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Road Safety Management Model

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Abstract Traffic accidents are a serious problem in every society. Traffic safety is a science that analyzes road accidents with material damage, lightly injured, severely injured and killed persons. This paper proposes that road safety investment can be optimised by the development of a road safety management model. Road safety strategies typically include a basket of engineering, enforcement and education/training measures but there does not appear to be any management model which permits the optimisation of road safety investment. The proposed model utilises linear programming to predict changes in road safety resulting from safety interventions. It is mainly based on research in the areas of engineering and enforcement since there is little published research on the correlation between education and accident reduction. The model output provides the accident reduction and associated costs resulting from feasible road safety strategies. This should benefit policy makers when allocating resources. This example will be good experience for Traffic safety management system in the Republic of Macedonia.
Keywords Management, Model linear programming, Road Safety

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1. Introduction

Traffic safety management is a systemic approach to reducing traffic accidents and the consequences of them. In any case, the positive experiences from the developed countries that have achieved a high level of traffic safety as the draft models for traffic safety management should be used. The three countries with the safest roads in Europe, Sweden, the United Kingdom and the Netherlands, implement comprehensive road safety strategies that involve local authorities, road users, emergency services, enforcement agencies, etc. Such strategies require a management system to optimize road safety levels. This paper proposes a linear programming technique to assist in the optimization of resources. Safety countermeasures that could be implemented in a road safety strategy are first examined. The selection of safety performance indicators is then discussed. Both safety countermeasures and performance indicators are then used in a linear programming model.

2. Road safety countermeasures

The three main approaches normally applied in road safety management are engineering, enforcement and education. It is considered that the success of road safety campaigns is increased through the implementation of countermeasures from all three approaches [1].

2.1. Engineering countermeasures

In the continuation will be shown separately in three tables countermeasures from the three subgroups.Engineering road safety interventions primarily relate to measures that involve the treatment of the roadway. These vary from new warning signs to road realignment or the installation of traffic calming schemes. The majority of Ireland’s road network comprises of undivided two lane roads. This type of road presents the greatest accident risk to motorists; a recent study has shown that the fatal accident rate on undivided roads in Ireland is 9 times that on motorways [2]. Obviously it is not possible to upgrade all roads to motorways but there are many other engineering safety measures available. For example, if a considerable number of accidents involve vulnerable road users, traffic calming measures which reduce vehicle speeds and provide additional footways may be appropriate. A ‘before and after’ study of traffic calming schemes on Irish inter- urban routes found that the average accident rate reduced from 8 accidents per annum to 3.5 accidents per annum [3]. Typical accident reductions resulting from engineering measures are shown in Table 1.

Table 1. Typical reductions in accidents from engineering measures [4]

Countermeasure	% accident reduction
Installation of general warning signs	25
Upgrading of roadway delineation	15
Installation of no passing zone through delineation	40
Lighting of at grade intersections (overall)	30
Lighting of at grade intersections (night)	50
Installation of right-turning lanes	35
Installation of rumble strips	25
Improvement of road surface	25
Installation of crash barrier (fatal accidents)	65
Sight distance improvements	30
Improvement of horizontal alignment	40
Construct grade-separated interchange	55

2.2. Enforcement countermeasures

Enforcement has been shown to significantly reduce traffic accidents. Research in Ireland indicates that a 1% increase in the number of hours spent on police surveillance could yield a 2.6% reduction in the number of serious injury accidents [5]. The European Transit Safety Council estimates that 50% of traffic accidents could be avoided if road users complied completely with road traffic regulations [1]. If traffic violations were eliminated, it has been estimated that fatalities could be reduced by as much as 63% [6]. Three specific violations contribute considerably to accident fatalities, speeding, drink driving and seat belt use [7].

Table 2. Effects of manual and automatic speed enforcement.

Effect	Manual enforcement	Automatic enforcement
% Reduction in accident frequency	2 – 4	20 – 24
% Reduction in no. KSI* accidents	14 – 58	17 – 38
% Reduction in mean speed	3.6 – 4.5	4
Average speed reduction (km/h)	3.6	2.9 – 6.9
Distance halo (km)	1.6 – 3.5	1 – 10
Time halo (days)	1 – 63	not applicable

*KSI = Killed and Seriously Injured.

Excessive speed is by far the most prevalent traffic offence [1]. A considerable reduction in fatalities resulted from the introduction of penalty points for speeding in Ireland in late 2002. Unfortunately, this effect has since diminished due to a lack of enforcement. A number of studies have investigated the impact of enforcement on traffic accidents including the use of fixed and mobile speed cameras. Table 2 summarises the researched effects of both manual and automated speed enforcement.

2.3. Education countermeasures

Education including driver training is considered an essential component of road safety management and advertising forms part of most road safety campaigns. However, it has proved difficult to apportion accident reduction figures to education countermeasures.

3. Road safety performance indicators

Road safety can be assessed in terms of accident frequency and resultant costs but simply counting crashes or injuries can produce an imperfect indication of the level of road safety. For example, the under reporting of traffic accidents, as high as 50% for minor accidents and 25% for serious injury accidents in Ireland [2], can produce an apparent change in the number of reported accidents.

Accident counts need to be supplemented by other measurements that are causally related to crashes or injuries in order to indicate performance [10]. These additional measurements are referred to as safety performance indicators. Regular monitoring of such performance indicators can improve the understanding of road accident trends by providing a more complete picture of the level of road safety and by pointing to the emergence of new problems at an early stage. Some EU member states have shown that safety performance indicators can be used efficiently for monitoring the progress of road safety policies in meeting their desired targets and for permitting interventions where necessary [10]. The most commonly used safety performance indicators for road transport in Europe include speed measurement, seat belt and crash helmet usage and drink driving incidence.

Table 3 suggests performance indicators for the evaluation of Irish road safety. It should be noted that these performance indicators require further refinement.

4. Linear programming model

One of the central components of the road safety management process is the allocation of resources. It is suggested that linear programming can be used to optimise the road safety countermeasures. The objective of this model is to provide a system of road safety management whereby different road safety measures/strategies (inputs) are analysed and the resultant effects (outputs) are quantitatively estimated.

4.1. Scope of the model

The safety situation on a specific route is first quantified. The level of safety achieved through the implementation of selected engineering and/or enforcement road safety interventions is then estimated. The output generated by the model represents the expected magnitude of road safety in terms of accident severity and cost. Ideally, the model should also indicate if the proposed road safety measures are cost effective.

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4.2. Formulation of the model

The model operates on the basis of estimating the effectiveness of the selected input variables (road safety measures).

Table 3. Suggested safety performance indicators for Ireland.

Category	Subject	Indicator
Primary indicator	Distance travelled	Accidents/million vehicle kilometres of travel
	Fatality rate	Accident fatalities/100,000 population
Behaviour	Speed	% cars above legal limit % HGV's above legal limit Standard deviation 85th percentile
	Alcohol	% accidents between 21:00 and 03:00 % above legal limit
	Seat belts	% car occupants using seat belts
	Enforcement	No. of surveillance hours
Vehicles	Primary safety	% compliance with headlight and tyre tread depths
	Secondary safety	% cars achieving Euro-NCAP standards
Road	Road design and construction quality	% road network achieving Euro-RAP standards % motorways, dual carriageways and 2+1 roads % network safety audited No. of high accident locations
Vulnerable road users	Road construction	No. of traffic calming schemes
	Speed	% motorcyclists above legal limit
	Drivers	% learner drivers; % drivers under 25 % foreign drivers
Trauma management	Arrival time	% achieving response times

The effectiveness estimation apportions the expected accident reduction benefits to the road safety measures. These benefits are correlated with performance indicators so that outputs can be produced in relation to different road users and/or road categories.

A linear programme typically consists of two parts, an objective function and constraints. The objective function is an equation that defines the quantity to be optimised. In the case of road safety management, linear programming is used to maximise the average cost saved by preventing road traffic accidents (objective function) subject to the implementation costs, geometrical constraints imposed by the road and resource constraints.

The hypothesis is that a linear programme can represent the magnitude of the road safety situation by defining the effects of the implemented road safety measures. In combining the effects of different road safety measures and their corresponding constraints, a representation (model) of the level of road safety may be attained. Linear programming assumes that a problem can be approximated by linear functions. Therefore, the objective function and the constraints are assumed to be linear. Since the real situation seldom corresponds exactly with the model due to uncertainties and assumptions, sensitivity analysis of the optimal solution can indicate the quantitative effects of changing the constraints. Thus, the constraints which have the greatest effect on the optimisation of the objective function (minimising the cost of road traffic accidents) can be identified.

5. Conclusions

The above simple example was selected to illustrate the use of linear programming as a road safety management tool. Rather general assumptions were made regarding the effectiveness of the road safety countermeasures and the costs of the countermeasures were omitted. The simplex linear programming method was also used to determine the optimum combination of interventions, which can be expanded to include for further safety interventions. Sensitivity analysis can also be carried out to investigate the implications of increasing the level of countermeasure implementation. In conclusion, the proposed linear programming approach allows different road safety measures to be combined and their collective effect to be examined. This should be very useful in getting the best return from road safety resources.

The Republic of Northern Macedonia is a candidate country for the European Union. With the reforms made in all spheres and significant development, my country expects a date for negotiations in the near future. This means that more attention needs to be paid to reducing traffic accidents as a social problem. For this purpose it is necessary to establish a system of Traffic Safety Management.

Experiences from developed countries that are processed in the paper represent only one roadmap for implementing the model of linear programming shown. Certainly this model can not be used in full with the same countermeasures and parameters, but it should be adapted according to the conditions in the Republic of Macedonia.

REFERENCES

[1] Danchevska, V., "Transport Policy as a Function of Sustainable Development in the Economy of the Republic of Macedonia", Doctoral dissertation, 2015.

[2] Kevin R. Fall, W. Richard Stevens, TCP/IP Illustrated, Volume 1: The Protocols, 2nd ed., Addison-Wesley, USA, 2011.

[3] Mayank Suhirid, Kiran B Ladhane, Mahendra Singh, Vishwas A Sawant, "Lateral Load Capacity of Rock Socketed Piers Using Finite Difference Approach", ŽU Žilina, Transport and Communicationh, vol.1, no.1, pp.1-8, 2011.

[4] Mohemed Almorsy, John Grundy and Amani S. Ibrahim, "Collaboration-Based Cloud Computing Security Management Framework" , in Proceedings of 2011 IEEE 4th International Conference on Cloud Computing, pp. 364-371, 2011.

[5] Online Available: http://fpedas.uniza.sk.

[6] A. Karnik, "Performance of TCP congestion control with rate feedback: TCP/ABR and rate adaptive TCP/IP", M. Eng. thesis, Indian Institute of Science, India, 1999.

[7] J. Padhye, V. Firoiu, D. Towsley, "A stochastic model of TCP Reno congestion avoidance and control", Univ. of Massachusetts, Tech. Rep. 99-02, 1999.

[8] Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specification, IEEE Std. 802.11, 1997.