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DEVELOPMENT LEVEL OF ANALYSIS FOR ROAD COST MODELS

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Abstract. The importance of accurate estimates during the early stages of infrastructure projects has been widely recognised for many years. In an early estimation there is a compromise between the amounts of information available and accuracy of estimation. In this paper three levels of analysis were proposed such as regional, country and project levels for road cost models in order to provide an efficient data usage. The data for our research were obtained from the World Bank's ROCKS database, which contains unit costs for road projects from over 80 developing countries.

Keywords: road cost model, unit cost, cost, level of analysis, project.

1. Introduction

The importance of road cost models arises when it is required to estimate the unit cost of a project on the basis of preliminary data of the project. Road cost models can be used for benchmarking to avoid cost overruns, by comparison with similar projects. In the research described here, data have been obtained from the World Bank's ROCKS (Road Costs Knowledge System) database, which contains unit costs and other project details from over 80 developing countries. There are about 2000 records in this database. The project types cover a range from routine maintenance, such as surface treatment, to development, such as new highway construction [1].

The error in estimation varies during a project development cycle from the concept development phase, through the design, advertisement, and bid/award phases, to the construction phase. As the project progresses, the accuracy of cost estimation increases because the details of the project become clearer. According to Schexnayder et al (2003) at the initial stage the accuracy of the estimate is between about ± 25 and ± 50 % , owing to the less well-defined project details and other uncertainties due to both internal and external factors [2].

Recent research review reveals that there is a problem in cost estimation at the conceptual stage of the project cycle. In the US, a study of the variation between actual and estimated costs of 258 transportation projects by Flyvbjerg et al concluded that not only costs are underestimated in almost 9 out of 10 projects but also that actual costs are, on average, 28 % higher than the estimated costs [3]. However, the most interesting conclusion in this study is the fact that the same amount of underestimation exists today as existed 30–70 years ago. Another statistical study was undertaken by the World Bank Transport Unit (ROCKS, 2004); in this study, data from 65 developing countries were used to make comparisons between estimated costs at appraisal and actual costs at completion. Among these projects 62 % were underestimated, and the rest overestimated. Accurate cost estimation at the early stages of project development is a challenging task not only for developed countries but also for developing countries. Therefore, there is a need for better cost estimation techniques to be developed.

Levinson et al have developed a regression model to predict the cost of new links and expansion as a function of the year of completion, duration of construction, and the distance from the nearest downtown [4]. Buys et al investigated the upgrading of the road network and expansion of overland trade in sub-Saharan Africa [5]. They developed a cost model based on work types and country specific data.

2. Objective

The objective of this paper is to present a method for developing comprehensive road cost models that provide better prediction accuracy and implement efficient data

Table 1. Variables description

Regional level					
Variables	Percentiles				
	10	25	50	75	90
GDP per capita (US $ 2004,PPP)	1617	2399	3344	8584	12994
Annual mean percipitation (mm)	460	627	1187	1622	2348
Road network density (km per 1000 km^2)	61	122	204	657	1211
Pavement width (m)	6,0	7,0	7,0	7,3	8,0
Length of coastline divided by area (km per 1000 km^2)	0	0,886	2,334	4,331	10,585
Country level					
Work duration (months)	3,0	6,0	11,5	24,0	48,0
Road length (km)	4,5	8,8	18,8	45,0	110,0
Pavement width (m)	6,0	6,7	7,0	7,0	14,0
Rate of work progress multiplied by pavement width (months)	0,56	1,56	5,02	11,17	27,98
Project level					
Pavement width (m)	7	7	7	7,3	8,5
Surface thickness (mm)	40	40	40	50	110

usage according to the level of analysis. These changes should provide planners and decision-makers in road agencies with tools to do the following:

1. To estimate accurately the unit cost in various cost studies,
2. To conduct cost studies at different levels of analysis.

The levels of analysis are the regional, country, and project levels. Cost determinants become more detailed as the level of analysis moves from the regional to the country level, and even more detailed as it moves to the project level.

3. Description of data

Data from the ROCKS database was employed for this research. This database has records about 2000 highway projects from over 80 developing countries around the world. The main disadvantage of databases is the existence of missing values, and ROCKS is no exception. In order to efficiently use the available data, the database was subdivided into groups. Table 1 shows description of variables. For regional-level analysis, the degree of landlockedness was defined by dividing the length of the coastline by the area of the country. For country-level analysis, the rate of work progress multiplied by pavement width (RWP) was used to take into account project completion of a given project.

4. Methodology

4.1. Level of analysis

For regional-level analysis, the following data were extracted from the whole database: country, project type, pavement width, and unit cost. The largest numbers of projects are in the Africa and Asia regions, where there are 408 and 326 projects, respectively. The third largest number is in the Europe region, with 266 projects. The South America and East Asia regions have 164 and 160 projects, respectively. The smallest number of projects is in the Central America region – only 61. The unit cost varies widely within and between regions. For example, for 40–59 mm asphalt overlay, the unit cost is between 30 000 and 95 000 US$/km in the Africa region. On average, the corresponding cost varies from 48 700 US$/km in the South America region to 84 000 US$/km in the Central America region.

For country-level analysis, the following data were extracted from the ROCKS database: country, project type, work duration, road length, pavement width, contractor type and unit cost. Armenia, Ethiopia, Ghana, the Kyrgyz Republic, the Lao DPR, Nigeria, Poland, and Uganda were selected for this type of analysis because only the data for those countries contain the work duration. The total number of projects was 318, with the data sets for Ghana and Uganda being the largest, containing 133 and 74 projects, respectively.

For project-level analysis, the following data were selected: country, project type, pavement width, surface thickness, terrain, climate, contractor type and unit cost. The number of projects was 63, taken from Ethiopia, the Kyrgyz Republic, the Lao DPR, and Nigeria. Only four types of projects were available for this type of analysis, namely asphalt overlay, partial widening, reconstruction, and widening by adding two lanes.

Fig 1 describes the data used for each level of analysis. The figure shows that at the regional level the project details are limited, but at the project level the amount of detail is greater. In contrast, the number of observations is high at the regional level but low at the project level. This phenomenon can be observed not only in ROCKS but also in other databases.

Road cost models at the country level are useful for performing cost variation analysis within a country. As in

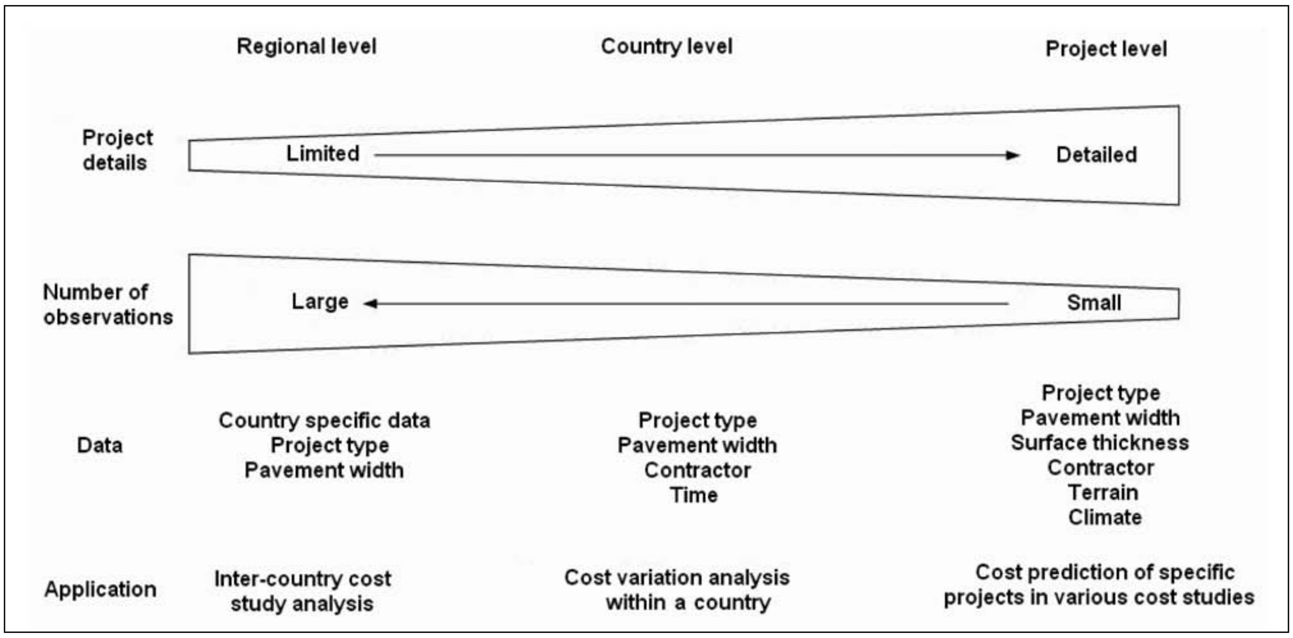

Fig 1. Efficient use of ROCKS database according to the level of analysis

the case of the regional level, the necessary data in country-level analysis for building road cost models include the project type and the pavement width, but also the contractor type, i e whether the contractor is local, a joint venture, or foreign. Time is a key variable in country-level analysis. There is a strong relation between cost, time, and quality in every infrastructure project. Time in country-level analysis is expressed in terms of rate of work progress. The work duration is the time required to complete a given project in days, months, or years. The rate of progress of the work is slightly different, and is not available in the database. The rate of work progress was calculated from the available data by dividing the work duration by the total road length. From time to time, road agencies need to analyse cost variation between different regions in their country. Road cost models at the country level assist project managers in performing cost variation analysis based on a time-cost trade-off.

Project-level analysis includes the following data: project type, pavement width, surface thickness, contractor type, the terrain through which the road passes, and the climate of the region where the road is located. In other words, projects are described in detail. This type of analysis can be used to predict the unit costs of very specific projects in a given location.

4.2. Multiple-regression models

At the regional level, the model specification was defined as follows:

$$\log UC_{ij} = \alpha_0 + \alpha_1 \log G_i + \alpha_2 \log RND_i + \alpha_3 \log PW + \alpha_4 \log AP_i + \alpha_5 DL_i + \sum_j \beta_j PT_j + \varepsilon_{ij}, \quad (1)$$

where UC_{ij} – unit cost of project type j in country i, US\$ 2004/km; G_i – GDP per capita of country i, US\$ 2004, PPP; RND_i – road network density of country i (km per 1000 km^2); PW – pavement width, m; AP_i – annual mean precipitation of country i, mm; DL_i – dummy variable for project type.

The GDP per capita represents a country's development level, and therefore it was included in the regression equation (GDP was obtained from International Monetary Fund, 2005). It takes into account the amount of financial resources allocated to the road sector, which, in turn, affects indirectly the unit cost of projects. The road network density represents what each country's road agency has to maintain and upgrade periodically. In order to observe how climate affects the unit cost, annual mean precipitation has been included in the equation (climate data was obtained from Tyndall Centre for Climate Change Research). To be able to make predictions for projects with geometric parameter, the pavement width has been used. The project types vary from adding an asphalt overlay, through widening by adding two bituminous lanes, to reconstruction. In total, 38 types of projects were included in the analysis. The length of coastline divided by area was taken into consideration as proxy for imported raw materials, which may be in short supply in a given country.

At the country level, the data were fitted to the following model specification:

$$\log UC_j = \alpha_0 + \alpha_1 \log RWP + \sum_j \beta_j PT_j + \sum_j \gamma_j CTR_j + \varepsilon_{ij} \quad (2)$$

where UC_j – unit cost of project type *j* US$ 2004/km; *RWP* – rate of work progress for a given pavement, months; PT_j – dummy variable for project type; CTR_j – dummy variable for contractor type.

The country-level regression model differs from the previous model by inclusion of the rate of work progress, which is a proxy for project completion speed and takes into account uncertainties in time delays. Additionally, the dummy variable "contractor type" is included, which characterises how resources are managed by different type of contractors, ie local, joint-venture, and foreign contractors. The number of project types included here decreased to 24.

At project level, the specification of the regression model was as follows:

$$\log UC_j = \alpha_0 + \alpha_1 \log PW + \alpha_2 \log PST + \sum_j \beta_j TR_j + \sum_j \gamma_j CL_j + \sum_j \lambda_j CTR_j + \sum_j \varphi_j PT_j + \varepsilon_{ij} \quad (3)$$

where UC_j – unit cost of project type, US $ 2004/km; *PW* – pavement width, m; *PST* – pavement surface thickness, mm; TR_j – dummy variable for terrain type; CL_j – dummy variable for climate; CTR_j – dummy variable for contractor type; PT_j – dummy variable for project type.

The project-level regression model includes the pavement surface thickness, the predominant terrain through which the road passes, and the climate of the region where the road is located. The terrain and climate directly affect the unit cost of a project. There were only three types of projects available with such detailed information.

5. Results

The coefficients and t statistics of our road cost models are shown in Tables 2–4. At the regional level of analysis, the results suggest that a 1 % increase in GDP leads to a 0,06 % decrease in unit cost. A 1 % increase in road network density leads to a 0,04 % increase of unit cost. An increase in pavement width by 1 % yields a 0,28 % increase in unit cost. At the country level of analysis, the results suggest that a 1 % increase in the rate of work progress for a given pavement width leads to a 0,07 % increase in unit cost. At the project level, the model is not as significant as in other two cases. One reason for this is the limited number

Table 2. Unit cost determinants, regional level

Dependent variable: log project unit cost (US $/km)	Coefficients	t stat
Log GDP per capita	–0,06	–2,63*
Length of coastline divided by area	1,27	1,80**
Log annual mean precipitation	–0,08	–2,85*
Log road network density	0,04	2,54*
Log pavement width	0,28	3,06*
Asphalt overlay 40 to 59 mm	–3,55	–6,32*
Asphalt overlay 60 to 79 mm	–3,22	–5,70*
Asphalt overlay 80 to 99 mm	–2,82	–5,02*
Asphalt overlay < 40 mm	–3,97	–7,00*
Asphalt overlay > 99 mm	–2,54	–4,51*
Double surface treatment	–4,47	–7,89*
Fog seal	–5,89	–10,41*
Heavy grading	–8,29	–13,66*
Light grading	–9,82	–16,65*
New bituminous 2L highway	–0,79	–1,40
New bituminous 4L expressway	–0,34	–0,57
New bituminous 4L highway	–0,14	–0,23
New concrete 2L highway	–0,83	–1,43
New unsealed 1L road	–3,00	–4,71*
New unsealed 2L highway	–4,38	–5,54*
Partial widening to bituminous 2L	–2,69	–4,53*
Partial widening to bituminous 2L and reconstruction	–2,37	–4,19*
Partial widening to unsealed 2L and reconstruction	–4,55	–7,01*
Regravelling	–5,30	–9,40*
Routine maintenance 1L road	–8,53	–10,71*
Routine maintenance bituminous 2L highway	–6,74	–11,77*
Routine maintenance block 2L highway	–6,71	–9,78*
Routine maintenance unsealed 2L highway	–7,73	–12,75*

Continued Table 2

Dependent variable: log project unit cost (US $/km)	Coefficients	t stat
Reconstruction bituminous	–2,49	–4,45*
Reconstruction concrete	–2,46	–4,17*
Reconstruction unsealed	–3,98	–7,00*
Spot regravelling	–9,69	–12,20*
Slurry seal or cape seal	–5,41	–9,47*
Single surface treatment	–4,89	–8,66*
Upgrading block to bituminous 2L highway	–2,11	–3,09*
Unsealed preventive treatment	–6,24	–10,96*
Upgrading unsealed to bituminous 2L highway	–2,28	–4,04*
Upgrading unsealed to concrete 2L highway	–2,25	–3,45*
Upgrading unsealed to unsealed 2L highway	–3,89	–6,73*
Widening adding bituminous 1L and reconstruction	–2,25	–3,95*
Widening adding bituminous 2L	–0,58	–0,91
Widening adding bituminous 2L and reconstruction	–1,07	–1,86**
Intercept	15,13	22,50*
Observations	1387	
Adj R squared	0,89	
* t statistics significant at 1 %, ** t statistics significant at 5 %		

Table 3. Unit cost determinants, country level

Dependent variable: log project unit cost (US $/km)	Coefficients	t stat
Log rate of work progress multiplied by pavement width	0,07	2,01**
Contractor foreign	–0,25	–1,4
Contractor local	–0,35	–2,04**
Asphalt overlay 40 to 59 mm	3,11	5,67*
Asphalt overlay 60 to 79 mm	3,83	6,06*
Asphalt overlay 80 to 99 mm	4,07	7,48*
Asphalt overlay < 40 mm	2,74	4,97*
Asphalt overlay > 99 mm	4,34	7,91*
Double surface treatment	2,48	4,69*
Fog seal	1,57	2,98*
New bituminous 2L highway	6,15	11,07*
New bituminous 4L highway	7,03	9,34*
New concrete 4L highway	7,02	9,52*
Partial widening to bituminous 2L	4,12	5,66*
Partial widening to bituminous 2L and reconstruction	4,33	8,22*
Reconstruction bituminous	1,97	3,78*
Reconstruction concrete	0,39	0,74
Regravelling	4,44	8,46*
Routine maintenance bituminous 2L highway	5,30	7,02*
Routine maintenance unsealed 2L highway	3,24	5,94*
Single surface treatment	1,94	3,13*
Slurry seal or cape seal	2,04	3,23*
Unsealed preventive treatment	0,81	1,57
Upgrading unsealed to bituminous 2L highway	4,71	8,79*
Upgrading unsealed to unsealed 2L highway	3,15	5,57*
Widening adding bituminous 2L and reconstruction	5,31	8,74*
Intercept	7,87	14,63*
Observations	318	
Adj R squared	0,92	
* t statistics significant at 1 %,** t statistics significant at 5		

Table 4. Unit cost determinants, project level

Dependent variable: log project unit cost (US $/km)	Coefficients	t stat
Log pavement width	–2,37	–1,38
Log surface thickness	3,01	3,61*
Mountainous	–0,20	–1,01
Rolling	–0,41	–1,24
Arid/sub-tropical – hot	1,03	1,69**
Arid/temperate – freeze	–2,00	–2,18**
Humid/tropical	0,87	1,16
Semi-arid/temperate – freeze	–2,25	–2,77*
Sub-humid/sub-tropical – cool	1,20	1,64**
Foreign	0,03	0,12
Local	0,11	0,35
Partial widening to bituminous 2L and reconstruction	–0,40	–0,40
Reconstruction bituminous	0,51	0,56
Widening adding bituminous 2L and reconstruction	0,90	0,64
Intercept	5,17	2,16**
Observations	57	
Adj R squared	0,43	
* t statistics significant at 1 %,** t statistics significant at 5 %		

of observations. The adjusted R2 is equal to 0,9 for the regional- and country-level analyses, whereas for the project-level analysis it is as low as 0,4. On the basis of these results, the regional- and country-level road cost models are good for predicting the costs of new projects. The coefficients of the dummy variables represent differences in intercept. To prevent perfect multicollinearity, one class in each dummy-variable set was dropped.

6. Conclusions

The use of different levels of analysis cannot only provide an efficient usage of data but also be useful for conducting various cost studies, depending on the study nature. The idea of a level of analysis is based on several questions, namely those of what variables to use, how many observations are available, and when to use a particular model. Road cost models built at the regional level can be applied to predict costs of new projects in a given region. Country-level road cost models provide a better solution to making predictions about certain types of projects within a country. Road cost models at the project level are built on a very detailed information. They can be used to predict the unit cost of a project about which we have a detailed information. Therefore regional and country level road cost models are useful for preliminary cost studies, but project-level models can be used during feasibility studies.

References

1. ROCKS. Road Costs Knowledge System (v. 2.2), The World Bank, Transport Unit – TUDTR, 2004. http://www.worldbank.org/transport/roads/rd_tools/rocks_main.htm, accessed in March 1, 2006.
2. SCHEXNAYDER, C. J. and MAYO, R. E. Construction Management Fundamentals, McGraw-Hill Higher Education, Boston, MA, 2003.
3. FLYVBJERG, B. H.; METTE, S. and BUHL, S. Underestimating Costs in Public Works Projects, Error or Lie. *Journal of the American Planning Association*, Vol 68, No 3, 2002, p. 279–292.
4. LEVINSON, D. and KARAMALAPUTI, R. Predicting the Construction of New Highway Links. *Journal of Transportation and Statistics,* Vol 6 (2/3), 2003, p. 81–89.
5. BUYS, P.; DEICHMANN, U. and WHEELER, D. Seminar at Center for Global Development, 2006. http://www.cgdev.org/doc/event%20docs/Trans–Africa%20Network%20(Color%20Version).pdf, accessed in April 1, 2006

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