CETRA2010 17–18 May 2010, Opatija, Croatia
First International Conference on Road and Rail Infrastructure

OPTIMIZED ROAD MAINTENANCE FOR ROAD USERS

Barbara Brožek, Johann Litzka
Institute for Transportation Science, Vienna University of Technology, Austria

Abstract

Within operating and maintaining road infrastructure the main issues are material and structural optimization and among these in all aspects the effects on economy. Currently maintenance concepts focus on the reduction of total costs for the agencies; still there are major costs for road users, third parties and environment, which have to be considered in order to refer to the total economic costs.
This research summarizes all user costs, occurring in terms of time, accident and vehicle operating costs. The road condition (directly linked to the effect on road users), type of maintenance strategies and traffic management as well as the duration of the construction are taken into consideration.
In the current Austrian pavement management system (VIAPMS_Austria) road users are only applied as weighting factor using the AADT-value. One option of integrating road user costs is by modifying the optimization criterion (benefit/cost ratio). The costs remain solely as agency cost, but the definition of the benefit has to cover all user aspects and include all user costs incurred. Concluding benefits could be summarized as total user cost savings over the whole analysis period for the chosen maintenance strategy.
Through changing the optimization criterion the proposed maintenance strategies change radically. Above all, there is a reduction in the duration of the construction work, which is accompanied by profound reduction of the treatments. As the benefits consist solely of user cost aspects consequently the condition of the road structure will be neglected. The methodology proposed offers the possibility to introduce boundary conditions for guaranteeing a good road condition.
This research offers an optimized pavement management system which comprises agency and road user aspects. In a sample application for a part of the Austrian motorway and expressway network user cost savings could be achieved though the proposed maintenance strategies, totaling more than 7 times the inserted agency costs.

Keywords: user cost, pavement management, optimization tool, time cost, condition related costs

1 Pavement management in Austria

The Austrian road network consists of approximately 120.000km of roads thereof are 2.000km highways and expressways. Due to the different condition and ages of the sections operating and maintaining becomes more and more an issue.
In order to fulfil those expectations efficiently a modern pavement management system (VIAPMS_Austria) has been implemented. It aims at an optimal performance of all money invested focusing mainly on a good performance for the road agencies. Road users in this aspect are applied only as weighting factor using the AADT-value.

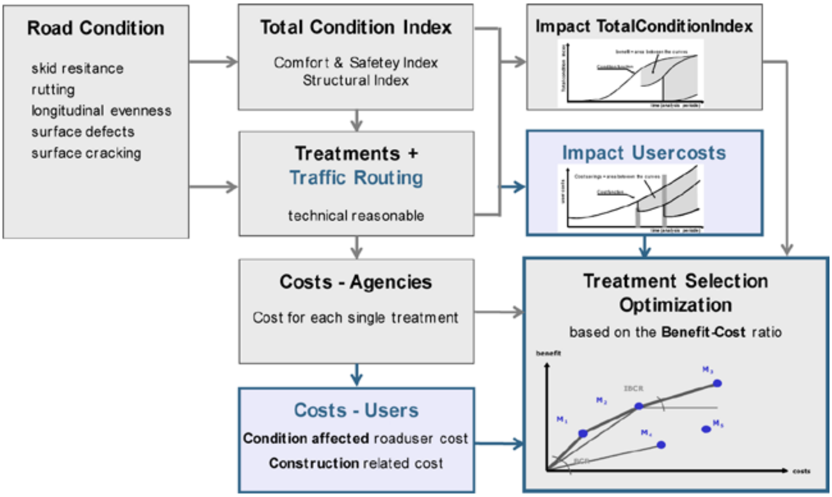

Figure 1 Overview Austrian Pavement Management System

The grey outline in Fig. 1 gives a short overview on the conventional pavement management system in Austria, which is mainly based on the road condition but also takes into account the traffic volume and the road inventory data. Thereof the Total Condition Index (TCI) is calculated and developed for the whole analysis period. This index summarizes the different condition parameters and consists of the Structural Index (to reflect the condition of the whole construction package) and the Comfort Index (related mainly to the surface condition).

With this information and the total of all possible maintenance and rehabilitation strategies, which are essential to secure a good road condition, the benefit (referred to as the change of the TCI due to the treatment) and the costs (agency costs) could be calculated [1]. Furthermore on the basis of the benefit cost ratio and the budget available the optimal strategy for each segment could be chosen.

The blue parts refer to the road users as the main criteria for good roads and basis for the optimized road maintenance. Therefore the benefit in terms of the impact on the road users and the calculation of total user costs can be implemented using the results of a recent research project [2].

Finally this tool makes it possible to choose between agency optimized and road user optimized maintenance management strategies and always keeps an eye on the precondition of the restricted maintenance budgets.

2 Road user costs

Costs for road users may occur at two different time frames within a life cycle of a road or any other related asset. First there are costs which are directly related to the road condition. As seen in Table 1 they could be summarized in the three categories: time costs, accident costs and vehicle operating costs.

The progression of the additional road user time cost in relation to the deterioration of the relevant condition parameters (road roughness indicated as IRI) is shown for 1000 vehicles in Fig. 2. If the road is in a moderate condition, the additional time cost for one individual compared to a very good condition is rather small, but summing up all users involved they grow to an important figure. Similar graphs (Fig. 3) are shown for the accident cost (in relation to skid resistance and rutting – as it could be calculated applying the findings from Schulze et.al. [3] and Kamplade [4]) and the relation between speed and vehicle operating costs on the highways and freeways.

Table 1 Categories of condition affected road user costs

Cost	Decisive factor	Relevant condition parameter
Time costs	Speed	Longitudinal evenness
		Waterfilm depth
Vehicle operating costs	Inclination	
	Speed	Longitudinal evenness
		Waterfilm depth
Accident costs	Additional accident rate	Skid resistance
		Ruth depth

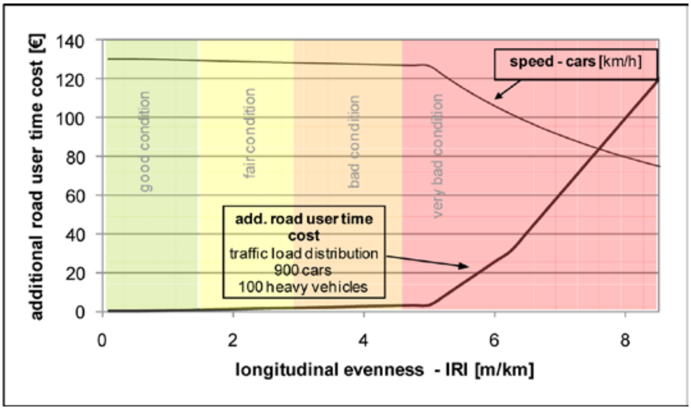

Figure 2 Development of additional Road User Time Cost (example for specific vehicle composition)

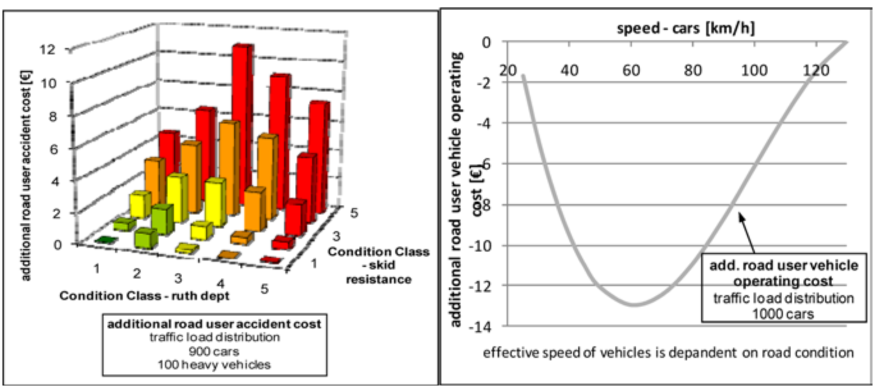

Figure 3 Development of additional Road User Costs (example for specific vehicle composition)

Beside the road condition also the maintenance treatment itself has high impact on the road users. Especially in sections where the traffic load is close to the capacity limit. In those cases a treatment, which indicates a reduction in capacity causes delay and the formation of queues. This disturbance to road users can be directly calculated in terms of construction related additional time costs. They may also include the additional time which is needed for passing the construction area at a lower speed. This impact and the other relevant issues are summarized in Table 2.

Table 2 Categories of construction related road user costs

Cost	Decisive factor	Relevant condition parameter
Vehicle operating costs	Speed	Construction site transit speed
Accident costs	Additional accident rate	Applied traffic routing
Time costs (construction site transit)	Speed	Construction site transit speed
Time costs (queuing)	Capacity	Applied traffic routing
	Traffic load	Traffic increase

Not only does the decision on the type of rehabilitation have strong influence on the total value of construction related road user costs, but there is also the question on the type of traffic management (responsible for the residual capacity which can be guaranteed) and the duration of the construction work.

3 Optimization process

3.1 Implementation of road user aspects in the PMS

As it is possible within acceptable effort to quantify all arising road user costs this provides a perfect basis for the implementation of user aspects in the maintenance management. Not only as weighting factor for the comparison of different sections (as done before), but also in the algorithm for the treatment selection and optimization process.
There are different ways to realize this concept. One is to integrate the road users by adapting the existing (standard) optimization criterion, which before consisted solely of the TCI and the required agency budget. The modification aims at the integration of road users in all relevant decisions.
The decision criterion is defined as the incremental benefit-cost ratio which could be built comparing the strategies, whereas the user-benefit is generated by the overall reduction of user costs by implementing this strategy in comparison to a basic strategy without any major treatment. The benefit itself has to be calculated in two steps, as shown in Fig. 4. First the benefit on condition affected road user costs due to the strategy (light blue area) has to be calculated. This value has to be diminished by the construction related road user costs (dark blue bar). All costs occurring are issued in terms of present costs in order to enable the comparison.

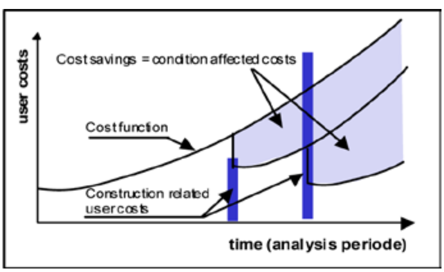

Figure 4 Calculation of total user benefits

3.2 Section results

The effects from integrating user cost aspects in the management algorithm could be best seen on the basis of an example. The single highway section considered here has a length of about 5km and is in a moderate condition (TCI~3,5) at the beginning of the analysis period (which lasts for 20 years), whereas the surface condition is in a slightly worse condition than the structure. The main values calculated for this section are shown for three possible strategies (year of action) in Table 3.

Table 3 Example section treatment costs and benefits (NPV)

	Surface (year 3) Replacement (year 17)	Surface (year 3) Reinforcement (year 19)	Surface (year 3)
Cost criteria			
Costs of treatment (Agency costs)	3 740 260 €	1 468 770 €	523 923 €
Benefit criteria			
Standard optimization: Total condition index	246 540	229 530	135 160
User cost optimization: Savings condition affected costs	11 557 894 €	11 552 439 €	11 475 398 €
Construction related costs	1 512 994 €	493 310 €	259 693 €
Total user benefits	10 044 900 €	11 059 129 €	filter to secure good structural condition

The example shows that cheaper treatments which do not reach the total depth (as the reinforcement compared to the replacement) still achieve a higher user cost benefit. This is mainly caused by the shorter construction time which goes along with less interruption and lower construction related user costs. Nevertheless a good condition of the road substance has to be secured, therefore a filter which sets a minimum for the structural index has been implemented to ensur a given minimum condition and avoid only "cosmetic" measures.

3.3 Network results

The calculation can be done for one section, but mainly it will be used for a whole network with a variety of sections differing in construction, condition and traffic load, but with one overall budget. This has also been done to an example network, which represents the Austrian motorways and expressways (see also [2]). The distribution of the chosen treatments for the standard optimized PMS as well as the user cost optimized algorithm is shown in Fig. 5. As shown in Fig. 5 the optimization on the user-costs savings causes a strong reduction of the number of maintenance activities and their severity. On the other hand the user-cost benefits can be increased up to 250% (compared to the benefits gained with the standard application). In respect to the inserted budget this benefit totals more than 7 times the agency costs. Consequently, as the condition index is not the main aim of the user-cost optimization, the total condition deteriorates. This could be best seen in Fig. 6 comparing the share with value bad and very bad (especially in the last four sequences when no more treatments are set). With the restriction to not let the substance value fall below the warning level (between fair and bad) at the end of the analysis period, a well balanced maintenance concept for road agencies and road users could be achieved.

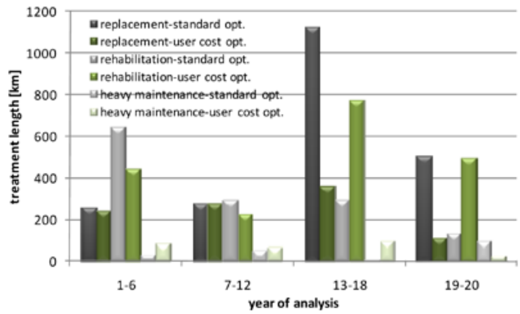

Figure 5 Treatment distribution of example network

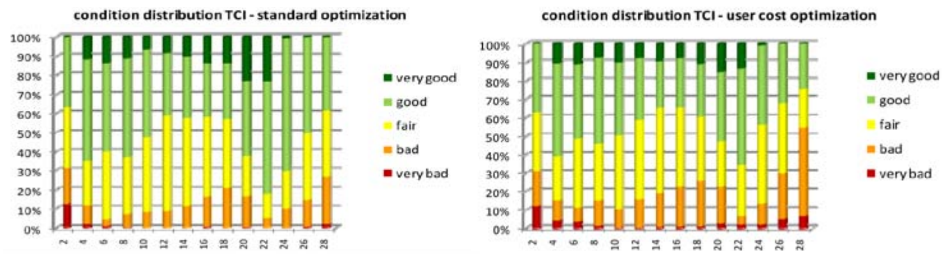

Figure 6 Condition distribution of example network

4 Conclusion

Taking road user aspects into consideration has a major effect on the maintenance strategies proposed within the pavement management system. This implementation leads to a minimum of disturbance and therefore to less replacement and more surface maintenance treatments. As shown the implemented algorithm covers two aspects: Firstly a good total condition of the road construction is secured and secondly the user cost savings are maximized (under the financial boundary condition) and could be significantly raised in comparison to the current pavement management system.

References

[1] Weninger Vycudil A.: Entwicklung von Systemelementen für ein österreichisches Pavement Management System, Wien, 2003.

[2] Brožek B., Litzka J. und Weninger Vycudil A.: Entwicklung eines Nutzerkostenmoduls im österreichischen PMS–Development of a User Cost Module in the Austrian PMS, Schriftenreihe Straßenforschung, Heft 585, BMVIT, Wien, 2009.

[3] Schulze K.H., Dames J., Lange H. und Wehner B.: Untersuchungen über die Verkehrs-sicherheit bei Nässe. Forschung Straßenbau und Straßenverkehrstechnik, Heft 189, Bonn, 1975.

[4] Kamplade J.: Auswirkung von Verschleiß und Verformung der Fahrbahnoberfläche auf die Verkehrssicherheit. Road and Traffic 2000, International Road and Traffic Conference, Berlin, 1988.