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"Objective" Evaluation of A Highway Contractor's Performance

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Abstract: *The Hungarian public procurement procedure for highways projects is based exclusively on the financial aspect of the proposals. (Usually, the lowest price bids win.) However, this practice implies an important potential risk: the winner offering the lowest price can produce a low-quality work which might cause much higher loss at national economy level than the benefit coming from its relatively low price. Recognizing this fact, a research work was initiated in KTI to evaluate major highway contractors acting in Hungary by evaluating the actual performance of their past road projects.(It was supposed that if a contractor proved to have been worked at a low quality level in the past, it would not perform better in the future, either). The average deterioration rates of various project groups based on the results of their yearly surface defect assessment carried out on the whole network in Hungary are calculated for the projects built in a given year using high number of samples, selected randomly from the road data bank. Besides, the pavement performance models of various road types based on 20-year monitoring of trial sections are also utilized. The ESAL-value in the year of construction, and the one in 2010 are also taken into account. Based on these values, quality indices are given to the actual yearly deterioration rate of a given project executed by the contractor investigated. The average of these quality indices for a given contractor is a fairly appropriate parameter to characterize its general quality level during a multi-year period in the recent past. These particular average indices permit the comparison of the general "contractor quality levels" of various competing contractors and the eventual consideration of this indicator in the evaluation of bids submitted by a firm in a future public procurement. Another obvious advantage of applying the suggested evaluation methodology is the increased competition between road pavement industries (firms) that can lower prices and save public money. A case study is shown proving the applicability of the suggested contractor evaluating methodology. Finally, some ideas on the further development of the procedure are presented.*

Keywords: *highway performance, pavement lifetime, quality of road construction, paving contractor, public procurement.*

1. Introduction

1.1. Background

The lack of available highway funds is a typical phenomenon all over the world. In Hungary, the situation has been worse than the European average. As a consequence, general pavement deterioration could have been observed mainly on the non-expressway public roads of some 30,000 km total length. The poor pavement quality causes serious national economy losses (additional costs). It has (can have) several reasons including the quality level of contractor.

The principal aim of a research work carried out by KTI (Institute for Transport Sciences) Non-profit Ltd., Budapest, Hungary was to review the actual quality level ("degree of performance") of the highway contractors which have been and presumably will be active on the Hungarian national highway network [Gáspár, 2011].

A statistical-type methodology was developed and used for the possibly "objective" characterization of construction quality. The first phase of research work could provide so-called "contractor quality indicators" for the main 5 contractors proving the applicability of the methodology developed [Gaspar, 2012]. A proposal was also made for the further development of pre-sently still rather simplified evaluation methodology.

1.2. Main Parameters Influencing Road Pavement Performance

The end of pavement lifetime can be defined by an unacceptable level of at least one condition parameter (like density, bearing capacity, unevenness) when the pavement cannot be operated efficiently any more. This intervention level is actually a predetermined performance criterion. The deterioration speeds of various condition parameters are usually not the same, that is why the reaching the intervention level by any of pavement condition parameters means the end of pavement life.

Attaining an intervention level would result logically in the rehabilitation of pavement (or other condition improving activity). However, it is not a rare case that not sufficient highway funds are available for the needed actions, and the poor quality pavement is operated for several more years. (So, the so-called "financial pavement life" can and should be distinguished from "technical pavement life" [Gaspar, 2004]).

The main parameters influencing the speed of actual road pavement deterioration are as follows:

- traffic parameters (mainly the heavy axles passed should be considered together with relevant climatic and pavement width – lateral wander – information; traffic evolution rates for various vehicle types are dependent on the level of expected economic prosperity in the region),
- environmental factors (some of them are known already in design phase; others can be just forecasted with various reliability; sub-grade soil type determines its load bearing capacity and water sensibility; unfavourable climatic and/or hydrological conditions can be counteracted by efficient drainage system; the observed and predicted consequences of climate change can be also among the decisive parameters),
- design characteristics (the quality level of related valid standards and specification is combined here with the competency and conscientiousness of designer; under Hungarian conditions, the often very short design period can also influence the project quality),
- construction-related parameters (level of qualitative and quantitative realization of design, competent and conscientious activity of contractor; different interests of client and con-tractor can be approached by using performance based contracts [Nunn et al., 1994]),
- rehabilitation-related parameters (the quality of design and execution of pavement condition improving actions like road rehabilitations done close to their optimal realization time-point),
- Quality of specifications (high level and up-to-date, related design, construction, rehabilitation, maintenance etc. standards and specifications).

2. METHODS

2.1. Former Hungarian Research in the Field

In the mid-1980s, the poor financial situation in Hungary practically did not allow –except for new motorway sections – to build new road projects; instead of it, rehabilitation (mainly strengthening) type interventions came into prominence. Ministry of Transport commissioned KTI research institute to evaluate all Hungarian road strengthening projects constructed in the period 1976 to 1986 [Gáspár, 1991; Merrill et al., 2006]. The main data types collected were:

- location and date of pavement strengthening projects,
- strengthened pavement structure,
- contractor of the project,
- qualification data at opening to traffic (quality class, guaranteed time),
- (eventual) repairs between opening to traffic and condition inspection at the end of guaranteed period,
- condition inspection outcome at the end of guaranteed period,
- condition data (needed maintenance actions) on 3-4-5-6-7-year old pavement strengthen-ing projects,
- (The most probable) reason(s) of – the eventual – early pavement deterioration on the sections.

Some of the conclusions drawn of the almost decade-long research project were as follows:

- 10-20 times yearly fluctuation in yearly mileage of strengthened projects could have been detected in some of the counties,

- no significant changing as a function of time could be identified in the quality classification at opening to traffic: Class I 75-80%, Class II 15-20%, Class III and rejected 4-8%,
- the typical defect types detected during the first 3 years of the age of strengthened pavements: stripping of aggregate, linear cracks, depression, potholes, pavement edge failures,
- typically, the early quality problems were very often the consequences of poor paving practice (usually too low asphalt layer density!), much less due to poor asphalt mixing,
- very rarely, a repeated pavement strengthening became necessary on the 2-3-year old strengthened pavements,
- no clear tendency could have been revealed in the time change of general pavement quality during the decade investigated,
- some recommendations done on the future quality improvement of road pavement strengthening projects:
  - more severe quality management system for asphalt contractors,
  - more intensive local competition between asphalt industries,
  - increased role of past reference projects in road construction public procurements,
  - top managers' bonuses, as well as the whole income of company technologists and quality controllers depending on the past quality of road project in (state-owned) road industries,
  - more experienced Client staff, mainly site quality inspectors,
  - more efficient quality control for basic material (aggregate, bitumen, limestone filler, etc.) suppliers,
  - Increased financial resources from state budget for the highway sector.

In the mid-2000s, another Hungarian research work at KTI [Gáspár, 2004] investigated the nation-al economy level advantages of the use of performance (based) specifications and contracts in the road sector. The responsibility of the State as the proprietor of the Hungarian national highway network of 31,000km total length – in addition to that of road operators - was emphasized in maintaining the network at a reasonable condition level. Development and maintenance of roads are multi-player activities. Even if the roles of designers, controllers, administrators, etc. in the high quality of the "product" are not negligible, the Client and the contractor are able to influence significantly the appropriateness of the new road pavement. Their basic interests can be formulated as follows:

- Client: the highest quality at the lowest possible price,
- Contractor: the still just acceptable quality (higher quality would need more expenditure) at the highest possible price.

This traditional conflict of interests can be alleviated by orienting the contractor towards the better quality and long-term-planning by quality deduction, guarantee period, well-functioning quality management system, etc. However, the really effective way can be the inclusion of pavement performance indicators [COST, 2008] into road specifications and construction contracts. Following the traditional procedure (recipe) and end-product contract types, the performance-based con-tracts concentrate on the indicators characterizing the pavement performance as a function of time during the operation period of the road section. These numerical performance criteria have to be measurable. The contractor has to prove the long-term fulfilling of these requirements for obtaining the whole contracted sum. The wide-spread PPP-contracts offer a practical way for the easing of the traditional conflict of interests mentioned before.

2.2. Some Related Foreign Literature Sources

An American homepage [www.everlast, 5 things; www.everlast, choosing] informs about the many factors that can affect the price and outcome of an asphalt paving project. The following will help you make an informed decision when choosing a paving contractor:

- Insurance coverage **(**min. $500,000 per policy coverage, $1-$2 million is even better),

- Material selection. (having low quality asphalt installed can affect the look and longevity of asphalt pavement; requesting higher grade asphalt with less recycled material is always a wiser choice),
- Type of equipment (properly maintained equipment is important to any road project).
- Sufficient crew **(**being understaffed not only affects the overall outcome of your asphalt paving project, but it can delay the project even further),
- Down pavement (reputable asphalt paving companies do not require any deposits; depositing funds with a contractor may run the risk of misuse of funds by the contractor),
- Search the web (identifying their services, reviews from past customers, bad ratings?),
- Scheduling an appointment (meeting the contractor in person, benefits for both parties),
- Ask questions (how long has been in business, past experience, liability issues, coverage, planned schedule for the project, etc.),
- Ask for references (a list of completed projects with addresses, names and phone numbers),
- The lowest bid is not always the best (review all proposals, clear description of the work to be performed? all proposals comparable in price and quantities? guarantee period, reason of extremely low bid? trust, experience, and accountability: deciding factors in choosing a contractor, not price!).

The construction of asphalt concrete is a complex process involving many critical stages during which factors that affect the quality of the asphalt pavement performance might be overlooked [Bubshait, 2001]. The newly constructed highway pavements in Saudi Arabia have exhibited a low quality of performance. There are various parameters that contributed to the quality of performance. Highway contractors were surveyed regarding the factors that control pavement performance. Factors that affect the pavement quality of performance were identified using a comprehensive questionnaire survey, and ranked on a scale according to their impact. These include six managerial factors: the qualifications of the owner's inspection team and the contract-or's personnel, the contractor's experience, the contractor's workforce and equipment capability, the contractor's qualifications, delay in progress payment, and amount of work subcontracted; five design-and specifications-related factors, namely structural design, aggregate quality, asphalt mix design, mix composition, and asphalt characteristics; and five construction practice-related factors, namely aggregate characteristics, placement and compaction process, uniformity of materials, mixing operation control, and acceptable procedure.

2.3. Suggested Methodology

The main idea of the contractor evaluation methodology is to review whether the operational performances of various road projects having carried out by a given contractor are above or below an expected (average) level. (This very level is highly dependent on the local conditions). If a sufficient number of projects are used for the characterization of a contractor, its quality level can be qualified at a reasonable reliability that is almost objectively. This kind of quality information on various contractors can be later highly utilized by the interested Clients and road operators in the evaluation of road construction public procurement bids considering fully the valid relevant legal specifications, as well.

The recommended methodology for the evaluation of main Hungarian road contractors has the following steps.

- Identification of the factors influencing expected life cycle (traffic performance) of road construction and rehabilitation projects should be identified highlighting the role (consequences) of eventual poor construction quality. Here every parameter mentioned in point 2 is to be considered. In the case of road sections constructed just 4-8 years ago, not the actual life cycle should be determined, just the actual deterioration speed (rate) of road pavement that is com-pared to an expected (average) one
- A list of the contractors of recent road (construction, rehabilitation, pavement structure strengthening etc.) projects is produced. (Usually, road data bases do not include any in- formation on the contractor of a road project that is why, this case, other sources should be found). Just the

general contractors of road projects are to be investigated, the subcontract-ors are not considered in the analysis for the following reasons:

- The activity of a subcontractor in a road rehabilitation project is generally closely connected with the work of the general contractor or another subcontractor making it impossible to evaluate the actual performance (quality) of a subcontractor separately,
- General contractor selects a subcontractor taking full responsibility on its activity (performance).

The information gathering of contractor performance should cover just the construction firms that are still active in the road business of the country in question since the outcomes of the planned evaluation are supposed to be utilized in the future road construction-type public procurements.

Besides, only the road projects including the construction of new pavement structural layers are considered because the performance of this kind of projects can be "monitored" using road data bank information, (So, e.g. surface dressings or traffic engineering type activities are excluded from this investigation).

- The next step is to evaluate the actual life cycle or pavement performance of the projects. There are two main options here:
  - When already a new condition improving action (e.g. resurfacing or pavement strengthening) was performed several years after the completion of the project investigated, the end of actual life cycle to be considered in the present analysis is obvious (excluding the possibility of an "over-operation" due to financial constraints).
  - When the performance of a project before the end of actual life can be character-ized by evaluating the deterioration speed and comparing it to the expected speed.
- Then the expected life cycle or deterioration speed is determined. A possible reference life cycle is the "pavement design life" of the road section (in Hungary, typically, 10-15 years) which can be modified by some local technical or financial factors. The pavement performance models if available can be also used for the selection of expected life. (In Hungary, the yearly monitoring of 60 trial sections since 1991 [Gaspar, 2010] resulted in pavement performance models for 4 condition parameters and 14 "road section classes", which are the combinations of pavement type – traffic size – sub-grade soil type [Gáspár, 2014]. As an example, Fig. 1 presents the actual deterioration curves of a trial section on 5 condition parameters).

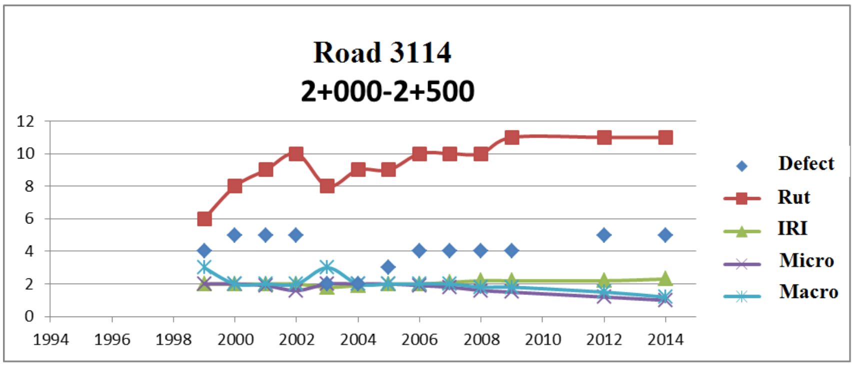

Fig1. *Deterioration curves of a trial section monitored since 1999*

These pavement performance models can be also used for the determination of reference deterioration speeds. This latter parameter can come from the averaging of a reasonably high number of project deterioration speeds; it is important that these projects can be selected randomly from road data base.

- The next step is the comparison of actual pavement life cycle (deterioration) values and the reference (expected) ones. A decision has to be made on the pavement condition parameter(s) used in the evaluation; there are several options here:
  - choosing the condition parameter the level of which reaches the intervention level before the other ones,

- choosing pavement bearing capacity as a condition parameter characterizing pavement structural fatigue,
- choosing a “complex condition parameter” coming from the sum or mean value of typical pavement condition parameters (e.g. bearing capacity, unevenness, rut depth, pavement surface defects),
- Choosing a condition parameter (e. g. surface defects in Hungary) that is qualified on every pavement section each year.

The following factor to be considered is the actual traffic evolution rate of the pavement section investigated during the past life cycle. Its traffic size can be (and frequently is) basically different from the one forecasted in the design phase. It is obvious that much higher traffic volume than expected accelerates pavement deterioration.

The comparison between actual and expected performance values can be done by calculating their ratio and expressing it in %-values. This indicator is characteristic for the quality of the project in question.

- If sufficient (e.g. min.20) projects of a contractor are qualified using the procedure outlined in point e.), the average of their quality indicators can be considered as “contractor quality indicator” characterizing the past performance of the construction firm. It is very likely that the quality of its future works would not be different from the one experienced before. This kind of information can be useful for the evaluation of construction tender bids presuming that past contractor performance can (should) be expected in the future, as well.

3. Results and Discussion

3.1. Simplified Calculation

The research work of KTI [Gáspár, 2011] concentrated not only on the development of the methodology for qualifying the actual performance of road projects carried out by various contractors, but also carried out a simplified, trial calculation in order to prove the applicability of the recommended procedure, actually to validate it.

The simplified methodology has the following phases:

- Selection of some 500 highway projects on Hungarian national highway network with their contractors (various highway client organizations provided with the designation of contractor firms).
- Shrinking the project list to the works covering also the construction of at least one pavement structural layers (otherwise its changing in condition, performance cannot be followed from road data bank information) and to the projects which are at least 3-year old allowing enough time for the evaluation of pavement deterioration trends.
- Selection the list of presently still active road contractors which have at least 20 (statistically manageable number!) projects on the list (actually 5 construction firms were chosen).
- Choosing a project for each contractor, and checking if every data type is available in the Hungarian road data bank for a later complex quality (performance) control described in point 3. The following data types needed were available: detailed site identification and geometrical information; pavement structural layers with types, thicknesses and construction years; contractors of various layers; average daily traffic and average daily standard (100 kN) heavy axle load repetition number for each year; condition data – bearing capacity measured value and score, longitudinal unevenness measured value and score, rut depth measured value and score, pavement surface defects score – for each year of investigation period.
- Further reduction of the project list by omitting the projects built after 2007 since an investigation period below 3 years was considered as too short to judge the pavement deterioration process.
- Gathering of the following information about the “homogenous” road sections for the analysis: starting and ending mileage of sections; year of past pavement rehabilitation; ANET (daily repetition number of 100 kN standard heavy axle loads) on the section in the year of rehabilitation;

ANET on the section in 2010 (most recent available traffic information in Hungarian road data bank); RBAL (pavement surface defects score between 1 and 5) of the section in the year of rehabilitation; RBAL of the section in 2010; besides, the pavement sections are classified in 4 traffic categories as a function of road type and ANET (motorways, highly-, moderately- and lightly-trafficked non-expressways). The reasons for selecting RBAL – pavement surface defects score – for this simplified analysis were: rather complex condition parameter; ranked for the whole road network every year; its intervention limits are practically independent on the traffic size of the section [NCHRP, 1995].

- Determination of “expected average yearly pavement deterioration speed” (expressed in score/year) for each traffic category and rehabilitation year by selecting incidentally min. 20 sections from Hungarian road data bank, and averaging their yearly deterioration speeds based on pavement defect scores (the reference performance value was calculated on “general” data bank information because the use of this kind of performance data could ensure that the reference value is also influenced by the same – here not considered – “disturbing factors” as the projects investigated are). In the planned future detailed analysis, these “disturbing factors” – like client or design-related mistakes or high financial constraints – could be taken into account, and so, the reference deterioration rate would be section-specific; in this phase, also the actual traffic evolution rate of the road sections is also considered which could modify the life cycle considered if the changing in traffic is significantly different from the forecasted one in the design phase.
- Calculation of the “actual average yearly pavement deterioration rate” (expressed in score/year) for each project investigated, then the determination of “project quality indicator” by dividing the relevant actual and reference values (the indicator characterizes whether the given road project has deteriorated quicker or slower than the country-wide average selected as reference value).
- Determination of “contractor quality indicator” by averaging the relevant, min. 20 “project quality indicators”; it results in an indicator which supplies a reasonable reliable information on the quality of road projects carried out by the road construction firm in question.

The equations of calculation applied were as follows.

$$MM_{firm,i} = \frac{\sum_{k,l,m} MM_{i,k,l,m}}{p_i} \quad (1)$$

Where

$MM_{firm,i}$ (calculated) contractor quality indicator for i^{th} firm,

$MM_{i,k,l,m}$ quality indicator of m^{th} project of i^{th} firm for k^{th} intervention year and l^{th} traffic size,

p_i number of projects investigated carried out by i^{th} firm.

$$MM_{i,k,l,m} = \frac{L_{i,l,k,m}}{Lbase_{i,k,l}} \quad (2)$$

Where

$L_{i,l,k,m}$ actual deterioration speed of the m^{th} project carried out by i^{th} firm for k^{th} intervention year and l^{th} traffic size,

$Lbase_{i,k,l}$ average deterioration speed of projects selected incidentally from data base for k^{th} intervention year and l^{th} traffic size (reference value in this group).

$$Lbase_{i,k,l} = \frac{L_{j,k,l}}{n_{k,l}} \quad (3)$$

Where

$L_{j,k,l}$ deterioration speed of jth project selected incidentally from data bank for kth intervention year and lth traffic size,

$n_{k,l}$ number of sections selected incidentally from data bank for kth intervention year and lth traffic size.

$$L_{j,k,k} = \frac{RBAL_{j,k,l,2010} - 1}{Imod_{j,k,l}} \tag{4}$$

Where

$RBAL_{j,k,l,2010}$ surface defects score in 2010 of jth project selected incidentally from data bank for kth intervention year and lth traffic size,

$Imod_{j,k,l}$ modified age in 2010 of jthproject selected incidentally from data bank for kth invention year and lth traffic size.

$$Imod_{j,k,l} = \frac{Iact_{j,k,l}(ANET_{j,l,2010} - ANET_{j,k,l})}{2ANET_{j,k,l}} \tag{5}$$

Where

$Iact_{j,k,l}$ actual age in 2010 of jth project selected randomly from data bank for kth intervention year and lth traffic size,

$ANET_{j,l,2010}$ mean daily repetition number of 100 kN standard axle loads in 2010 on jth project selected randomly from data bank for lth traffic size,

$ANET_{j,k,l}$ mean daily repetition number of 100 kN standard axle loads in kth intervention year on jth project selected incidentally from data bank for lth traffic size

$$Iact_{j,k,l} = 2010 - E_{j,k,l} \tag{6}$$

Where

$E_{j,k,l}$ kth intervention year of jth project selected randomly from data bank for lth traffic size.

3.2. Some Results Obtained

Using the simplified evaluation technique outlined in point 3.1 actually 5 contractors which are still active in Hungarian highway construction were investigated. The project data were available from the construction (intervention) period between 2002 and 2007. So, they were 3-8 years old in 2010 (at the time of past available condition and traffic information in road data bank). All of them were still operating in 2010; so, none of the life cycles had been completed by then.

Following the analysis steps described, the reference deterioration speeds in surface defects score/year were determined for each year between 2002 and 2007, and each of the 4 traffic categories using the mean yearly deterioration value of min. 20 relevant projects selected incidentally from the data bank. The pavement ages until 2010 were modified as a function of actual heavy traffic evolution of the sections during investigation period between the rehabilitation year and 2010. (Linear traffic progression was supposed). The same modification procedure was performed for the road sections investigated. The ratio of actual reference deterioration speed resulted in “project quality indicators”, and their mean values for each construction firms provided the “contractor quality indicators”.

Table 1 presents the number of projects selected for the planned analysis as a function of traffic category (motorway, light, medium and heavy categories), contractor (5 multinational road construction firms with decade-long history in Hungary) and the year of condition improving intervention (road pavement resurfacing or strengthening, usually preceded by the removal of one or more “old” pavement layers).

Table1. *Number of projects selected for the planned analysis as a function of traffic category, contractor and intervention year*

Contractor	Traffic category	Number of projects							
		2002	2003	2004	2005	2006	2007	2008	Total
I.	motorway	4	6	13	2				25
	heavy								
	medium				1				1
	light				10	6	2		18
	Sum	4	6	13	13	6	2		44
II.	motorway		1						1
	heavy							6	6
	medium						1		1
	light						6	12	18
	Sum		1				7	18	26
III.	motorway					4			4
	heavy					1	4		5
	medium						9		9
	light					3	5		8
	Sum					8	18		26
IV.	motorway								
	heavy					1	2	24	27
	medium				1		1		2
	light					1	1		2
	Sum				1	2	4	24	31
V.	motorway								
	heavy								
	medium						6		6
	light						14		14
	Sum						20		20
Sum total::		4	7	13	14	16	51	42	147

Table 2 is just an example for the calculation of project quality indicators for a given contractor, construction year of pavement strengthening, road type using as a reference rate the average deterioration rate of 22 strengthened sections selected randomly of road data bank.

Table 3 presents an example of the 29 tables produced which summarize the main steps of the calculation project quality indicators for various rehabilitation year – traffic – contractor combinations. (If the yearly deterioration speed of a section was 0, an extremely favourable value of 3 was taken as project quality indicator). Best (1) surface defects score was supposed to be in the year of each pavement rehabilitation project.

Table2. *Calculation of the Project Quality Indicator for a contractor using its quality data of pavement strengthening projects done in 2002 (example)*

Section	**ANET2002**	**ANET2010**	**TC**	**AvT**	**TE**	**RBAL2010**	**AA**	**MA**	**YD**	**PQI**
1.	1,079	6,794	4	397	3.65	3	8	29.2	0.07	1.55
2.	974	7,834	4	4404	4.52	5	8	36.2	0.11	0.96
3.	1,079	6,794	4	3937	3.65	3	8	29.2	0.07	1.55
4.	974	7,834	4	4404	4,52	4	8	36.2	0.08	1.28
Road sections selected randomly of road data bank										
v.1	3,784	15,200	4	9,492	2.51	3	8	20.1	0.10	
v.2	3,784	15,200	4	9,492	2.51	4	8	20.1	0.15	
v.3	3,784	15,200	4	9,492	2.51	3	8	20.1	0.10	
v.4	3,784	15,200	4	9,492	2.51	5	8	20.1	0.20	
v.5	3,401	13,832	4	8,617	2.53	5	8	20.3	0,20	
v.6	3,654	14,898	4	9,276	2.54	4	8	20.3	0.15	

v.7	3,401	13,832	4	8,617	2.53	4	8	20.3	0.15	
v.8	3,567	12,120	4	7,844	2.20	3	8	17.6	0.11	
v.9	3,567	12,120	4	7,844	2.20	2	8	17.6	0.06	
v.10	3,475	12,464	4	7,970	2.29	3	8	18.3	0.11	
v.11	1,079	6,794	4	3,937	3.65	3	8	29.2	0.07	
v.12	1,996	7,926	4	4,962	2.49	3	8	19.9	0.10	
v.13	2,362	9,193	4	5,778	2.45	3	8	19.6	0.10	
v.14	1,241	7,371	4	4,306	3.47	3	8	27.8	0.07	
v.15	986	15,042	4	8,014	8.13	2	8	65.0	0.02	
v.16	1,238	6,876	4	4,057	3.28	5	8	26.2	0.15	
v.17	812	7,185	4	3,999	4.92	2	8	39.4	0.03	
v.18	2,923	7,490	4	5,207	1.78	3	8	14.2	0.14	
v.19	2,329	7,495	4	4,912	2.11	4	8	16.9	0.18	
v.20	1,518	7,359	4	4,439	2,92	3	8	23.4	0.09	
v.21	812	7,185	4	3,999	4,92	2	8	39.4	0.03	
v.22	812	7,185	4	3,999	4,92	3	8	39.4	0.05	
Reference mean deterioration rate									0.11	

Table3. *Calculation of project quality indicators (example)*

Section	ANET 2004	ANET 2010	TC	AvT	TE	RBAL 2010	AA	MA	YD	PQI
I.	3810	16802	1	10306	2.70	3	6	16	0.12	1.43
II.	2384	16802	1	9593	4.02	3	6	24	0.08	2.13
III.	1612	7316	1	4464	2.77	5	6	17	0.24	0.73
IV.	1612	6794	1	4203	2.61	2	6	16	0.06	2.76
V.	1687	6794	1	4240.5	2.51	3	6	15	0.13	1.33
VI.	1687	6794	1	4240.5	2.51	3	6	15	0.13	1.33
VII.	1687	6794	1	4240.5	2.51	3	6	15	0.13	1.33
VIII.	1687	6794	1	4240.5	2.51	1	6	15	0.00	3.00
Road sections selected incidentally from road data bank										
1	2076	3945	1	3010.5	1.45	5	6	9	0.46	
2	4236	13191	1	8713.5	2.06	5	6	12	0.32	
3	4236	13191	1	8713.5	2.06	3	6	12	0.16	
4	3810	15454	1	9632	2.53	2	6	15	0.07	
5	3685	15608	1	9646.5	2.62	1	6	16	0.00	
6	2879	7928	1	5403.5	1.88	3	6	11	0.18	
7	3597	9193	1	6395	1.78	3	6	11	0.19	
8	895	6081	1	3488	3.90	5	6	23	0.17	
9	895	4845	1	2870	3.21	2	6	19	0.05	
10	3597	9193	1	6395	1.78	3	6	11	0.19	
11	898	4845	1	2871.5	3.20	1	6	19	0.00	
12	2912	6929	1	4920.5	1.69	3	6	10	0.20	
13	2912	6513	1	4712.5	1.62	4	6	10	0.31	
Reference mean deterioration speed									0.18	

Legend for Tables 2 and 3:

ANET mean daily repetition number of standard (100 kN) heavy axles (standard axles/day),

TC traffic category code (1 for motorways, 2 for heavily-trafficked non-expressways, 3 for moderately-trafficked non-expressways, 4 for lightly trafficked non-expressways),

AvT average ANET during investigation period (standard axles/day),

TE actual traffic evolution rate during investigation period, RBAL2010 pavement surface defects score (between 1 and 5) in 2010,

AA actual pavement age in 2010 (years),

MA modified pavement age in 2010 (years) due to traffic evolution different from the expected one,

YD yearly deterioration rate (surface defects score/year),

Reference mean average deterioration rate of the rates of20+ strengthened pavement deterioration rate sections randomly selected of road data bank

PQI project quality indicator (reference yearly deterioration rate divided by the actual deterioration rate of the project investigated).

These project quality indicators are averaged for each contractor to obtain the so-called contractor quality indicator, as a global index for the characterization of the long-term performance (quality) of the contractor’s “products”.

When calculating the pavement deterioration rates, very rarely, the best (1) surface defects note was recorded at the end of the investigation period. Since it means 0 note/year deterioration rate, the project quality indicator was taken 3, the theoretically most favourable value.

Calculated as the average of their project quality indicators, the following contractor quality parameters were given for the 5 competing firms:

- Contractor I, 44 projects

  (1,55+0,96+1,55+1,28+0,87+1,75+0,94+4,55+1,14+1,10+1,43+2,13+0,73+2,76+1,33+1,33+3,00+0,67+0,65+0,65+1,29+0,65+0,57+2,69+1,31+3,00+0,71+2,65+1,41+1,47+1,12+1,81+2,14+2,36+1,18+0,36+3,00+3,00+0,73+0,74+1,21+2,15+0,68)/44=**1,50.**
- Contractor II, 26 projects

  (1,83+1,10+1,55+0,49+0,46+0,46+0,46+0,46+3,00+0,47+1,34+3,00+0,72+3,00+0,23+0,31+0,23+0,31+0,23+0,23+0,46+3,00+0,62+0,78+0,42+0,43)/26=**0,98.**
- Contractor III, 26 projects

  (3,00+1,17+1,17+0,58+0,79+3,00+0,19+3,00+1,00+1,60+3,00+3,00+1,11+1,35+0,57+3,00+3,00+3,00+3,00+1,26+2,09+0,45+1,35+0,35+2,51+3,00)/26=**1, 82.**
- Contractor IV, 31 projects

  (3,00+3,00+0,51+3,80+3,00+0,95+1,37+1,00+3,00+0,47+3,00+3,00+0,91+0,46+3,00+0,37+0,27+3,00+0,31+3,00+3,00+1,13+0,44+3,00+0,72+0,80+3,00+0,22+3,00+3,00+ 0,98)/31 =**1, 83.**
- Contractor V, 20 projects

  (0,42+1,32+0,66+0,83+0,78+1,21+0,21+0,56+0,79+1,86+1,69+0,38+0,77+0,67+1,64+0,86+3,00+0,65+1,37+1,47)/20=**1, 06.**

It can be seen from the recent results of simplified analysis that Contractors III and IV have considerably higher „contractor quality indicators” (better performance?) than the rest has.

4. CONCLUSION

The trial calculation has proved the applicability of this methodology for making distinction between the quality parameters (performances) of various highway contractors. Actually this kind of information could be used in the evaluation of road construction tender bids if these indicators are based on reliable, detailed calculation. The idea of the whole approach is that the eventual some % savings in construction cost are not acceptable from national economy viewpoint if the poor performance of the project causes much higher additional expenditures because of its early and/or increased maintenance and rehabilitation needs. Another positive consequence of the general use of the proposed project quality analysis methodology can be that increased competition between pavement contractors can lower prices and save public money. At the same time, stimulating competition between pavement industries is a win-win for everyone - taxpayers, public authorities and industry!

The methodology selected for the characterization of the performance (this case, deterioration rate) of various pavement sections can be taken as appropriate since the reference deterioration rate (average rate of min 20 sections chosen randomly from road data bank) implies also the effects of the eventual performance influencing factors independent on the contractor, similarly to the performance of the pavement section under investigation.

The following steps could be recommended for the future further development of the project evaluation method:

- Involvement of many pavement sections with possibly long history for the characterization of a road pavement contractor's performance;
- General contractor and main sub-contractors;
- Widened data gathering for the sections on its pavement condition parameters before rehabilitation, traffic evolution during investigation period, design in-formation, quality management system during construction, pavement qualification out-come, guarantee period, condition improving activities during and/or at the end of guarantee period;
- Detailed information on the repair and non-structural maintenance carried out on the pavement sections during the period investigated;
- Detailed information on the structural maintenance performed on each pavement section during the period investigated;
- Identification of the performance-influencing factors that can be considered independent on the activities of contractor, these are, typically, client-, design- or operator-related mistakes or over-weighted vehicles, serious financial constraints at the time of construction, eventually, natural catastrophes;
- Estimation of the synergistic effect of the factors mentioned in point 6, then considering it at the evaluation of contractor's performance OR if it cannot be done reliably, exclusion of this section from the analysis;
- Consideration of actual (mainly heavy) traffic evolution rate of the road sections which could also modify the life cycle considered if the changing in traffic is significantly different from the forecasted one in the design phase; thus, a "modified life cycle" can be calculated in the determination of the pavement deterioration rate;
- Gathering all pavement condition (e.g. surface defects, bearing capacity, longitudinal un-evenness, rut depth) data time series in the period in question, from the opening of the section to traffic on;
- Characterization of some of the condition parameters by non-linear deterioration trends as e.g. the condition evolution of longitudinal and the transversal unevenness of pavement surface is modelled by exponential functions in the Hungarian trial section monitoring [Gáspár, 2014];
- Decision about the list of pavement condition parameters to be used in the deterioration rate analysis for a given pavement section;
- Selection of weighing factors for the condition parameters to be considered in the calculation of the "complex deterioration rate"of a pavement section (e.g. bearing capacity 5, surface defects 2, unevenness 1, rut depth 3).

The systematic collection and analysis of road contractors' performance information characterized by the relative deterioration rates of the pavement sections constructed by them several years ago would provide – hopefully in the not too far future – with a useful tool for the Clients in their selection of road-related public procurement bids. In such a way, the Client would be able to represent the long-term national economy interests in their decisions by heavily considering also the actual "quality references" of bidders, in addition to bid prices. It is obvious that a contractor would build a project by an increased national economy level risk if its past projects have proved to be constructed at a below-average quality level.

REFERENCES

Bubshait, A.A., Quality of Pavement Construction in Saudi Arabia, Practice Periodical on Structural Design and Construction, 3(6), pp. 129- 136, (2001).

COST 354 Action, Performance Indicators for Road Pavements, Final Report, Vienna, Austria, 68 p, (2008).

Gáspár L., Some quality-related aspects of Hungarian road pavement strengthening projects, Construction- Quality 3(28), pp.25-35, (in Hungarian), (1991)

Gáspár L., Highway pavement performance, Road and Civil Engineering Review, 64 (11), pp. 7-12, (In Hungarian), (2004).

Gaspar L., Highway Performance Modelling, Proceedings of Int Conf on Development in Road Engineering, National Institute of Technology, Rourkela, India, pp. 24-36, (2010).

Gáspár L. (project manager), Performance analysis of road pavement strengthening, Project report 2161-224-1-0, KTI Non-Profit Ltd., Hungary, 85 p, (In Hungarian) ,(2011).

Gaspar L., Evaluation of highway contractors based on the actual performance of their past projects, CD-ROM Conference Proceeding, TRA Transportation Research Arena Europe, Athens, pp. 1-9, (2012).

Gáspár L. (project manager), Evaluation of trial section monitoring results for road management purposes, Project report 2161-001-5-4, KTI Non-Profit Ltd., 96 p, (In Hungarian) (2014).

Merrill D., van Dommelen A. and Gaspar L., A review of practical experience throughout Europe on deterioration in fully-flexible and semi-rigid long-life pavements, Int J Pavement Engineering, Special Issue Long-Life Pavements, 2(7), pp. 101-109, (2006).

NCHRP Synthesis 212, Performance-Related Specifications for Highway Construction and Rehabilitation, Transportation Research Board, Washington D.C., 48 p. (1995).

Nunn M. E. and Smith T., Evaluation of Performance Specification in Road Construction, Project Report 55, Transport Research Laboratory, United Kingdom. (1994)

www.everlastblacktop.com/5-things-to-know-when-choosing-an-asphalt-paving-contractor/

www.everlastblacktop.com /choosing-a-paving-contractor/

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