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Road Safety Risk Assessment: An Analysis of Transport Policy and Management for Low-, Middle-, and High-Income Asian Countries

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Abstract: Road safety assessment has played a crucial role in the theory and practice of transport management systems. This paper focuses on risk evaluation in the Asian region by exploring the interaction between road safety risk and influencing factors. In the first stage, a data envelopment analysis (DEA) method is applied to calculate and rank the road safety risk levels of Asian countries. In the second stage, a structural equation model (SEM) with latent variables is applied to analyze the interaction between the road safety risk level and the latent variables, measured by six observed performance indicators, i.e., financial impact, institutional framework, infrastructure and mobility, legislation and policy, vehicular road users, and trauma management. Finally, this paper illustrates the applicability of this DEA-SEM approach for road safety performance analysis.

Keywords: risk analysis; safety; accidents; GIS; data envelopment analysis; structural equation model

1. Introduction

Road traffic accidents are one of the most critical problems for human life. Despite widespread measures being used to control and minimize this problem, road traffic accidents are facing a growing trend, day by day. According to the World Health Organization (WHO) report on road safety for 2015, road traffic injuries cause more than 1.25 million deaths each year and have an enormous effect on human life and development [1,2]. More specifically, these events are the major cause of death among young people aged between 15 and 29 years [3]. The cost associated with deaths and injuries is approximately 3% of the GDP in low- and middle-income countries. In spite of this huge human and economic loss, actions to fight this global challenge are still insufficient [4,5].

> Addressing the preventable problem of inadequate road safety requires the dedicated action of multiple ministries, most notably law, planning, transport, education, public information, and health. The range of measures to ensure road safety includes improving the built environment (e.g., safer road design, regulating sidewalks and traffic lights, introducing safe bicycle lanes), law enforcement and education to increase seatbelt use and helmet wearing while reducing speeding and drink driving, better vehicle standards, and improved post-crash response. Road safety measures that provide safer, more sustainable public transport options are also particularly promising and can support synergies between health, transport and carbon emission reduction targets [6].

Economic development, on one side, has increased motorization all over the world, particularly in low- and middle-income countries [4]. The increased number of motor vehicles requires more roads and higher demand for better measures of road safety and protection. In the year of 2014, the number of motor vehicles increased by 16% all around the globe; however, it is important to note that the road network has not been developed at the same rate [7,8]. Considering the fatality rate (deaths in road crashes per 100,000 of population) as a road safety indicator, that of the Southeast Asian Region (17) is still higher than that of Europe (9.3) [3]. This alarming situation highlights the need for promoting risk prevention actions across nations. As mentioned above, the traffic accident and injury statistics depict the worst position of the low- and middle-income regions, where the fatality rate is almost twice that of developed countries [3]. In the Asian region, the road safety situations of low-, middle-, and high-income countries have a different pattern, as shown in Figure 1. According to WHO, the fatality rate (FR) comparison shows that average FR values for low-, middle-, and high-income countries are 17.10, 18.31, and 13.80, respectively [3].

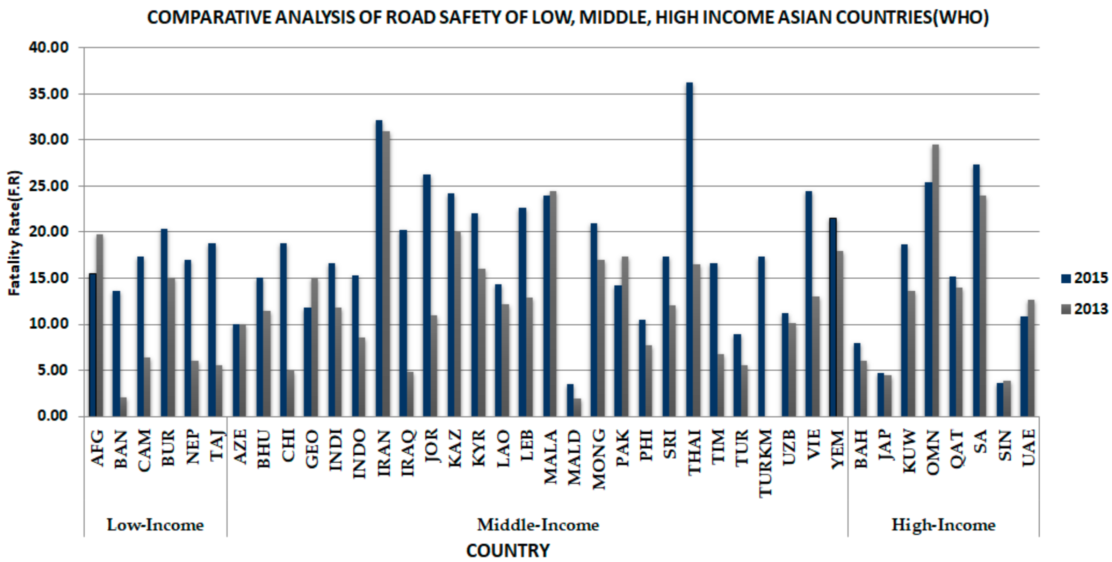

Figure 1. Comparative analysis of road safety of Low-Income, Middle-Income, and High-Income Asian Countries (source: World Health Organization (WHO)).

To control road traffic accidents, countries have developed and implemented various road safety programs. It is important to note that developed countries have succeeded in controlling traffic accidents. These attainments are the product of making infrastructure safer, improving the safety of vehicles [9], and executing a number of other interventions recognized to be effective at reducing road traffic injuries. Having good quality data to monitor the impact of these efforts is also critical to signifying their accomplishment. However, developing and less-developed countries have not yet achieved this level of success [10,11]. Regular road inspections are an important measure that help to ensure the quality of roads and road surfaces [12]. Considering some major factors (i.e., (1) institutional framework; (2) alcohol usage and speeds; (3) protective systems; (4) vehicles; (5) infrastructure and roads; and (6) trauma management, etc.), the focus of this study is to statistically develop and explore the relationships between the predictors of road traffic fatalities resulting from such events.

A smooth and good-conditioned road promises greater driving and road safety as compared to poor-conditioned roads which increase the probability of traffic accidents. Similarly, speed limits also play an important role in road safety. Restricting speed limits in high-density areas helps to promote road safety. Therefore, an exploration of the association of risk and road safety management indicators will help us to scientifically discuss the relationship between them and will also provide insight into designing effective and efficient road safety policy. In this study, we aim to evaluate the road safety risk of low-, middle-, and high-income Asian countries, a region with a combined population of 4.4 billion (60% of the world), with GDP US $35.334 trillion (Nominal) and US $57 trillion purchasing power parity (PPP) [13,14]. Considering the importance of this area, a structural equation model (SEM-)analysis-based approach is also applied to assess the statistical relationship between the risk and the factors involved in risk increment. The prime objective of this study is to analyze the road safety risk situation of Asian countries with reference to their economic condition (Low, Middle, or High Level). Furthermore, we evaluate the relationship of financial impact, institutional framework, infrastructure and mobility, legislation and policy, road user–vehicular impact, and trauma management with the risk levels of Asian countries.

2. Related Studies

2.1. Risk and Road Safety Analysis

Road safety analysis is related to the survival of humans on roads and, during road safety risk evaluation, 'risk' is associated with a number of fatalities and known as a road safety outcome. In the field of road safety, the risk is defined as 'the road safety outcome to the amount of exposure', as shown in Equation (1):

$$\text{Risk} = \frac{\text{Road Safety Outcome}}{\text{Exposure}}. \tag{1}$$

Researchers have calculated exposure according to the availability of data; some have used passenger kilometers traveled, population, number of registered vehicles, etc. [15,16]. Risk assessment is necessary for road safety performance analysis. Previously, road safety outcome was directly related with and calculated using the different exposure variables, but handling the multiple variables remained a problem. It is necessary to evaluate the risk and its relationship with the road safety performance indicators. The concept of Safety Performance Indicators (SPIs) was developed by the European Transport Safety Council (ETSC) [17].

The reason for the SPIs development was the assumption that accidents and injuries are only the tip of the iceberg because they occur as the 'worst case' result of unsafe operational conditions in the road traffic system. Thus, SPIs can be defined as measures that are causally related to accidents or injuries and are used in addition to the figures about accidents or injuries, in order to indicate safety performance or understand the processes that lead to accidents [18].

2.2. DEA and Road Safety Risk Analysis

Data Envelopment Analysis (DEA) is one of the nonparametric approaches developed by Chames, Cooper, and Rhodes [19] in 1978, and is an established technique in the field of road safety. As given in [20], its mathematical expression is as follows.

$$\begin{aligned} &\max E_0 = \textstyle\sum_{i=1}^{m} v_i x_{i0} \\ &\text{Subject to } \sum_{r=1}^{s} u_r y_{r0} = 1 \\ &\sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} u_r y_{rj} \le 0,\ j = 1, L,\ n \\ &u_r, v_i \ \ge 0, r = 1, L, S,\ i = 1, L, m \end{aligned} \tag{2}$$

Previously, risk evaluation was based on different parameters like public risk and traffic risk. The public risk was calculated on the basis of the ratio between fatalities and population, and traffic risk was calculated on the basis of registered vehicles. The process of producing a composite value of the risk mean value was undertaken to evaluate the risk, but DEA provides an opportunity to combine multiple variables. This is because DEA is a technique that maintains a mechanism of multiple inputs and multiple outputs for the evaluation of risk [20]. A conceptual diagram of the DEA model is shown in Figure 2. It is a linear programming technique for measuring the relative performance of entities or units of a similar pattern. Countries are considered to be Decision-Making Units (DMUs) for the application of the DEA model, and the risk level is calculated by applying the road safety outcome and exposure variables.

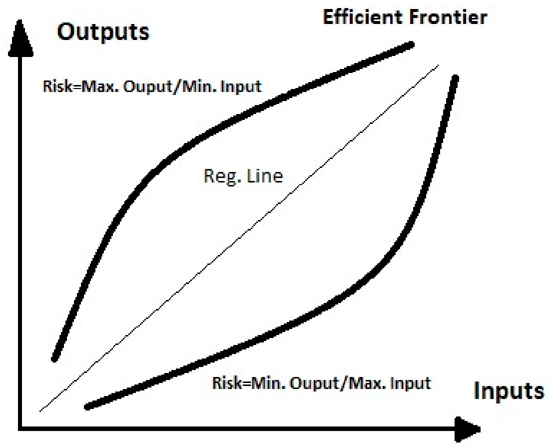

Figure 2. Basic Data Envelopment Analysis (DEA) Model Conceptual Diagram.

In this concept, while calculating risk in the traffic safety field, the lowest level has been considered as the frontier of safety. In the case of efficiency evaluation, Efficiency is calculated by maximizing output and minimizing input, while, for calculating risk, we minimize the output and maximize the input. The simplest form of calculating Efficiency by DEA is as follows.

Efficiency: The basic concept of the DEA Efficiency calculation is as in Equation (3).

$$Efficiency = \frac{Weighted\ Sum\ of\ Output}{Weighted\ Sum\ of\ Input} = \frac{Maximize\ Output}{Minimize\ Input} \tag{3}$$

Following the above-explained concept, Risk is calculated as in Equation (4):

$$\text{Risk} = \frac{\text{Weighted Sum of Output}}{\text{Weighted Sum of Input}} = \frac{\text{Minimize Output}}{\text{Maximize Input}} = \frac{\text{Road Safety Outcome}}{\text{Exposure}}. \tag{4}$$

During the application of the DEA model, Lingo software was used (programming-based), which produced the risk values for each Decision-Making Unit (DMU), i.e., Asian country, in our case. DEA was introduced by researchers in the field of road safety by assigning weights for the construction of composite performance indicators; then, for the evaluation of road safety rankings, a risk value was calculated. That risk value was based on outputs and inputs considering road fatalities per million inhabitants [21]. Further, an improvement was tested in the model by testing it along with six inputs: alcohol, speed, protective systems, infrastructure, vehicles, and trauma management [22]. The application of DEA in this manner further encouraged the use of multiple inputs and multiple outputs, and it was then tested with 13 inputs and 4 outputs. The concept of a multiple-layer DEA (MLDEA) was also tested [23]. Previously, the European region was targeted for learning and research due to the availability of detailed data from agencies. Population, passenger kilometers, and number of registered cars were considered as inputs, while fatalities were used as outputs. The concept was further strengthened by the application of cross-efficiency for the final risk scores [20]. Researchers considered applying this concept at a more local level by using it for Annual Road Safety Authority budget allocation and assessing road safety teaching hours' impact on involvement of drivers in crashes at the municipality level [24]. At the State level within the country of Brazil, this model was calibrated and tested by using mortality rates and fatality rates as outputs. Another calibration of this DEA model was performed for 27 police departments in Serbia by following the previous concept of public and traffic risk, comparing the road safety performance of 27 sectors [25].

2.3. SEM and Road Safety Risk Analysis

Structural Equation Modelling (SEM) is a technique that can handle a large number of endogenous and exogenous observed variables simultaneously. SEM consists of a set of equations that are specified by direct links between variables [26]. For road crash data analysis, "SEM is adopted as a latest procedure which can handle large data set and variables. However, in SEM, we can introduce 'latent variables' which are the unobserved variables and represent unidimensional concepts in their purest form. Other terms for these are unobserved or unmeasured variables and factors" [27]. SEM grants the specialist the ability to simultaneously examine two or three relations of reliance and autonomy among latent variables by methods for observed factors, and is thus a standout amongst the most current multivariate techniques utilized in the sciences [28–30]. Partial Least Squares (PLS-)SEM is similar to the use of multiple regression analysis. Its main objective is to boost the explained variance in the build setup and to decide the initial classification of the information, principally in view of the qualities of the estimating model [28,30]. The PLS-SEM is named "Partial Least Squares" on the grounds that the elements are evaluated by methods for a series of least squares, while the expression "Partial" is derived from the use of an iterative estimation system for the parameters in groups (per latent variable), to the detriment of the whole model, at the same time [31]. In SEM, the deciding of the event, which is not always unambiguous (latent construct), occurs through indicators that fill in as substitutions for the latent variable of interest [28,30]. In this manner, through the amalgamation of a few things in a scale, the immaterial idea of consideration can be estimated in an indirect way. In the course models, charts are utilized to outwardly show the theories and hypothetical relations among factors. In Figure 3, the inactive builds are spoken to by utilizing circles or ovals (Y1 till Y4), the indicators (observed or occurring factors) are spoken to by the method for rectangles (x1 till x10). The relations among the builds and amongst indicators and develops are represented by arrows. In PLS-SEM, the arrows dependably factor in a solitary heading, speaking to a directional relationship. Arrows pointing in a solitary bearing are respected by a predictive connection and, if there should arise an occurrence of a solid hypothetical establishment, they can be interpreted as causal connections. At last, the error terms (e.g., e7 or e8), reflexively connected to the endogenous construct, portray non-clarified change when the course forms are estimated [28].

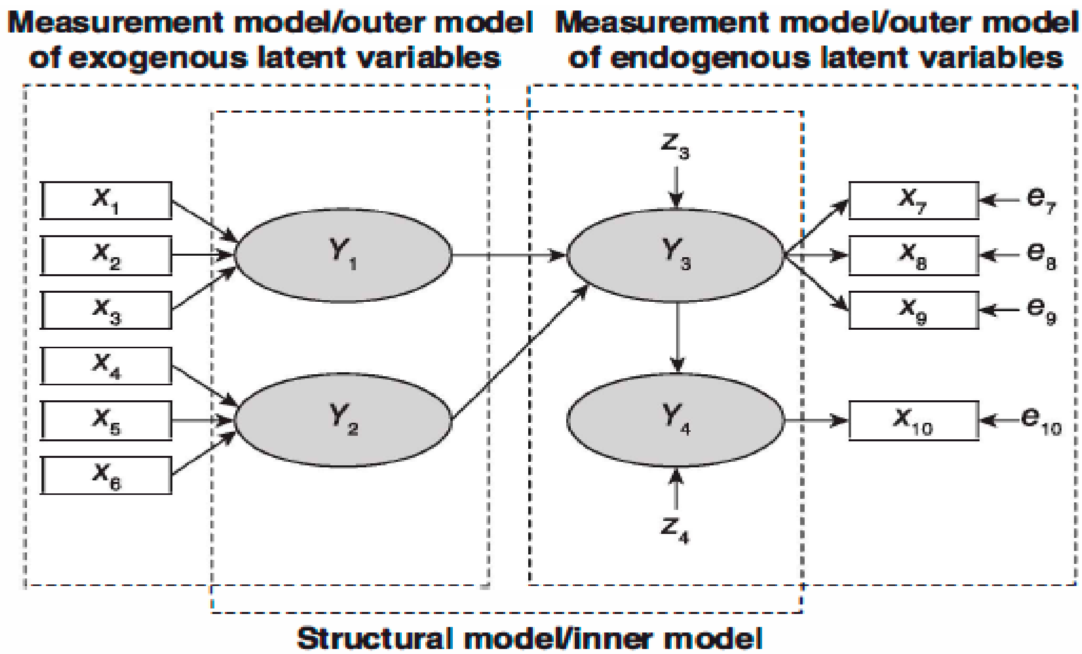

Figure 3. A Conceptual Structural Path Model.

As per elaboration in Figure 3, a PLS course mannequin comprises of two components: Structural mannequin (additionally called internal model concerning PLS-SEM), which proves the relations (ways) between the constructs; and the estimating designs (likewise alluded to as external forms in PLS-SEM), which alludes to the relations between the develops and the indicating factors (rectangles). The estimation of the model offers observational measures of the relations between the constructs (basic model) and between the indicators and constructs (estimating models) [28]. The experimental measures allow contrasting the auxiliary models and the hypothetically settled reality. Thus, the wellness of the hypothesis to the information can be resolved. Thus, utilizing PLS-SEM, the analysts rely upon measures that demonstrate the prescient limit of the model to judge its quality. More precisely, the appraisal of the subsequent auxiliary and estimating models in PLS-SEM lays on an arrangement of non-parametric evaluation criteria, utilizing methodology like bootstrapping and blindfolding. In this regard, the appraisal of measuring models (relations between the indicators and constructs) includes composite reliability; variance extracted; indicator reliability; and discriminant validity if there should be an occurrence of reflexive models; and variance extracted; collinearity amongst indicators; and the significance and importance of outer weights in developmental models. The appraisal of the basic model (relations between constructs), then again, considers: the coefficient of determination (R^2) [28,30,32–35]. Hence, the PLS-SEM approach not just offers a scope of favorable circumstances in examination with the original multivariate methods, being exceptionally adaptable regarding the premises and test dimensioning; yet additionally gives a few likenesses OLS Regressions [28,30]. Analysts have recently utilized it in recent publications. Moreover, it has a phase wise structure, as discussed in the introduction of SEM. It has provided an edge over the conventional OLS analysis techniques which has a gap regarding the occasional ignorance of relations of X and Y variables of the models under analysis, and lack of control of direct and indirect impact in the relations dependent and independent of moderating and mediating effects in developed models. These models cause potential difficulty to fully understand the relationships of interest [28,30].

During the application of SEM in the field of road safety, "accident location (where the accident took place), pavement type, horizontal alignment, vertical alignment, vehicle type, driver's gender, driver's age, road surface condition, the day (weekend or weekday), weather condition, day or nighttime were modelled against the number of deaths, the number of injured persons, the number of involved vehicles, and the number of damaged vehicles. Findings end up with the analysis that road factors, driver factors and environmental factors were strongly related to the accident size" [26]. A similar type of analysis was conducted to evaluate the relationship between accident severity and accident type [36], between gender, anxiety, depression, reward sensitivity, sensation seeking propensity and risky driving [37], between psychological symptoms, sensation seeking, aggression, dysfunctional drinking habits, aberrant driving behavior, speed and accidents [38]. So SEM is an established technique for crash data analysis for road safety research. Through the application of SEM, we can analyze the large data variables related to road safety situations in Asian countries. Analysis of risk level with reference to road safety indicators will be helpful in understanding road safety performance of countries.

2.4. DEA-SEM Combination

When the DEA is used as a risk analysis tool, Decision Making Units (DMUs) are viewed as alternatives while inputs/outputs are regarded as criteria. In using DEA, the risk score of any unit is calculated as the minimization of a ratio of weighted outputs to weighted inputs, subject to the condition that all units of the available data set should have similar patterns [39]. After calculation of the risk score with the help of DEA, application of SEM to analyze the relationship of large data sets of important factors with the calculated risk can be helpful in understanding and decision making regarding factors can be helpful in reducing the risk. A similar combination of DEA with SEM has been used for educational analysis that public expenditure on education as a percentage of GDP is the most effective output variable for literacy level [40]. Operating expenses is an imperative management task for productivity improvement of hotels [39], environmental 'sustainability' of intensive dairy farming depends on particular farming systems and circumstances [41]; environmental efficiency negatively impacts on profit while profit positively impacts on environmental efficiency in the textile industry [42]. So using this DEA-SEM combination will be a new application in the field of road safety and will be helpful for decision making.

2.5. Advantages of Using DEA-SEM Method

Since DEA offers some benefits to other approaches such as: (1) DEA is able to handle multiple inputs and outputs; (2) DEA does not require a functional form that relates to inputs and outputs; (3) DEA optimizes each individual observation and compares them against best practice observations; (4) DEA can handle inputs and outputs without knowing a price or weights and; (5) DEA produces a single measure for every DMU that can be easily compared with other DMUs, and also have some limitation as: (1) DEA only calculates relative efficiency measures; and (2) As a nonparametric technique, statistical hypotheses tests are quite difficult [43,44]. However, Partial Least Square-Structural Equation Model (PLS-SEM) offers frequent benefits to researchers as it is efficient with: (1) abnormal data; (2) small sample sizes; and (3) formative measured constructs [28]. PLS is characterized as a technique most suitable where the research purpose is a prediction or exploratory modeling. In general, covariance-based SEM is preferred when the research purpose is confirmatory model [34,45]. Furthermore, it has the ability to model multiple dependents as well as multiple independents, ability to handle multicollinearity among the independents, robustness in the face of data noise and missing data, and creating independent latent variables directly on the basis of cross-products involving the response variable(s), making for stronger predictions. However, "PLS is less than satisfactory as an explanatory technique because it is low in power to filter out variables of minor causal importance" [46].

2.6. Research Gap

Since DEA is a common benchmarking tool for efficiency and risk evaluation [47,48], it has been popular with its multi stage property but it has shortcoming with respect to its hypothesis testing, which reduces its application. Therefore, a powerful technique SEM (PLS) has been joined with DEA to fill that gap. Finally, the predictive potential of SEM and the optimization capacity of DEA performs complementary features, thus envisioning a prominent modeling option [47,48]. Using the strength of SEM technique to deal with non-normal data and formatively measured constructs [28] will improve the decision-making process. Now, it is time to apply this performance evaluation DEA-SEM technique in the field of road safety for the decision-making process. This is the first study for application of DEA-SEM(PLS) approach for road safety performance analysis for a case study of Asian countries which will lead decision makers to better visualize the Riskiest countries and key factors for road safety condition improvement.

3. Construction of Hypothesis and Model

Conceptual model and hypothesis development is one of the major tasks for analyzing the road safety performance and the impact of interrelation of latent contributing variables. Following the SafetyNet [49], concept of using road safety performance indicators, the detailed hypothesis is explained as follows:

3.1. H1: Financial Impact → Risk

Economist have also termed loss of human lives as a huge loss of economy under certain circumstances. They have explained as it direct economic costs and indirect economic costs. The value of life per se road safety factor as well [50]. The direct cost includes medical, legal emergency and property related damages, while some time goes on if these factors have continuity [51]. The indirect economic cost of accidents related to those services and products which are produced only because of crash occurrence [52]. Statisticians have estimated that in the the Asian EST countries crash related costs have been about 1.1% of GDP in 2010 for fatalities and 3.6% of GDP for crashes in 2010 only [52]. So an evaluation of financial impact is necessary with the risk level of low, middle and high income Asian countries.

3.2. H2: Institutional Framework → Risk

Institutional frameworks are the major factors, which are related to the safety level. Therefore, it is necessary to analyze the impact of relationship of presence of lead agency to deal with road safety situations, mechanism of availability of funding in national budgets, existence of national road safety strategy for funding to implement strategy and fatality reduction targets. A proper framework is needed to deal with the road safety situation and risk level [3]. The world is focusing on reducing traffic to a 50% fatality reduction target (five million fatalities and 50 million serious injuries) by the end of 2020 [53] by following a proper institutional framework, so the impact of institutional framework on risk level is needed to be investigated [3].

3.3. H3: Infrastructure & Mobility → Risk

Infrastructure and mobility are directly related to road fatalities which is backed by a stream lined road safety audit mechanism, policies for promoting walking and cycling and investment in public transport [3]. For preventing crashes or reducing their severity, road safety audit is the process as an effective road safety tool [54]. A road safety system is designed for safety of the public and their mobility. Usually, road safety audit is necessary and a relation of this factor with the risk level needs to be investigated. Road condition and mobility facilities are of major concern for road safety conditions.

3.4. H4: Legislation and Policy → Risk

Speed limit is one of the major factors of road traffic safety issues [55–57]. The effectiveness of speed related factors is related to enforcement of limit [15]. Sector wise impact of speed limit is influential on urban and rural roads especially on motorways. Reducing speed limit has a significant impact on reducing fatalities and injuries [58]. Importance of protection systems like motorcycle helmets, seat belt and child restraint law is also directly related to the risk level of countries [3,59]. Overall, crashes are also related to these mechanisms of protections.

3.5. H5: Vehicular-Road User → Risk

Vehicles are designed for a safer road mobility. Sometimes quality and fitness of vehicles are compromised in low-income countries. Road user's vehicular category, which is involved in a large number of fatalities, is related to car and cycle users. Another assumption to be investigated is that there is a relationship between road user's vehicular impact and the risk level. There is a relationship between type of vehicle and crashes [56,59,60], as occupants of new cars are three times less involved in crashes than those of old vehicles [1].

3.6. H6: Trauma Management → Risk

Trauma management is related to the system responsible for rapid response to the medical treatment of injured people in the crashes [17]. The facility of trauma management is connected with the availability of medical treatment for the survival of life after crashes. Especially in developing countries, injury crashes result in fatalities. Researchers have concluded that 50% of fatalities occur during the crashes while others are within a few hours of the crashes [61]. If a proper medical facility is available, then the risk level of the country can be improved by reducing fatalities. Pharmacare and medical treatments, and in time availability of medical aid and proper hospital emergency treatment as a chain process, can not only save lives but also disabilities [62]. The conceptual model is shown in Figure 4.

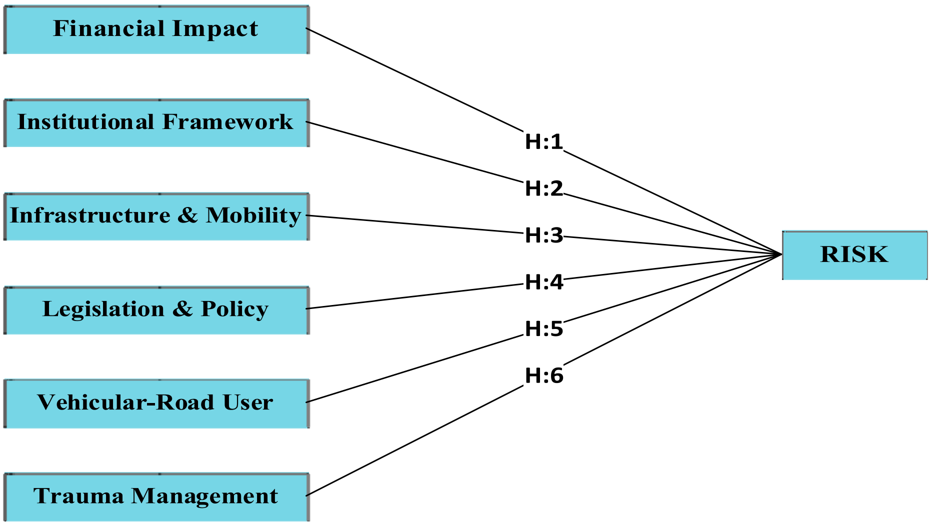

Figure 4. Conceptual Research Model.

4. Materials and Methods

4.1. Study Area

Asia is considered among the largest parts of the world and largest continent of the world with almost approximately 4.5 billion inhabitants (2016), which accounts for almost 60% of the human population of the globe. Asia covers an area of 44,579,000 square km (17,212,000 mi^2), about 30% of Earth's total land area and 8.7% of the Earth's total surface area. As fatality rates of the South-East Asian Region is 17 per 100,000 population higher than the European Region which is 9.3 (almost half), it is necessary to evaluate the road safety situation in this largely populated region. Globally, due to road traffic injuries, more than 1.2 million people die each year, and this has a huge impact on human life and development. According to the WHO, the majority of the causalities are aged between 15 and 29 years, and cost reaches almost 3% of GDP; for low- and middle-income countries it increases up to 5% [3]. According to the WHO, "The rise in global road traffic deaths has been largely driven by the escalating death toll on roads in low and middle-income countries—particularly in emerging economies where urbanization and motorization accompany rapid economic growth" [3]. So, forty one countries of Asian Regions have been selected for road safety analysis and are grouped on the basis of income level (low, middle and high). According to the World Bank, "low-income economies are defined as those with a GNI per capita, calculated using the World Bank Atlas method, of $1025 or less in 2015; lower middle-income economies are those with a GNI per capita between $1026 and $4035; upper middle-income economies are those with a GNI per capita between $4036 and $12,475; high-income economies are those with a GNI per capita of $12,476 or more" [63]. The fatality data with reference to income group, population and registered vehicles of the selected forty-one countries are shown in the Table 1.

Table 1. Description of Basic Road Safety Data for Asian Region with reference to Income Group.

Country	Fatalities	Pop(M)	TRV(M)	IG	Country	Fatalities	Pop(M)	TRV(M)	IG
Afghanistan	4734	30.5	0.66	1	Maldives	12	0.3	0.06	2
Azerbaijan	943	9.4	1.14	2	Mongolia	597	2.8	0.68	2
Bahrain	107	1.3	0.55	3	Burma	10,809	53.2	4.31	1
Bangladesh	21,316	156.5	2.09	1	Nepal	4713	27.7	1.18	1
Bhutan	114	0.7	0.07	2	Oman	1881	21.6	5.99	3
Cambodia	2635	15.1	2.46	1	Pakistan	25,781	182.1	9.08	2
China	26,1367	1385.5	250.14	2	Philippines	10,379	98.3	7.69	2
Georgia	514	4.3	0.95	2	Qatar	330	2.1	0.65	3

Table 1. *Cont.*

Country	Fatalities	Pop(M)	TRV(M)	IG	Country	Fatalities	Pop(M)	TRV(M)	IG
India	207,551	1252.1	159.49	2	Saudi Arabia	7898	28.8	6.60	3
Indonesia	38,279	249.8	104.21	2	Singapore	197	5.4	0.97	3
Iran	24,896	77.4	26.87	2	Sri Lanka	3691	21.2	5.20	2
Iraq	6826	33.7	4.52	2	Tajikistan	1543	8.2	0.41	1
Japan	5971	127.1	91.38	3	Thailand	24,237	67	32.48	2
Jordan	1913	7.2	1.26	2	Timor-Leste	188	1.1	0.06	2
Kazakhstan	3983	16.4	3.93	2	Turkey	6687	74.9	17.94	2
Kuwait	629	3.3	1.84	3	Turkmenistan	914	5.2	0.85	2
Kyrgyzstan	1220	5.5	0.96	2	UAE	1021	9.3	2.67	3
Laos	971	9.7	1.44	2	Vietnam	22,419	91.6	40.79	2
Lebanon	1088	4.8	1.68	2	Yemen	5248	24.4	1.20	2
Malaysia	7129	29.7	23.82	2	-	-	-	-	-

For the visualization of the road safety data, GIS-based maps have been produced. Road traffic fatalities with reference to population are shown in Figure 5 and, with reference to income group are shown, in Figure 6.

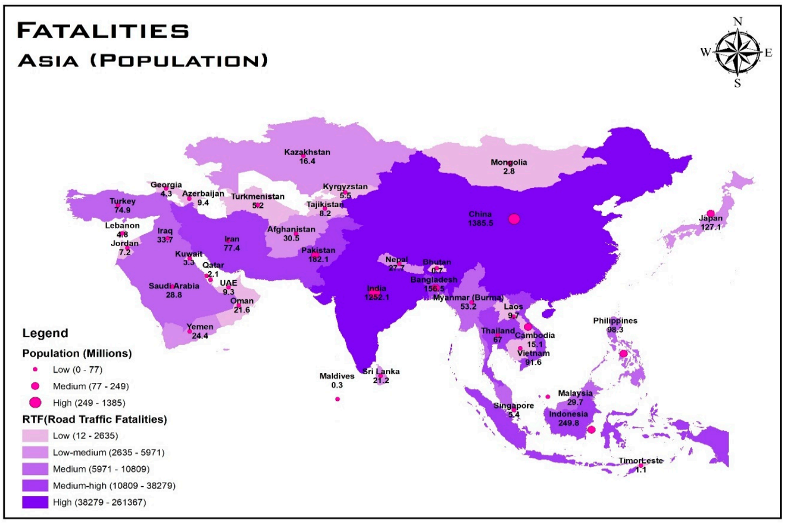

Figure 5. Road safety of Asia fatalities on the basis of populations within regions.

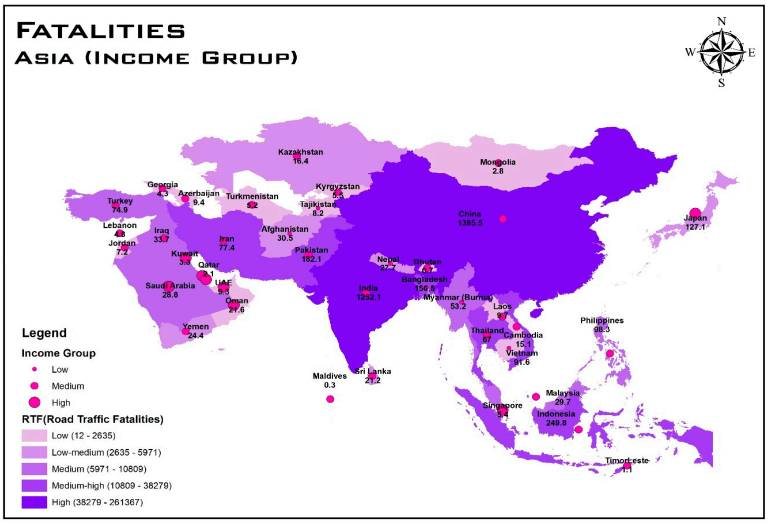

Figure 6. Road safety of Asia fatalities on the basis of income group within regions.

4.2. Methodology

Basic Framework for this study is based on DEA-SEM (an already established combination) and is shown in Figure 7. It consists of two phases, in the first phase, risk value of selected forty-one countries is calculated by the DEA method while in the second phase, PLS-SEM technique has been used to evaluate the relationship of different factors with the calculated risk value. A major focus of this research is to identify those factors, through which road safety situations can be improved. It is one of the key processes to identify most appropriate factors for road safety improvement.

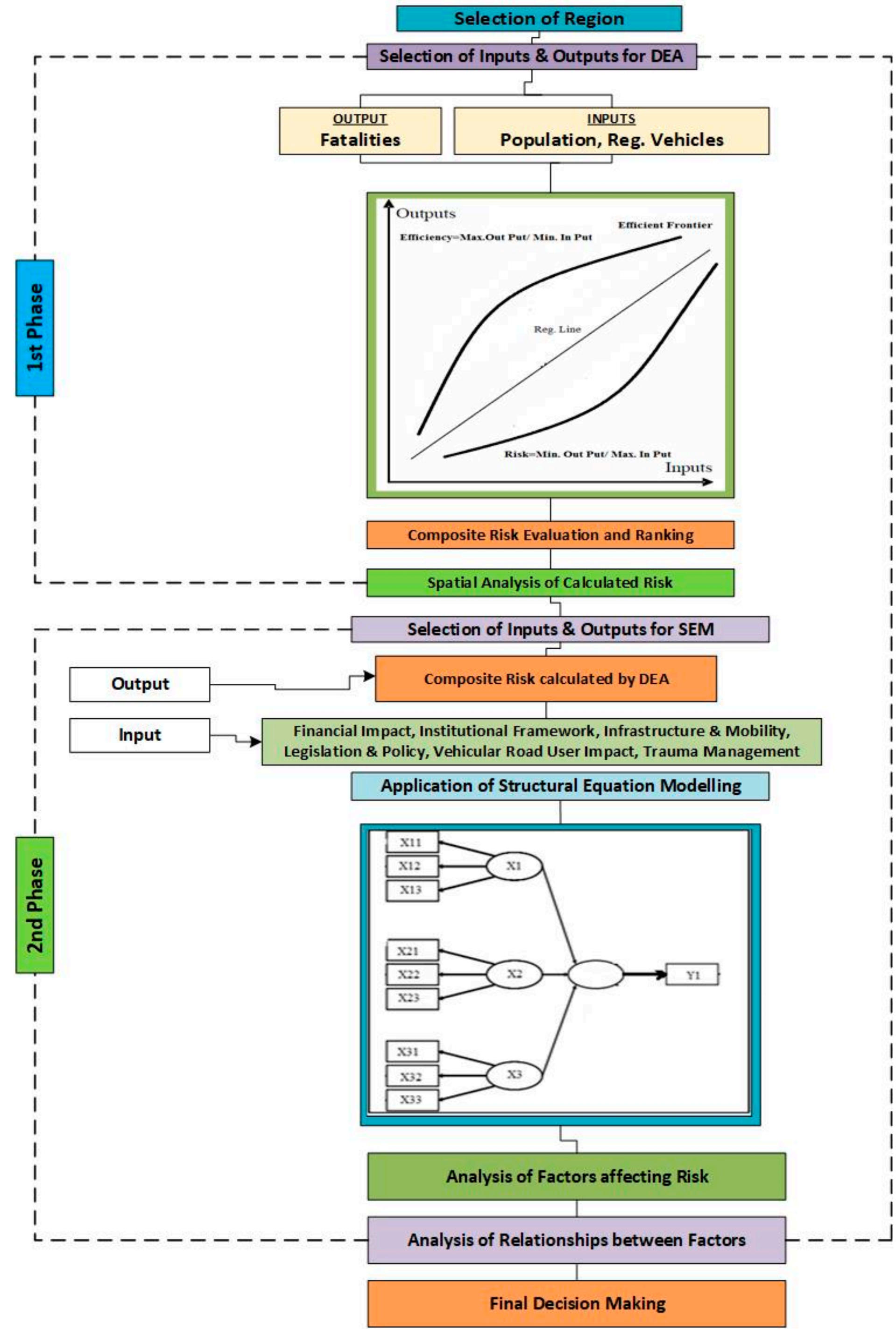

Figure 7. Methodological framework for risk evaluation and analysis.

4.2.1. Phase-1-Data Envelopment Analysis-Risk Evaluation

The first phase of risk evaluation is related to number of fatalities, population, and a number of registered vehicles. The target set for the analysis is basically to minimize the fatalities with the increase of population and vehicles. The summary of statistics of these variables is shown in Table 2. This data has been considered for 41 countries of Asia from WHO [3], for the year 2013. To confirm the validity of the DEA model condition, an isotonicity test [64] was conducted. An isotonicity test comprises inter-correlations between inputs and outputs for detecting negative correlation and was applied and the presence of the inputs and outputs was reasonable due to a positive result. However, there are no diagnostic checks for improper model specification detection in DEA [65]. However, "as a general rule of thumb, the minimum number of DMUs is higher than three times the number of inputs plus outputs" [66]. In our study, with a total of two inputs and one output, a set of nine data points would be optimal; we have 21 data DMUs.

Table 2. Summary of Basic Road Safety Data for Risk Evaluation (Phase-I).

Variable	Description	Mean	SD	Min.	Max.
RTF	Road Traffic Fatalities(Number)	18,480	52,051	12	261,367
Population	Population of the Country in Millions	106.30	291.40	0.3	1385.5
TRV	Total Registered Vehicles in Millions	20.98	49.93	0.06	250.14

Source: WHO (2015).

Risk: basic concept of DEA-Risk calculation in connection with Equation (1) and Equation (4) is as:

$$\text{Risk} = \frac{\text{Weighted Sum of Output}}{\text{Weighted Sum of Input}} = \frac{\text{Minimize Output}}{\text{Maximize Input}} = \frac{\text{Road Safety Outcome}}{\text{Exposure}} \quad (5)$$

Although the basic model has been explained in the literature review simple expression is Equation (6) as:

$$\text{Risk} = \frac{u_1 y_{1j} + u_2 y_{2j} + \ldots + u_k y_{kj}}{v_1 y_{1j} + v_2 y_{2j} + \ldots + v_l y_{lj}} \quad (6)$$

where

u_k = weight of output k,
y_{kj} = amount of output k from unit j,
u_l = weight of output l,
y_{lj} = amount of output l from unit j.

Following the similar concept of using inputs and outputs, fatalities have been considered as outputs and the target is to minimize the output while population and registered vehicles are the inputs as the target is to maximize the input. So, the equation to calculate the risk value through DEA is as:

$$\text{Risk} = \frac{U_1(\text{Fatalaties})}{V_1(\text{Population}) + V_2(\text{Numb.of Registered Vehicles})} \quad (7)$$

where

U_1 = weights for 1st output
V_1 = Weights for 1st Input, V_2 = weights for 2nd Input.

Risk assessment and analysis are easily conducted through the application of DEA. Road safety outcome in our case is road traffic fatalities while input is exposure (i.e., population and registered vehicles). Taking advantage of using multiple inputs, a single output can be generated to evaluate the performance of an entity. In this case, our required output is risk which is directly related to number of fatalities. If the crash data available is limited, it has more exposure variables or output variables, even then this method is useful because it was designed for multiple inputs and multiple outputs. Following the above-explained concept, risk has been calculated as shown in Table 3.

Table 3. Risk calculation of Asian countries with DEA method.

Country	Fatalities(No.)	Population(Mil)	RV(Mil)	DEA Risk	Rank
	Output	Input	Input		
Thailand	24,237	67	32.48	8.53	1
Iran	24,896	77.4	26.87	8.09	2
Saudi Arabia	7898	28.8	6.60	7.32	3
Jordan	1913	7.2	1.26	7.28	4
Kazakhstan	3983	16.4	3.93	6.45	5
Kyrgyzstan	1220	5.5	0.96	6.08	6
Yemen	5248	24.4	1.20	5.90	7
Vietnam	22,419	91.6	40.79	5.88	8
Lebanon	1088	4.8	1.68	5.70	9
Mongolia	597	2.8	0.68	5.65	10
Myanmar (Burma)	10,809	53.2	4.31	5.57	11
Iraq	6826	33.7	4.52	5.55	12
China	261,367	1385.5	250.14	5.17	13
Tajikistan	1543	8.2	0.41	5.16	14
Turkmenistan	914	5.2	0.85	4.82	15
Cambodia	2635	15.1	2.46	4.78	16
Timor-Leste	188	1.1	0.06	4.68	17
Nepal	4713	27.7	1.18	4.66	18
Sri Lanka	3691	21.2	5.20	4.61	19
Malaysia	7129	29.7	23.82	4.58	20
India	207,551	1252.1	159.49	4.54	21
Bhutan	114	0.7	0.07	4.46	22
Kuwait	629	3.3	1.84	4.35	23
Afghanistan	4734	30.5	0.66	4.25	24
Qatar	330	2.1	0.65	4.03	25
Pakistan	25,781	182.1	9.08	3.88	26
Bangladesh	21,316	156.5	2.09	3.73	27
Indonesia	38,279	249.8	104.21	3.73	28
Georgia	514	4.3	0.95	3.21	29
Philippines	10,379	98.3	7.69	2.89	30
UAE	1021	9.3	2.67	2.85	31
Azerbaijan	943	9.4	1.14	2.75	32
Laos	971	9.7	1.44	2.74	33
Turkey	6687	74.9	17.94	2.37	34
Oman	1881	21.6	5.99	2.27	35
Bahrain	107	1.3	0.55	2.00	36
Maldives	12	0.3	0.06	1.08	37
Singapore	197	5.4	0.97	1.00	38
Japan	5971	127.1	91.38	1.00	39

After calculating Risk value from the DEA method, Asian countries have been ranked according to the risk level of these countries. A risk value of 1 was idealized as one the best values to be considered as one of the finest and safest countries of the region, while going above that point provides the hint of risk and a country with the 8.53 being the highest value and considered as the most risky. The graphical representation of results is shown in Figure 8 (arrows showing the most risky within groups) and a GIS-based risk map has been drawn to visualize the risk value pattern of countries as shown in Figure 9.

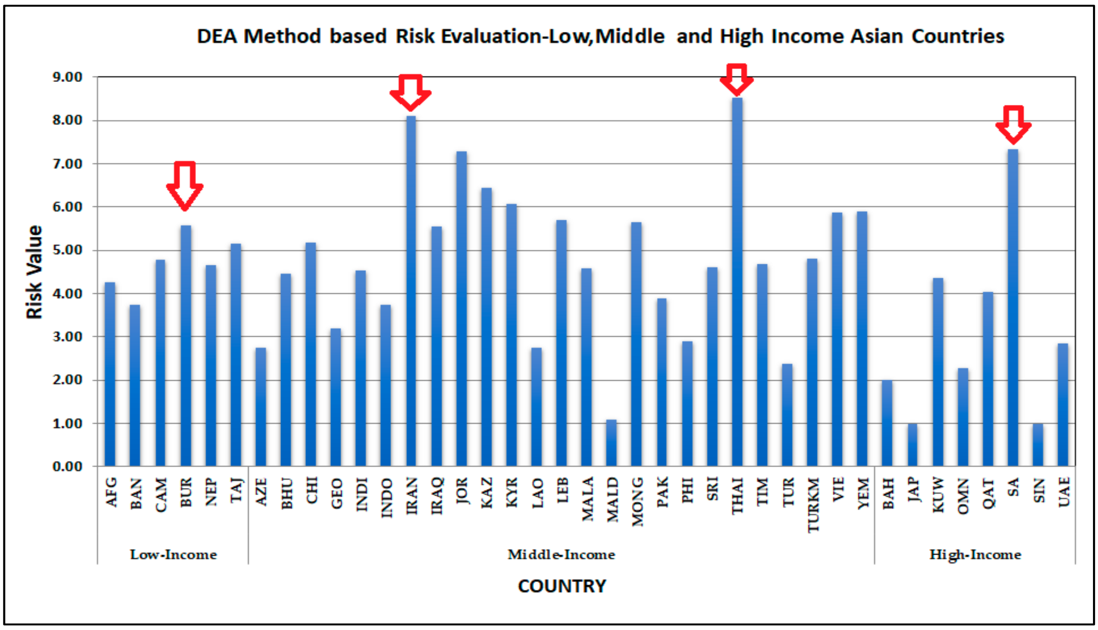

Figure 8. Graphical representation of risk values of Asian Countries.

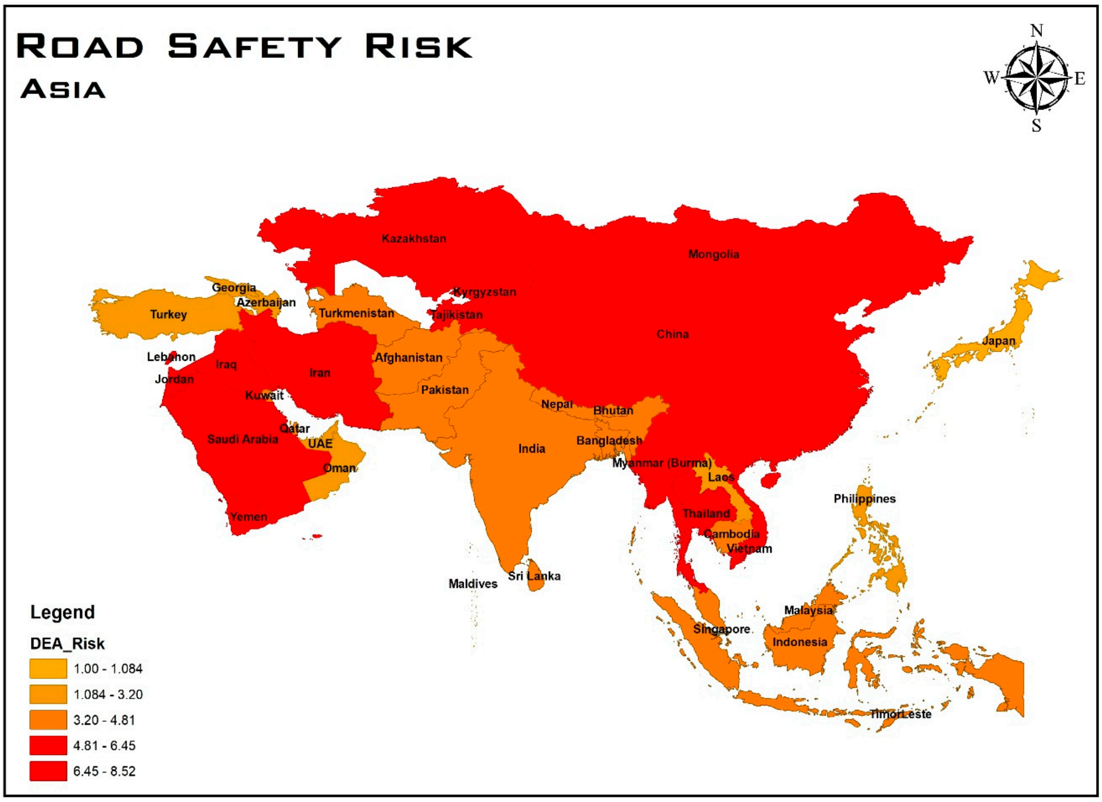

Figure 9. Road safety of Asia-DEA-method-based risk level of the Countries.

4.2.2. Phase-2 (Structural Equation Modeling)

In the second phase, PLS-SEM technique is selected to analyze the relative impact of the factors affecting the risk. Smart PLS-SEM is suitable for a small sample size and does not require normal distribution [33]. PLS-SEM technique provides an advantage to prioritizing all the factors on their relative importance basis. The developed conceptual model was strained in Smart PLS software [30,67] for simulation work in assessing the effect of manifest variables (inhibiting factors) on road safety performance. PLS simulation of the model is applied by evaluating and considering certain parameters, which include factor loading, reliability, and validity tests. The pattern of each construct and factor is shown in Figure 10 for analysis. This construct of research has been followed on the basis of WHO data patterns.

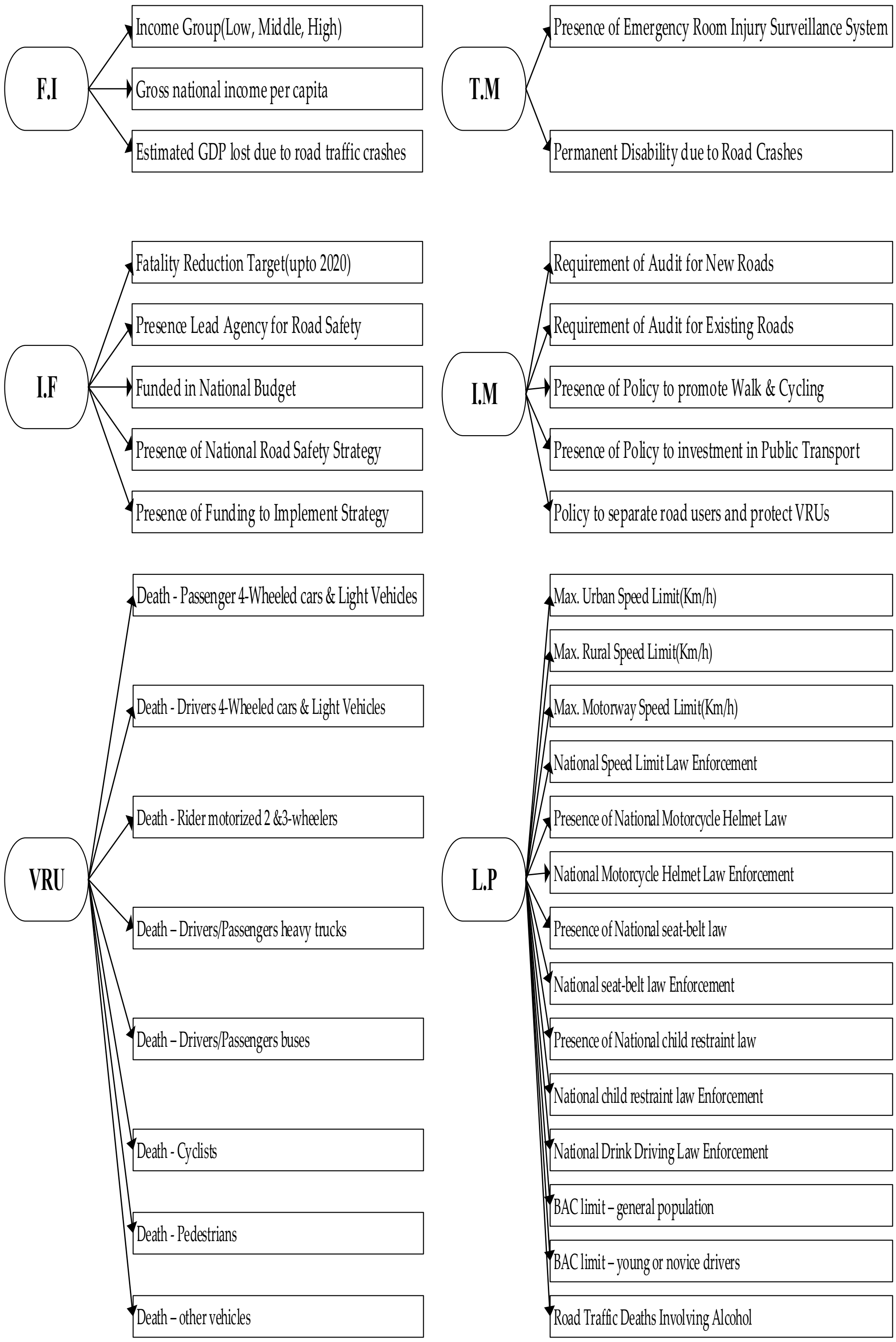

Figure 10. Path diagrams showing the combination of manifest variables.

So risk (calculated by DEA model) is taken as the dependent variable and six factors as independent variables, description shown in Table 4.

Table 4. Data Description of the Factor affecting Risk Level for Structure Equation Modeling.

	Variable	Description	Mean	SD	Min.	Max.
F.I	IG	Income Group (1-Low,2-Middle,3-High)	–	–	1	3
	GNICPC	Gross national income per capita (US$)	11,681	18,362	690	86,790
	GDPL_PCENT	Estimated GDP lost due to road traffic crashes (%age)	2.43	1.16	0.25	6.00
I.F	FRT	Fatality Reduction Target (upto 2020) (%age)	0.23	0.20	0.00	0.50
	LA	Presence Lead Agency for Road Safety (1 = Yes, 0 = No)	–	–	0	1
	FNB	Funded in National Budget (1 = Yes, 0 = No)	–	–	0	1
	NRSS	Presence of National Road Safety Strategy (1 = Yes, 0 = No)	–	–	0	1
	FIS	Funding to Implement Strategy (1 = Full, 2 = Partial, 3 = No)	–	–	1	3
I.M	ANR	Requirement of Audit for New Roads (1 = Yes, 0 = No)	–	–	0	1
	AER	Requirement of Audit for Existing Roads (1 = Yes, 0 = No)	–	–	0	1
	PPWC	Presence of Policy to promote Walk & Cycling (1 = Y, 0 = N)	–	–	0	1
	PIPT	Presence of Policy to investment in Public Transport (1 = Y, 0 = N)	–	–	0	1
	PRSU	Policy to separate road users and protect VRUs (1 = Y, 0 = N)	–	–	0	1
L.P	MUSL	Max. Urban Speed Limit (Km/h)	60.08	17.07	30	100
	MRSL	Max. Rural Speed Limit (Km/h)	90.44	19.74	30	120
	MMSL	Max. Motorway Speed Limit (Km/h)	109.87	15.07	50	140
	NSLL_ENF	National Speed Limit Law Enforcement (1 Low-10 High)	5.62	2.11	1	10
	NMHL	Presence of National Motorcycle Helmet Law (1 = Yes, 0 = No)	–	–	0	1
	NMHL_ENF	National Motorcycle Helmet Law Enforcement (1 Low-10 Hi)	5.97	2.81	0	10
	NSBL	Presence of National seat-belt law (1 = Yes, 0 = No)	–	–	0	1
	NSBL_ENF	National seat-belt law Enforcement (1 Low-10 High)	5.18	2.86	0	10
	NCRL	Presence of National child restraint law (1 = Yes, 0 = No)	–	–	0	1
	NCRL_ENF	National child restraint law Enforcement (1 Low-8 High)	1.08	2.30	0	8
	NDDL_ENF	National Drink Driving Law Enforcement (1 Low-10 High)	5.51	3.03	0	10
	BACLGP	BAC limit-general population (g/dL)	0.05	0.02	0	0.08
	BACLYND	BAC limit-young or novice drivers (g/dL)	0.04	0.02	0	0.08
	RTDIA_PCENT	Road Traffic Deaths Involving Alcohol (%age)	10.63	7.53	0.45	34
T.M	ERISS	Presence of Emergency Room Injury Surveillance System	–	–	0	1
	PDRTC_PCENT	Permanent Disability due to Road Crashes (%age)	4.34	5.27	0.006	18
VRUI	D_P4WCLV	Death-Passenger 4-Wheeled cars & Light Vehicles (0-1)	0.19	0.13	0	0.61
	D_D4WCLV	Death-Drivers 4-Wheeled cars & Light Vehicles(0-1)	0.18	0.12	0	0.46
	D_RM23W	Death-Rider motorized 2 &3-wheelers (0-1)	0.22	0.21	0	0.73
	D_CYC	Death-Cyclists (0-1)	0.04	0.04	0	0.17
	D_PED	Death-Pedestrians (0-1)	0.24	0.09	0.03	0.43
	D_DPHT	Death-Drivers/Passengers heavy trucks(0-1)	0.04	0.04	0	0.16
	D_DPB	Death-Drivers/Passengers buses (0-1)	0.04	0.06	0	0.35
	D_OTH	Death-other vehicles (0-1)	0.06	0.11	0	0.57

Note: F.I = Financial Impact; I.F = Institutional Framework; I.M = Infrastructure & Mobility; L.P = Legislation & Policy; T.M = Trauma Management; VRUI = Vehicular Road User Impact (Source: WHO (2015).

The concept of a factor loading value of 0.5 is regarded as acceptable; the manifest variables with loading values of less than 0.5 should be dropped [25,26]. Some researchers [27] argue that 0.4 should be the acceptable loading, however, some [21] suggested that "manifest variable with loading values between 0.4 and 0.7 should be reviewed before elimination. If elimination of these indicators increases the composite reliability then remove or otherwise maintain the factors. The cut-off value taken for outer loading is 0.5, an iterative process is adopted for the elimination of the manifest variables" [68]. By considering calculations on the basis of the above criteria, a measurement model is evaluated by an iterative process to discard the weak manifest variables from the developed model. From the data set shown in Table 4, a schematic diagram has been developed with the help of the SEM technique which shows the importance of each factor as shown in Figure 11.

Hence, a total of two iterations were involved in this study, all those factors having loading less than 0.5 have been removed [32,68,69] except crucial factors. Finally, a modified schematic diagram has been developed with the help of the PLS-SEM technique which shows the importance of each factor as shown in Figure 12.

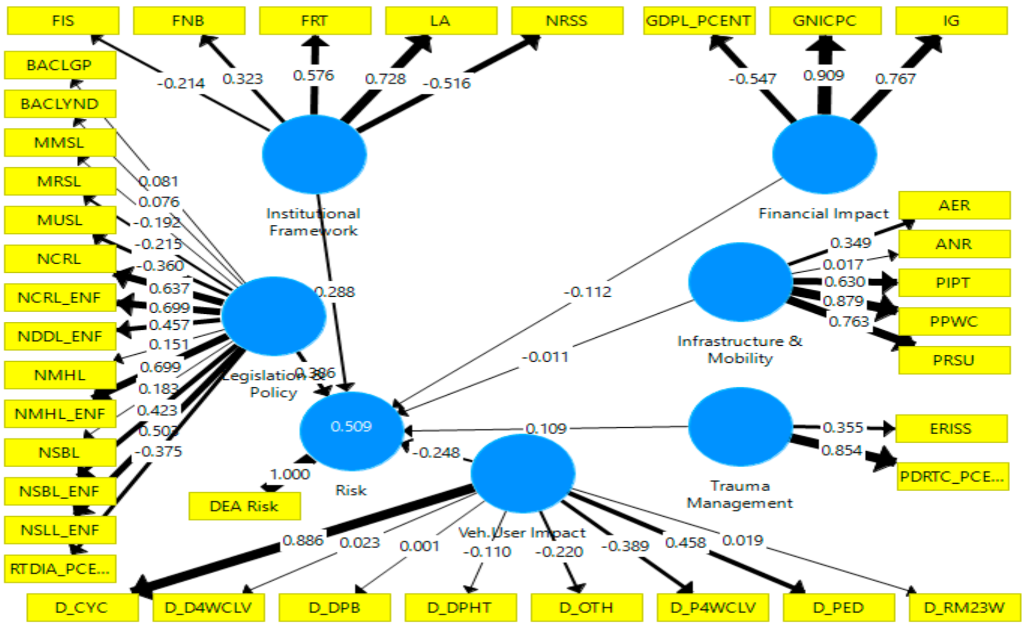

Figure 11. SEM model for risk analysis (with all items).

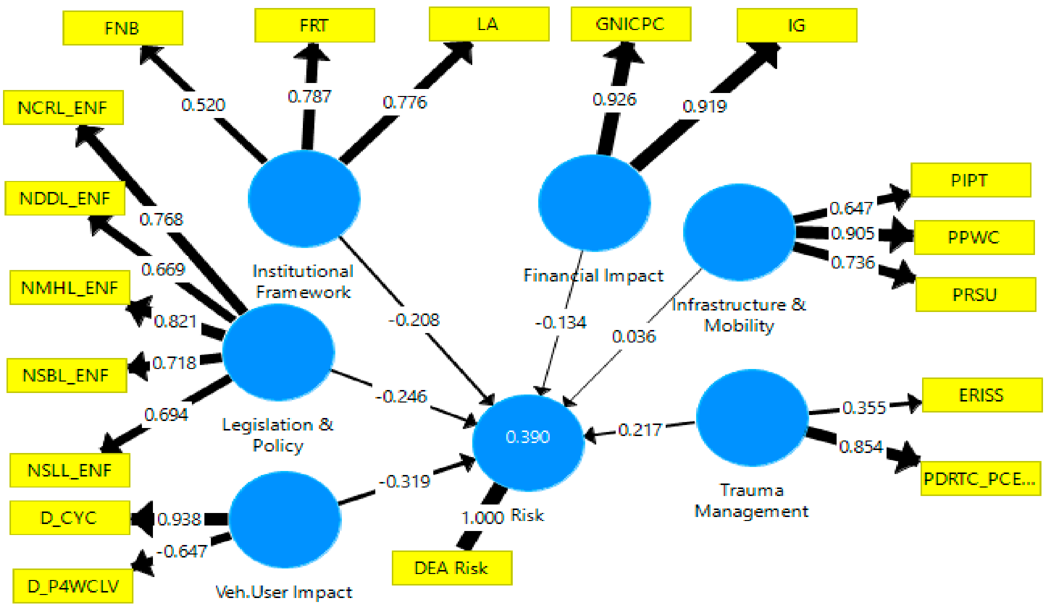

Figure 12. Modified SEM model for risk analysis.

5. Results and Discussion

5.1. Risk Analysis

After the application of DEA, a risk value is calculated to indicate the safety performance of different countries. Safety performance of Asian countries was to be compared on the basis of their economic level. Road safety benchmarking is considered as one of the best methods to evaluate the safety performance, but also ranking of the countries (DMUs) provides grounds to start the discussion for safety levels of certain countries. To learn lessons for improvement, it is necessary to have a comparative performance analysis, and then, available applicable options can be learned from those countries who are performing better with respect to road safety. Two comparative graphs which have been divided on the basis of income groups shows the safety performance of Asian countries (shown in Figure 13).

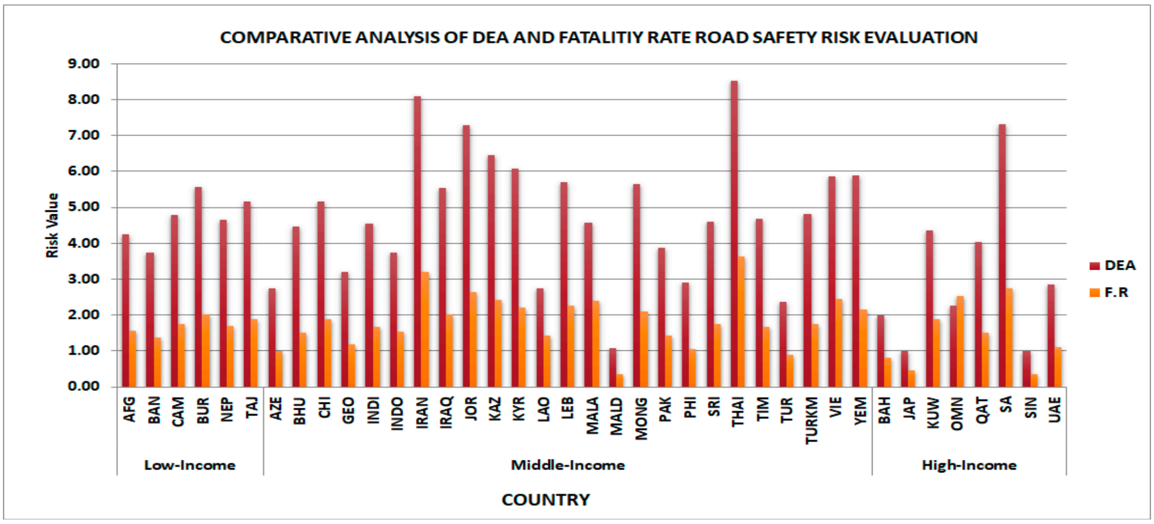

Figure 13. Comparative analysis of DEA and FR method-based risk value of Asian Countries.

From the graphs, we can see that from both methods most dangerous countries with respect to road safety are Burma (Myanmar), Iran, Thailand and Saudi Arabia. The DEA method is considered to be superior regarding fatality rate (death per 100,000 population) as DEA considers multiple variables (i.e., population and registered vehicles) while fatality rate only considers population. A comparative performance of both methods has been elaborated by graphical representation (as shown in Figure 14) that by considering multiple variables, ranking and risk value differ. A negative value of ranking difference shows that road safety performance of these countries was under estimated by the fatality rate value.

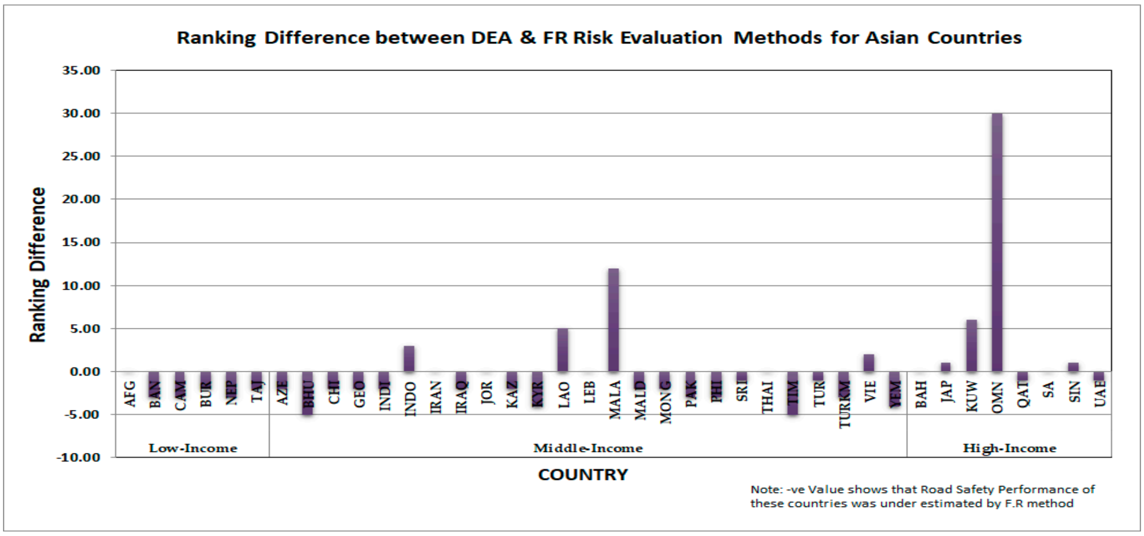

Figure 14. Ranking difference between DEA and FR methods.

After calculating risk, it is further necessary to investigate the impact of financial condition on safety performance of countries with reference to other factors. On the basis of average and section-based performance, low and middle-income countries are of major concern.

5.1.1. Analysis of Low-Income Asian Countries

As the discussion from the financial resource, it is not feasable to compare low-income countries with high-income countries. Although target to reduce fatalities should be similar, when recommending a solution, financial conditions of a country should be taken into account. So a comparison within an income group can be interesting to overview the performance of a country among its income peers. From the analysis, we can conclude that the following three countries are underperforming in case of road safety among low-income countries:

- Burma (Myanmar)
- Tajikistan
- Cambodia

Therefore, these three countries should be a target for improvement in road safety performance and these can be a test case to learn the lesson for road safety research.

Burma (Myanmar):

While analyzing low-cost countries, Myanmar has never allocated money in the national budget for road safety. Problems like lack of vehicle standards, trauma management, policies to promote walking or cycling, national seat-belt laws, national child restraint law, and national drink–driving law are major contributing factors in its high-risk level. With a WHO estimated road traffic fatalities figure of 10,809, the fatality rate per 100,000 population is 20.3 and estimated GDP loss due to road traffic crashes is 0.5%, which show low safety conditions for this country. Lack of quality data (as a reasonable data is produced by a University research) shows governmental non-seriousness regarding road safety issues [3].

Tajikistan:

A low-income country with per capita income of US $990 has a problem of missing or partially funding road safety, there is no fatality reduction target, without policies to promote walking or cycling and lack of vehicle standards. According to the WHO, estimated road traffic fatalities are 1543 and rate per 100,000 population is 18.8; it is does not have a national seatbelt law, or national child restraint laws. A targeted research by major contributors to fatalities, for pedestrians (33%) and passengers (36%) [3] should be conducted to reduce fatalities.

Cambodia:

Another low-income country with a per capita income of US $950 has similar problems of partial funding to implement strategy, lack of policies to promote walking or cycling, and lack of policies to encourage investment in public transport and vehicle standards. A country where the WHO estimated 2635 road traffic fatalities at a rate per 100,000 population rate of 17.4, with a GDP loss due to road traffic crashes of 2.1% needs to focus on riders of motorized two- or three-wheelers (71%) who are the highest contributors in fatalities. It also has no national drink–driving law, national motorcycle helmet law (poor), national seat-belt law (poor) and national child restraint law(0) [3].

A major improvement plan for road safety condition of these countries should be adopted.

5.1.2. Analysis of Middle-Income Asian Countries

In case of middle-income countries, due to a large number of countries, we have selected five top worst countries, which are:

- Thailand
- Iran
- Jordan

- Kazakhstan
- Yemen

Thailand:

Among the middle-income countries, Thailand is a country with an income per capita of US $5340; being an emerging economy, it has partial funding to implement road safety strategies. Infrastructure has a problem that there is no formal audits for new road construction projects, regular inspections of existing road infrastructure, policies to promote walking or cycling and vehicle standards. It is a country that has WHO estimated road traffic fatalities of 24,237 at a rate of 36.2 per 100,000 population contributing 3.0% GDP loss. Targeted research for vehicle contributors in fatalities, motorized two- or three-wheelers riders (73%) is required. For law enforcement agencies, there is a potential to perform the implementation of national speed limit law enforcement law and national child restraint law [3].

Iran:

Iran is economically even better than Thailand but it is a country with an income per capita of US $5780; it lacks funding in the national budget while funding to implement safety strategy is also partially done. Moreover, the fact to worry about is that fatality reduction target is only 10%. Dealing with the infrastructure, an audit mechanism is missing; no vehicle standards applied. Analyzing the statistics, WHO estimated road traffic fatalities as 24,896 with a 32.1 rate per 100,000 population having 6.0% GDP loss due to road traffic crashes (which is very high). Policy wise, national motorcycle helmet law and national child restraint law enforcement is missing. It requires a focused research on this issue with a target of major fatality contributors i.e., passengers of four-wheeled cars and light vehicles (24%) [3].

Jordan:

Another middle-income country with an income per capita of US $4950; it has a problem of no funds in the national budget for road safety, while funding to implement strategy is also partial, although a fatality reduction target of one death per 10,000 vehicles (2014–2016) is somewhat reasonable. But implantation to achieve this target looks weak, as there is lack of policies to promote walking or cycling and vehicle standards application. Weak trauma management setup is also one of the major setbacks to achieve such a fatality reduction target. With WHO-estimated road traffic fatalities of 1913 at a rate per 100,000 population of 26.3 with GDP loss of 1.2%, this shows a lack of law enforcement conditions of national drink–driving law and national motorcycle helmet law as well as missing national child restraint laws [3]. According to WHO analysis, pedestrians (36%) are in danger in this country due to high contributions in road traffic fatalities; a focused research regarding pedestrians is required.

Kazakhstan:

Statistical data of this country shows WHO-estimated road traffic fatalities of 3983 at a rate per 100,000 population of 24.2 but all factors are taken into account (funding, infrastructure, trauma management, legislation policy and enforcement) [3], which shows that there is lack of authoritative control of data collection systems and missing or manipulated data has been provided. A focused research on occupants of four-wheeled cars and light vehicles (61%) [3] is required because they are the largest contributors to road fatalities.

Yemen:

One of the middle-income countries according to the WHO which has a series of the problem that it does not have any lead agency for road safety issues, with no funds in the national budget and no fatality reduction target. Policies to promote walking or cycling and applying vehicle standards are also missing. It has 5248 WHO-estimated road traffic fatalities, at 21.5 per 100,000 population. Policy and the institutional mechanism are lacking as national speed limit law (0), national drink–driving law (0), national motorcycle helmet law (low), national seat-belt law (low), and national child restraint law(low) are absent [3]. The road safety data analysis mechanism is also missing, which shows the level of interest in saving human life and road safety.

5.1.3. Analysis of High-Income Asian Countries

Sometimes, even good financial condition is undermined by the poor management and policy implementation mechanism, as we can observe in case of these countries:

- Saudi Arabia
- Kuwait
- Qatar

Saudi Arabia:

In high-income group countries, Saudi Arabia lacks seriousness in the field of road safety as there is no fatality reduction target set by this country. Statistics show that the WHO has estimated 7898 road traffic fatalities at a rate per 100,000 population of 27.4, which is an alarming situation in a high-income country. There is a major gap in policy and law enforcement as the situations of national motorcycle helmet law (low), national seat-belt law (low) and national child restraint law (low), need to be reconsidered [3]. The road safety data analysis mechanism is also missing which shows the level of interest in saving human life and road safety.

Kuwait:

Kuwait is one of the richest countries of the world with a gross national income per capita of US $45,130. In the field of road safety, there is a fatality reduction target of 15% which is less than the global target of 50%. Even after being the richest country, there is a deficiency in trauma management and policies to promote walking or cycling because the social trend is focused towards cars (four-wheelers) out of a total 1841416 registered vehicles, 1,670,540 are cars and four-wheeled light vehicles (91%), so trends towards cycling are minimal. Still, law regarding vehicle standards is missing. Statistics show that the WHO has estimated road traffic fatalities at 629 at a rate per 100,000 population of 18.7 because of the small population. Policy and law enforcement are not active as the performances of national speed limit law (low), national seat-belt law (low) and national child restraint law (missing) are under question [3]. Road safety data analysis and collection mechanism are also missing.

Qatar:

Qatar is considered as a high-income country with the highest gross national income per capita of US $86,790, but fatality reduction targets set by this country are less than 17% (less than the standard 50%). The WHO estimated 330 road traffic fatalities at a rate per 100,000 population of 15.2. There is lack of implementation of national child restraint law. It requires a focused research on this issue with a target of major fatality contributors, i.e., drivers and passengers of four-wheeled cars and light vehicles (34%) and (38%), respectively [3].

Overall analysis of these three groups shows that low income countries are actually striving for their existence so focus towards road safety problems is out of the question, because it is a tertiary issue for them. Improvement in infrastructure and public transport mechanisms are beyond their reach; some countries are struggling within their political and regional destabilization. In their list of improvement and progress, road safety is not anywhere, so a joint effort is required in this regard to finance them in these issues. In middle-income countries, although consciousness about road safety is existing to improve its level and to safeguard, a major change in institutional frame work and legislation is required for financial backup and law enforcement. However, for high-income countries seriousness and education to solve road safety problem are required. They have finances, resources, policy, management, and legislation but seriousness to improve road safety conditions is not there; it should also be discussed and motivated. Within Asia, there should be some road safety centers for research and analysis, who should maintain and control road safety situation backed by high-income countries like China, Saudi Arabia, Kuwait and Qatar. A combined data maintenance setup can also help to monitor and improve road safety performance of Asian countries for human life and safety.

5.2. Analysis of Factors

5.2.1. Measurement Model Evaluation

In this study, a structural equation modeling (SEM) approach using Smart PLS statistical software [70] was applied to test the hypotheses in the conceptual research model as shown in the Figure 3. Smart PLS is known for the statistical analysis with low sample size and normality [33]. The process of application of PLS-SEM is conducted in several steps. In this procedure, carefully examining factors under a construct is done and a formation of the structural diagram is formatted to analyze the relationship between dependent and independent variables. So the evaluation process involves four steps as follows [71]:

- Individual Item Reliability and Convergent Validity
- Discriminant Validity
- Structural Relationships
- Overall Model Fitness

These four major criteria have been explained in detail with reference to Tables 5–7.

Table 5. Risk evaluation by structural equation modeling analysis.

Construct	Factors	Estimates		
		Loading	**AVE**	**CR**
F.I	GNICPC	0.926	0.852	0.920
	IG	0.919		
I.F	FRT	0.787	0.497	0.742
	LA	0.776		
	FNB	0.520		
I.M	PPWC	0.905	0.593	0.811
	PIPT	0.647		
	PRSU	0.736		
L.P	NSLL_ENF	0.694	0.542	0.855
	NMHL_ENF	0.821		
	NSBL_ENF	0.718		
	NCRL_ENF	0.768		
	NDDL_ENF	0.669		
T.M	ERISS	0.355	0.427	0.560
	PDRTC_PCENT	0.854		
VRUI	D_P4WCLV	−0.647	0.650	0.108
	D_CYC	0.938		
Criteria [32,35,68,69]		≥0.4	≥0.50	≥0.70

Note: AVE = Average Variance Extracted; CR = Composite Reliability.

1. Individual Item Reliability and Convergent Validity

To evaluate individual item reliability, a correlation of the items is analyzed with their respective latent variables, which is basically evaluated by evaluating the standardized loading (or simple correlation) [71]. In the start, all of the considerable factors are considered under certain formation, then, on the basis of factor loading, all weak variables are removed. In our case, all the selected variables were included in the construction of models as shown in Figure 10, following the range of 0.4–0.7 as a rule. So, after applying the PLS-SEM model [32,68], first iteration and final modified iteration can be viewed in Figures 10 and 11. Thus, finally, all those variables are remaining which have higher factor loading, some are exceptionally retained due to the importance of the variables; even their factor loading was less than 0.5. Moreover, to analyze, the convergent validity is used to measure the internal consistency, which is related to the calculation of composite reliability (CR) and average variance extracted (AVE) [72]. According to studies, "Composite reliability (CR) measure can be used to check how well a construct is measured by its assigned indicators" [71]. The standard value as a benchmark is considered to be 0.70 [32,72]. "Average variance extracted (AVE) is applied to "assess internal consistency of the construct by measuring the amount of variance that a latent variable captures from its measurement items relative to the amount of variance due to measurement errors. A basic assumption is that the average covariance among indicators has to be positive". "It is stated that AVE should be higher than 0.5 which depicts that at least 50% of measurement variance is captured by the latent variables" [72,73]. The results of individual item reliability and convergent validity are presented in Table 5. As can be observed in Table 5, infrastructure and mobility and legislation and policy constructs exceed these criteria, with AVE and CR generally equal or greater than 0.5 and 0.7, respectively, and the square-root of the AVE being close to 0.6 [74,75]. Furthermore, the relationship to confirm the existence of discriminant validity of the designed construct measurements has been applied in this study.

2. Discriminant Validity

Discriminant validity is also established by associating the square root of the average variance extracted to the correlations with other latent variables [73]. If the diagonal values are larger than any other correlation, then this establishes adequate discriminant validity. If this standard is not met (i.e., a correlation is stronger than the diagonal value) then the AVE is lower than the shared variances with other latent variables. This means that the model will require to be re-evaluated to define if items with either low loadings or high cross-loadings can be dropped in order to increase the AVE or decrease the shared variance with another latent variable [76,77]. For this procedure, a Fornell and Larcker method [73] is followed, which states that square root of AVE in each latent variable can be used to establish discriminate validity if this value is larger than other correlation values among the other latent variables. So, a table which consists of the required square root of AVE values is produced by the Smart PLS software which shows a type of latent variable correlation [75]. The structural diagonal based formation, shown in the Table 6, provides a correlation as other techniques provide similar types of relationships, which show that there is a higher relationship among factors, and hence, the condition is fulfilled.

Table 6. Fornell–Lacker criterion analysis for discriminant analysis.

Factors	FI	IM	IF	LP	TM	VI
FI: Financial Impact	0.923					
IM: Infrastructure and Mobility	0.372	0.770				
IF: Institutional Framework	−0.071	0.389	0.705			
LP: Legislation and Policy	0.515	0.373	0.168	0.736		
TM: Trauma Management	−0.282	0.000	0.064	−0.208	0.352	
VI: Vehicular-Road User Impact	0.086	−0.140	0.035	0.080	−0.403	0.806

3. Structural Relationships

A final output target was to analyze the relationship between risk and six factors, Table 7 provides the concept of T-statistics for the hypothesized relationship analysis in this study. The target of

T-statistics is 1.645 (p-value < 0.10) which does not confirm the statistical significance of the research [75] relationship between risk value and factors affecting risk; the hypothesis testing showed that trauma management (TM) is the key factor which is significant. This confirms the hypothesis number H:5, according to which, there is a strong relationship between risk and TM as shown in Figure 15.

Table 7. Hypothesis testing of relationship between factors and risk.

Relationship Hypothesis	P. Coff.	T. Stat	p-Value	R^2
H1: Financial Impact → Risk	−0.134	0.820	0.413	
H2: Infrastructure & Mobility → Risk	0.036	0.222	0.824	
H3: Institutional Framework → Risk	−0.208	1.283	0.200	0.390
H4: Legislation and Policy → Risk	−0.246	1.018	0.309	
H5: Trauma Management → Risk	0.217	1.665	0.097 *	
H6: Vehicular R User Impact → Risk	−0.319	1.332	0.183	

* Sig (p < 0.10).

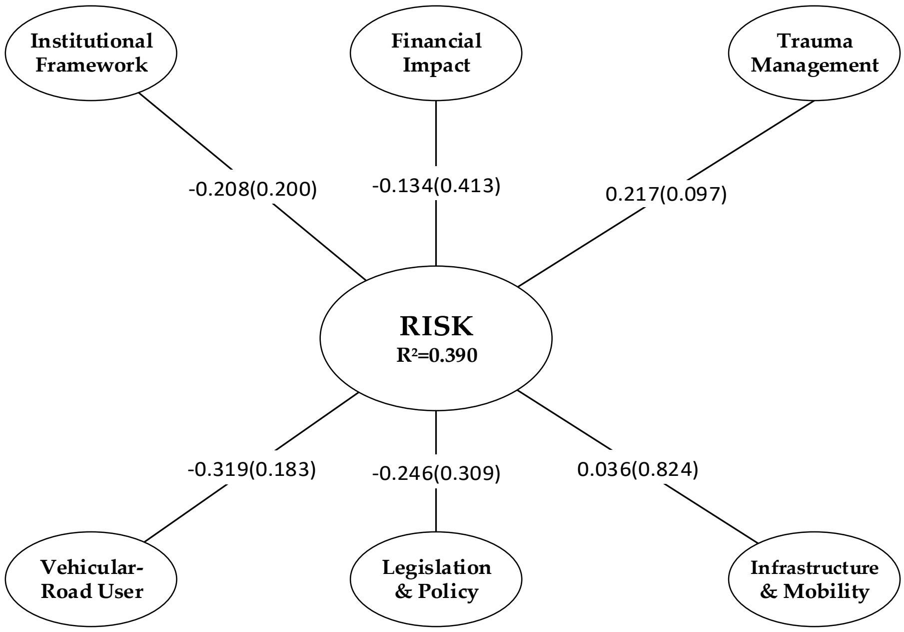

Figure 15. Results of Structural Relationship of the Model.

4. Overall Model Fitness

Overall, model fitness is analyzed by testing global validity and explaining the power of the model. This is done by estimating the goodness of fit (GoF) [75]. "Goodness of Fit (GoF) index is defined as the geometric mean of the average communality and average R^2 for all endogenous constructs. It can be used to determine the overall prediction power of the large complex model by accounting for the performance of both measurement and structural parameters", that is an advantage of GoF over other measures like RMSE, R^2, Q^2, CFI etc. [78]. GoF is associated with communality which is considered as 0.5 [73] and R^2 (R^2 small is considered as 0.02, medium as 0.13 and large as 0.26) [75,79]. As goodness of fit (GoF) is under root average communality multiplied by R^2, thus, it results in $GoF_{small} = 0.10$, $GoF_{med} = 0.25$ and $GoF_{Large} = 0.36$ [80]. R^2 for the relationship between risk and the factors as shown in Table 7 is 39%. This indicates that the research model explains more than 39% of the variance in the endogenous variables (financial impact, infrastructure and mobility, institutional framework, legislation and policy, trauma management and vehicular road user impact). The significance of trauma management revealed that one of the major concerns in developing countries and even in developed countries is that urgent emergency services, can save lives and might also convert injuries to disabilities.

Although the basic model has been explained in the literature review, a simple equation is:

$$GoF = \sqrt{\overline{AVE} \times R^2} \tag{8}$$

$$GoF = \sqrt{0.5935 \times 0.390} \tag{9}$$

$$\mathrm{GoF} = 0.481 > 0.36 \tag{10}$$

where GoF and its Criteria [71,79,80]:

$$\mathrm{GoF_{Small}} = 0.10,\ \mathrm{GoF_{Med}} = 0.25,\ \mathrm{GoF_{Large}} = 0.36 \tag{11}$$

Since GoF value of the developed model is higher than the criteria for the substantial model i.e., 0.481 > 0.36, we conclude that the developed model is substantial in explaining the road safety risk problem of the Asian region.

5.2.2. Major Problematic Factors

Road safety problems and life loss are two interrelated issues and are related to economic factors i.e., direct economic costs and indirect economic costs [50]. The direct cost includes medical, legal emergency and property-related damages, while sometimes it goes on if these factors have continuity [51]. From the analysis, we can observe that the lower and middle-income countries are already striving for their survival and have less attention focused towards road safety problems, so there is no monitoring mechanisms in those countries for road safety. However, in high-income countries, lack of implementation is the major issue. Institutional framework is also not backed by a strong budget and presence of a lead agency to deal with road safety situations and to implement safety strategy and fatality reduction target. A proper framework is a needed to deal with the road safety situation and risk level [3]. The World is focusing on reducing traffic fatality by 50% (five million fatalities and 50 million serious injuries) by the end 2020 [53], but Asian countries are still not focused to target maintaining the previous level [3]. Asia has one of the biggest issues of legislation and policy. There are laws for the speed limit, motorcycle helmet and seat belt but still, implementation and management are an issues. Asia is still fighting to focus on these three major legislative issues, on the other hand, child constraints are still not under consideration in a large number of countries. Trauma management is related to the system responsible for rapid response to the medical treatment of injured people in the crashes [17]. The facility of trauma management is connected with the availability of medical treatment for the survival of life after crashes. Especially in developing countries, injury crashes result fatalities due to unavailability of medical facilities, i.e., lack of trauma management. Researchers have concluded that 50% of fatalities occur during the crashes while others are within few hours of the crashes [61]. If a proper medical facility is available, then a risk level of the country can be improved by reducing fatalities. Pharmacare and medical treatments, in time availability of medical aid and proper hospital emergency treatment as a chain process, can not only save lives but also disabilities [62]. During the analysis, as shown in Figure 16, the most alarming is the fact that there is a large difference between the State-reported and WHO-reported fatalities, i.e., under-reporting by the State database. This difference of figures varies between 0% and 88% which is an alarming fact. This under reporting involves many factors (i.e., (1) fatality reporting definition and recording (2) deliberate under reporting (3) lack of proper management systems for data collection (4) trauma Management, etc.).

One of the contributing differences of reporting related to fatalities is an issue, as in Europe fatalities are reported in three phases, i.e., (1).Fatalities at the spot; (2) Fatalities within seven days of injury crash; and (3) Fatalities within 30 days of injury crash [3]. However, in Asia, this definition is not followed, and the majority of the countries focus on only on spot fatalities. This lack of road safety record management not only deceives the policy managers but also missleads in fact finding. A combined Asian road safety database requirement would therefore maintain the road safety related data for analysis and research.

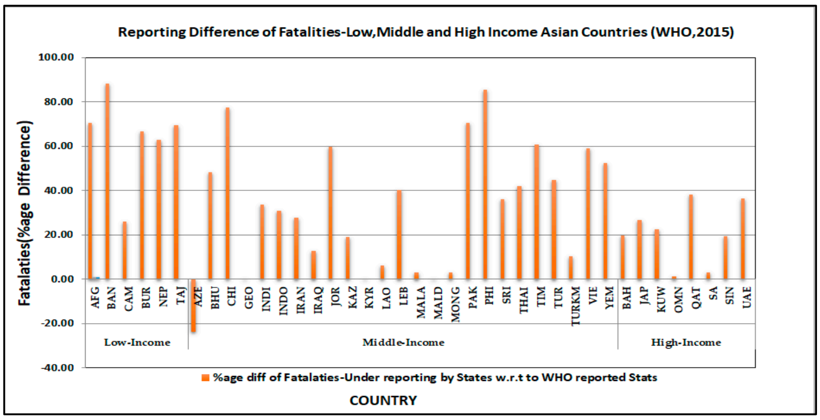

Figure 16. Percentage difference in State-reported and WHO-reported road crash fatalities.

6. Conclusions

The purpose of this study was to investigate the road safety condition of low and middle-income countries of the Asian region. In particular, the focus was to analyze six major sectors which are directly related to road safety conditions. A detailed literature review directed towards a two stage methodology to analyze the road safety condition of Asia by first calculating the risk value of all countries and, then, to develop the relationship between risk and factors contributing to risk increment. DEA, as one of the benchmarking tools to calculate risk was adopted, and after calculation, ranking was done to idealize the risky countries within the Asian region. In second phase PLS-SEM, was used a structural output mechanism to visualize a large set of variables in relation to the risk level. Road traffic accidents are, nowadays, the most incessant reason of injuries and fatalities. Guidelines to adopt the variables and development of constructs were followed by available WHO [3] patterns and similar formats of analysis were adopted. In the background, the target was studying the major contributing factors of road traffic crash fatalities [81–83]. Studies are available regarding road crashes associated with high speeding, unfastened seat belts and disobeying other road conducts causing many crashes [84]. The study was based on the financial condition of countries (so per capita income) which was the punching variable for analysis, but the major focus was on the institutional framework as it was related to financial planning and target execution. Infrastructural development and major transport policy-making decisions for mobility were also taken into consideration. Road safety audit mechanisms, promotion of public transport, and promotion of cycling were also within this periphery. Trauma management, which remained a crucial factor (significant factor as shown in SEM based analysis) for road safety researchers was taken as a major construct variable. Trauma management is related to two major factors, i.e., efficient injury surveillance systems and control of permanent disabilities by in-time medical treatment. So fatalities can be reduced by improving trauma management.

For a policy maker and road safety analyst, this two-stage method can help to identify, the major influencing factors with different WHO-identified peripheries (i.e., finance, institutional framework, infrastructures, legislation along with policy, vehicular along with human impact and trauma management). From the analysis of large data sets of variables for the Asian region, it was found that the road safety level is affected by these above-mentioned six factors. Furthermore, it was found that for road safety case analysis, these factors are directly associated; financial states of the countries are linked with two major factors i.e., income group and gross national income per capita. Institutional framework is associated with the fund available in the national budget for road safety or not; fatality reduction target is kept or not and there is a road safety lead agency available or not. Infrastructure and mobility has an impact on policy of investment in public transport and policy for promotion for cycling and walking. Although legislation and policy are present, enforcement of factors like speed limit, helmet laws, seat-belt laws, child restraint laws and drink driving laws are of major concern. Trauma management is a type of post-crash care performance, which is associated with the presence of emergency room injury surveillance systems and permanent disability due to road crashes. Vehicular and road user impact is related to the death/killing associated with the users of vehicles (i.e., cars/trucks/buses) as passengers or drivers, cyclists and as pedestrians. This thorough arrangement of road safety indicators gave a strong beginning stage to estimating national road safety advancement in the Asian region for improvement. In comparison to the European region, previously, researchers have not focused in this direction for the Asian region. However, by application of this proposed combination mechanism, policy makers and decision makers can not only analyze the road safety situation in a systematic way, but also can indicate the factors, which can be focused during the management and governance at State and agency level.

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References

1. World Health Organization (WHO). *World Report on Road Traffic Injury Prevention*; World Health Organization: Geneva, Switzerland, 2004.
2. Nantulya, V.M.; Reich, M.R. The neglected epidemic: Road traffic injuries in developing countries. *BMJ* **2002**, *324*, 1139–1141. [CrossRef] [PubMed]
3. World Health Organization (WHO). *Global Status Report on Road Safety 2015*; World Health Organization: Geneva, Switzerland, 2015.
4. Kopits, E.; Cropper, M. *Traffic Fatalities and Economic Growth*; Policy Research Working Paper No. 3035; World Bank: Washington, DC, USA, 2003.
5. Murray, C.J.; Lopez, A.D. Mortality by cause for eight regions of the world: Global Burden of Disease Study. *Lancet* **1997**, *349*, 1269–1276. [CrossRef]
6. World Health Organization (WHO). Good Governance—The Case of Road Safety. Available online: http://www.who.int/healthpromotion/conferences/9gchp/good-governance-road-safety/en/ (accessed on 15 April 2017).
7. Montazeri, A. Road-traffic-related mortality in Iran: A descriptive study. *Public Health* **2004**, *118*, 110–113. [CrossRef]
8. Norman, L.G.; Organization, W.H. *Road Traffic Accidents: Epidemiology, Control, and Prevention*; Public Health Papers No. 12; World Health Organization: Geneva, Switzerland, 1962.
9. Lajunen, T. Personality and accident liability: Are extraversion, neuroticism and psychoticism related to traffic and occupational fatalities? *Personal. Individ. Differ.* **2001**, *31*, 1365–1373. [CrossRef]
10. Petridou, E.; Skalkidou, A.; Ioannou, N.; Trichopoulos, D.; Police, H.R.T. Fatalities from non-use of seat belts and helmets in Greece: A nationwide appraisal. *Accid. Anal. Prev.* **1998**, *30*, 87–91. [CrossRef]
11. Vahdati, S.S.; GhafarZad, A.; Rahmani, F.; Panahi, F.; Rad, A.O. Patterns of road traffic accidents in north west of Iran during 2013 New Year Holidays: Complications and casualties. *Bull. Emerg. Trauma* **2014**, *2*, 82–85.
12. Violanti, J.M. Cellular phones and traffic accidents. *Public Health* **1997**, *111*, 423–428. [CrossRef]
13. International Monetary Fund (IMF). *World Economic Outlook Database*; IMF: Washington, DC, USA, 2014.
14. International Monetary Fund (IMF). *Nominal GDP-Billions of U.S. Dollars*; IMF: Washington, DC, USA, 2017.

15. Al Haji, G. *Towards a Road Safety Development Index (RSDI): Development of An International Index to Measure Road Safety Performance*; Linköping University Electronic Press: Linköping, Sweden, 2005.
16. SafetyNet. *State of the Art Report on Risk and Exposure Data. Safetynet Deliverable 2.1*; Yannis, G.E.A., Ed.; European Commission: Brussels, Belgium, 2005.
17. European Transport Safety Council (ETSC). *Transport Safety Performance Indicators*; European Transport Safety Council: Brussels, Belgium, 2001.
18. Gitelman, V.; Doveh, E.; Hakkert, S. Designing a composite indicator for road safety. *Saf. Sci.* **2010**, *48*, 1212–1224. [CrossRef]
19. Charnes, A.; Cooper, W.W.; Rhodes, E. Measuring the efficiency of decision making units. *Eur. J. Oper. Res.* **1978**, *2*, 429–444. [CrossRef]
20. Shen, Y.; Hermans, E.; Brijs, T.; Wets, G.; Vanhoof, K. Road safety risk evaluation and target setting using data envelopment analysis and its extensions. *Accid. Anal. Prev.* **2012**, *48*, 430–441. [CrossRef] [PubMed]
21. Hermans, E.; van den Bossche, F.; Wets, G. Combining road safety information in a performance index. *Accid. Anal. Prev.* **2008**, *40*, 1337–1344. [CrossRef] [PubMed]
22. Hermans, E.; Brijs, T.; Wets, G.; Vanhoof, K. Benchmarking road safety: Lessons to learn from a data envelopment analysis. *Accid. Anal. Prev.* **2009**, *41*, 174–182. [CrossRef] [PubMed]
23. Shen, Y.; Hermans, E.; Ruan, D.; Wets, G.; Brijs, T.; Vanhoof, K. A generalized multiple layer data envelopment analysis model for hierarchical structure assessment: A case study in road safety performance evaluation. *Expert Syst. Appl.* **2011**, *38*, 15262–15272. [CrossRef]
24. Alper, D.; Sinuany-Stern, Z.; Shinar, D. Evaluating the efficiency of local municipalities in providing traffic safety using the Data Envelopment Analysis. *Accid. Anal. Prev.* **2015**, *78*, 39–50. [CrossRef] [PubMed]
25. Rosić, M.; Pešić, D.; Kukić, D.; Antić, B.; Božović, M. Method for selection of optimal road safety composite index with examples from DEA and TOPSIS method. *Accid. Anal. Prev.* **2017**, *98*, 277–286. [CrossRef] [PubMed]
26. Lee, J.-Y.; Chung, J.-H.; Son, B. Analysis of traffic accident size for Korean highway using structural equation models. *Accid. Anal. Prev.* **2008**, *40*, 1955–1963. [CrossRef] [PubMed]
27. Golob, T.F. Structural equation modeling for travel behavior research. *Transp. Res. Part B* **2003**, *37*, 1–25. [CrossRef]
28. Hair, J.F., Jr.; Sarstedt, M.; Hopkins, L.; Kuppelwieser, V.G. Partial least squares structural equation modeling (PLS-SEM) An emerging tool in business research. *Eur. Bus. Rev.* **2014**, *26*, 106–121. [CrossRef]
29. Ringle, C.M.; da Silva, D.; Bido, D.D.S. Modelagem de equações estruturais com utilização do SmartPLS. *REMark* **2014**, *13*, 54–71.
30. Do Nascimento, J.C.H.B.; da Silva Macedo, M.A. Structural Equation Models using Partial Least Squares: An Example of the Application of SmartPLS® in Accounting Research. *Rev. Educ. Pesqui. Contab.* **2016**, *10*. [CrossRef]
31. Lee, L.; Petter, S.; Fayard, D.; Robinson, S. On the use of partial least squares path modeling in accounting research. *Int. J. Acc. Inf. Syst.* **2011**, *12*, 305–328. [CrossRef]
32. Chin, W.W. The partial least squares approach to structural equation modeling. *Mod. Methods Bus. Res.* **1998**, *295*, 295–336.
33. Chin, W.W.; Newsted, P.R. Structural equation modeling analysis with small samples using partial least squares. *Stat. Strateg. Small Sample Res.* **1999**, *1*, 307–341.
34. Garson, D. *Partial Least Squares: Regression & Structural Equation Modeling*; Statistical Associates Publishing, 2016. Available online: https://www.researchgate.net/publication/318722955_Partial_Least_SquaresRegression_and_Structural_Equation_Models (accessed on 20 February 2017).
35. Gye-Soo, K. Partial Least Squares Structural Equation Modeling (PLS-SEM): An application in Customer Satisfaction Research. *Int. J. u-e-Serv. Sci. Technol.* **2016**, *9*, 61–68. [CrossRef]
36. Yun Kyung, B.; Jin Hee, K.; Jin-Hyuk, C. Traffic Accident Analysis for Highway on Weather Condition and Time. In Proceedings of the International Conference on Transport, Environment and Civil Engineering (ICTECE'2012), Kuala Lumpur, Malaysia, 25–26 August 2012.
37. Scott-Parker, B.; Watson, B.; King, M.J.; Hyde, M.K. A further exploration of sensation seeking propensity, reward sensitivity, depression, anxiety, and the risky behaviour of young novice drivers in a structural equation model. *Accid. Anal. Prev.* **2013**, *50*, 465–471. [CrossRef] [PubMed]

38. Sümer, N. Personality and behavioral predictors of traffic accidents: Testing a contextual mediated model. *Accid. Anal. Prev.* **2003**, *35*, 949–964. [CrossRef]
39. Wu, W.-W. Applying DEA and PLS path modeling for efficiency evaluation. *Ann. Tour. Res.* **2009**, *8*, 1228–1237.
40. Lorcu, F.; Bolat, B.A. Comparison of Secondary Education Pisa Results in European Member States and Turkey via DEA and SEM. *J. WEI Bus. Econ.* **2015**, *4*, 7–17.
41. Soteriades, A.D.; Stott, A.W.; Moreau, S.; Charroin, T.; Blanchard, M.; Liu, J.; Faverdin, P. The Relationship of Dairy Farm Eco-Efficiency with Intensification and Self-Sufficiency. Evidence from the French Dairy Sector Using Life Cycle Analysis, Data Envelopment Analysis and Partial Least Squares Structural Equation Modelling. *PLoS ONE* **2016**, *11*, e0166445.
42. Jiang, L.; Folmer, H.; Bu, M. Interaction between output efficiency and environmental efficiency: Evidence from the textile industry in Jiangsu Province, China. *J. Clean. Prod.* **2016**, *113*, 123–132. [CrossRef]
43. Blumenberg, S. *Benchmarking Financial Processes with Data Envelopment Analysis*. 2005. Available online: www.is-frankfurt.de/publikationenNeu/BenchmarkingFinancialProcesses1208.pdf (accessed on 20 June 2017).
44. Charnes, A.; Cooper, W.W.; Lewin, A.Y.; Seiford, L.M. *Data Envelopment Analysis: Theory, Methodology, and Applications*; Springer Science & Business Media: New York, NY, USA, 2013.
45. Shackman, J.D. The use of partial least squares path modeling and generalized structured component analysis in international business research: A literature review. *Int. J. Manag.* **2013**, *30*, 78.
46. Tobias, R.D. (Ed.) *An Introduction to Partial Least Squares Regression*; SAS Institute: Cary, NC, USA, 1997.
47. Kwon, H.-B. Performance modeling of mobile phone providers: A DEA-ANN combined approach. *Benchmarking* **2014**, *21*, 1120–1144. [CrossRef]
48. Kwon, H.-B. Exploring the predictive potential of artificial neural networks in conjunction with DEA in railroad performance modeling. *Int. J. Prod. Econ.* **2017**, *183*, 159–170. [CrossRef]
49. Hakkert, A.; Gitelman, V.; Vis, M. Road safety performance indicators: Theory. *Deliverable D3* **2007**, *6*. Available online: http://erso.swov.nl/safetynet/fixed/WP3/sn_wp3_d3p6_spi_theory.pdf (accessed on 20 February 2017).
50. Elvik, R.; Amundsen, A.H. Improving road safety in Sweden. *TØI Rep.* **2000**, *490*, 2000.
51. Lloyd, D.; Wilson, D.; Tuddenham, F.; Goodman, G.; Bhagat, A. Reported road casualties Great Britain 2012. Great Britain: Department for Transport. Available online: https://http://www.gov.uk/government/uploads/system/uploads/attachment_data/file/2:2013 (accessed on 20 February 2017).
52. Wismans, J.; Skogsmo, I.; Nilsson-Ehle, A.; Lie, A.; Thynell, M.; Lindberg, G. Implications of road safety in national productivity and human development in Asia. In Proceedings of the Eighth Regional EST Forum in Asia, Colombo, Sri Lanka, 19–21 November 2014; pp. 1–51.
53. Guria, J. Required Expenditure: Road safety improvement in low and middle income countries. In *Addendum: Revised Estimates of Fatalities and Serious Injuries and Related Costs. Report to the World Bank Global Road Safety Facility*; New Zealand Institute of Economic Research: Wellington, New Zealand, 2009.
54. Macaulay, J.; McInerney, R. *Evaluation of the Proposed Actions Emanating from Road Safety Audits*. 2001. Available online: https://www.onlinepublications.austroads.com.au/items/AP-R209-02 (accessed on 20 February 2017).
55. Aljanahi, A.; Rhodes, A.; Metcalfe, A.V. Speed, speed limits and road traffic accidents under free flow conditions. *Accid. Anal. Prev.* **1999**, *31*, 161–168. [CrossRef]
56. Belmont, D.; Forbes, T. *Effect of Average Speed and Volume on Motor-Vehicle Accidents on Two-Lane Tangents*; Institute of Transportation and Traffic Engineering, University of California: Oakland, CA, USA, 1953.
57. Elvik, R. Effects on accidents of automatic speed enforcement in Norway. *Transp. Res. Rec.* **1997**, 14–19. [CrossRef]
58. Balkin, S.; Ord, J.K. Assessing the impact of speed-limit increases on fatal interstate crashes. *J. Transp. Stat.* **2001**, *4*, 1–26.
59. Milton, J.C.; Mannering, F.L. *The Relationship between Highway Geometrics, Traffic Related Elements, and Motor Vehicle Accidents*; Washington State Department of Transportation: Washington, DC, USA, 1996.
60. O'donnell, C.; Connor, D. Predicting the severity of motor vehicle accident injuries using models of ordered multiple choice. *Accid. Anal. Prev.* **1996**, *28*, 739–753. [CrossRef]
61. European Transport Safety Council (ETSC). *Reducing the Severity of Road Injuries through Post Impact Care*; European Transport Safety Council: Etterbeek, Belgium, 1999.

62. Hussain, L.; Redmond, A. Are pre-hospital deaths from accidental injury preventable? *BMJ* **1994**, *308*, 1077–1080. [CrossRef] [PubMed]
63. Bank, W. World Development Indicators. Available online: http://data.worldbank.org/products/wdi-maps (accessed on 12 August 2017).
64. Avkiran, N.K. An application reference for data envelopment analysis in branch banking: Helping the novice researcher. *Int. J. Bank Mark.* **1999**, *17*, 206–220. [CrossRef]
65. Galagedera, D.; Silvapulle, P. Experimental evidence on robustness of data envelopment analysis. *J. Oper. Res. Soc.* **2003**, *54*, 654–660. [CrossRef]
66. Raab, R.L.; Lichty, R.W. Identifying subareas that comprise a greater metropolitan area: The criterion of county relative efficiency. *J. Reg. Sci.* **2002**, *42*, 579–594. [CrossRef]
67. PLS, S. *Smart-PLS: Next Generation Path Modeling (V.3)*. 2017. Available online: https://www.smartpls.com/downloads (accessed on 15 February 2017).
68. Memon, A.H.; Rahman, I.A. SEM-PLS analysis of inhibiting factors of cost performance for large construction projects in Malaysia: Perspective of clients and consultants. *Sci. World J.* **2014**, *2014*, 165158. [CrossRef] [PubMed]
69. Hair, J.F.; Black, W.C.; Babin, B.J.; Anderson, R.E.; Tatham, R.L. *Multivariate Data Analysis*; Prentice Hall: Upper Saddle River, NJ, USA, 1998; Volume 5.
70. Ringle, C.M.; Wende, S.; Will, S. SmartPLS 2.0 (M3) Beta, 2005. Available online: http://www.smartpls.de (accessed on 20 February 2017).
71. Memon, A.H.; Rahman, I.A. Analysis of cost overrun factors for small scale construction projects in Malaysia using PLS-SEM method. *Mod. Appl. Sci.* **2013**, *7*, 78. [CrossRef]
72. Hair, J.F.; Ringle, C.M.; Sarstedt, M. PLS-SEM: Indeed a silver bullet. *J. Mark. Theory Pract.* **2011**, *19*, 139–152. [CrossRef]
73. Fornell, C.; Larcker, D.F. Evaluating structural equation models with unobservable variables and measurement error. *J. Mark. Res.* **1981**, *18*, 39–50. [CrossRef]
74. Chin, W.W. Issues and opinion on structural equation modeling. *MIS Q.* **1998**, *22*, 7–16.
75. Chinomona, R.; Mofokeng, T.; Pooe, D. The influence of condition of minibus taxis, compliance with road rules on quality of service and commuter satisfaction in Harrismith, South Africa. *Mediterr. J. Soc. Sci.* **2013**, *4*, 319. [CrossRef]
76. Lowry, P.B.; Gaskin, J. Partial least squares (PLS) structural equation modeling (SEM) for building and testing behavioral causal theory: When to choose it and how to use it. *IEEE Trans. Prof. Commun.* **2014**, *57*, 123–146. [CrossRef]
77. Henseler, J.; Ringle, C.M.; Sarstedt, M. A new criterion for assessing discriminant validity in variance-based structural equation modeling. *J. Acad. Mark. Sci.* **2015**, *43*, 115–135. [CrossRef]
78. Tenenhaus, M.; Vinzi, V.E.; Chatelin, Y.-M.; Lauro, C. PLS path modeling. *Comput. Stat. Data Anal.* **2005**, *48*, 159–205. [CrossRef]
79. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*; Lawrence Earlbaum Associates: Hillsdale, NJ, USA, 1988; pp. 20–26.
80. Akter, S.; D'Ambra, J.; Ray, P. An evaluation of PLS based complex models: The roles of power analysis, predictive relevance and GoF index. In Proceedings of the 17th Americas Conference on Information Systems (AMCIS 2011), Detroit, MI, USA, 4–7 August 2011; pp. 1–7.
81. Söderlund, N.; Zwi, A.B. Traffic-related mortality in industrialized and less developed countries. *Bull. World Health Organ.* **1995**, *73*, 175. [PubMed]
82. Singh, H.; Dhattarwal, S. Pattern and distribution of injuries in fatal road traffic accidents in Rohtak (Haryana). *J. Indian Acad. Forensic Med.* **2004**, *26*, 20–23.
83. Yang, B.-M.; Kim, J. Road traffic accidents and policy interventions in Korea. *Inj. Control Saf. Promot.* **2003**, *10*, 89–94. [CrossRef] [PubMed]
84. Naci, H.; Chisholm, D.; Baker, T.D. Distribution of road traffic deaths by road user group: A global comparison. *Inj. Prev.* **2009**, *15*, 55–59. [CrossRef] [PubMed]