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The Prediction of the Costs of Maintenance

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Summary

During the life time of a construction the costs for operation and maintenance exceed the initial construction costs by a factor of at least 3 to 5. More and more investors and owners realise this fact and put more emphasis on the real life cycle costs of a building. They want in particular to know the future costs for maintenance and the factors determing them. This knowledge is requested already in the phases of investment studies and preliminary design. Two approaches are being presented and illustrated in this paper. For obtaining reliable results the two approaches should be applied in combination. During the design phase the bottom up approach can also be used to evaluate different options for the construction with regard to the respective to the maintenance costs to be expected. Therefore the presented instruments are supporting the investor in choosing the most suitable strategy.

1. The significance of the prediction of the costs of operation and maintenance

Owners, planners and users of constructions and buildings are realising more and more that the costs for maintenance and operation are at least as important for the economy as the initial construction costs. Investigations prove that the aftermath of the initial investment may vary between 1 and more than 20% per year. The lower values of 1 to 10% are standing for appartment and office buildings, values in the range of 10 to 20% for public infrastructures, utilities and industrial buildings and the the values over 20% resulting from schools and hospitals. In a life time cycle view these aftermath costs for operation and maintenance exceed the initial construction costs easily by a factor of 3 to 5.

Up to now, very often only the annual costs of the initial investment for the construction, i.e. interests and redemption charges have been analysed already in the early phases of planning. But the decisionmaking bodies and investors need facts and figures of the life cycle costs including the costs for operation and maintenance in order to properly assess the chances and risks of a planned investment. One major problem consists in predicting the annual costs of operation and maintenance already in the early design phase.

2. Two approaches for the prediction of the costs of maintenance

In this paper the prediction of the costs of maintenance for constructions in the design phase (or in an early phase of operation) is explained in more detail. We distinguish between the top down and the bottom up approach.

2.1 Top down approach

The expected costs for maintenance for a specific construction are predicted by comparison with similar constructions. The experience gained from these similar constructions must be tranponded to the construction in question. The problem is to define and find data of similar constructions and to define the rules for proper transponding of these data. The top down approach consists of the following 4 steps:

2.1.1 Define similar constructions and subsystems
The construction for which the costs of maintenance should be determined must be subdivided into construction parts or subsystems for which data gained by experience are available. In some cases global data of more or less identical constructions are available and therefore no subdivision is necessary.

2.1.2 Data of similar constructions and subsystems
For each identified subsystem data must be found comprising investment or construction costs and costs of maintenance. Best results are obtained, when the two subsystems to be compared coincide very well and when long term records such as information about the type of maintenance work executed and its costs for each year are available. But even if you dont find such an ideal situation, do not hesitate to look for information and data everywhere - including in other countries. Remember that different subsystems have quite different needs of maintenance. It is therefore more important to distinct and define the subsystems adequately and make some extrapolations based on sound engineering judgement than to apply gained good records at the „wrongly" defined subsytem.

2.1.3 Characteristic values
For each of the defined subsystems a curve of characteristic values must be calculated. The characteristic value of one year is defined by the quotient of costs of maintenance of this specific year and the initial construction costs. One of the main traps in using characteristic values is the problem of the index-linking of currencies. We strictly adhere to the principle that the characteristic value of the year „x+n" is defined by the maintenance costs of the year „x+n" divided by the construction costs in the currency of the year „x+n". The construction costs which you will normally find in the records are the costs in the year „x". They must be indexed to the year „x+n". We strongly propose to use strictly such normalised characteristic values which are neutral to inflation. Note that these indexed construction costs at „x+n" do not correspond to the real construction costs you would face, if you wanted to build in the year „x+n". Normally the latter would be much higher, due to increased environmental and other requirements.

2.1.4 Maintenance costs
Since the curves of the yearly characteristic values for each subsystem gained in the third step are normalised with regard to currency values and indexes, it is easy to calculate the expected costs for maintenance over the years: Just multiply the characteristic value for one specific year with the construction costs of the respective subsystem and you have the maintenance costs for this subsystem for the specific year (of course expressed in the same currency value as the construction costs).

2.2 Bottom up approach

The expected costs for maintenance of a construction are being calculated by summing up the costs for every single maintenance task to be performed over the years for each subsystem. The problem consists in identifying all individual maintenance tasks, their return period and the costs for each execution. The bottom up approach consists of the following 4 steps:

2.2.1 Define maintenance units
The construction for which the maintenance costs shall be determined must be divided in its main parts and each part must be further divided in maintenance units. This definition of the maintenance units must be made strictly in view of the performance of the maintenance tasks, i.e. together with step 2. The maintenance units are not identical to the construction units and are also different to the subsystems defined in the top down approach.

2.2.2 Define maintenance tasks
For each maintenance unit all maintenance tasks from surveillance and tuning up to replacement and to partial reconstruction over a period of approximately 30 years have to be identified. It is important to define the maintenance units as per step 1 and the maintenance tasks as per step 2 from a very practical point of view. For each defined maintenance task the moment of its first occurrence, its interval and its costs have to be determined. Keeping in mind the great variety of the maintenance tasks it is obvious that the intervals vary from several times per year to once every 30 or even more years.

2.2.3 Calculate yearly maintenance costs
By summing up all data of the step 2 the maintenance costs can be calculated year by year for each maintenance unit, for each system or main part and finally for the entire construction.

2.2.4 Smoothening over 5-year periods
Due to the fact that the timing of the maintenance tasks, based on intervals as per step 2 (such as 1, 2, 5, 10, 15, 20, etc. years), you will automatically get peaks in the maintenance costs calculated as per step 3. In reality the timing of the execution of the different maintenance tasks is determined by the condition of the maintenance unit and can be chosen up to a certain extent (preventive maintenance). In order to reflect this fact, the results as per step 3 are smoothened over 5 year periods.

3. Application for a complex road system

Both approaches have been recently applied for a complex road system in Switzerland. It consists mainly of a tunnel system in an urban area and it is still in the design phase. In the following the main characteristics of the two apporaches are illustrated.

3.1 Illustration of top down approach

In view of the road system still in the design phase and considering the data and information sources which have been available to us , we have defined the following subsystems:

- tunnel construction comprising excavation, lining and inner construction in concrete and steelwork;
- roadwork;

- electromechanical systems including electrical and ventilation systems, systems for monitoring and control, sanitary systems;
- buildings comprising ventilation caverns, air intakes and outlets, transformer buildings, control centers, warehouses, etc.

For each subsystem data from different countries from more than 100 tunnels, from different types of roads and different types of buildings as well as all kinds of electrical, sanitary and ventilation systems have been evaluated. Out of these informations the following characteristic value curves have been calculated (see figure 1). The result of the calculation of the expected maintenance costs is integrated in figure 3.

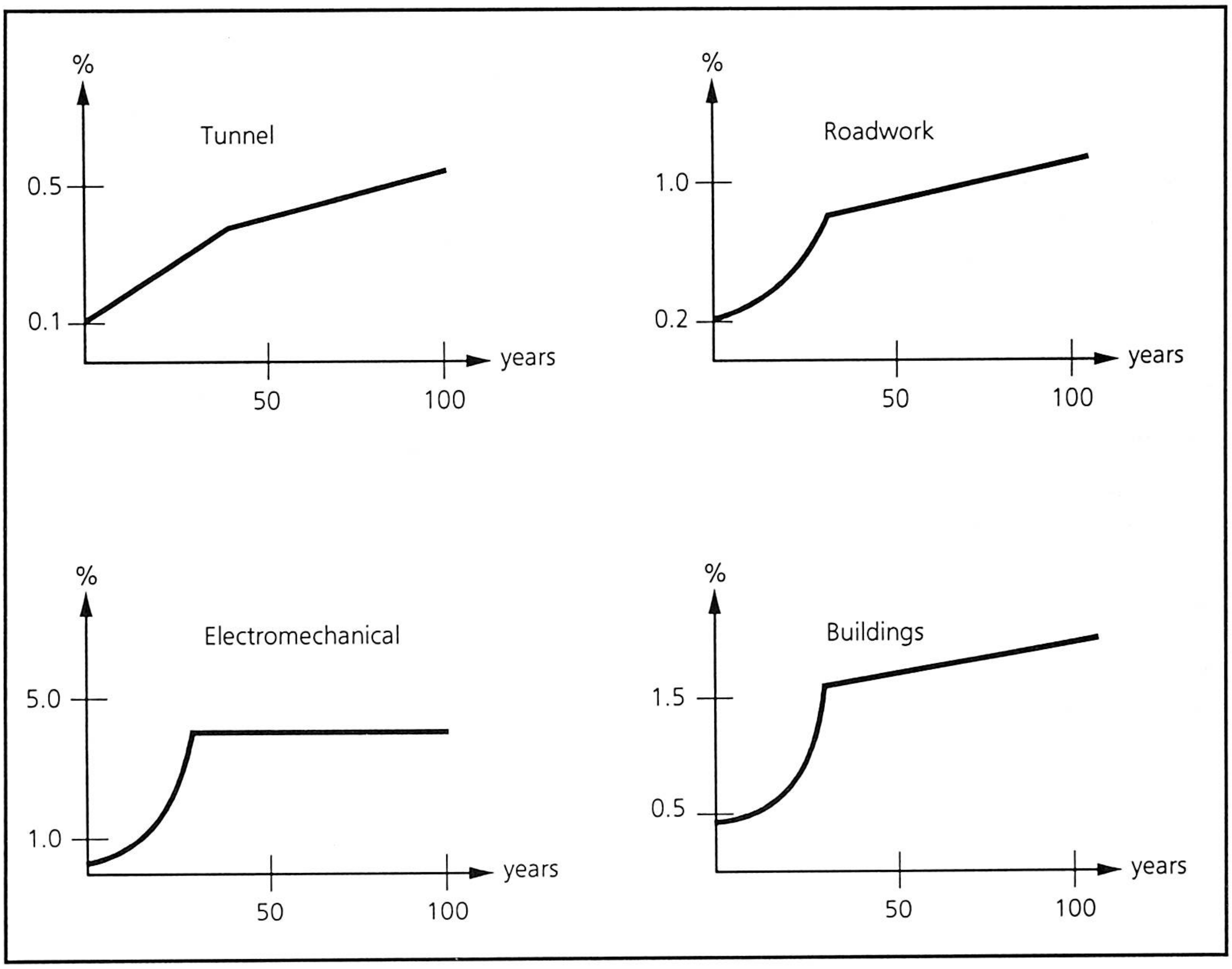

Fig. 1 Characteristic value curves for top down approach

3.2 Illustration of bottom up approach

The entire road system has been divided into approximately 20 main parts and a total of roughly 50 maintenance units. A total of 150 maintenance tasks have been defined. In addition to the cost estimate also an estimate of the duration has been made for each maintenance task. This would allow to predict also the interference of maintenance work with the traffic flow. The results of the bottom up approach are illustrated in figure 2.

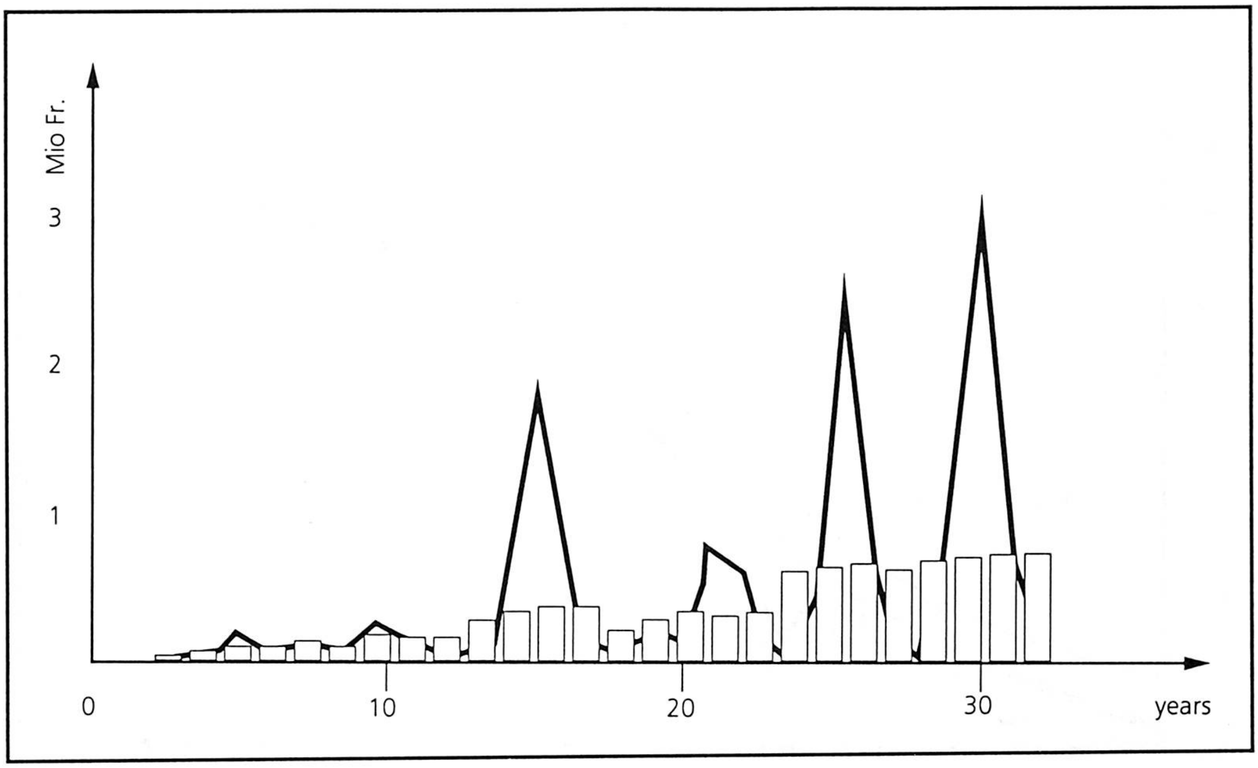

Fig. 2 Annual maintenance costs with 5 years period smoothening for bottom up approach

3.3 Prediction of the costs of maintenance for complex road system

In figure 3 the results of the two approaches are presented in one single graph. Generally speaking both approaches are fitting pretty good. Obviously the bottom up approach gives more accurate figures in the short to medium range i.e. up to 20-30 years, because it better takes into account the start up phase when the systems are new. It also covers the period when most of the electromechanical systems have already been completely renewed at least once. On the other hand the top down approach gives a better forecast of the longterm costs beyond the age of 50 years, because it reflects the growing maintenance costs when the civil engineering parts of the road system and the tunnel construction must be renewed.

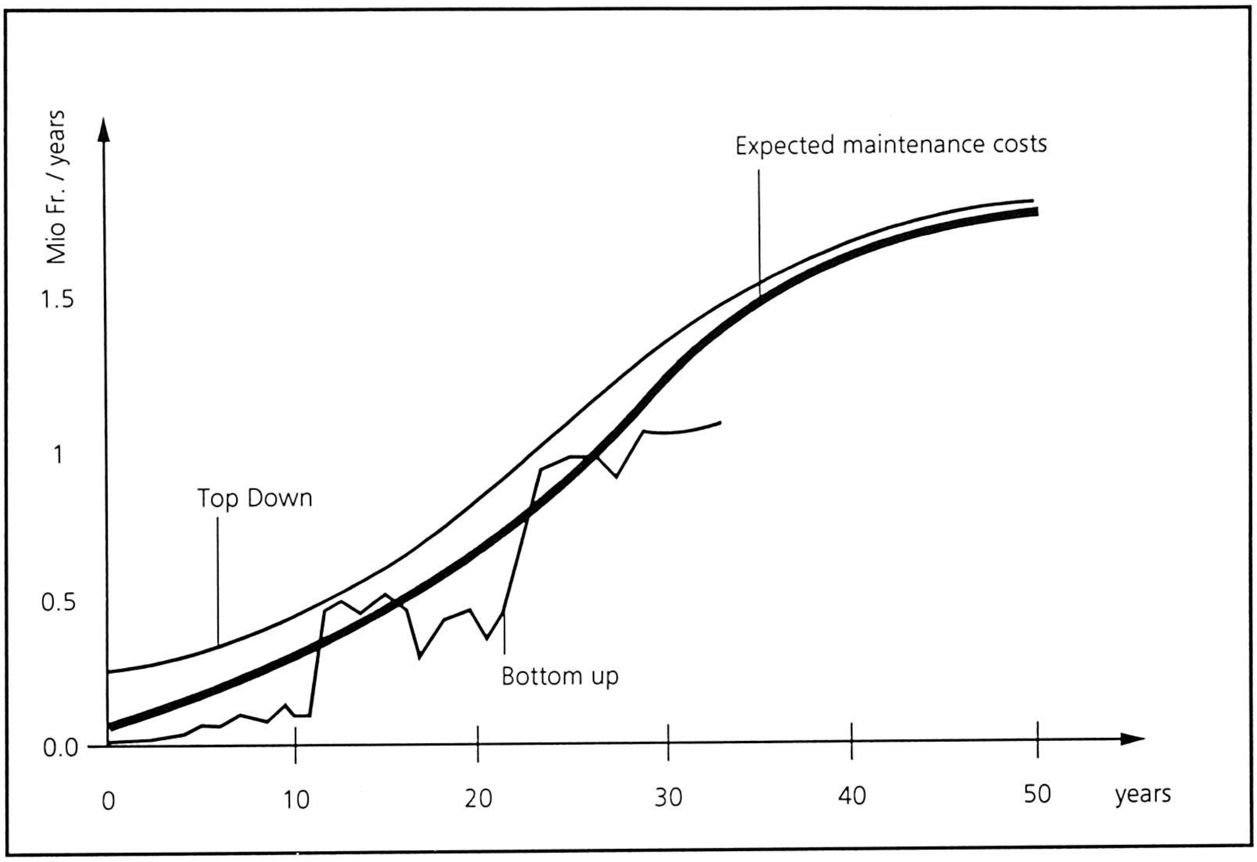

Fig. 3 Prediction of the costs of maintenance with both approaches

4. Outlook

The results of this early analysis of the maintenance costs to be expected can be used by the investor for decisionmaking. During all phases of design and realisation the presented tools, especially the bottom up approach, allows to determine the consequences of different design options. E.g. a design strategy to minimum maintenance costs or any other strategy is possible. It goes without saying that the same tool can also be used during the phase of operation for the ongoing rolling planning of all maintenance activities including budgeting, workforce planning and minimising the interference of maintenance with operation.