A Study on the Life Cycle Cost Calculation of the Maglev Vehicle Based on the Maintenance Information

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ABSTRACT: Life cycle costing is one of the most effective approaches for the cost analysis of long-life products such as the maglev vehicle. Life cycle costing includes the cost of concept design, development, manufacture, operation, maintenance and disposal. Especially, life cycle costing in the railroad industry has been focused on the maintenance cost even the maglev vehicle. In this paper, the standard, guide and maintenance information of railroad vehicle were investigated, and the unique corrective and preventive maintenance templates and software of maglev vehicle were proposed. Maintenance cost of a few major sub-systems of maglev was predicted by using the proposed templates and software. It is expected that these templates and software can help maglev vehicle operators make maintenance strategies with consideration of the cost parameter.

1 INTRODUCTION

Life Cycle Cost (referred to as LCC) means all costs from concept design and development of such system, production, operation and management, maintenance, and discard [1]. The concept of LCC was applied to US Department of Defense in 1970s, and hereafter the region was enlarged to device industry such as generation facilities and chemistry plant and to large system industry which variable regions such as aviation system, railroad system, etc. are fused in also from 1990s [2].

Especially it needs maintenances much due to long usage(more than 25 years) and it costs too much as well as the system is complex in the case of railroad system[1][3]. Therefore it may be fairly said that it is the important issue to calculate the maintenance cost in LCC calculation of railroad system. So in this research, we performed the development study of software and template of maintenance information related to repair and preventive maintenance which is suitable for magnetic levitation train and railroad system by analyzing the data related to various standards and guides to calculate the correct maintenance cost of magnetic levitation and railroad system as part of LCC modeling development of magnetic levitation and railroad system.

2 LIFE CYCLE COSTING IN RAILROAD INDUSTRY

2.1 IEC 60300-3-3

The international standard for life cycle costing, IEC 60300-3-3 has been prepared by International Electrotechnical Commission. The life cycle phases of a product suggested at the standard are consisted of concept and definition, design and development, manufacturing, installation, operation and maintenance, and disposal. Therefore, the total cost can be calculated by summing the incurred costs at each stage as shown in Fig. 1. The total cost incurring during the phases can be divided into acquisition cost, ownership cost and disposal cost.

$$LCC = C_{\text{acquisition}} + C_{\text{ownership}} + C_{\text{disposal}} \quad (1)$$

Acquisition cost can be readily evaluated compared to ownership cost which is often a major component of LCC because it is visible. Disposal cost may or may not be significant cost depends on the industry. Generally the disposal cost has been ignored in railway industry.

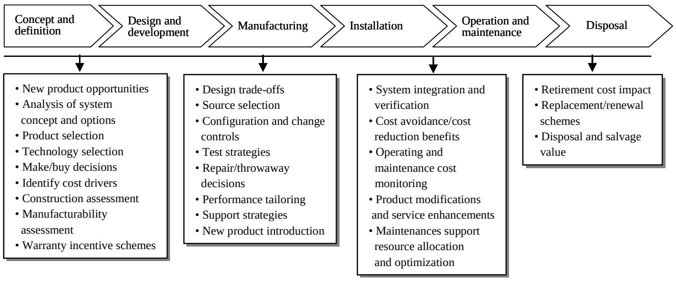

Figure 1. Life cycle phases of typical system [4]

2.2 *UNIFE LCC model*

In UNIFE LCC model, the total life cycle cost, similar to that of IEC model, can be divided into acquisition, ownership and disposal cost through whole life stage which is defined as concept and definition, design and development, manufacturing, installation including on-site testing and commissioning, operation and maintenance, and disposal stage. Since it is customer oriented life cycle cost calculation model, it emphasizes mostly the investment, operation and life support cost. The disposal cost is often neglected.

$$LCC = C_{\text{investment}} + C_{\text{operation}} + C_{\text{life support cost}} \quad (2)$$

2.3 *Life cycle costing process*

As shown in Fig. 2, generally, the life cycle costing activities begin with defining the problem to be modeled. Life cycle cost modeling is highly dependent on the scope and objectives of a model. The definition of scope covers the system characteristics like system availability and safety integrity level. And operational requirements and maintenance strategies should be developed before developing life cycle cost model.

Cost elements which represent the individual costs should be defined systematically to avoid ignoring significant cost element. Development of a cost breakdown structure of a model is well known method to identify cost elements. The cost breakdown structure presents a breakdown of costs incurred over the major phases of the life cycle of a product. And the product or work breakdown structure is composed of a detailed breakdown of hardware, service and data identifying all major tasks and supporting work package.

After defining the cost elements, we have to put relationships among them in system modeling stage. The relationships should be modeled from many viewpoints such as availability, maintainability, logistics, risk and human error in the system.

Since the accuracy of input data is crucial to improve the certainty of life cycle cost analysis. A great effort should be given to prepare a set of data. A set of data for LCC analysis can be collected through surveys or questionnaires, target research, statistics, cost reports, historical database, contracts and cost proposal et al. When actual data is not available, the data may be estimated by applying stochastic, parametric or analogous techniques.

To make a long-term financial plan, a cost profile over the whole life is key information. A cost profile of each design case should be compared on a common basis or reference point, when making financial judgments. A cost profile can be developed by considering the effect of inflation, interest rate, and exchange rates, taxation etc.

In the evaluation stage, sensitivity analyses should be performed to identify high cost contributors. This information reveals cost drivers so that alternatives may be effectively found. Also uncertainties of the input data should be considered.

Life cycle costing is an iterative work to find the most desirable alternatives. The iterative work means that a baseline system, which is an initial design concept, maybe improved throughout the iterative LCC analysis.

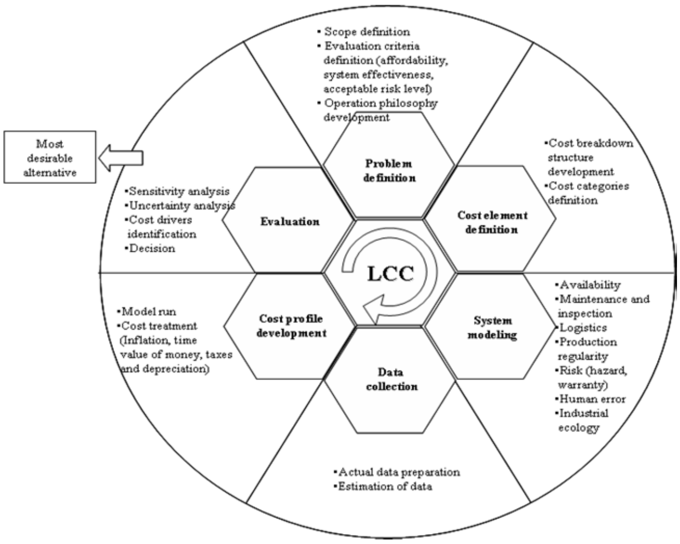

Figure 2. A typical life cycle cost modeling process [7]

3 MAINTENANCE INFORMATION TEMPLATE FOR THE MAGLEV SYSTEM

To calculate the costs of preventive maintenance tasks for the maglev and railroad system, maintenance information templates (for both preventive maintenance and corrective maintenance) appropriate for maglev system were utilized based on an analysis of relevant standards and models [8-10]. The main purpose of the maintenance information template for the maglev and railroad system used in this study is to calculate the expected costs of maintenance. The templates include items to calculate expected maintenance costs [4, 5] and items of RAMS (Reliability, Availability, Maintainability & Safety) for the maglev and railroad system [11].

The “maintenance unit” of a maintenance task is set at the SRU (Shop Replaceable Unit) level, which is the sub-part level at which the actual repair maintenance is conducted after the removal and/or attachment, rather than the LRU (Line Replaceable Unit) level, which is the removal/attachment level. The operators actually conduct maintenance tasks at the SRU level. If only the LRU is considered, there is no way to calculate failures at the sub-part level, at the SRU, after a part is replaced at the LRU level [4].

Therefore, the adequacy of the maintenance task is evaluated and the failure consequences are analyzed at the SRU level where the actual maintenance is conducted for the braking system. As shown in Tables 1 and 2, when the “maintenance level” is defined, the first line and the second depot are combined into the same maintenance level and are defined as the “line” level. At the third place, where the SRU repair is conducted, the component workshop is defined as the “shop” level in the suggested template. Such classification is drawn by combining the opinions of the maintainer, operators and the manufacturer’s designers [12, 13]. The “maintenance unit” of maintenance tasks according to the maglev and railroad system failure modes is defined by the designer, whereas the “maintenance levels” are defined by the operator’s maintenance operation policies. The SRU’s “failure mode” analysis item, relevant to an evaluation of the maintenance tasks, is added to the template. In addition, the material cost necessary to calculate the maintenance cost includes the cost of consumable materials as well as the cost of the SRU level spare parts used by the line and the shop. However, one of the differences between the corrective maintenance template and the preventive maintenance template is the quantity of maintenance used when calculating maintenance cost. In corrective maintenance, the quantity of maintenance depends on the failure rate (failure/hour) of the SRU failure mode, whereas in preventive maintenance, the quantity of maintenance depends on the interval (day, month, year, or km) as previously designed.

Moreover, even when there is maintenance information, as in Tables 1 and 2, for the calculation of the expected expenses incurred during maglev and railroad system maintenance, the global data items should be defined separately. These include labor costs, the number of trains, annual average mileage and life cycle information [4, 6].

Table 1. Corrective maintenance template items

ID. No	
Item Name (SRU)	
Quantity	
Failure mode	
Maintenance task	
Spare Parts	
Failure rate (in failure/h)	
Repairable (Y/N)	
Line (1st, 2nd) Material cost	Spare Part Cost
	Consumable Part Cost
Shop (3rd) Material cost	Spare Part Cost
	Consumable Part Cost
1st, 2nd line	Personnel
	Man hours
3rd shop	Personnel
	Man hours
Skill level	
Notes	

Table 2. Preventative Maintenance Template items

ID. No	
Item Name (SRU)	
Quantity	
Failure mode	
Maintenance Action Codes	
Maintenance Task	
Spare Parts	
Interval	
Interval unit (km/d/m/y)	
Line (1st, 2nd) Material cost	Spare Part Cost
	Consumable Part Cost
3rd shop Material cost	Spare Part Cost
	Consumable Part Cost
1st, 2nd line	Personnel
	Man hours
3rd shop	Personnel
	Man hours
Skill level	
Notes	

4 LCC SOFTWARE FOR THE MAGLEV SYSTEM

And, we developed LCC analysis software based on such Maintenance information template for the maglev system. LCC analysis software is a software by which we predicts the necessary cost in the operation during Life Cycle Cost(LCC) and in introduction of system of magnetic levitation train system. First of all, the costs are classified by "Initial Investment Cost" and "Operation and maintenance cost" like figure 3 in LCC S/W, and are calculated by sectionalizing the detail cost as per cost.

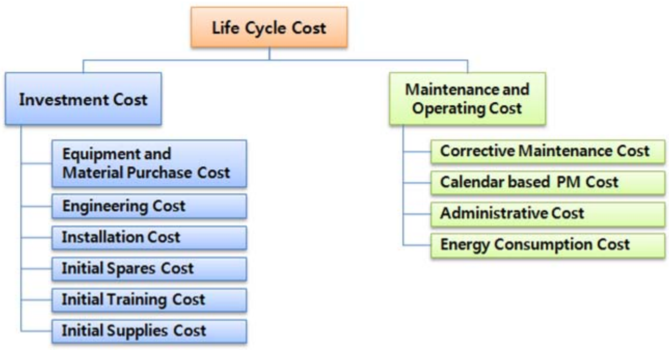

Figure 3. Cost structure of LCC software

At this time, "Initial Investment Cost" in LCC S/W is calculated by sum of reserve stock cost, training and education cost, purchase and install cost of system, engineering cost, consumables purchase cost, and maintenance equipment purchase cost like figure 3, and the initial investment cost is calculated by way that it is generated whenever the life period arrives and it introduces at the first time as per system.

And, "Cost of Operation and Maintenance" includes two models, outline and detail model according to calculation method, and the entry item and calculation method is different as per each model. The detail model can be used, in which we can LCC cost by using detail maintenance information if there is detail information related to breakdown and repair such MTBF, MTTR, period of preventive maintenance of each item and you know the structure of low item which composes magnetic levitation train and railroad system, and the outline model, and outline mode can be also used, in which LCC cost is calculated by using minimum maintenance information. But, the software was developed so that the annual maintenance cost can be calculated by using simulation method which causes maintenance and preventive maintenance according to period of preventive maintenance and failure rate, receiving the number and unit price, the number of reserve stocks, maintenance information, preventive information, information of consumables when repairing, etc in detail according to each item of system to calculate LCC cost in case of detail mode. Especially the cases that each item is impossible to repair and possible to repair are classified, and the software was developed for the LCC to be calculated by reflecting cost item which is caused in the course of maintenance of railroad and real magnetic levitation system, estimating the repair cost by applying and selecting replacement cost of item, unit price of item, consumables, etc properly as per each case. Generally the failure rate and period of preventive maintenance are different in case of each item. Therefore, the analysis is more realistic in Detail model than in outline model because the cost of maintenance is different every year. First of all LCC Cost can be calculated by summing during the lifespan of system, calculating the cost of annual management and maintenance after receiving and adding the minimum information such as cost of maintenance of 1 year-unit, preventive maintenance cost, administrative management cost, energy cost, etc in case of outline model.

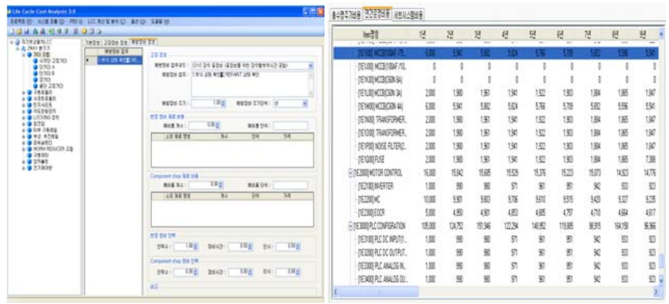

Figure 4. LCC Software

Also, these two modes facilitate the LCC analysis by showing and converting from LCC result of future value which is calculated by introducing the concept of interest ratio in LCC calculation into current value. And, the result of LCC calculation facilitated the analysis by showing it as chart like figure 4 and expressing as figure in detail as per sub system, year, kind of cost, and the analysis function was structured to supply the function which sends the table of result with file and makes it possible to analyze the sensitivity by creating alternative. And, LCC S/W stores all result data and entry data which are used in calculation into database, and it is possible to develop the database by using Microsoft Access(*.mdb) format and to execute it for itself without the connection of network. And, it is possible to send/receive by using Microsoft Excel file to use database in similar projects by various workers, and the software was developed to make it possible to share it between the analyzers by send/receive function by Microsoft SQL Server.

5 CONCLUSIONS

In this study, we presented a life cycle cost (LCC) model and software for the Maglev and Railroad system. Our model focused on calculating the maintenance process. The accuracy of LCC model is depended on the reality of simulation model and data base for calculation. Generally, the LCC model and software verification processes take much time and it is hard to quantify the difference between physical system operation condition and that of assumed. Also the uncertainty of input data needs be tested from many points of view.

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