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Title:
Investment strategies over full cycle of life of a flexible pavement.

1. Introduction

A pavement is one of the basic elements constituting road infrastructure, therefore it directly influences a generally conceived level of safety and quality in transportation services, regarding both general and commercial users. Also, its condition has a substantial influence on the final logistic cost of production and services in many areas of life.

Technical condition of road pavement influences continuity of transportation which is an integral part of development of many areas of economy of every country. It is a priority task for every administration, which has under its management the communal or municipal property, to wisely invest over its full cycle of life into the road pavement, thus securing right conditions for continuous, safe, efficient, and economically optimised transportation.

Should the manner of investment in the road pavement be wrong, the number of pavements which delay transportation might increase, and direct risk for traffic safety would grow higher? Such a situation might result in the increase in running costs of vehicles, and a decrease in transport services quality and traffic safety.

It should be, therefore, well considered which method of strategy of good maintenance of the pavement ought to be selected, in view of the resources available to the long term Investor (Manager), so that the proper technical condition in any one moment of technical life of the pavement structure be retained. Because of the fact that it is a broad area, the author has focused his research and discussion on the area of flexible pavements, analysing the full cycle of their technical life. This choice is related to the fact that, nowadays, this type of pavement prevails within road assets in Europe. Within the framework of this paper, an example has been chosen to illustrate the issues dealt with by the author in his research work.

2. Discussion of the analysed economic strategies over the full cycle of life of the pavement.

The paper compares two economic strategies of construction and maintenance of flexible pavements over the full cycle of their life. Therefore, a “classic” strategy has been selected, which is commonly used, and a “capital related” strategy, put forward by the author.

The classic strategy is based on building the target construction of a flexible pavement, designed on the basis of a mean daily traffic (MDT) index expressed in calculation axles moving along a calculation lane.
Over time, when the pavement is used, subsequent stages of maintenance works are introduced, thus improving serviceability features of the pavement, on condition that the load capacity of the structure within the designed period of use does not exceed a point of emergency, and the structure itself does not require strengthening.
In case of the classic strategy, employed basing on the indications from the Pavement Status Assessment System (PSAS), within the framework of the Pavement Maintenance System (PMS), control measurements of such elements as load capacity, evenness, roughness, and visual assessment, are carried out every

year. Basing on the above listed factors, current status indices are defined.

The capital strategy is based on building a pavement structure dimensioned for substitute category and traffic, arrived at on the basis of a safe period of usage, defined according to a method employing a destructive load criterion (DLC), developed and recommended by the author for use in the capital strategy.

During the period of use of the pavement, regular maintenance work is done according to an assumed schedule which is aimed at improving the serviceability features of the pavement and, at the defined critical points of usage, basing on the recommended DLC method, appropriate type of work is done to adjust the load capacity of the structure to the forecast destructive loads so that the structure might work within the safety limits not exceeding the upper limit of emergency status.

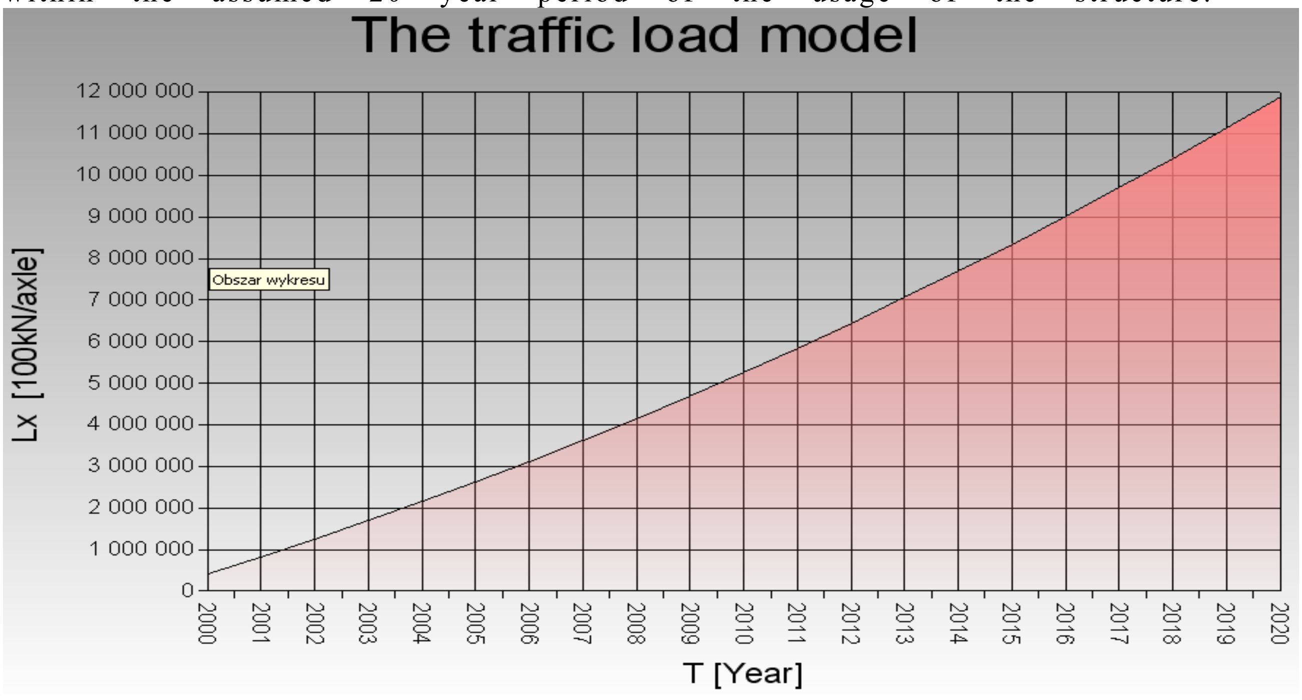
In case of capital strategy, it is recommended to apply annual surveys of serviceability (visual assessment + evenness and roughness), and in three year spans – the measurements of safety (load carrying capacity) of the structure. Basing on the measurement results, current indices of technical status should be defined, and a periodical curve of degradation for homogenous pavements drawn which, in the future, will allow for developing a correction model for the DLC method which will enable us to optimise the basic DLC method.

3. The forecast model of traffic load during the time of usage of the pavement structure

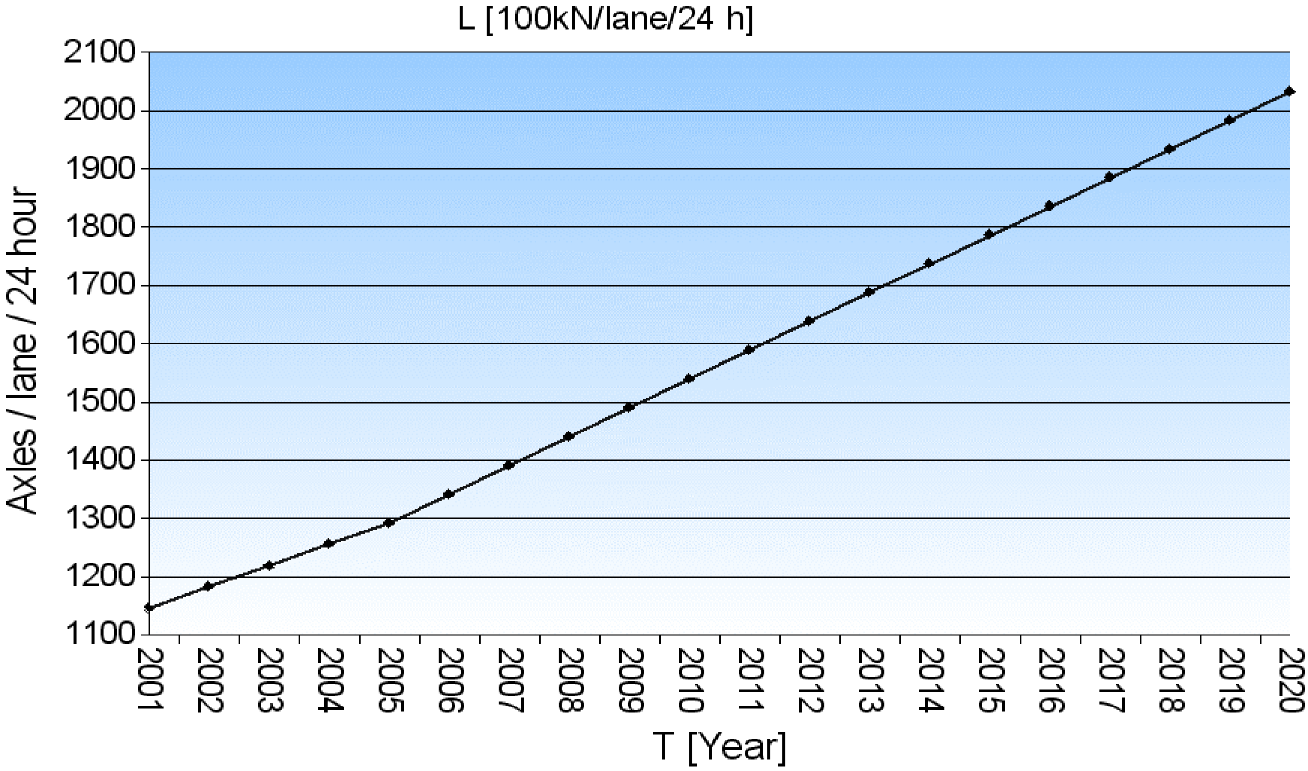
The forecast model has been formulated basing on the results of measurements of the General Traffic Measurement Survey for non-urban roads carried out in 2000.

For the purpose of the analysis presented in this paper, a model based on the GTMS 2000 has been chosen, for a control and measurement checkpoint located along the section of the National Road number 11, between the towns of Środa Wielkopolska and Kórnik, which is representative for a road section with medium traffic load in Poland.

The graphs below illustrate the traffic load model selected for the analysis within the assumed 20 year period of the usage of the structure.



Picture 1



Picture 2

4. Algorithms of selection of pavement structure for classic and investment strategies

The algorithm of structure and maintenance of the pavement, defined according to the economic strategies being compared, has been presented in the table:

"K" algorithm (classic strategy)

a. Traffic forecast for the half of the pavement usage period expressed in calculation axles of 100 kN/ calculation lane
b. Defining the working condition of the pavement (temperature range; soil and hydrological conditions)
c. Calculating the traffic category for the value which had been calculated in "a"
d. Selecting a typical structure or individual dimensioning, basing on the forecast traffic category, in accordance to items "a" and "b"
e. Selecting typical maintenance activities, based on the Pavement Status Assessment System (PSAS)

"I" Algorithm (capital strategy):

a. Defining the working conditions of the pavement (temperature range; soil and hydrological conditions)
b. A graph of changes in forecast traffic over full cycle of life of the pavement
c. A graph of load carrying capacity under axles over full cycle of life of the pavement
d.. Defining the final overload moments – changes in traffic category over time due to the passage of destructive axles
e. Defining substitute traffic category, in accordance with the DLC method
f. Identifying critical points of pavement work basing on the safety index, in accordance with the DLC method
g. Identifying accessory points – a moment of improvement of serviceability

parameters, in accordance with the DLC method
h. Selecting a typical structure of the pavement, or individual dimensioning, based on traffic category, in accordance to "e", having taken into consideration the conditions stemming from "a"
i. Selecting a schedule of maintenance activities for periods of time identified in accordance to items "f" and "g"
j. Monitoring and adjustments within the maintenance schedule, in accordance to the Status Parameters Evaluation System (SPES)

5. Pavement structure selection for classic and capital strategies

As to the analysed strategies, two kinds of pavement structure have been suggested, selected from a catalogue, from among typical pavement flexible structures, for appropriate traffic categories. The traffic categories have been defined, accordingly, basing on "K" and "I" algorithms presented earlier in the paper. Furthermore, a third type of structure has been analysed, called a long life pavement, suggested following EEC and US experiences.
As to the long life pavement, a maintenance strategy has been assumed, basing on the improvement of serviceability parameters over its full cycle of life, assuming that the parameter which defines its load capacity shall not exceed an emergency value, within the period of time equal to the usage of traditional pavements selected for the capital and classic strategies. Table below present the selected structures of the pavement.

Table 1

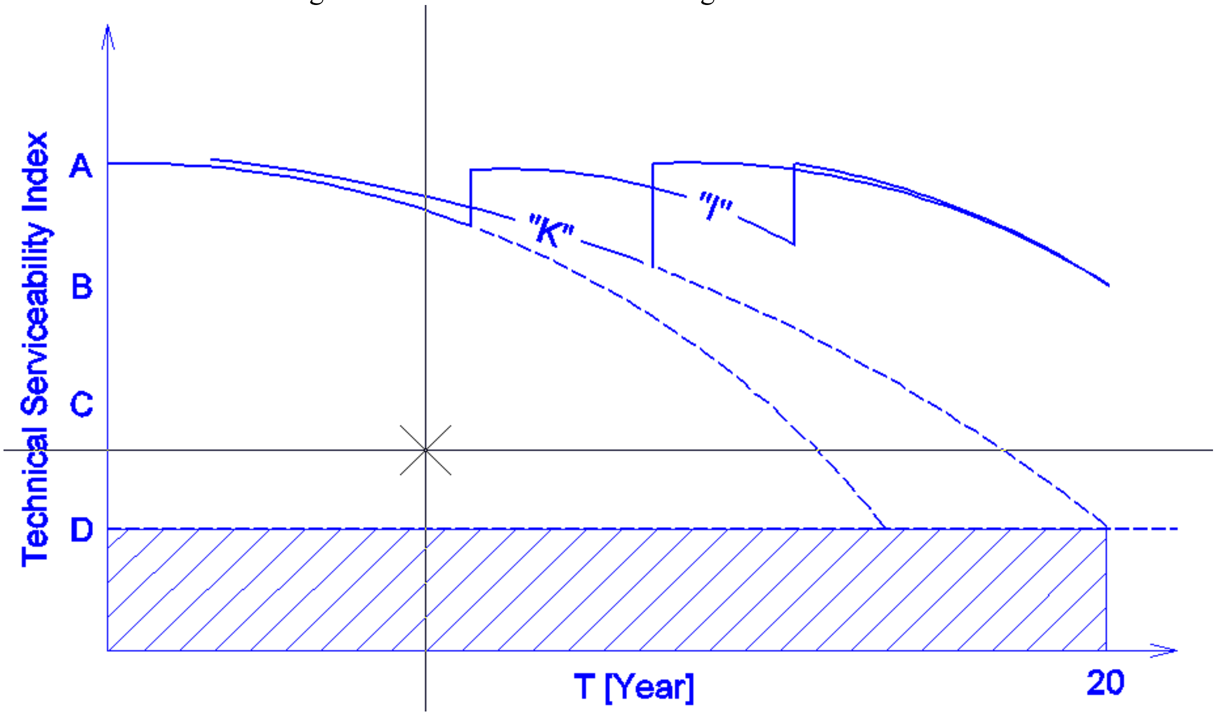
Pavement Layer	**Construction 1 "Typical" Strategie "I"**	**Construction 2 "Typical" Strategie "I"**	**Construction 3 "Typical" Strategie "K"**	**Construction 4 "Typical" Strategie "K"**	**Construction 5 "Long Life"**
Wearing course	SMA [4]	SMA [4]	Asphaltic concrete with increased resistance to formation of wheel tracks [5]	Asphaltic concrete with increased resistance to formation of wheel tracks [5]	SMA [7]
Bonding layer	Asphaltic concrete [8]	Asphaltic concrete [8]	Asphaltic concrete [8]	Asphaltic concrete [8]	Asphaltic concrete with increased resistance to formation of wheel tracks [18]
Base course	Asphaltic concrete [10]	Asphaltic concrete [16]	Asphaltic concrete [14]	Asphaltic concrete [20]	Asphaltic concrete -Strongly- [10]
Accessory course	Mechanically stabilised crushed aggregate [20]	Subsoil	Mechanically stabilised crushed aggregate [20]	Subsoil	Subsoil

Subsoil of elasticity (secondary) coefficient not less than 120 Mpa.
The thickness of layers on the presented drawings is given in centimetres, and the bonds between layers have not been shown

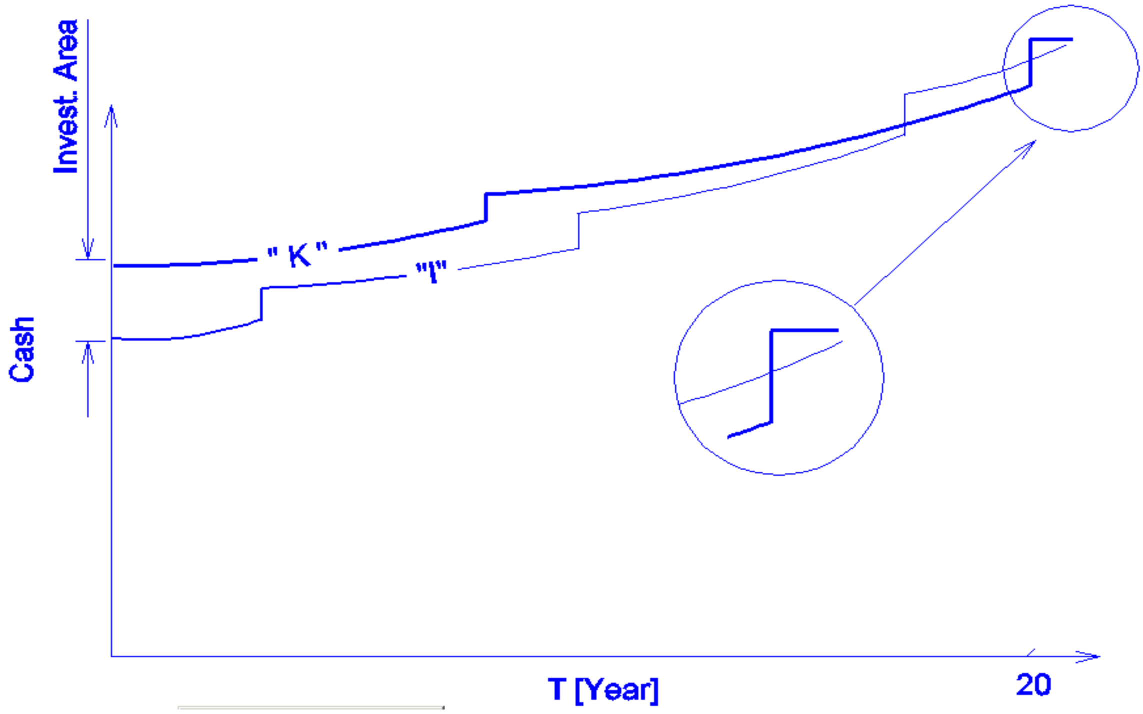
6.0 Investment schedules assumed for the analysed economic strategies.

Investment schedules presented below pertain to the full life cycle of the pavement.

Investment schedules assumed for the analysed economic strategies are depicted by the graphs of changes in indices of the pavement condition over its full cycle of life. The graphs presented below reflect the basic indices illustrating the changes of index values over time, having taken into consideration the investments following from the economic strategies which had been assumed.



Picture 3



Picture 4

7. Summary

1. The cost of constructing the pavement in case of the “K” strategy is higher than in case of the “I” strategy
2. The financial analysis takes into consideration the following elements: construction costs, current maintenance and renovation work, as well as user costs (delays in journeys, accidents), and the profit gained by saving the resources which have not been invested in case of the “I” strategy, profit from the improvement of the technical condition of the pavement, profit related to the improvement of traffic safety, profit related to forecasted remaining lifetime of the pavement after the assumed usage time has passed (the pavement’s life cycle).
3. Employing the “I” strategy allows for making a profit from the resources which have not been invested and, therefore, is recommended for the Investors (Managers), as it allows for the optimisation of spending incurred throughout the long process of investment expressed in the maintenance the road pavement in good condition over the whole cycle of life.
4. Employing the “I” strategy is, however, possible only after the incremental budget has been introduced, and the changes in the legislature. Detailed discussion is provided by the author in his research publication on the assessment of feasibility of practical introduction of capital strategy in Poland, where the necessary changes in legislature with regard to financing road construction have been described.

Abstract:

The pavement is one of the basic components of road infrastructure and, therefore, directly influences general levels of transport safety, as well as the quality of transportation services in human and cargo traffic. It also exerts a major influence on the final logistic costs of production and services in many aspects of everyday life. The continuity of transportation, which is closely tied to the development of a number of areas in the economy of every State, depends on the technical condition of the road pavement. Making proper investments in the complete course of life of the road pavement, a policy which makes sure that the conditions for continuous, safe, efficient, and economically optimised transportation are satisfied is a priority for every administration managing municipal funds.

If investments in the road pavement are not carried out properly, there usually are more and more road pavements the condition of which cause delays in transportation, and directly compromises traffic safety. Such a situation increases the running costs of vehicles, and decreases the transportation service levels and comfort of travelling. At the moment, the majority of pavements in Europe, (nearly 75% of all pavements) are flexible road pavements. Due to the prevalent number of flexible pavements in Europe, the author analyses investment in the course of complete life cycle of the pavements, with a stress on flexible pavements. The paper presents basic assumptions and definitions in the area of analysis of life cycle costs of a flexible road pavement, as well as profits associated with proper long range investment. The second part of the paper discusses different investment strategies in the course of a complete life cycle of the road pavement, and proposes a procedure of evaluating investment strategies.