

DRAFT MODEL FOR CREATING A FINANCIAL INDICATORS OF BRIDGE CONSTRUCTION

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ABSTRACT

The paper deals with a problem of developing, defining and applying budgetary indicators of engineering constructions, and particularly bridges. It is a draft of a Model for development of budgetary indicators of bridge construction in the pre-investment phase of a project. It could, according to classification and evaluation in terms of criteria and search for the most accurate valuation unit of complex structures such as bridge construction, serve investors and public administration authorities for rapid investment planning and professional control of completed buildings. Such a unique tool has never been developed in the Czech Republic so far.

Bridges as buildings complement any landscape and in the outer parts of cities, they often establish a viewpoint. They belong among important parts of any highway or expressway. Without them, it would be impossible to establish grade-separated crossings with other roads - roads, railway lines or sections of rivers. They are also important in overcoming obstacles of natural and artificial character such as deep valleys, lakes, or steep mountainsides.

The aim of the paper is to analyse a current state of the valuation of bridges and the subsequent establishment and validation of the Model for the development of budgetary indicators of the bridge construction.

KEYWORDS

Bridges, basic budgetary costs, budgetary indicators, preliminary cost overview, budget, concrete, founding, rocks, abutments, wings, pillars, bridge deck, field

INTRODUCTION

“Bridge – an engineering work or a statue?”

Recently, we have been seeing increasingly more signs that construction of Czech highways and roads, and the related construction of highway and road bridges, is more costly both when compared with economically equivalent Central European states and with economically more advanced Western European states. This concerns both construction of new bridges and unsatisfactory condition of already built road and highway bridges. The most widespread opinion is that the current condition of most bridges is unsatisfactory and that it is caused by many factors including above all:

- age of the constructions (see D1 highway bridges),
- significantly increased and more dynamic load as compared with original assumptions,

- bad quality of earlier used insulation and other materials,
- insufficient maintenance and not ensuring timely repairs of small defects,
- atmospheric and chemical effects,
- failures caused by unexpected events (accidents etc.).

RESEARCH GOAL

The research was conducted at the Faculty of Civil Engineering - Department of Economics and Management in Civil Engineering within the preparation of the dissertation. The goal of the research is to analyse a current situation in pricing and, on the resulting basis, to propose a model for creation of budget indicators of bridge structures.

A significant part of the system of pricing of buildings and constructions is evaluation of construction projects in the phase of planning and calculation of construction costs. Budget indicators, or also the prices according to purpose measuring units, are the basic elements for the first calculation of price of buildings and constructions in the phase of pre-project preparation of a construction project. This calculation is a professional estimate of the future price of the construction, which serves as first-level information for investors related to the future price of the construction work. It is necessary to have especially a construction study proposal documentation for planning permission proceedings at your disposal.

Overview of used research methods:

- Analysis and synthesis
- Correlation and regression analysis
- Descriptive statistics – statistic classification of data – histogram of frequencies.

Two basic research questions arise in connection with the above-mentioned opinion:

- Why do study results often state a high price for construction of a bridge structure?
- Do budget indicators from the companies ÚRS PRAHA, a.s. and RTS, a.s. reflect the actual reality?

Summary of the literature connected with the subject of paper:

- Spon's Civil Engineering and Highway Works Price Book [1]
- Stráský, J. (2001). *Betonové mosty* [2]
- Bridge Engineering: Construction and Maintenance [3]

Current situation of the issue in the Czech Republic

Main used budget indicators of a construction structure (RUSO)

The basic elements necessary for the first calculation of price of constructions in the pre-investment phase of a construction project are budget indicators. These budget indicators are created by special private organisations in CZR, such as:

- ÚRS PRAHA, a.s., [4]
- RTS Brno, a.s., [5]
- Ředitelství silnic a dálnic ČR (publicly inaccessible on the basis of realised constructions),
- IBR Consulting s.r.o. (publicly accessible updated prices for pricing of construction in the phase of DÚR).

Professional literature covering the topic of bridges is mostly technically oriented in the Czech Republic. This refers to the book called “Betonové mosty I / Concrete Bridges I” taking into consideration the relation between technical design and price [6]. From among the international sources, particularly German professional literature reports on this topic. [7]

Currently, as of 2013 – 2014, approximately 17 445 bridges are recorded in the Czech Republic, of which 1 568 are on highways and skyways, 3 286 bridges on I-class roads, 4 516 bridges on II-class roads and 8 075 bridges on III-class roads [8].

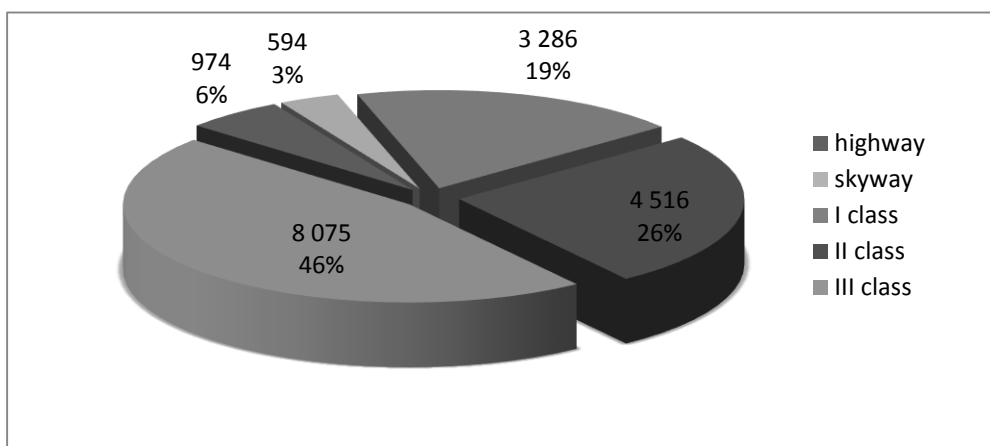


Fig. 1: Classification of bridges according to the type of the road, Source: own elaboration

The following graph shows an overview of bridges on highways and I, II and III-class roads according to the type of the load-bearing structure. The most frequent bridges from the perspective of characteristics of the used material are bridges with concrete load-bearing structure.

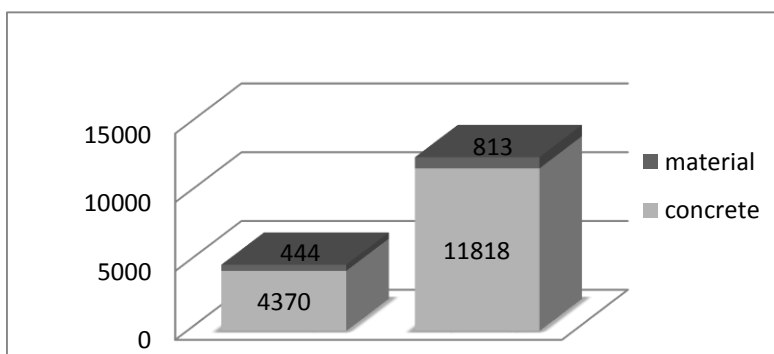


Fig. 2: Overview of bridges according to the type of the load-bearing structure, Source: own elaboration

Predominance of bridges with concrete load-bearing structure is one of the main reasons for focus of this work.

According to the Czech construction standards, acceptable differences between the calculated and real costs are within the range of $\pm 15\%$. [9]

Characteristics of the subject of the solution

Solution procedure

To find a correct solution for the given issue, it is necessary to know bridges from the technical and price point of view.

Item budgets were elaborated by means of the software ASPE on the price level 2013 (basic budget costs without VAT and without costs on placement of the construction) on the basis of project documentation and bill of quantities. It is a software "Automatizovaný System Podnikové Ekonomiky" (Automated Corporate Economy System), which is designed for preparation and realisation of constructions and which is used especially for realisation of roads and it is also very important for elaboration of bridge cost calculations.

Random effects related to general constructions and works were removed from item budgets. The price does not include:

- Elaboration of a bridge sheet,
- testing of material by an independent testing centre,
- testing of constructions and works by a testing centre of the contractor – preliminary agreement,
- testing of constructions and works by a testing centre of the contractor,
- other requirements – land survey measurements,
- geodetic surveying,
- assessments, inspections, revision reports,
- main bridge inspection,
- documentation of actual realisation in a digital form.
- disposal site fee

In general, it applies that each bridge is an original with regard to its position, technology and other effects. Therefore, items related to general constructions and works are not used in the proposal of creation of budget indicator. The analysis shows that in the case of bridge constructions, general constructions and works form 4 – 5% of the total basic budget costs. **The disposal site fee is considered only at the general level in the proposed model.**

For a better transparency, a table was elaborated for 13 samples of designed bridges with the load-bearing structure "prefabricated prefa girder". The table shows deviations from the real basic budget costs as compared with costs determined according to the indicator price ÚRS Praha, a.s. and RTS Brno, a.s. on the price level 2013. It includes basic budget costs without VAT and it does not include costs of placement of the construction.

Tab. 1: Bridges PREFA GIRDER, Source: own elaboration

Bridge name	Basic budget costs (BBC) compared with costs according to the indicator price of URS PRAHA, a.s. (%)	Basic budget costs (BBC) compared with costs according to the indicator price of RTS Brno, a.s. (%)
Bridge D1 203	87,14	95,46
Bridge D1 046 km 44,294	162,40	174,06
Bridge D1 045 km 43,444	167,01	178,88
Bridge D1 194	98,26	107,07
Bridge D1 200 km 161,976	76,92	84,78
Bridge Litoměřice - Mlékojedy	45,08	51,53
Bridge D1 069km	32,82	38,72
Bridge D1 071 behind the municipality Studený	16,56	21,75
Bridge D1 066km u Lokte	28,81	34,53
Bridge D1 140	5,12	9,80
Bridge D1 050 km 47,864	-16,61	-12,90
Bridge D1 044 km 42,661	-27,12	-23,88
Bridge D1 139 km 106,27	-35,47	-32,60

On the basis of costs mentioned in *Tab. 1* we could say even surprising deviations, which show us the percentage manifestation of the real costs compared with costs according to the indicator price established by the companies ÚRS Praha a.s. and RTS Brno on the price level 2013, it will be necessary to find new budget indicators, to classify the bridges and their material characteristics more precisely and to define the basic evaluation unit.

Methodology for creation of price indicators of bridge Structures

Proposal of a new classification for concrete bridges, which is based on general classification of bridges:

- According to the type of transport:
 - road bridges.
- According to the type of obstacle (from the perspective of the bridge project):
 - highway and skyway overpasses,
 - highway and road bridges,
 - embanked bridges,
 - single-span bridges,
 - urban viaducts,
 - bridges across rivers,
 - bridges across deep valleys,
 - pedestrian bridges.

- According to technologies:
 - prefabricated structure,
 - monolithic structure,
- According to the load-bearing structure:
 - board structure,
 - beam construction (beam + box girder),
 - arched bridges,
 - suspension and hanging bridges.
- Frame culverts and embanked structures. [10]

Tab. 2: Proposal of a new classification of bridge structures, Source: own elaboration

821 BRIDGES			Number of bridges	Classification according to the bridge material characteristics					
821 1 Road bridges				1	2		3		
821 11 CONCRETE BRIDGES	1	Highway and skyway overpasses	16				9		7
	2	Highway bridges	17		7		2		8
	3	Road bridges	13		8		5		

Construction material characteristics:

- 1 monolithic concrete prestressed board structure
- 2 monolithic concrete prestressed beam structure
- 3 assembled from parts of prestressed PREFABRICATED GIRDER [11]

Selection of relevant criteria, defining their variants and creation of the basic representative – price indicator of the given bridge structure.

The proposed methodology has been applied on the database of 46 concrete bridges, which are classified into 7 groups according to construction material characteristics

Example:

Road bridges, concrete bridges, highway and skyway overpasses, load-bearing structure assembled from parts of prestressed PREFABRICATED GIRDER.

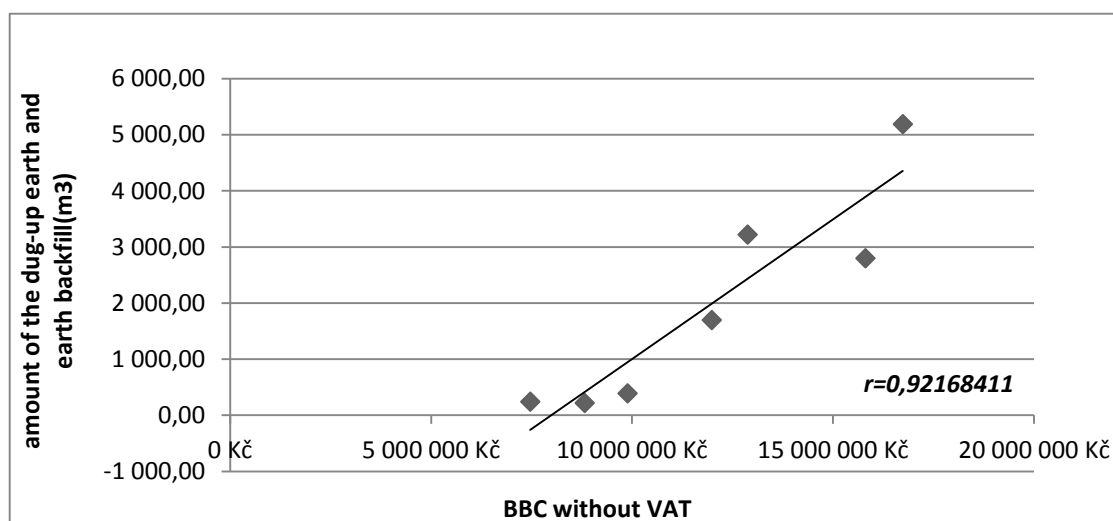
821 11 13

Tab. 3: Bridges - PREFABRICATED GIRDER, Source: own elaboration

Bridge name	Bridge parameters (m, m, m, m, m ²)					BBC without VAT and CPC in PL 2013	BBC/areas and L-BS
	Length L-BS	Span	Aver. span	Bridge width	L-BS area		
Bridge D1 066km u Lokte	45,7	21,7+22,3	22	6,6	331,55	11 977 171 CZK	36 125 CZK
Bridge D1 069km	47,7	22+24	23	7,7	367,29	12 867 848 CZK	35 035 CZK
Bridge D1 071 behind the municipality Studený	37,7	36	36	10,5	395,85	15 802 087 CZK	39 919 CZK
Bridge D1 140	48,47	24,35+24,12	24,24	7,8	378,066	16 734 667 CZK	44 264 CZK
Bridge D1 194	51,34	24,8+24,8	24,8	7,7	375,84	8 821 071 CZK	23 470 CZK
Bridge D1 200 across highway on a field path 161,976 km	49,8	24,5+24,5	24,5	7,7	375,84	9 885 140 CZK	26 301 CZK

The anticipated dependency between the variables was discovered by means of the correlation and regression analysis:

- BBC and amount of the dug-up earth, backfill and embankment (m³)
- BBC and amount of concrete including bridge supports, wings, cornice (m³)


 Fig. 3 BBC/amount of the dug-up earth and earth backfill (m³), Source: own elaboration

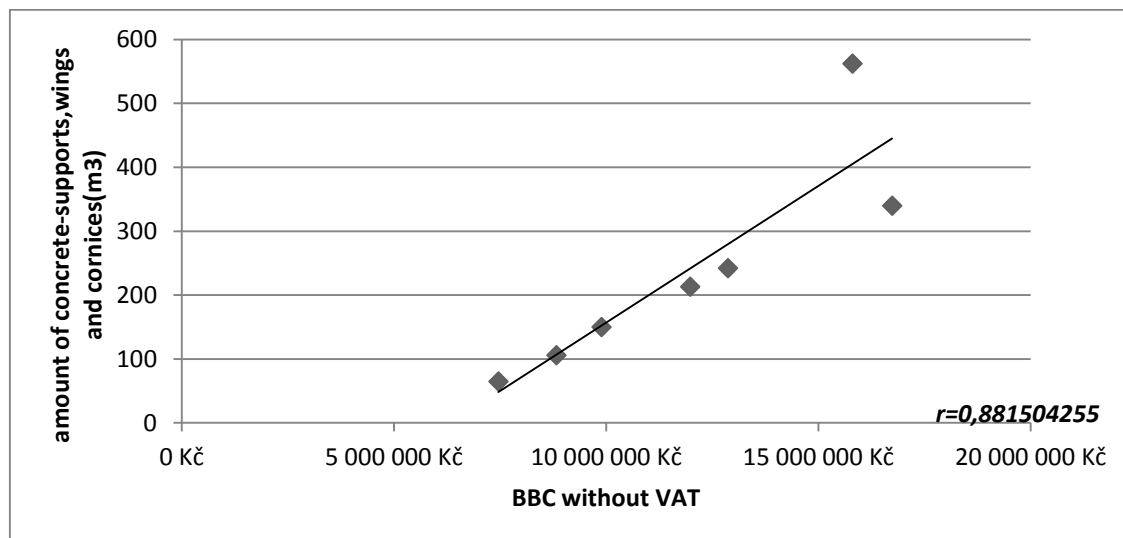


Fig. 4: BBC/amount of concrete-supports, wings and cornices (m^3), Source: own elaboration

Last step of the proposed methodology is creation of the basic representative – price indicator of the particular bridge structure with the given material characteristics.

- To define variants on the basis of comparative statistics methods, where the occurrence frequency of variants for the proposed relevant criterion was determined.
- Variants with the most frequent occurrence for each relevant criterion were selected and, on the basis of the method mentioned in the previous step, 3 representatives were defined, which have similar values in their selected criteria.

The representative – price indicator was selected with basic parameters and resulting averaged guide price for $1m^2$ of the area of the load-bearing structure **37 026CZK/m²**. Values, which are stated in the proposed relevant criteria, were determined by means of arithmetic means with the number in the absolute value.

Selected representative

Indicative price/m ²	CZK37. 026per square
Amount of digging works	1 001 – 5 000m ³
Foundation difficulty	1 – surface area
Class of rocks	II – III
Amount of concrete in m ³	
(Bridge supports, wings and cornices, ŽL class, B37)	201 – 500m ³
Bridge floor area	301 – 400m ²
Number of fields	2

As bridges are also designed in different values than the selected representative, it was necessary to optimise the price of the real or particular bridge with regard to its designed parameters, especially in the following variants, which include the individual relevant criteria.

- Class of rocks higher than III
- Amount of digging works to 100m³, 101-1000m³, over 5000m³
- Foundation difficulty special foundation -2 (boreholes, piles, sheet-pile walls)
- Number of fields 1, 3 and more
- Area of bridge floor to 300m², 401-600m², 601-900m², over 901m²

The newly proposed indicators of an average guide price (budget price) were related to the measuring unit m² in the following table on the basis of the above-mentioned methodology for creation of a representative of a bridge structure.

Tab. 4 Guide price indicators related to m², Source: own elaboration

821 BRIDGES			Number of bridges	Classification according to the bridge construction material characteristics					
821 1 Road bridges				1		2		3	
821 11 CONCRETE BRIDGES	1	Highway and skyway overpasses	16			37 300 CZK	9	37 000 CZK	7
	2	Highway bridges	17	35 600 CZK	7	31 300 CZK	2	30 200 CZK	8
	3	Road bridges	13	33 600 CZK	8	32 900 CZK	5		

Results from the suggested methodology for “Road bridges – Concrete bridges” are the basis for a model for creation of budget indicators of a bridge structure.

CONCLUSION

The resulting model will enable simple specifying of investment costs for construction of new concrete bridges as civil structures (i.e. highway and road bridges, including highway and motorway flyovers). It may be used in the pre-investment phase allowing fast and specifically exact pricing of planned investment. Investors and/or designers may use it as well as other professionals.

There are 17.445 bridges of different age in the Czech Republic. Determining construction costs of their repair, maintenance, or modernisation will be topic of the day in the upcoming years (due to the life expectancy of for instance bridge floor insulation, as it is around 20 years). This is why the Model will be designed allowing adding more modules.

- Module OC – steel-concrete bridges.
- Module PK – backfilled structures – bio-corridors.
- Module OU – repair and maintenance of bridges.
- Module RE - modernisation of a bridge.
- Module RM – construction of railway bridges, industrial, water-management corridors, and pedestrian bridges.

It must be considered that investment costs defined by the model do not contain related costs unsubstantiated in the database of directional costs, and these are first of all:

- cost of project documents,
- cost of geodetic survey,
- testing of structures and work by contractor's test lab – preliminary,
- testing of structures and work by contractor's test lab,
- other requirements – geodetic surveying, expert opinions, check-ups, revision reports,
- key bridge inspection,
- digital as-built documents,
- VRN (NUS) / additional budgeted cost (site-related costs),
- VAT.

On the other hand, the market environment (contractors' interest to build) sometimes pushes investor costs down by as much as 20-30 per cent compared to directional costs specified in the Model. Yet the Model is structured in such a manner so that the basic entry data could be updated and still maintain costs relative to affecting parameters.

ABBREVIATIONS

ÚRS PRAHA, a.s. - the successor to the oldest organisation of this type in the Czech Republic that was the state-owned Ústav pro racionalizaci ve stavebnictví / Institute for Rationalization in Construction Engineering liquidated at the beginning of the 1990s.

821 11 13 - Concrete bridges Highway and skyway overpasses assembled from parts of prestressed PREFABRICATED GIRDER .

BBC - basic budget costs

CPC - costs on placement of the construction

PL 2013 - price level 2013

L-BS - load-bearing structure

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