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Road Safety Management and Comparison of Low Cost and High Cost Plans And Selection of the Most Appropriate Plan

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Abstract
This paper is aimed at controlling different access roads and activity-based gathering locations of Ahvaz-Andimeshk- Pol-e Zal axis, considering high cost and low cost engineering plans and finally selecting the best plan by comparing the above mentioned plans. Thus by estimating transportation request, analyzing low cost and high cost engineering plans including such factors as time, cost, quality, service life and durability, studying driving accidents and human and financial losses, and selecting the best plan, such results as improvement of transportation safety coefficient, low traffic to accelerate economic and social activities, public satisfaction, saving in fuel consumption through the shortest paths and finally protection of environment can be achieved with a view to provide sustainable road safety. Also comparison of early-return and late-return plans revealed that early-return plans, despite reducing accidents by 15 percent at the first stages, will not reduce accidents in long term. Late-return plans bring about more favorable results by studying roads thoroughly. This paper compares one of the examples of this area plans.
Keywords: - Road safety, access control, project costing

Introduction

Safety plans have been raised by safety scholars and policy-makers of the world and can be utilized in different conditions and anywhere in the world; albeit, due to some deterrent factors, some of these plans cannot be implemented. To select the most optimal plan among low cost and high cost plans by comparing them, an efficient practical method known as cost – benefit analysis is required. Safety road plans have two main conditions namely, priority of benefits over costs and ability to solve the problem (Aminizadeh, M., 2010). Finding the best option to increase the economic returns is the main objective of assessing an executive project. This occurs when the rate of economic returns caused by improvement of safety level and reduction of accidents can be specified by allocating a certain amount of money to each reduced accident to be compared with the project implementation cost. To prioritize different plans stemming from various traffic safety strategies, an accurate estimate of direct and indirect costs of traffic accidents is required (Dionne, Georges, et al., 2013). Improvement of roads safety involves paying attention to three factors namely, human, road, and vehicle. Regardless of the uncontrollable factor, i.e. vehicle, human factor plays the greatest role in the accidents occurrence that is caused by human mistake and lack of knowledge about safety matters. Therefore, coping with human mistakes and training traffic rules are among the most important methods of safety improvement. The next factor is road and its surrounding environment. Road safety is usually an issue improved by road safety management and road safety engineering. Road safety management analyzes safety matters from a macro perspective (Vereek, Lode, et. al., 2008). Finding the best option for increasing the rate of economic returns of a project is the objective of the project assessment. This occurs when the rate of economic returns caused by improvement of safety level and reduction of accidents can be specified. To compare implementation costs of a project with economic benefits of its implementation, the ratio of costs to benefits of each accident must move towards zero (Weiss, M., et al., 2010).

By offering an economic analysis, this paper is aimed at providing a base for indentifying the role of economic analysis in decision-making and processes in the economic evaluation methods of transportation and road safety plans.

1. Literature Review

1.1 Theoretical Bases

Road safety audit: it is a systematic, official, and managerial process that applies safety knowledge with the aim of preventing accidents occurrence in the roads network (Elvik, R. 2013).

Road privacy: it refers to the area of lands allocated to the road and owned by the government (Weijermars, W., et al., 2013).

Road bed: it refers to an area occupied practically by the road. The road bed is confined to the interface between natural land and embankment (Daniel A., et al., 2012).

Roadway surface: it includes a surface used for vehicles traffic (Gaudry, M., et al., 2013).

Guard rail: it is a metal bar that is intended to prevent cars from going off the road when the road surface is above the natural ground (Andersson, H., 2013).

Road shoulder: it is a reserved area by the verge of a road (Oster, Clinton V. et. al., 2013).

Accidents severity: it is a measurement criterion indicating the number of days lost as a result of accident. As the accident is more severe, more time is lost as a result of the accident (Bolduc, D., et al., 2013).

1.2 Research Background

(Ettema, Dick, et. al, 2013), this paper presents an empirical test of the satisfaction with travel scale (STS) that was developed to measure travelers' satisfaction with travel. STS measures travel satisfaction in terms of two affective (positive activation versus negative de-activation and positive de-activation versus negative activation) and one cognitive dimension. (Gaudry, M. et. al, 2013),This first part of the state-of-the art focuses on the origins of road safety modeling, covering data, early models and the public health context of model formulation and use. (Gaudry, M. et. al, 2013), The second part of the state-of-the-art focuses on the development of the founders' double streams explaining single-outcome indicators (probability of accidents and fatalities, respectively) by fixed form regression, as outlined in the Part 1. Following Page (1997, pp. 67–122, 2001) and others, we use as turning point of the evolution of both aggregate and discrete approaches the DRAG-1 model of 1984, itself based on aggregate data, which introduced four key innovations in principle applicable to both streams. (Gaudry, M. et. al, 2013), the third part of the state-of-the-art focuses on the future of road safety modeling and on conjectures concerning the evolution of national safety indicators. In the absence of econometric developments specific to road safety modeling, the research future must rely on pre-existing statistical procedures of econometrics applied to discrete/count and to aggregate data. In terms of contents, growing interest in the heterogeneity of road accident outcomes by category of victims could lead to treatments of this issue across research streams, say by top-down and bottom-up developments, but this speculation does not rest on extant adequate formulations of the issue of road user class and victim analysis. (Aparicio I. et. al, 2013), this paper presents the results of applying DRAG methodology to the identification of the main factors of influence on the number of injury and fatal accidents occurring on Spain’s interurban network. Nineteen independent variables have been included in the model grouped together under ten categories: exposure, infrastructure, weather, drivers, economic variables, vehicle stock, surveillance, speed and legislative measures. Highly interesting conclusions can be reached from the results on the basis of the different effects of a single variable on each of the accident types according to severity. (Bolduc, D. et. al, 2013), this paper presents a methodological disaggregated approach to analyze the impact of interventions on road safety. The model aims to describe the accident rates of an individual using mileage as a measure of risk exposure. The model is formulated as a system of equations that takes into account interactions between the mileage of a given individual and the other drivers. Once estimated, the model acts as a simulator allowing us to measure the performance of policy interventions to increase road safety. (Andersson, H, 2013), This study analyzes stated willingness to pay (WTP) for traffic safety, the use of traffic safety equipment, and the consistency between the two. Using data from a Swedish contingent valuation study we find that the estimated value of a statistical life (VSL) based on the respondents' rear-seatbelt usage is similar to the estimate found using the respondents' stated WTP.

2. Materials and Methods

2.1 Geographical Location of Khuzestan Province

Khuzestan Province covering an area of 64.236 km² is located at the southwest of Iran bordering Persian Gulf and Arvand Rud, and it is the center of Iranian oil extraction. Its capital is Ahvaz. Khuzestan borders Lorestan Province from north, Isfahan Province from northeast, Ilam Province from northwest, Chaharmahal and Bakhtiari Province and Kohgiluyeh and Boyer-Ahmad Province from east and southeast, Persian Gulf from south, and Iraq from west. Information presented in the following is based on observations of Ahvaz- Andimeshk transit road.

2.2 Region Properties

2.2.1 Route and Cross-Section

Near 90 percent of information used by drivers is visual information. So, providing optimal conditions for visibility is a main requirement for safe driving. Ahvaz- Andimeshk route is a highway with an authorized speed of 110 km/h and horizontal curves located at a paved region. Horizontal curves of the route are completely open and enjoy proper visibility along the road. The intersections of this highway do not have the required geometric features and some of them do not have proper visibility. Existence of a lot of intersections created by natural persons without observing any standard is another feature of this route. The turn-offs lack speed decreasing and increasing lines and sufficient roadway and shoulder width, and many of them are not asphalted. Many intersections have been created by natural persons without observing technical properties.

2.2.2 Intersections, Access and Turn-offs

One of the main problems of this route is its intersections that can be divided into two authorized and unauthorized groups. These intersections have been created by different users of road margin including residential regions, farmers, and shop-keepers. Some of these intersections are not asphalted and have been connected to the road without observing any standard and some of them are very close to each other. The distance of lanes of traffic moving in opposing directions is relatively large in some points of the road, but this distance is reduced in most parts, and somewhere there is no median as well. Thus there is no proper stage for implementing safe turn-off.

2.2.3 Vertical Signs

Despite enforcement of Road Safety Bylaw and its declaration by the country Management and Planning Organization, a remarkable number of safety signs and equipments of this road does not comply with the provisions of the above mentioned bylaw in terms of design, dimensions, and location. Studying their current conditions and designing and locating new signs based on this Bylaw are inevitable for guiding traffic properly and providing proper on-time information to the road users. This matter results in applying an accurate method based on traffic technical and engineering principles besides uniformity of signs.

2.2.4 Horizontal Signs

In general, except for areas overlaid recently, the roads have lateral and medial linings with proper reflex at night and day; and in some points, cat's eye reflexes have been installed that some of them have been dug out of the ground or have sunken into the asphalt pavement due to heat and softened asphalt. Lane markings have been simply drawn in the lateral and medial parts, and no particular pattern in intersections and turn-offs and no hachured arrows and lines in special parts have been applied. For residential regions, using horizontal signs is useful.

2.2.5 Marginal Way Risk Management

Although guardrails have been installed in the required areas, there are still many waterways and precipices that need guardrail. The guardrail of some of the bridges and waterways do not have required strength as well. Also guardrails have not been connected to the fences properly and beginning and end of the guards are not safe. This can be also seen in the bridges and waterways.

2.2.6 Asphalt Pavement

Road pavement in different parts of the route has different quality, so it is proper in some parts and improper in some others. In some parts, the effects of tarring on the asphalt surface are seen and in latitudinal gradients, asphalt shrinkage can be observed. This matter reduces sliding resistance coefficient of road surface. Dislodged materials and aggregates on the asphalt surface are seen along the way particularly in the main roads.

3. Implementation and Calculations

Road safety plans have been raised by safety scholars and policy-makers in the world and can be utilized in different conditions and anywhere in the world. Due to some deterrent factors, implementation of some plans is not possible. To select the most appropriate plan from among low cost and high cost plans by comparing them, an efficient practical method known as cost – benefit analysis is required.

The proposed road safety plans that are applicable to Ahvaz – Andimeshk - Pol-e Zal route are divided into two groups in terms of utilization period; first, plans with infinite utilization period (low cost engineering plans) and second, plans with certain utilization period (high cost and long term engineering plans).

3.1 Calculations of Ahvaz- Andimeshk Route

Implemented and ongoing projects of Ahvaz- Andimeshk route are as following.

Ahvaz – Andimeshk road	Intersection of Dehloran- Andimeshk threeway
Andimeshk – Pol-e Zal	Intersection of Andimeshk – Dez Dam
	Andimeshk – Pol-e Zal freeway

3.1.1 Profitability Time of Late-Return (High-Cost Engineering) Plans

- Intersection of Dehloran-Andimeshk threeway

With regard to Forensic statistics in 11 months of 1391 (2012), 27 accidents have occurred in this axis including 2 fatal accidents, 3 injury accidents, and 22 loss accidents. With regard to the statistics, table 1 presents the calculation results.

Table 1- late-return plans calculations (Dehloran-Andimeshk three-way)

Cost (Million Rial)	Calculations
Fatal accidents cost	2 * 7202.9 = 14405.8
Injury accidents cost	3 * 248.3 = 744.9
Loss accidents cost	22 * 36.9 = 811.8
Total costs	14405.8 + 744.9 + 811.8 = 15962.5
* Adjustment coefficient	15962.5 * (12/11) = 17413.6
** 80 percent reduction	17413.6 * 0.8 = 13930.8
*** Budget restriction	90000 ÷ 13930.8 = 6.46

* As one month (Esfand) of 1391 has not been considered, the coefficient is multiplied by (12/11).

** A high cost plan reduces 80% of accidents.

*** This plan needs a 90 billion Rial budget at the present juncture.

This plan will reach profitability within 6 ½ years.

- Intersection of Andimeshk-Dez Dam

With regard to Forensic statistics in 11 months of 1391, 29 accidents have occurred in this axis including 2 fatal accidents, 3 injury accidents, and 24 loss accidents. With regard to the statistics, table 2 presents the calculation results.

Table 2- late-return plans calculations (Andimeshk- Dez Dam)

Cost (Million Rial)	Calculations
Fatal accidents cost	2 * 7202.9 = 14405.8
Injury accidents cost	3 * 248.3 = 744.9
Loss accidents cost	24 * 36.9 = 885.6
Total costs	14405.8 + 744.9 + 885.6 = 16036.3
* Adjustment coefficient	16036.3 * (12/11) = 17494.1
** 80 percent reduction	17494.1 * 0.8 = 13995.3
*** Budget restriction	70000 ÷ 13995.3 = 5

* As one month (Esfand) of 1391 has not been considered, the coefficient is multiplied by (12/11).

** A high cost plan reduces 80% of accidents.

*** This plan needs a 70 billion Rial budget at the present juncture.

This plan will reach profitability within 5 years.

- Andimeshk – Pol-e Zal freeway

With regard to Forensic statistics in 11 months of 1391, 246 accidents have occurred in this axis including 18 fatal accidents, 12 injury accidents, and 216 loss accidents. With regard to the statistics, table 3 presents the calculation results.

Table 3- late-return plans calculations (Andimeshk- Pol-e Zal)

Cost (Million Rial)	Calculations
Fatal accidents cost	18 * 7202.9 = 129652.2
Injury accidents cost	12 * 248.3 = 2979.6
Loss accidents cost	216 * 36.9 = 7970.4
Total costs	129652.2 + 2979.6 + 7970.4 = 140602.2
* Adjustment coefficient	140602.2 * (12/11) = 153384.2
** 80 percent reduction	153384.2 * 0.8 = 122707.3
*** Budget restriction	2000000 ÷ 122707.3 = 16.3

* As one month (Esfand) of 1391 has not been considered, the coefficient is multiplied by (12/11).

** A high cost plan reduces 80% of accidents.

*** This plan needs a 70 billion Rial budget at the present juncture.

This plan will reach profitability within 16 years and 4 months.

3.1.2 Profitability Time of Early-Return (Low Cost Engineering) Plans

- Intersection of Dehloran-Andimeshk three-way

Table 4 presents micro costing of Dehloran three-way low cost plan with 2 turn-offs.

Table 4- Plan micro costing (Dehloran-Andimeshk tree-way)

Lining	Main lane	Continuous line $4 * 2000^{m} * 14000^{Rls.} = 112000000^{Rls}$ Broken line $2 * 2000^{m} * 14000^{Rls.} * (2/3) = 37400000^{Rls.}$
	Sub-lane	Continuous line $4 * 1000^{m} * 14000^{Rls.} = 56000000^{Rls}$ Broken line $2 * 1000^{m} * 14000^{Rls.} * (2/3) = 18700000^{Rls.}$
Extrusion	Main lane	$4 * 10 * 5 * 1000000^{Rls.} = 200000000^{Rls.}$
	Sub-lane	$2 * 10 * 5 * 1000000^{Rls.} = 100000000^{Rls.}$
Information boards	(armed concrete)	$9 * 17000000^{Rls.} = 153000000^{Rls.}$
Flashing light	(solar)	$3 * 15000000^{Rls.} = 45000000^{Rls.}$
Turn-off	(200 meter length)	$2 * 1500000000^{Rls.} = 3000000000^{Rls.}$

Lighting costs has been estimated 500 million Rials for this plan. Total costs estimated for this plan is 4220 million Rials.

Benefit – cost of Dehloran three-way, considering total costs of accidents of this area in 1391, is estimated 17400 million Rials, long term project cost at present (intersection) is 90000 million Rials, and short term project cost at present (the above plan) is 4250 million Rials. Benefit – cost annual calculations of Dehloran three-way are presented in table 5.

Table 5- Benefit – cost calculation (Dehloran-Andimeshk three-way)

	First year	Second year	Third year	Fourth year	Fifth year	Sixth year	Sum
* accidents cost	17400	17400	17400	17400	17400	17400	104400
Long term plan	90000	-	-	-	-	-	90000
Short term plan	4250	1000	1180	1390	1640	1930	11390
** (80% reduction)	3480	700	140	30	6	1.25	4357
*** (15% reduction)	14800	12570	10680	9080	7720	6560	61410
Benefit-cost ratio of long term plan	10000 ÷ 90000						1.11
Benefit-cost ratio of short term plan	43000 ÷ 11390						3.7

Benefit-cost ratio of short term plan	Benefit-cost ratio of long term plan	*** (15% reduction)	** (80% reduction)	Short term plan	Long term plan	* cost of accidents	
171080÷54820 = 3.12	256650÷90000 = 2.85	89920	4357	54820	90000	261000	15^{th} year
187200÷64920 = 2.88	274000÷90000 = 3.04	91200	4357	64920	90000	278400	16^{th} year

* based on the existing plan, ** accidents of long term plan, *** accidents costs of short term plan.

- ✓ For short term plan in the second year, one billion Rials have been considered for maintenance costs of the plan and an inflation rate of 18% has been considered for each year.
- ✓ Accidents cost reduction has been 80% for long term plan and 15% for short term plan.
- ✓ All amounts are in million Rials.

\- Intersection of Andimeshk- Dez Dam

Calculations of this axis have been similar to Dehloran- Andimeshk three-way. To summarize calculations, 13^{th} and 14^{th} years calculations have been only presented in table 6.

Table 6- calculations of 13^{th} and 14^{th} years (Andimeshk- Dez Dam)

Benefit-cost ratio of short term plan	Benefit-cost ratio of long term plan	*** (15% reduction)	** (80% reduction)	Short term plan	Long term plan	* cost of accidents	
139059÷39410 = 3.52	223123÷70000 = 3.18	88441	4377	39410	70000	227500	13^{th} year
154779÷46660 = 3.31	240623÷70000 = 3.43	90221	4377	46660	70000	245000	14^{th} year

\- Andimeshk – Pol-e Zal freeway

Calculations of this axis are similar to two prior axes. To summarize calculations, calculations of 13^{th} and 14^{th} years have been only presented in table 7.

Table 7- calculations of 13^{th} and 14^{th} years (Andimeshk - Pol-e Zal)

Benefit-cost ratio of long term plan	** (80% reduction)	Long term plan	No plan (bilateral)	
195565.3÷2000000 = 0.97	38343.3	2000000	1993994.6	13^{th} year
2109035.5÷2000000 = 1.05	38343.3	2000000	2147378.8	14^{th} year

4. Conclusions

According to the obtained numbers and with regard to 80% cost reduction for high cost plans per year, accidents costs have been decreased after nearly 5 years and it will move towards zero, considering road and environment factors as effective factors on accident occurrence. Despite great time and costs spent in long term plans implementation, we will reach 80% profitability (return on the initial investment) after 6 years by saving as a result of accidents reduction. Based on benefit-cost analysis, comparison of high cost plans and low cost plans after 14 years (Intersection of Dez Dam) and 16 years (Intersection of Dehloran three-way) reveals that the ratio of benefit to the costs of high cost plans is more than ratio of benefit to costs of low cost plans; and consequently we witness absolute superiority of high cost plans in long term. with respect to the indirect costs of accidents including loss of human life, loss of ability to work and produce in the society, costs of mental injuries, grief, and economic effects of accidents cultural and social consequences including disintegration of families, children behavioral abnormalities, different costs of delay of these two competitor projects (high cost plans and low cost plans), and different initial investments, low cost plans have more proper economic return compared to high cost plans in the first years of plan implementation. Instead, high cost plans protect human life more than low cost plans. Hence, high cost plans are preferred despite lower ratio of benefit to cost during the first years in these plans compared to low cost plans in order to respect the human dignity. Based on studies and field visits of long term (high cost engineering) projects, these plans incur enormous costs due to high initial investment, great time, and the country inflation rate if the project is interrupted (problems caused by imperfect initial studies). Therefore, carrying out accurate and proper zero phase studies is essential and it is regarded as the first step and pre-requisite of these plans. Since Andimeshk – Pol-e Zal route (second part of case study) is one of the most important transit roads of the Province in terms of topography, and with regard to high volume of traffic and consequently high rate of accidents and existence of many black spots, short term plans are not practical and affordable; and freeway construction has been put on the agenda as a long term plan. Most intersections and turn-offs of Ahvaz- Andimeshk road are not sufficiently safe due to lack of obstacle-free area in the road margin, precipices, power poles, trees, not repaired guardrails, lack of energy absorber bumpers. Ahvaz-Andimeshk route has been designed such that permits drivers to drive by high speed, while there are no facilities for walkers particularly children, motorcyclists and cyclists. There are many uncontrolled spaces in many parts of the road like gas stations, factories, kiosk owners, and no traffic management strategy has been adopted in this regard. Before bridges and waterways, there is rarely a longitudinal shield. This means that when vehicles get out of control, they bump against the bridge channel or wall. Contractors do not observe safety standards in maintenance operations, lining, guard rail installation, and road asphalt overlay. Based on studies and interviews, rescue bases have been established improperly; though they cover the road thoroughly considering 20 minutes as rescue time, number and location of rescue bases must be reviewed to achieve 15 minutes as the rescue time. Management of access roads and turn-offs in Ahvaz- Andimeshk- Pol-e Zal route is a matter of particular magnitude and is deemed as a major problem. Management of these intersections and turn-offs can prevent many accidents and will be an effective measure in reducing traffic accidents. Parking lots existing in the path are not sufficient considering significant volume of heavy vehicles traffic and they must be built in places that remove needs of drivers with regard to the region climatic conditions. Proper use of trees in the roads privacy provides a refreshing atmosphere for the road users and prevents fatigue and drowsiness. Road safety management, sustainable control of driving accidents and their damages are only possible through creating a systematic process and cooperation of different related entities in the framework of certain strategies and plans. To achieve this, a national determination at all levels particularly among road experts and specialists is required. This will not be feasible unless all aspects of accident occurrence are managed in the framework of a written plan and through a clear strategy. With respect to high rate of fatal traffic accidents in the country and that a remarkable percentage of the country accidents occur in this axis, studying effective factors on road accidents of this axis is vital. If several event-prone points are close to each other, road safety plans for one point may be effective on others. Reduction of event-prone points involves gathering accidents information and developing evaluation of the results which require budget, implementation method, and political power. All countries are faced with restrictions in these resources.

- **Suggestions**

✓ Since maximum volume of traffic and also most accidents occur in Ahvaz- Andimeshk- Pol-e Zal axis, more research and investment are required.
✓ Formulating a plan for identifying and prioritizing event-prone areas, creating proper databases containing accidents and event-prone areas information.
✓ Assigning plans in the form of EPC contracts which transfer design, implementation, and utilization to the contractor up to a certain time.
✓ Strengthening and increasing mechanized controls including speed control cameras.
✓ More supervision of automobiles technical control.
✓ Establishing a permanent economic committee, engineering for identifying indices in evaluating event-prone areas and assigning responsibilities to the related authorities.
✓ Necessity of research activates and applying traffic engineering principles.
✓ Increasing marginal parking lots, correcting steep gradients and all factors resulting in accident.
✓ Prohibiting factors that distract drivers like cell phone, posters, etc.

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