high level of the same indicator. For example a
decrease of 10% of traffic risk at low level as many developed countries seek to achieve
this goal (e.g. from 1.2 to 1.08) is perhaps more significant than a same decrease at high
level (e.g. from 300 to 270).

At the same time, it might be better if we state a target value for the minimum and
maximum values that are identified, according to a special performance scale for each
indicator. This can be estimated on the idea that there is potential progress ahead for all
countries in road safety development. The indicators contribute differently to the RSDI.
The low values of traffic risk, personal risk and severity index show a good safety level
in a country, while in contrast the safety issue increases continuously with increase of
the values of other indicators.

Table 5.1: The selected indicators will be used in the analysis of RSDI

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Indicators</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Risk</td>
<td>- Fatalities per 10,000 vehicles</td>
<td>1.2</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>- Fatalities per 100,000 people</td>
<td>0.50</td>
<td>70.0</td>
</tr>
<tr>
<td>Personal Risk</td>
<td>- Percentage of vehicles not motorcyclists</td>
<td>5</td>
<td>95</td>
</tr>
<tr>
<td>Vehicle Safety</td>
<td>- Percentage of roads paved</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Road user</td>
<td>- Percentage of front-seat belt use</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Behaviour</td>
<td>- Percentage of crash helmet use</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Urban Population</td>
<td>- Percentage of urban population</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>Income level</td>
<td>- Income: Gross Domestic Product (GDP) per capita (in current U.S. dollars)</td>
<td>100</td>
<td>40,000</td>
</tr>
<tr>
<td>Health level</td>
<td>- Life expectancy (years)</td>
<td>25</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>- Severity index (% of number of fatalities per total casualties)</td>
<td>1</td>
<td>40</td>
</tr>
<tr>
<td>Education level</td>
<td>- Adult literacy rate (% of persons over 15 years able to read and write)</td>
<td>1</td>
<td>100</td>
</tr>
</tbody>
</table>

Maximum and minimum values obtained from sample of several countries with different levels of development.
Sources: IRF, WDI, United Nations, Globesafe database.

There are few indicators that are already widely used in international indices which will
make RSDI easy to understand and more valid. The UNDP has considerable resources
to decide which indicators to use in the HDI and determine best practices from different
sources and countries. The examples used in the RSDI contexts and taken from HDI
are: ‘Life expectancy (years)’, ‘Adult literacy rate’ and ‘Gross domestic product per
capita’. However, ‘Life expectancy’ alone is not enough to measure the health level.
One needs to make the selection more specific. I therefore added severity index to this
dimension (health level). As discussed earlier, the severity index decreases with better
medical facilities and rescue services.
In appendix 1, the descriptive statistics of all selected macro-indicators is presented. The table shows the actual values (before normalisation) and the differences in the indicators among the ASEAN countries and Sweden. These eleven indicators allow regional/international comparisons and RSDI construction. A brief look to the table shows that the severity index is not fully correlated (ASEAN data) with life expectancy and this is probably due to unreliable figures for injuries in some ASEAN countries.

Other interesting features of RSDI include a development of disaggregated indicators across municipalities in the country. This provides a useful basis for local policy makers to address their own problems compared to other municipalities and counties in the country. The prospects using the RSDI approach for big cities are discussed briefly in (Al Haji & Asp, 2004). As might be known, municipality data often has homogenous definitions (standards) and nearly similar socioeconomic conditions and levels of mobility. It is also possible to construct RSDI in terms of homogenous risks by different road users, age groups and types of vehicles.

5.4.2 Normalising (standardising) the indicators

The second step of the RSDI construction process is the normalisation of the values of indicators before integrating them together into RSDI. The indicators have different scales and units. The idea of normalisation makes all indicators acquire the same magnitude before mixing them together (like comparing oranges with apples). We need to ensure that no value will dominate others in the final RSDI scores. For instance, countries have different scales in population and total networks. Besides the units of indicators vary from one indicator to another, for example the percentage of paved roads will range from 0 to 100, while GDP per capita will be on thousands of units. If we add both values directly to the RSDI, the "GDP per capita" would always dominate the other indicator(s).

There are many techniques used to normalise the indicators and each technique has its own advantages and disadvantages. These techniques depend on data availability, sample size of countries and the expected (wanted) influence of variables in the final index. The most common methods used in normalisation data of international indices are the general linear transformations techniques that are listed below for the first three methods, while the other methods use special techniques:

1) Distance between the actual value and the best and worst values. It depends on whether the safety level has an increasing or decreasing rate of in the change in the values of an indicator. For example, by normalising the indicator ‘paved roads’ I use the formula:

\[
\text{Normalisation} = \frac{(\text{Actual value} - \text{Minimum value})}{(\text{Maximum value} - \text{Minimum value})} * 100
\]  

(5.1)
For traffic risk I use the following formula, because a low value of traffic risk shows a good safety level in a country:

\[
\text{Normalisation} = \frac{\text{Maximum value} - \text{Actual value}}{\text{Maximum value} - \text{Minimum value}} \times 100 \tag{5.2}
\]

2) Distance between the actual value and the mean:

\[
\text{Normalisation} = \frac{\text{Mean}}{\text{Actual value}} \tag{5.3}
\]

\[
\text{Normalisation} = \frac{\text{Actual value}}{\text{Mean}} \tag{5.4}
\]

3) Distance to the target/goal (estimated value ahead) or to the maximum value. If the minimum value in the formula (5.1) is zero, we will arrive at these formulas as well:

\[
\text{Normalisation} = \frac{\text{Target value}}{\text{Actual value}} \tag{5.5}
\]

\[
\text{Normalisation} = \frac{\text{Actual value}}{\text{Target value}} \tag{5.6}
\]

4) Normalisation to the previous year by dividing the value from one year to the next (percentage annual change). One example of this technique is the Index of Economic Well-Being (Saisana and Tarantola, 2002).

5) Normalisation to the standard deviation, which assumes a normal distribution to the data with mean zero and unit standard deviation. This technique is commonly applied in multivariate methods (e.g. principal components):

\[
\text{Normalisation} = \frac{\text{Actual value} - \text{Mean value}}{\text{Standard deviation}} \tag{5.7}
\]

This technique is used, for instance, by the Environmental Sustainability index (OECD, 2002).

6) Non-normalisation methods of data are applied when all indicators have the same scale, for instance all variables are percentage. In this case there is no dominant (does not mean important) variable in scale or unit. This technique is used by the Human Poverty Index (HPI).

7) Different normalisations in the same index. The Human Development Index (HDI) uses a non-linear normalisation to standardise the GDP index by taking the logarithm of the actual values of GDP per capita in order to reduce the influence of high-income countries to others.
In Table 5.2, I compare different normalisation techniques through an example of traffic risk between different ASEAN countries and Sweden.

Table 5.2: Traffic risk as an example of using different normalisation techniques

<table>
<thead>
<tr>
<th>Normalisation Techniques</th>
<th>Traffic Risk</th>
<th>Distance to standard deviation (formula 5.7)</th>
<th>Distance to the mean (formula 5.4)</th>
<th>Distance from max-min (formula 5.2)</th>
<th>Distance to the target (formula 5.6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunei</td>
<td>1,14</td>
<td>-1,05</td>
<td>0,10</td>
<td>99,9</td>
<td>1,3</td>
</tr>
<tr>
<td>Cambodia</td>
<td>22,73</td>
<td>1,28</td>
<td>2,09</td>
<td>19,6</td>
<td>25,3</td>
</tr>
<tr>
<td>Indonesia</td>
<td>12,19</td>
<td>0,14</td>
<td>1,12</td>
<td>58,8</td>
<td>13,5</td>
</tr>
<tr>
<td>Laos</td>
<td>20,87</td>
<td>1,08</td>
<td>1,92</td>
<td>26,5</td>
<td>23,2</td>
</tr>
<tr>
<td>Malaysia</td>
<td>4,88</td>
<td>-0,65</td>
<td>0,45</td>
<td>86,0</td>
<td>5,4</td>
</tr>
<tr>
<td>Myanmar</td>
<td>27,99</td>
<td>1,85</td>
<td>2,57</td>
<td>0,0</td>
<td>31,1</td>
</tr>
<tr>
<td>Philippines</td>
<td>9,79</td>
<td>-0,12</td>
<td>0,90</td>
<td>67,7</td>
<td>10,9</td>
</tr>
<tr>
<td>Singapore</td>
<td>2,97</td>
<td>-0,86</td>
<td>0,27</td>
<td>93,1</td>
<td>3,3</td>
</tr>
<tr>
<td>Thailand</td>
<td>5,23</td>
<td>-0,61</td>
<td>0,48</td>
<td>84,7</td>
<td>5,8</td>
</tr>
<tr>
<td>Vietnam</td>
<td>10,94</td>
<td>0,01</td>
<td>1,00</td>
<td>63,4</td>
<td>12,2</td>
</tr>
<tr>
<td>Sweden</td>
<td>1,11</td>
<td>-1,06</td>
<td>0,10</td>
<td>100,0</td>
<td>1,2</td>
</tr>
</tbody>
</table>

* StDev: 9,26, Mean: 10,89, Minimum: 1,11, Maximum: 27,99 and the Target value: 0,9

As shown in the table the traffic risk is scaled between 0 to 100 by applying formula (5.2). The normalisation techniques can be tested to show whether the results are highly influenced by any of the methods used in this normalisation. For this empirical sample (11 countries), all countries did not show any change by using any of the techniques. I prove this by comparing the correlation between each pair of methods as illustrated in Figure 5.2. The correlations are perfect (R-sq=100%) and we can therefore generalise that the results obtained in this study are not influenced by any normalisation method choices.

![Figure 5.2: The correlation between different normalisation methods for a road safety performance](image-url)

This may lead us to admit that the chosen sample of countries is rather small and perhaps this analysis will differ if we take a larger sample of countries. This will perhaps lead to the values having more skewed distribution.
5.5 Weighting the variables

The choice of weights for multidimensional indices is crucial if any change in weight values occurred, that will change the country’s ranking. In addition the change of approach (methodology, system) in calculating the index will change the weights and the final results of the index. The weights can be measured or estimated empirically from data collected, subjectively from expert’s opinion or based on statistical and theoretical background.

The eleven indicators chosen earlier will have different importance (weight) in the RSDI. We first need to give weights to the indicators in the sub-index (dimension), for instance in the health dimension and then weighting all dimensions together. The weights are valued on their importance and impact on the whole situation of road safety. This could be shown in the correlation between the indicator and the road safety improvement. It is possible to give all indicators equal weights in order to make the index simpler. However in this case, if we add all indicators in the same index together, the equal weights will give more score to the dimensions that have included many indicators (e.g. the socioeconomic dimension). Hence, we have to consider the dimensions only when we calculate RSDI.

Giving more weights to the indicators with high availability in international sources is crucial. The weighting according to missing data is not simple, maybe we can give less weight to the indicators with more missing data, but here we will approach the question of data collection and this can skew the good scores of RSDI towards countries with more availability of data.

Frederik (2002) has explained the advantages and disadvantages of different weightings methods used in several research studies. The study demonstrated the reasons behind the choice. It concluded that the weighing remarks are always questionable: “No weighting system is above criticism”.

Four methods for determining the weights are considered in this study through two objective methods, which are: ‘simple equal average’ and ‘principal components analysis (PCA)’; and other two subjective methods, which are ‘assessment technique from expert’s opinion’ and ‘assessment technique from literature and theory review’. The PCA method is a statistically based option. The ‘simple equal average’ method uses equal weights to all indicators and countries, whereas the other methods give different weights dependent on the importance of indicators.

5.6 Combining the chosen indicators into RSDI by using different techniques

In principle, four main approaches will be used to calculate RSDI and determine which one is best. The idea as in other indices is to experiment with different approaches and weights and to compare the obtained results afterwards, before deciding on one or more
techniques to be used in future. In all four approaches, all countries will be classified into three groups by achievements in RSDI ranged from 0 till 100 where high road safety development (with RSDI of 70 or above), medium (40 till 70) and low (less than 40). Each RSDI value can show how far a country has to be developed to provide safer roads. It shows the progress it has made toward the maximum possible level of road safety development. A description of these approaches is as follows:

5.6.1 Approach 1: Using Simple Average

In many international composite indices (i.e. HDI), all the included variables are given the same weight. This means that all indicators in the composite index have the same importance. Following this methodology, the selected indicators and dimensions through RSDI are given equal weights. All the eleven indicators are normalised and the performance of each indicator ranges from 0 to 100. In country j, we normalise the indicator li by using the method (distance between the actual value and the best and worst values):

$$I_{ij} = \frac{1}{n} \sum_{i=1}^{n} \left( \frac{\text{max}(I_i) - I_{real}}{\text{max}(I_i) - \text{min}(I_i)} \right)$$

Or

$$I_{ij} = \frac{1}{n} \sum_{i=1}^{n} \left( \frac{I_{real} - \text{min}(I_i)}{\text{max}(I_i) - \text{min}(I_i)} \right)$$

The selection of the formula depends on the safety level if it has an increasing or decreasing rate in the change with respect to the value of indicator.

The dimensions are calculated as the simple average of the included indicators. Each dimension is given equal weight (one-ninth) in the final RSDI. The *Road Safety Development Index* (RSDI) is defined as the simple average of these nine dimensions for country j as:

$$RSDI_j = \frac{1}{9} \sum_{i=1}^{9} D_i$$

Where:  
D_i: the normalised dimensions for country j

The minimum and maximum values are taken as the actual values in the selected countries. The maximum value of RSDI is 100 and it shows how far the country is from this target. The minimum value of RSDI is 0. All countries are developed to some degree in road safety, so no country will get a 0 score. Also the criteria of several indicators will make the 100 score as a target. These targets would be set for each indicator and they bring together the best values available across the globe. In the long run, RSDI would benefit from the progress of the international targets in road safety and other performance standards (e.g. the Swedish Vision Zero).
Following this approach (methodology), I measure the RSDI (along with the normalised values of dimensions) for the sample of ASEAN countries and Sweden by combining all the nine dimensions of road safety together. In the appendix 2, I present the RSDI values of these countries. The results range from 0 to 100. The higher values indicate a higher level of safety in the country. The lower values indicate the worst performance in country in terms of road safety level and vice versa. The mean value of RSDI can be estimated as roughly 40-50 for the whole sample. The RSDI value shows the achievement each country has made. This direct and simple ranking is quite useful to policy makers and ordinary people since it will show the scale of the problem clearly and easily. The appendix 2 also indicates that RSDI level is high for Sweden followed by Singapore and Brunei. The lowest RSDI values are found in Vietnam, Cambodia and Laos. The Cambodia and Laos have almost near RSDI values.

The results of RSDI differ considerably between the chosen countries. To understand these outcomes, one needs to investigate the differences of the combined dimensions. A look of the appendix 2 and Figure 5.3 shows that Sweden is the best performing country in terms of ‘traffic risk’, ‘road user’s behaviour’, ‘GDP per capita’ and ‘education level’. Singapore has higher levels with respect to ‘road situation’ and ‘urban population (% of total population)’. Brunei got the best score in the indicator ‘vehicle safety’. Not surprisingly, Myanmar scored number one in ‘personal risk level’ (normalised) because (as discussed earlier) a country at an early level of motorisation tends to have a growing number of traffic-related deaths, but with low growth in the number of population-related deaths (personal risk).

![Figure 5.3: The outcome differences on road safety dimensions between ASEAN countries and Sweden (in 2003)](image)

I classify the countries into three groups by achievements in RSDI ranged from 0 till 100 where high road safety development (with RSDI of 70 or above), medium (40 till
70) and low (less than 40). This methodology (Figure 5.4) puts Sweden, Singapore and Brunei at the top level of the list and is followed by Malaysia, the Philippines, Thailand and Indonesia. On the other hand, Myanmar, Vietnam, Cambodia and Laos have a low level of RSDI.

High RSDI level (with RSDI of 70 or above):

Medium RSDI level (40 till 70):

Low RSDI level (less than 40):

Figure 5.4: The three RSDI groups of ASEAN countries and Sweden
Moreover, these results show that RSDI correlates well with the Human Development Index (HDI) as shown in Figure 5.5. The coefficient of best-fit gives $R^2=89.6$, which seems highly correlated. This can be explained in terms of the relationship between road accidents and each of the HDI components, these are the level of income of the country, education and health level. Therefore, RSDI has the potential to be developed further and become a supplementary index to the Human Development Index in the future. Close examination of the figure shows that Myanmar obtained a higher RSDI rank than Vietnam and Cambodia compared with the HDI scores.

Julia (2003) explained why the equal weighting method is widely considered among many composite indices (i.e. HDI). In brief the reasons for this are: first, because it is a good method as we make the determination of weights less subjective. There are often difficulties surrounding the expert’s judgement of weights. Second, there is lack of interpretive meaning for some statistical methods. Finally, the fact that this method of equal weighting is good for transparency. This simple average shows that all countries are the same on the transparency dimension.

By contrast, it is not sensible to add a fixed average to all indicators and countries. One critical issue to HDI is that using fixed weights is equally important to all combined indicators (i.e. Michael, 2003). The following approaches give different weights to the indicators, so each dimension will receive an amount of weights depending on the importance of the indicators in each dimension.

5.6.2 Approach 2: Expert Judgements

The weightings in this approach are determined according to experts’ judgment. The principle of this approach is to submit checklists to a group of experts in road safety. They will be asked to mark the weights for different indicators and to assess the necessity of each indicator subjectively. The results (responses) will be transformed to
the rating system of RSDI, the larger weight is the more important and the total of weights should equal 100. This method has been proven to be a useful tool in some studies, for instance the *Growth Competitiveness Index* that developed by Harvard University (John et al. 2001). This index combines objective and subjective sub-indices together. The subjective variables are derived from a survey of business managers from around the globe. The expert opinion is also useful to assess the degree of development of particular indicator in a country. There are many important areas of road safety where it is hard to measure in quantitative forms. For example the assessment of the *National Road Safety Program (NRSP)* is based mainly on quality of information.

There are different techniques that can be applied in assessing the survey results and opinions of experts such as: the *Multi-Criteria Analysis* (Mendoza et al. 1999) and *Delphi Technique* (Harold et al. 1975). For now and because of the lack of our survey data, I do not discuss these methods further here.

The subjective results can be converted to the numerical scale of RSDI. One example of ranking this is using the technique shown in Table 5.3. A question that can be put to experts is: "would you mark the overall level (weight) of each indicator as excellent, good, average, poor or inadequate?" The subjective assessment will be graded as the RSDI scoring system from 0 to 100. The final sum of weights will be one.

<table>
<thead>
<tr>
<th>RSDI range</th>
<th>Inadequate</th>
<th>Poor</th>
<th>Average</th>
<th>Good</th>
<th>Excellent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 20%</td>
<td>10%</td>
<td>30%</td>
<td>50%</td>
<td>70%</td>
<td>90%</td>
</tr>
<tr>
<td>20-40%</td>
<td>20-40%</td>
<td>40-60%</td>
<td>60-80%</td>
<td>More than 80%</td>
<td></td>
</tr>
</tbody>
</table>

This approach depends on the expert panel and it requires a criterion assuming that the expert panels are recognised as fully qualified experts in the area of road safety. Besides, the combined information they have is good enough to judge on the issue we are dealing with. Moreover, it should be clear that it would be difficult to obtain the opinions of experts regularly and frequently.

### 5.6.3 Approach 3: Based on theories for each indicator

In some cases, we need to judge in the selection from experience and literature review. Weightings proposed here are based on literature experience and evaluation studies where we have to select among several alternatives, making a choice and evaluating the results afterwards. This alternative will not be the one finally chosen, we should review the weighting and the obtained results and if we disagree with this choice, we will make the necessary changes till we reach the optimal one in our perspective. We repeat the process again and so on.
By doing this, I rely on earlier studies that indicate accidents caused by a combination of five main dimensions (human-vehicle-environment-road-system). One of the major contributory factors in road accidents is human error. The size of this human error depends on the whole road system and traffic regulations. Rumar (1999) has shown that the major contributory factor in road accidents is the human factor. The results are taken from two in-depth studies and analyses carried out in the UK and USA. Both studies indicate that the human factor (road users), overlapping with other factors, is the major contributory factor in 94/95% of accidents as shown in Figure 5.6.

![Figure 5.6: Percentage of the major factors contributing to road accidents as obtained from two in-depth studies in Britain and USA (Rumar, 1999).](image)

Nearly all attempts to examine human factors found larger behaviour influences. Most of the accidents resulted from the violation of traffic laws. In one study carried out in Indiana State in USA presented in (Oppe, 1993), the frequencies of cause factors were calculated. The results have shown that in 70.7% of accidents the causes were human, 12.4% environmental and 4.5% vehicles. Furthermore, the measure of Traffic Risk is widely accepted in international comparisons and it deals with the fatalities rates per vehicles, per vehicles-km or per person-km.

In my view, I can say that both traffic risk (direct measure) and behaviour index (indirect measure) play an important role in calculating RSDI. I probably give them larger weights. An example of the choice of weights in my view is given as follows, the weights are shown in brackets: The most important indicators are: traffic risk and behaviour the weight of which is (25%) each. The second most important are: vehicle safety, road level, and personal risk, each of which has a weight of (10%). The least important indicators are socio-economic indicators: health index and income per capita, each of which has a weight of (5%). So, the formula is derived as follows:
RSDI = 0.25* (traffic risk) + 0.10* (personal risk) + 0.10* (vehicle safety) + 0.10* (road level) + 0.25* (road users behaviour) + 0.05* (urban population level) + 0.05* (income level) + 0.05* (health level) + 0.05* (education level)

Again the sum of all of the weights should be 1. The results of RSDI are presented in appendix 2. The RSDI ranges between 0 and 100. The higher values indicate higher levels of safety in the country. The lower values indicate the worst performance in a country in terms of road safety level. The table also indicates that the RSDI level is high for Sweden, Singapore and Brunei. The opposite picture is the case for the countries Vietnam, Cambodia and Laos as they obtained a lower level of RSDI.

As can be seen, by comparing these results from those shown by the ‘simple average’ method that RSDI scores are positively impacted through this choice of the ‘based on theories’ method. The weights and values slightly increase in most countries. Malaysia had the largest positive change, while Myanmar got the largest negative change. Thailand got a higher ranking compared to the Philippines by using this method. Similarly, Vietnam got a higher ranking than Myanmar by using this method.

When measuring RSDI, one has to remember that there are many indicators composed together into a single number and a lot of work was made behind the result (e.g. data collection, selection, weightings, etc.). Moreover, an understanding of this RSDI score/rank requires a closer look at the data behind each indicator. The illustration for example shown below (or Figure 5.4) can complement and explain the obtained RSDI results. It shows a considerable difference between these indicators and countries. This will be useful for identifying the problems in the country where the necessary actions should be taken in the future.

Figure 5.7: An illustration of the differences between various dimensions of road safety development in some ASEAN countries and Sweden (in 2003).
Principal Component Analysis is a multivariate technique used to find a combination of indicators. It describes the variation of the original data by means of a smaller set of dimensions (termed principal components) than the original number of indicators (data reduction technique). PCA is a very promising technique that is widely used in many fields of science and has also been used in the construction of some of the composite indices for instance the Internal Market Index for EU countries (Tarantoal, 2002). The PCA transforms the original indicators into new and uncorrelated components, which means that the principal components are measuring new and different indicators with different weights. The results of PCA can be obtained in a best score when the original indicators are highly correlated. The PCA technique requires all the indicators to be analysed together not only the dimensions as the previous methods did.

The data of indicators is first normalised to zero, mean and unit variance, which will ensure that all measurements have equal weights in the analysis by using the formula:

\[
\text{Normalisation} = \frac{(\text{Actual value} - \text{Mean value})}{\text{Standard deviation}}
\]

The adjustment data is transformed into a new set of uncorrelated principal components using the covariance matrix (or its correlation matrix direct when the indicators have a same patterns of units). PCA finds and calculates the eigenvalues and eigenvectors for the covariance matrix. The eigenvalues describe the variance and the sum of the eigenvalues is equal to the total number of indicators being analysed. Each indicator contributes to a proportion of the variance. The sum of variance of the PCs is equal to the sum of the variance of the original values. The coefficients (loadings or weights) for each PC are the eigenvector and each Principal Component is a linear combination of the original \( n \) indicators, where the first component \( Z_1 \) explains the maximum amount of variance, while the next principal component \( Z_2 \) explains the remaining variance of the original data or the next largest proportion of variance and so on. We must remember that all the components are set in decreasing order of importance so that \( \text{var}(Z_1) \geq \text{var}(Z_2) \geq \ldots \geq \text{var}(Z_n) \). Together, all the principal components account for 100% of the variation and each eigenvalue is the percentage of total variance for each component.

The general forms for the created principal components in the linear combination of the indicators are (Manly, 1994):

\[
\begin{align*}
Z_1 &= a_{11}X_1 + a_{12}X_2 + \ldots + a_{1n}X_n \\
Z_2 &= a_{21}X_1 + a_{22}X_2 + \ldots + a_{2n}X_n \\
& \vdots \\
Z_n &= a_{n1}X_1 + a_{n2}X_2 + \ldots + a_{nn}X_n
\end{align*}
\]
Where $a_i$ are the regression coefficients (eigenvectors) that satisfy the formula:

$\sum_{i=1}^{n} a_i^2 = 1$

In the calculation of RSDI we compute all data and we consider the number of principal components that could explain most of the variation. It is usually between 70% and 90%. We exclude the components whose eigenvalues are less than one. This technique allows us to pick out a minimal number of PCs that summarise the total variance and data. Here the weight is given to the indicators with higher variance in the original data. By examining the eigenvalues in Table 5.4, we can decide how many principal components to use. Since the eigenvalues of the first two components are more than unity (1.00), we have to consider only the first two principal components (PC1, PC2), which together explain 82.5% of the data, which is good.

Table 5.4: Eigenvalue analysis of the covariance matrix of standardised values

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Eigenvalues</th>
<th>Proportion of total Variance</th>
<th>Cumulative variance</th>
<th>First Eigenvectors (coefficients)</th>
<th>Second Eigenvectors (coefficients)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1: Traffic Risk</td>
<td>7.1271</td>
<td>0.648</td>
<td>0.648</td>
<td>0.331</td>
<td>0.262</td>
</tr>
<tr>
<td>X2: Personal Risk</td>
<td>1.9433</td>
<td>0.177</td>
<td>0.825</td>
<td>0.010</td>
<td>-0.651</td>
</tr>
<tr>
<td>X3: Vehicle Safety</td>
<td>0.8255</td>
<td>0.075</td>
<td>0.900</td>
<td>-0.298</td>
<td>0.359</td>
</tr>
<tr>
<td>X4: Roads level</td>
<td>0.4448</td>
<td>0.040</td>
<td>0.940</td>
<td>-0.326</td>
<td>-0.162</td>
</tr>
<tr>
<td>X5: Seatbelts usage</td>
<td>0.3013</td>
<td>0.027</td>
<td>0.967</td>
<td>-0.360</td>
<td>0.010</td>
</tr>
<tr>
<td>X6: Helmets usage</td>
<td>0.1877</td>
<td>0.017</td>
<td>0.985</td>
<td>-0.322</td>
<td>-0.045</td>
</tr>
<tr>
<td>X7: Urban Population</td>
<td>0.1171</td>
<td>0.011</td>
<td>0.995</td>
<td>-0.344</td>
<td>0.169</td>
</tr>
<tr>
<td>X8: Income level</td>
<td>0.0457</td>
<td>0.004</td>
<td>0.999</td>
<td>-0.351</td>
<td>0.115</td>
</tr>
<tr>
<td>X9: Life expectancy</td>
<td>0.0055</td>
<td>0.001</td>
<td>1.000</td>
<td>-0.355</td>
<td>-0.170</td>
</tr>
<tr>
<td>X10: Severity Index</td>
<td>0.0021</td>
<td>0.000</td>
<td>1.000</td>
<td>0.082</td>
<td>-0.508</td>
</tr>
<tr>
<td>X11: Education level</td>
<td>0.0000</td>
<td>0.000</td>
<td>1.000</td>
<td>-0.295</td>
<td>-0.147</td>
</tr>
</tbody>
</table>

By examining the eigenvectors for the PC1 and PC2, we reach the formula of each principal component. The first formula is:

$Z_1 = 0.331X_1 + 0.010X_2 - 0.298X_3 - 0.326X_4 - 0.360X_5 - 0.322X_6 - 0.344X_7 - 0.351X_8 - 0.355X_9 + 0.082X_{10} - 0.295X_{11}$

Here $X_1$ to $X_{11}$ are the standardised values of the original indicators. This component accounts for $(7.1271/11)= 64.8\%$ of total variance. There appears to be a contrast between $X_1$ (traffic risk), $X_2$ (personal risk), and $X_{10}$ (severity index) on one hand, and the other indicators on the other hand. As be shown, the values of $X_2$ and $X_{10}$ are very small, which means that neither value affects $Z_1$ very much. Both $X_2$ and $X_{10}$ can be neglected in this component. The formula shows that $Z_1$ will be high if $X_1$ is high and others are low.
In a similar way, the second principal component is:

\[ Z_2 = 0,262X_1 - 0,651X_2 + 0,359X_3 - 0,162X_4 + 0,010X_5 - 0,045X_6 + 0,169X_7 + \\
0,115X_8 - 0,170X_9 - 0,508X_{10} - 0,147X_{11} \]

These X₁ to X₁₁ are the standardised values of the original indicators. This component accounts for \( (1,9433/11) = 17.7\%\) of the total variance and there appears to be a contrast between X₁, X₃, X₅, X₇ and X₈ on one hand, and the other indicators on the other hand. The second PC has led to indicators in the data set that have little variation with small weights in the first formula. The formula shows that Z₂ is highly influenced by the indicators ‘X₂: personal risk’ and ‘X₁₀: severity index’ where they have higher weight compared to other indicators. Indicators have different positive and negative signs in relation to road safety. Myanmar scored high by using this technique due to it has better records in personal risk level and severity index. This is perhaps due to unreliable figures of injuries in terms of severity index. However, it is good to understand the nature of the equations themselves. The second PCA accounts only for 17.7\% of the total variance. In fact a PCA just makes finding the eigenvalues of the sample covariance matrix.

We can substitute the values of the indicators (shown in Appendix 1) for each country in both formulas, Z₁ and Z₂. The results are shown in Table 5.5. For a snapshot of the performance in the chosen countries, we Plot Z₁ and Z₂ and we see (Figure 5.8) both components are uncorrelated. I have classified the countries into three groups. The countries to the left of the vertical axis show good results. The countries in the upper right got worse results, while other countries are around the average.

![Score plot of the new scores of principal components](image)

Figure 5.8: Score Plot of the new scores of Principal Components in ASEAN countries and Sweden

80
It must be stressed that principal components analysis has produced two indices with different scales. Thus there is need to convert the PCA weights into one single value (RSDI) with scale range from 0 to 100. In doing this, I first normalise the values of $Z_1$ and $Z_2$ by using the simple average method:

$$Z_{i (standardised)} = \frac{(Actual\ value - Minimum)}{(Maximum - Minimum)}$$

The RSDI can be calculated by attaching PC1 and PC2 with their weights into RSDI as shown in Table 5.5. The percentage weightings are given to each of the two principal components:

$$RSDI = 78.44\% \text{ (Normalised } Z_1) + 21.56\% \text{ (Normalised } Z_2)$$

where the weight of $Z_1$ is calculated as: $64.40\% / (64.40\% + 17.70\%) = 78.44\%$

The weight of $Z_2$ is calculated as: $17.70\% / (64.40\% + 17.70\%) = 21.56\%$

Table 5.5: The adjustment procedures of PCA weights to match the scale of the RSDI

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Z1</th>
<th>Z2</th>
<th>Simple average normalisation $Z_1$</th>
<th>Simple average normalisation $Z_2$</th>
<th>RSDI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunei</td>
<td>-2.698</td>
<td>0.593</td>
<td>82.29</td>
<td>72.45</td>
<td>80.16</td>
</tr>
<tr>
<td>Cambodia</td>
<td>3.186</td>
<td>0.794</td>
<td>2.76</td>
<td>77.11</td>
<td>18.82</td>
</tr>
<tr>
<td>Indonesia</td>
<td>0.718</td>
<td>-0.273</td>
<td>36.12</td>
<td>52.36</td>
<td>39.63</td>
</tr>
<tr>
<td>Laos</td>
<td>3.391</td>
<td>0.706</td>
<td>0.00</td>
<td>75.07</td>
<td>16.21</td>
</tr>
<tr>
<td>Malaysia</td>
<td>-1.388</td>
<td>-2.057</td>
<td>64.58</td>
<td>10.96</td>
<td>53.00</td>
</tr>
<tr>
<td>Myanmar</td>
<td>2.493</td>
<td>1.780</td>
<td>12.13</td>
<td>100.00</td>
<td>31.11</td>
</tr>
<tr>
<td>Philippines</td>
<td>0.115</td>
<td>0.955</td>
<td>44.27</td>
<td>80.84</td>
<td>52.17</td>
</tr>
<tr>
<td>Singapore</td>
<td>-3.709</td>
<td>0.850</td>
<td>95.95</td>
<td>78.41</td>
<td>92.16</td>
</tr>
<tr>
<td>Thailand</td>
<td>-0.043</td>
<td>-1.439</td>
<td>46.40</td>
<td>25.30</td>
<td>41.84</td>
</tr>
<tr>
<td>Vietnam</td>
<td>1.946</td>
<td>-2.529</td>
<td>19.52</td>
<td>0.00</td>
<td>15.30</td>
</tr>
<tr>
<td>Sweden</td>
<td>-4.009</td>
<td>0.620</td>
<td>100.00</td>
<td>73.09</td>
<td>94.19</td>
</tr>
</tbody>
</table>

| Eigenvalue | 64.40\% | 17.70\% |
| Weights out of 100 | 78.44\% | 21.56\% |
| Mean       | 0.00    | 0.00    |
| StDev      | 2.670   | 1.394   |
| Minimum    | -4.009  | -2.529  |
| Maximum    | 3.390   | 1.780   |

The result of this approach indicates again that RSDI level is high for Sweden followed by Singapore and Brunei. The lowest RSDI values are found in Vietnam, Cambodia and Laos. This approach has shown approximately near results to the other two approaches (simple average) and (based on theories). This will be discussed further in the next section.

In summary, the Principal Component analysis appears to be a satisfactory method for constructing RSDI. It seems to be an appropriate method for simplifying the data and
finding the weights for RSDI index. It would be interesting to test this method further, but we do not yet know for sure how the results would be for a larger sample of countries. Noting that PCA is quite sensitive to missing data.

5.7 Comparisons of the RSDI approaches

Here, I provide a brief review of the methods developed in constructing RSDI. The point here is not to decide which approach techniques to use or to say which approach appears to be the best combinations of the indicators and weights or to say that the objective approaches are in some way meaningful methods or better than subjective approaches. Rather, to show the differences (uncertainty) of these RSDI results from all approaches. There are some special statistical tools used to measure the uncertainty and sensitivity of the input data in contribution to the output variance, for example the uncertainties analysis method (UA) and sensitivity analysis (SA); a review of these methods is available in Saisana et al. (2005). Due to the small sample size and the nature of data used in this study, a simple method in comparing the RSDI approaches and results is presented in Table 5.6 and Figure 5.9.

The results from all approaches are almost near to each other as shown in the Table 5.6. As can be also seen, by comparing the three approaches, the RSDI scores are slightly increasing in most countries through the choice of the ‘based on theories’ method. The RSDI rank remains unchanged by using the other two methods, which made a slight change in RSDI scores. The RSDI value of Thailand moved forward to higher place ahead of the Philippines by using the ‘based on theories’ method. Similarly, Vietnam got a higher ranking than Myanmar by using the same method.

In the same table, the countries are classified into three groups by using RSDI ranged from 0 till 100 where high road safety development (with RSDI of 70 or above), medium (40 till 70) and low (less than 40). Sweden is top of the RSDI list and Singapore is number two, followed by Brunei. Along with Malaysia rank 4, the Philippines, Thailand and Indonesia are ranked at the medium level of RSDI. At the bottom of the RSDI list, the countries Myanmar, Vietnam, Cambodia and Laos are allocated at the same level. The distances between the three groups can be calculated statistically as the distance between the mean of each group. From the table we see the results of the top group is rather so far ahead of the other at the medium level, while the distance between the low level and medium level are almost near.

It is advisable to choose one or more countries as an average of RSDI in the whole sample. The average number of RSDI is 40-50; therefore Thailand and the Philippines can be selected in this regard as they have values near the average. It is unnecessary to make a simple average of the three RSDI scores to determine the final grade for each country for the reason that this study is intended to show the distinction between the approaches rather than combining them all together.
Table 5.6: The RSDI scores and ranks from the empirical analysis and approaches

<table>
<thead>
<tr>
<th></th>
<th>RSDI 'Simple average'</th>
<th>RSDI 'Based on theories'</th>
<th>RSDI 'PCA'</th>
<th>Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>93,10</td>
<td>94,95</td>
<td>94,19</td>
<td>1</td>
</tr>
<tr>
<td>Singapore</td>
<td>91,71</td>
<td>92,44</td>
<td>92,16</td>
<td>2</td>
</tr>
<tr>
<td>Brunei</td>
<td>82,02</td>
<td>82,12</td>
<td>80,16</td>
<td>3</td>
</tr>
<tr>
<td>Malaysia</td>
<td>55,83</td>
<td>64,29</td>
<td>53,00</td>
<td>4</td>
</tr>
<tr>
<td>Philippines</td>
<td>53,21</td>
<td>51,28</td>
<td>52,17</td>
<td>5</td>
</tr>
<tr>
<td>Thailand</td>
<td>49,13</td>
<td>52,41</td>
<td>41,84</td>
<td>6</td>
</tr>
<tr>
<td>Indonesia</td>
<td>42,84</td>
<td>44,09</td>
<td>39,63</td>
<td>7</td>
</tr>
<tr>
<td>Myanmar</td>
<td>32,05</td>
<td>23,20</td>
<td>31,11</td>
<td>8</td>
</tr>
<tr>
<td>Vietnam</td>
<td>26,31</td>
<td>28,09</td>
<td>18,82</td>
<td>9</td>
</tr>
<tr>
<td>Cambodia</td>
<td>21,16</td>
<td>19,38</td>
<td>16,21</td>
<td>10</td>
</tr>
<tr>
<td>Laos</td>
<td>18,63</td>
<td>18,51</td>
<td>15,30</td>
<td>11</td>
</tr>
</tbody>
</table>

I make intervals for each country according to the uncertainty of the selected weights. Figure 5.9 shows that whatever is approach used and weights given; most countries will have nearly the same RSDI performance, except Malaysia, Thailand, Myanmar and Vietnam where they are highly influenced by the choice of the weights and approaches. The uncertainty change range in these countries is about 10%, which is taken as the difference between the maximum and minimum RSDI values for the country. In this way, it is possible to determine a best-fitting line to represent the RSDI average results in the three approaches, which can be used for determining the average weightings (this point is left as future work).

Figure 5.9: Comparing the RSDI scores between ASEAN and Sweden according to the change of weights/approaches

![Figure 5.9: Comparing the RSDI scores between ASEAN and Sweden according to the change of weights/approaches](image-url)
The RSDI ranks in ASEAN agreed well with the results of the models and analysis investigated earlier in Chapter 4. The RSDI index seems very promising and the results could then be presented and compared to other regions (e.g. Africa, OECD countries, East Asia & Pacific, Latin America & Caribbean, Middle East and North Africa, East Europe, Central Asia, etc).

5.8 RSDI is looking forward

The RSDI needs to be tested further and revised. More extensive analysis will be conducted in the future. The new edition of RSDI may focus on more indicators and dimensions. It is necessary to improve the accuracy and reduce the uncertainty of the final RSDI results. This means that there is always need to improve the methodologies and the assessment of weights. The RSDI needs to be tested on a larger sample of countries and from different parts of the world.

5.9 Concluding remarks

This chapter has described the development of the RSDI. It has illustrated how it may be used and applied. Also it has shown the possible benefits in using this composite index. The RSDI is a summary value and can be of interest to governments since it will show the scale of the road safety problem that they were probably not aware of. The RSDI can be considered as a unique way of assessing the road safety achievements in different countries. This index is a new approach and the obtained results are encouraging. RSDI has prioritised the key indicators in road safety and provided a broad picture compared to the traditional models in road safety. RSDI can be developed to become a supplementary index to HDI. However, I should be cautious in making any strong conclusions for now, particularly there is a large amount of information hidden behind the RSDI record (number). This needs more assessment and improvement. This index is sensitive to any change of weights; however the approaches used have shown near RSDI ranks. Although I used objective indicators in the RSDI, there were still subjective choices of indicators and weights. Last, more attention (time) should be paid in testing and developing good indicators because this is the key step to any successful RSDI in the future.
Conclusions and future work

This final chapter presents a brief summary of the research performed in this thesis in the context of RSDI construction. This is followed by recommendations for further work.

Several important issues need to be considered when designing RSDI, i.e., macroscopic indicators and models in road safety. The followings are the summaries of the chapters:

In chapter one, the outline of this thesis work was stated. The aim of the study was also highlighted. The introduction to the concept of Road Safety Development Index (RSDI) was briefly presented.

In chapter two, the scope of road safety problem worldwide was briefly reviewed. It aimed to show a comparative summary of the road safety situation across different regions over the world. This review made it clear that road safety is a serious problem almost everywhere and it concerns every country.

In chapter three, the theoretical background to all the potential macro-factors that could contribute to road accidents was presented. The relationship between each factor and the probability that road accidents may occur on the national level was conducted. One special criterion to select suitable indicators was used. This has enabled me to determine the key macro-performance indicators in road safety. It has become clear that the chosen indicators must be easy, available, measurable, and comparable worldwide. Moreover, these indicators must be able to indicate/monitor the country’s progress over time in road safety and allow international comparisons. The obtained set of indicators was listed and summarised in Table 3.2. The next step was to understand and explain the main published macroscopic studies and models that are used in describing and comparing the road safety development internationally. I have divided the reviewed models into cross-sectional models (time-independent models) and (time-dependent models). A starting point in this direction was to investigate Smeed’s equation, particularly in the relation between motorisation and fatality rates. Several models for
the description for the long-term curve of development in road safety were also presented. Models have shown that making a linear relationship between the logarithm of traffic risk and traffic volume rates could be suitable to explain the data development. It is necessary to add time to any future model. The results obtained in this chapter were sufficient to conclude that the road safety development in a country is not only measured by the parameters just given, it is more effective where there are a large number of factors involved in the model. In the rest of the chapter, the difficulty of obtaining reliable accident data in a country was shown.

In chapter four, prior to constructing the RSDI index, I tested some macroscopic models and indicators empirically. A data set is used from the ADB-ASNet project, concerning ten Southeast Asian countries (ASEAN). The data were gathered during our visits to the ASEAN countries. The trends and levels of road safety among the region between 1994 and 2003 were analysed. This comparative study was also undertaken to investigate whether the varieties in road safety between ASEAN countries could be explained by differences in a few indicators and socio-economic patterns (that were given in Chapter 3). The main indicators used here are traffic risk as killed per vehicle, motorisation measured as vehicle per person, and personal risk as killed per person. Special cases of comparisons were presented when both indicators are considered together and when they interact with other indicators such as urbanisation and severity index (killed per casualties). Those models and indicators were used to explain the differences and development in road safety among ASEAN countries. At early stages of motorisation personal risk has a small value while the traffic risk will be large. At second higher stage of motorisation, traffic and personal risks increased. The other level is a highly motorised country (e.g. Brunei and Singapore) in which traffic and personal risks decrease. The difference between the three levels is partly due to better engineering of vehicles/roads and greater understanding of the system by the road users. The data collected and results obtained from ASEAN were useful in testing the multidimensional index (RSDI) in the next chapter.

In Chapter five, the main question addressed here was: how do we integrate several aspects of road safety together in one simple and summary index? The methodologies and approaches that are used in the construction of RSDI were stated. Before performing the type of analysis, I examined the dimensions and macro-level indicators that are used in building this index. Eleven indicators were chosen in RSDI, which have been categorised in nine dimensions. Four approaches for determining the weights were considered in this study. I classified them into objective and subjective methods. The objective methods are the "simple equal average method" and "principal components analysis (PCA)". The subjective methods are "assessment technique from experts opinion" and "assessment technique from literature and theory review". The PCA method is a statistically based option. The "simple equal average method" method used equal weights for all indicators and countries, whereas the other methods gave different weights depending on the importance of indicators. The thesis examined the RSDI for the ten ASEAN countries and Sweden in 2003. The results from this study indicated a
remarkable difference between ASEAN countries even at the same level of motorisation. It was verified that Singapore and Brunei seem to have the best RSDI record among the ASEAN countries according to the indicators used, while Laos, Cambodia and Vietnam show lower road safety records. It was also shown that the selection of the weighting methods has an influence on the country’s ranking (RSDI results). In contrast, the normalisation methods did not show a clear impact on the RSDI results. Perhaps this will be not the case if I used a larger sample of the countries. However the approaches used have given near RSDI ranks. Although I used objective indicators in the RSDI, there were still subjective choices of indicators and weights. The RSDI ranks in ASEAN agreed well with the results of the models and analysis investigated earlier in Chapter 4.

The results obtained in this study are sufficient to make me believe that RSDI gives broader picture compared to the traditional models in road safety. It is hoped that such ranking will help country to assess its road safety achievements compared to other countries.

Suggestions for Future Work

The RSDI is in progress and it is necessary to test it further and examine it more thoroughly in future work. The following suggestions are made on how this research can be developed further and strengthen the obtained results:

1. The new edition of RSDI may seek more comprehensive data for a larger number of dimensions and indicators. There are several indicators that may play an essential role to the development of RSDI, but unfortunately these indicators are currently not available and they require further development and collection of data in future for a large number of countries, especially from developing countries. In the future it is hoped to develop a set of macro-indicators that will be widely useful, regularly updated, available and can cover future data needs. The indicators proposed in Table 3.2 must be put into practice in the future and tested. Perhaps there is a need to explore new methods that can measure/assess the indicators that have missing data and poor quality of data. Today these problems are quite frequent and it is probable that work on solving these problems will continue in the future.
2. The RSDI needs to be examined with a bigger samples of countries and from different parts of the world in order to determine whether the results obtained in this study may be generalised.
3. It is necessary to improve the accuracy and reduce the uncertainty of the RSDI results. There is a need to investigate new applications and alternatives to the methods whether they can provide better results. This includes: better assessment of weights, better selection of indicators and data, better normalisation methods, and better uncertainty methods.
4. Continued improvement of the RSDI transparency. The transparency can be increased by better accuracy, clear selection and judgement of indicators. It might be useful if international organisations and agencies are involved in the development of RSDI, because this would increase the transparency level.

5. Future research has to deal with the subjective indicators. Both dimensions "Organisational Structure" and "Enforcement Measures" are based purely on subjective assessments. It is believed that both dimensions can be developed further and become part of the RSDI. At this stage, it was a major problem to gather experts’ assessment regarding both dimensions and to measure subjective indicators.

6. Another suggestion, which follows from Chapters 3 and 4, is to investigate further the given macro-models that can be used for describing/comparing road safety developments between different countries. This investigation will compare these models and determine the models with the best fit of data. It is probably useful to make these models more specific and test them with the same empirical data as used by RSDI then to assess the results of RSDI with the results of those models.

7. Possible future work in RSDI will include suggestions for two composite indices; one devoted for LDCs "Less Developed Countries" and a second one for DCs "Developed Countries" for which they have good and more data collection. For instance, Brunei, Malaysia, Singapore and Thailand have more through detailed data than other countries. Thus, RSDI can be expanded further and built on more detailed analysis for these countries.

8. Continued improvement of the targets of indicators (see Table 5.1), particularly in the way to state a target value for the minimum and maximum values for each indicator identified, according to a special performance scale for each indicator. This can be estimated upon the idea that there is a potential progress ahead for all countries in road safety development.

9. It might be useful if international organisations and agencies are involved in the development of RSDI. Future work can collaborate with national and international agencies that apply similar indicators and/or methodologies. Besides, this can bring together several experts (multi-discipline team) from several professional fields of road safety, health, education, management, statistics, etc. This will be useful in identifying the indicators and dimensions that should be used in future.

10. Further development should include using special database (e.g. online Internet based tool) that collects and analyses the accident and exposure data for the purpose of RSDI comparisons between countries. This database should be regularly maintained to ensure the accuracy of data and the RSDI indicators. The Globesafe database in Sweden could be one example in this regard.

Finally it can be said that the outcomes from this study are very encouraging. The RSDI index is very promising and worth further applications with a bigger samples of countries and from different parts of the world. This index has the potential to become
one major measure in comparing road safety progress internationally. However, more extensive analysis and applications need to be conducted in the future before making any strong conclusions for now. This makes me conclude as I started this thesis work that the concept of "Road Safety Development" is a broad and complex concept. This requires deeper processes, integrated programs and much more cooperation between all the key national and international bodies. Therefore, I will leave this multidimensional index (RSDI) for more improvements in future projects.

Ghazwan Al Haji

Norrköping, Sweden
May 2005
References


Jacobs, G.D., Fouracre, P.R., (1977). Further research on road accident rate in developing countries. TRRL report LR 270. Transport and Road Research Laboratory, Crowthorne, Berkshire.


Appendix. 1: Basic Macro-Indicators in ASEAN countries and Sweden (year 2002):

<table>
<thead>
<tr>
<th>Country</th>
<th>Traffic Risk</th>
<th>Personal Risk</th>
<th>Vehicles not motorcycles (%)</th>
<th>Paved Roads (% of total)</th>
<th>Percentage of seat belts use (estimated)</th>
<th>Percentage of helmets use (estimated)</th>
<th>Urban population (% of total population)</th>
<th>GDP per capita</th>
<th>Life expectancy at birth</th>
<th>Severity Index</th>
<th>Adult literacy (%)</th>
<th>Human Development Index (HDI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunei</td>
<td>1.14</td>
<td>7.82</td>
<td>97.0</td>
<td>91.0</td>
<td>75</td>
<td>35</td>
<td>72.0</td>
<td>19,210</td>
<td>76.2</td>
<td>2.15</td>
<td>93.9</td>
<td>0.867</td>
</tr>
<tr>
<td>Cambodia</td>
<td>22.73</td>
<td>7.54</td>
<td>24.8</td>
<td>16.0</td>
<td>10</td>
<td>8</td>
<td>17.0</td>
<td>2,060</td>
<td>57.4</td>
<td>4.76</td>
<td>69.4</td>
<td>0.568</td>
</tr>
<tr>
<td>Indonesia</td>
<td>12.19</td>
<td>12.97</td>
<td>24.8</td>
<td>46.0</td>
<td>15</td>
<td>60</td>
<td>41.0</td>
<td>3,230</td>
<td>66.6</td>
<td>1.18</td>
<td>87.9</td>
<td>0.692</td>
</tr>
<tr>
<td>Laos</td>
<td>20.87</td>
<td>9.81</td>
<td>19.9</td>
<td>14.0</td>
<td>9</td>
<td>7</td>
<td>19.0</td>
<td>1,720</td>
<td>54.3</td>
<td>3.01</td>
<td>66.4</td>
<td>0.534</td>
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<td>Malaysia</td>
<td>4.88</td>
<td>25.64</td>
<td>51.8</td>
<td>76.0</td>
<td>70</td>
<td>75</td>
<td>57.0</td>
<td>9,120</td>
<td>73.0</td>
<td>11.92</td>
<td>88.7</td>
<td>0.793</td>
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<td>Myanmar</td>
<td>27.99</td>
<td>2.68</td>
<td>63.1</td>
<td>12.0</td>
<td>11</td>
<td>6</td>
<td>28.0</td>
<td>1,027</td>
<td>57.2</td>
<td>2.78</td>
<td>85.3</td>
<td>0.551</td>
</tr>
<tr>
<td>Philippines</td>
<td>9.79</td>
<td>4.96</td>
<td>62.3</td>
<td>20.0</td>
<td>30</td>
<td>30</td>
<td>59.0</td>
<td>4,170</td>
<td>69.8</td>
<td>1.15</td>
<td>92.6</td>
<td>0.753</td>
</tr>
<tr>
<td>Singapore</td>
<td>2.97</td>
<td>4.58</td>
<td>81.0</td>
<td>100.0</td>
<td>85</td>
<td>85</td>
<td>100.0</td>
<td>24,040</td>
<td>78.0</td>
<td>2.27</td>
<td>92.5</td>
<td>0.902</td>
</tr>
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<td>Thailand</td>
<td>5.23</td>
<td>20.41</td>
<td>29.1</td>
<td>94.0</td>
<td>30</td>
<td>35</td>
<td>20.0</td>
<td>7,010</td>
<td>69.1</td>
<td>0.85</td>
<td>92.6</td>
<td>0.768</td>
</tr>
<tr>
<td>Vietnam</td>
<td>10.94</td>
<td>16.15</td>
<td>5.6</td>
<td>25.0</td>
<td>15</td>
<td>3</td>
<td>24.0</td>
<td>2,300</td>
<td>69.0</td>
<td>29.84</td>
<td>90.3</td>
<td>0.691</td>
</tr>
<tr>
<td>Sweden</td>
<td>1.11</td>
<td>6.4</td>
<td>94.3</td>
<td>82.0</td>
<td>90</td>
<td>90</td>
<td>83.3</td>
<td>26,050</td>
<td>80.0</td>
<td>2.6</td>
<td>100.0</td>
<td>0.946</td>
</tr>
</tbody>
</table>

Notes: 1. X1, X2, X3, ..., X11 are the selected macro-indicators that used to calculate RSDI. 2. The first three indicators and X10 are derived from the ASNet database for ASEAN countries (which presented in Chapter 4), while the main source of data for these indicators in Sweden are the International Road Federation (IRF). 3. X4, X7, X8, X9, X11 and HDI are taken from the latest Human Development Report 2004 and the World Development Indicators (WDI). For details, see: http://hdr.undp.org/2004/ , http://www.worldbank.org/data/. 4. The source of X5 and X6 in ASEAN countries is ASNet database. In some cases, the ADB consultants estimated this data. For Sweden, X5 and X6 are taken from (Koornstra et al., 2002). 5. The seat belt use rates cover mostly the front-seat occupants only. 6. The GNP per capita is the GNP in current U.S. dollars as calculated by the United Nations and the World Bank.
### Appendix 2: RSDI scores using simple average technique and subjective theories:

<table>
<thead>
<tr>
<th>Country</th>
<th>Traffic Risk</th>
<th>Personal Risk (vehicles %)</th>
<th>Vehicle Safety (%)</th>
<th>Road’s Situation Paved Roads (% of total)</th>
<th>Road User’s Behaviour</th>
<th>Urban population (% of total population)</th>
<th>GDP per capita</th>
<th>Health Index</th>
<th>Education level</th>
<th>RSDI (Simple Average)</th>
<th>RSDI (Based on Theories)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>100,0</td>
<td>84,5</td>
<td>97,0</td>
<td>79,5</td>
<td>100,0</td>
<td>79,9</td>
<td>100,0</td>
<td>97,0</td>
<td>100,0</td>
<td>93,10</td>
<td>94,95</td>
</tr>
<tr>
<td>Singapore</td>
<td>93,1</td>
<td>92,4</td>
<td>82,5</td>
<td>100,0</td>
<td>94,0</td>
<td>100,0</td>
<td>92,0</td>
<td>93,7</td>
<td>77,7</td>
<td>91,71</td>
<td>92,44</td>
</tr>
<tr>
<td>Brunei</td>
<td>99,9</td>
<td>78,2</td>
<td>100,0</td>
<td>89,8</td>
<td>59,1</td>
<td>66,3</td>
<td>72,7</td>
<td>90,4</td>
<td>81,8</td>
<td>82,02</td>
<td>82,12</td>
</tr>
<tr>
<td>Malaysia</td>
<td>86,0</td>
<td>0,0</td>
<td>50,5</td>
<td>72,7</td>
<td>79,0</td>
<td>48,2</td>
<td>32,3</td>
<td>67,3</td>
<td>66,4</td>
<td>55,83</td>
<td>64,29</td>
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<td>Philippines</td>
<td>67,7</td>
<td>90,8</td>
<td>62,0</td>
<td>9,1</td>
<td>28,5</td>
<td>50,6</td>
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<td>84,7</td>
<td>23,0</td>
<td>25,7</td>
<td>93,2</td>
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<td>78,0</td>
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<td>52,41</td>
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<td>21,0</td>
<td>38,6</td>
<td>36,5</td>
<td>28,9</td>
<td>8,8</td>
<td>73,4</td>
<td>64,0</td>
<td>42,84</td>
<td>44,09</td>
</tr>
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<td>Myanmar</td>
<td>0,0</td>
<td>100,0</td>
<td>62,9</td>
<td>0,0</td>
<td>3,0</td>
<td>13,3</td>
<td>0,0</td>
<td>52,3</td>
<td>56,3</td>
<td>32,05</td>
<td>23,20</td>
</tr>
<tr>
<td>Vietnam</td>
<td>63,4</td>
<td>41,7</td>
<td>0,0</td>
<td>14,8</td>
<td>3,7</td>
<td>8,4</td>
<td>5,1</td>
<td>28,6</td>
<td>71,1</td>
<td>26,31</td>
<td>28,09</td>
</tr>
<tr>
<td>Cambodia</td>
<td>19,6</td>
<td>79,5</td>
<td>21,0</td>
<td>4,5</td>
<td>3,5</td>
<td>0,0</td>
<td>4,1</td>
<td>49,3</td>
<td>8,9</td>
<td>21,16</td>
<td>19,38</td>
</tr>
<tr>
<td>Laos</td>
<td>26,5</td>
<td>69,5</td>
<td>15,6</td>
<td>2,3</td>
<td>2,3</td>
<td>2,4</td>
<td>2,8</td>
<td>46,3</td>
<td>0,0</td>
<td>18,63</td>
<td>18,51</td>
</tr>
</tbody>
</table>

Notes: (D1, D2, D3….D9) are the selected dimensions that used to calculate RSDI.

The values are normalised by using the simple weighted average.