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DETERMINING THE ASSET VALUE AND AVERAGE DEPRECIATION KEY OF A TOLLED ROAD NETWORK

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Abstract: In the framework of the first revision of toll rates calculated before the launch of the HU-GO truck toll collection system in Hungary, in July 2013, the re-determination of the infrastructure costs related to the tolled road network became necessary. Replacement costs of the main road components (considered as being a substitute of asset values) were to be calculated using the so called Synthetic Method, since the net asset values of the tolled road networks weren't recorded separately in the books of the national road administration. Basic assumptions as well as main steps and results of the calculation of replacement cost (asset value), as well as of the average depreciation key are presented and some relevant conclusions are formulated.

Keywords: Infrastructure cost, Replacement cost, Road network, Road asset value, Toll rates, Traffic load, Condition index, Service life, Depreciation keys

1. Introduction

To calculate the tolls to be levied upon each categories of road vehicles (proportional to the cost caused by them when they are running on a given type of road (i.e. structure of pavement), the basic input element to be taken into account is the *infrastructure cost* of the tolled road network. Complying with the Eurovignette Directive [1], only the costs related to the construction, operation and development of the road infrastructure could be reclaimed from the road users, i.e. the *toll revenue* collected from road vehicles falling into a well-defined vehicle-category on a given type

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of road should not exceed their share within total infrastructure cost related to that type of road (otherwise 'overpricing' would occur).

The most important element of road infrastructure cost is the *asset value* (i.e. the value expressed in monetary terms) of roads and bridges constituting the road network. Either for calculating tolls to be levied upon each vehicle categories when a toll collection system is launched, or revising toll rates applied by an already functioning one, this asset value has to be determined.

According to the Eurovignette Directive referred to above, the asset value of a tolled road network in a given moment (calendar year) could be calculated either by the Perpetual Inventory Method (PIM), or by the Synthetic Method (SM). The former is based on the series of *road related expenses* duly recorded by the road operator during an appropriately long time period (15-20 years), while the latter is built upon regularly updated inventory of all elements of the road network (including their geometrical dimensions, physical and condition parameters), serving as a base to calculate *replacement costs* at a given moment (calendar year).

In European countries where the road expenditure data recorded by the national accounts are either missing or not detailed properly, so continuous and reliable data series are seldom available for a 15-20 year long period, it is recommended to use the Synthetic Method (see *Fig. 1*) to determine road asset value as an input to calculate toll rates ([2], [3]).

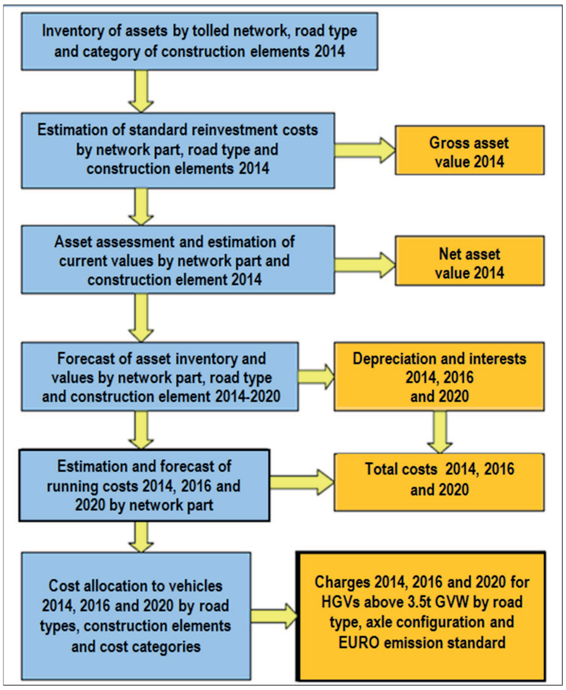

Fig. 1. Structure of toll calculation using asset values determined by the Synthetic Method (on the basis of [2])

2. Main steps of replacement cost calculation

The asset value of the tolled motorway/expressway network as well as the tolled main road network, respectively, has been calculated in consecutive steps as follows. Since the latest actual data available were that of calendar year 2014, this year has been chosen as a base year for the replacement cost of asset value calculation. Thus, to calculate replacement costs, road inventory data and condition indices, construction prices and unit costs are all expressed in 2014 terms in this paper.

Aiming to calculate replacement costs of the tolled motorway/expressway and main road networks, broken down according to these roads main structural components (pavement, road base, earthworks and dewatering system, bridges and engineering structures, plus others), the whole tolled road network (6,908 km in 2014) has been divided into four type of roads and homogenous sections within them, using the inventory data duly recorded by the National Road Databank (OKA), summarized in *Table I*.

Table I

Road inventory data (as recorded at the end of 2014) serving as a base for the asset value calculation according to the Synthetic Method

Road type		Number of tolled roads	Number of homogenous road sections	Summarized lengths of roads (km)
Sign	Item			
a	2×2 lane Motorways	11	171	1 176
b	2×2 lane Expressways	4	22	80
c	2×1 lane Expressways	4	16	69
a-c	Motorways/Expressways	19	209	1 325
d	2x1 lane Main roads	148	1.923	5 583
Total	Tolled road network	167	2.132	6 908

Construction costs at 2014 terms of each road types and their main parts were calculated by average unit costs determined using an actual data-set related to recently built new motorway, expressway and main road sections, collected for a relevant study prepared by Trenecon COWI [4]. Breakdown of construction costs of each road project included into the data-set created for the purpose of the replacement cost and asset value calculation is presented in *Table II*.

Complying with the requirements of the computing model intended to be used for allocation of infrastructure costs between vehicle categories, some cost items enumerated in the previous table were merged, reducing the number of cost components to be taken into account. Based on relevant studies and expert's experience, the ratio between the construction costs of upper layers of the asphalt pavement (wearing course + binder course = Structure I.) and those of the road base layers (Structure II.) was assumed for that data-merger as being equal to 60% / 40% [4], (see *Table III*).

The breakdown of average unit construction/replacement costs calculated for each road type as described above are presented in *Table IV*.

Table II

Breakdown of road construction costs

No.	Cost component
1	General items
2	Public utilities (electric energy, telecommunication, water supply, wastewater ducts, gas pipelines, etc.)
3	Pavement
3.1	Deplantation + demolition
3.2	Preparation of construction site + earthworks + road shoulders and central reserve + shaping
3.3	Upper layers of pavement and road base
3.4	Traffic engineering (signs, road marks, etc.) + guardrails and safety elements
3.5	Surface and underground dewatering system
4	Interchanges
5	Crossroads + parallel roads + other roads
6	Bridges and engineering structures(i.e. culverts)
7	Plantation + environmental protection
8	Others
Σ1-8	Total

Table III

Main components of construction cost, merged in compliance with requirements of cost allocation computing model

No	Consolidated cost element	Cost components
1	Earthworks and dewatering	3.1 + 3.2 + 3.5
2	Bridges and engineering structures	6
3	Structure I. - pavement	0.6 × (3.3 + 5)
4	Structure II. – road base	0.4 × (3.3 + 5)
5	Other	1 + 2 + 3.4 + 7 + 8
6	Interchanges	4

The average unit construction cost values at 2014 terms (calculated by statistical analysis as described above) were accepted as being related to new road sections designed and built on flat terrain, outside settlement boundaries, in compliance with recent standards and applying modern technologies in 2004 or later. To take into account the impacts of ageing, tear and wear, development of road construction technologies and machinery, the construction costs calculated above were reduced by 6% (experts' estimation) in case of road sections built or upgraded before 2004. According to that criterion, road sections were selected from the data-set and classified into these two groups respectively (see *Table V*).

It is worthwhile to mention, that the average unit construction cost of a 2×2 lane motorway/expressway calculated above on the base of a representative data-set is lagging far below the average unit cost of 16.3 million €/km (approximately HUF 5,000 million, 2014 terms) recommended by the official Guide to Cost-Benefit Analysis of Investment Projects published by the European Commission [5].

Table IV

Weighted average unit construction costs of road components (2014 terms)

Components	Motorways/Expressways		2x1 lane Main roads	
	Average unit construction cost (excl. VAT, HUF/km)	Share within total construction cost (%)	Average unit construction cost (excl. VAT, HUF/km)	Share within total construction cost (%)
Earthworks and dewatering	428 615 727	21%	214 101 030	39%
Bridges and engineering structures	499 767 171	24%	51 146 672	9%
Structure I. - pavement	327 688 612	16%	118 574 097	22%
Structure II. – road base	218 459 075	11%	79 049 398	15%
Other	447 852 882	22%	79 218 271	15%
Interchanges	115 612 181	6%	0	0%
TOTAL	2 037 995 649	100%	542 089 467	100%

Table V

Reduction of average unit construction cost (2014 terms) taking into account road age

Tolled road category	Average unit construction cost of a new road built on flat terrain, outside settlements between 2004-2014 (HUF/km, 2014 terms)	Average unit construction cost of a new road built on flat terrain, outside settlements before 2004 (HUF/km, 2014 terms)
Motorways/Expressways	2 037 995 649	1 834 196 084
Main roads	542 089 467	487 881 000

In the following step all road sections in the data-set were classified into three sub-categories, according to the topography of the terrain on which they were built, i.e.:

- road sections built on flat terrain;
- road section built on hilly terrain;
- road sections built on mountainous terrain.

Applying appropriate multipliers adapted from the latest (updated) version of the Guide to Cost-Benefit Analysis published by National Development Agency and COWI Consultants [6], the average unit construction costs related to the road sections built on flat terrain were modified by multiplying them with factors presented in *Table VI*.

The actual construction costs (considered as being the cost of replacement of a given road section by a newly built one) related to each and every tolled road section within a given road type, were calculated by multiplying relevant unit cost values with the recorded lengths of the road section under scrutiny. By that way construction cost values were determined for each road type (see *Table VII*).

Table VI

Multipliers used to reflect the impact of changing topographic conditions

Road type	Topography/terrain		
	flat	hilly	mountainous
Motorway 2×2 lane	1.0	1.20	1.25
Expressway 2×2 lane	1.0	1.25	1.30
Expressway 2×1 lane	1.0	1.30	1.35
Main road 2×1 lane	1.0	1.25	1.40

Table VII

Calculation of construction costs (2014 terms) for each type of road

Tolled road type	Lengths of roads (km)	Average unit construc-tion cost (million HUF/km)	Construc-tion cost (million HUF)	Construction cost corrected according to the age (million HUF)	Construction cost corrected according to topographic conditions (million HUF)
Motorways 2×2 lane	1 176	2 098.5	2 468.458	2 312.161	2 625.179
Expressways 2×2lane	80	1 890.5	150.738	136.345	163.859
Expressways 2×1 lane	69	1 178.4	81.276	81.276	81.276
Motorways/ Expressways	1 325	2 038.0	2 700.472	2 529.782	2 870.314
Main roads 2×1 lane	5 583	542.1	3 026.264	2 982.569	3 183.764
TOTAL	6 908	n.a.	5 726.736	5 512.351	6 054.078

Aiming to determine the actual condition parameters (serviceability) in 2014, reflecting the degree of physical deterioration (caused by changing weather conditions and traffic loads) of each and every road section under consideration, the average values of regular road condition survey results recorded by the National Road Databank (OKA) were used. The following condition parameters were taken into account:

- bearing capacity of pavement structure;
- pavement unevenness;
- surface defects;
- rut depths of pavement.

The average value of condition scores (1-good; 2-fair; 3-tolerable; 4-inadequate; 5-bad) related to each and every road section under scrutiny has been determined by calculating the mean value of the scores resulted from representative condition surveys carried out in 2014.

The weighted average value of condition scores related to every road section and road type have been calculated, using their lengths as weights. Then the weighted average condition scores reflecting the physical condition of road sections under scrutiny in 2014 were transformed into percentages expressing the deterioration rate of the condition compared to the original value (100%). The center of each condition class (reflecting the remaining life of the asset in percentage of its expected life span) has been selected as a base for interpolation applied to determine the replacement costs of the road sections under scrutiny (see *Table VIII*).

Table VIII

Indices reflecting physical condition of a road section

Condition class of the road	Score	Condition index reflecting remaining life
Good	1	90%
Fair	2	70%
Tolerable	3	50%
Inadequate	4	30%
Bad	5	10%

Aiming to calculate the replacement costs (considered as being equal to the asset value to be calculated) for each road type, the construction cost values presented above were eventually corrected by taking into account the degree of physical deterioration reflected by the relevant condition indices (see *Table IX*).

Table IX

Calculation of replacement costs/asset values (2014 terms)

Tolled road type	Length of road (km)	Average unit con-struc-tion cost (million HUF/km)	Construc-tion cost (million HUF)	Construc-tion cost corrected by road age (million HUF)	Construc-tion cost corrected by topography (million HUF)	Ave-rage condi-tion index in 2014 (%)	Replace-ment cost or asset value (million HUF)
Motorway 2×2 lane	1 176	2 098.5	2 468.458	2 312.161	2 625.179	82%	2 149.240
Expressway 2×2 lane	80	1 890.5	150.738	136.345	163.859	83%	135.838
Expressway 2×1 lane	69	1 178.4	81.276	81.276	81.276	76%	61.581
Motorways/ Expressways	1 325	2 038.0	2 700.472	2 529.782	2 870.314	82%	2 346.659
Main roads 2×1 lane	5 583	542.1	3 026.264	2 982.569	3 183.764	69%	2 193.555
TOTAL	6 908	n.a.	5 726.736	5 512.351	6 054.078	75%	4 540.214

These asset values (see last column in *Table IX*) calculated by the Synthetic Method were used as input data for allocation of road infrastructure cost between appropriately determined vehicle categories, aiming to calculate toll rates to be applied.

3. Calculation of an average annual depreciation key

To calculate the infrastructure costs at a given moment in the future (e. g. in any calendar year following the base year), it was also necessary to determine the depreciation keys for each and all main components of the road structure. For that purpose, first of all the expected service life of these main components has to be estimated (*Table X*).

Table X

Expected service life of a road's main structural components (years)

Cost element	Expected service life (years)
Other	10
Structure I. - Pavement	12
Structure II. – Road-base	20
Interchanges	20
Bridges and engineering structures	67
Earthworks and dewatering system	100

Assuming a linear depreciation function and taking into account the known share (%) of each main component within the total replacement costs, the yearly depreciation key of each component, as well as the yearly average depreciation key of the road as a whole have been calculated. The steps of this calculation (using data determined earlier for 2014) are illustrated in *Fig. 2* and *Fig. 3*, concerning the tolled network of motorways/expressways and that of main roads, respectively.

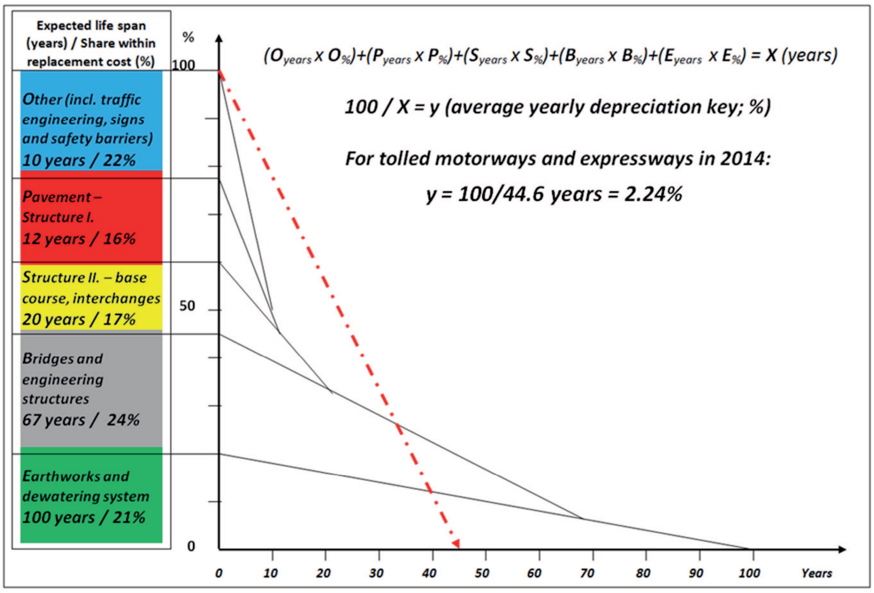

Fig. 2. Calculation of yearly average depreciation key for tolled motorways and expressways (2014)

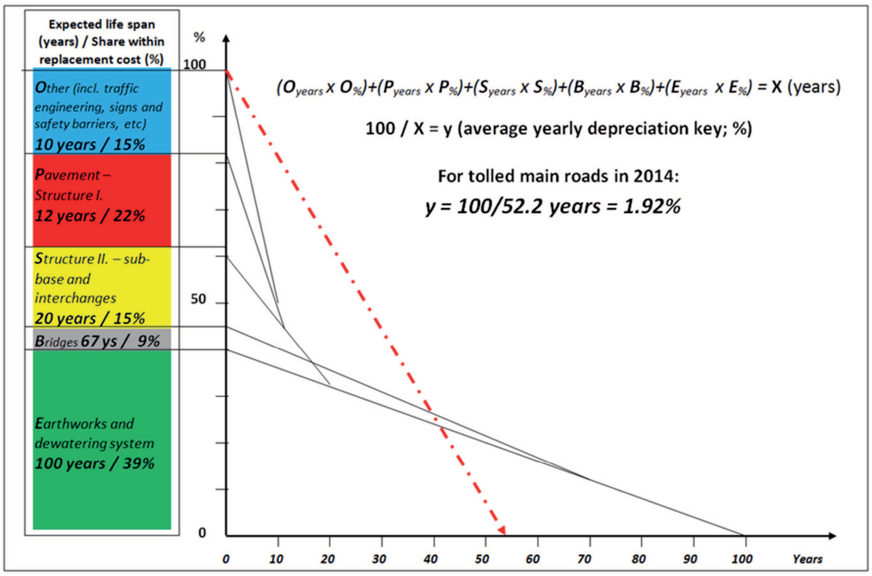

Fig. 3. Calculation of yearly average depreciation key for tolled main roads (2014)

Aiming to determine the yearly weighted average depreciation key for the entire tolled road network in Hungary, the gross unit replacement costs determined earlier by the Synthetic Method for the tolled network of motorways + expressways and main roads: HUF 2 038 million and HUF 542 million, respectively (in 2014 terms), were used as weighting factors.

Consequently, the following yearly weighted average depreciation key related to the entire tolled road network in Hungary:

$$[(2.038 \times 2.24) + (542 \times 1.92)] / 2.580 = 2.17\%$$

has been used for re-defining toll rates to be levied upon different vehicle categories.

4. Conclusions

Taking into consideration, that reliable road asset value data related to the tolled road network were apparently unavailable from the books of the national road administration, it has been decided to apply the Synthetic Method to determine them. Derived from a representative set of recently built motorway, expressway and main road sections, average unit replacement cost related to four different road types were calculated, taking into consideration changing topography, ageing, tear and wear due to traffic load, development of technology and average rate of condition’s deterioration reflected by results of regular representative surveys. These average unit replacement costs were then multiplied by the lengths of relevant road sections to obtain the actual replacement costs (2014 terms) which were considered as substitutes of asset values.

To calculate the infrastructure costs in any year in the future, it was also necessary to determine the depreciation keys for each main component of the road structure. Assuming a linear depreciation function and taking into account the share (%) of each main component within the asset value under consideration, their annual depreciation keys as well as the annual average depreciation key of the road as a whole have been calculated. All these input data were used successfully to re-calculate the toll rates applied in the HU-GO electronic truck toll collection system and proving that neither in the past, nor in the future there isn't any actual risk of eventual overpricing.

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