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Life Cycle Cost Prediction for Rolling Stocks in Maintenance Phase Based on VBA Language Program

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Abstract

In order to predict and analyze the LCC during rolling stocks' maintenance phase, provide the important support for the decision during rolling stocks' design, production, operation and disposal, mitigate the risks for high expenditure, the LCC prediction software is developed with VBA programming language in Microsoft Excel environment based on various rolling stocks' maintenance scenarios. This software can collect the LCC input and predict the LCC during rolling stocks' maintenance phase. The data input is based on the history data and RAMS information for each system and approved by the engineers. This software is validated by several systems and a specific metro project. It shows very wide applicability for LCC prediction for comparing and analyzing for customer and design and friendly interface to the users.

Keywords: *rolling stocks, life cycle costs, maintenance costs, software development, VBA*

1. Introduction

After a period of declining utilization, the use of rolling stocks is now booming increasing and is predicted to continue the increase in a very long period as the speed and convenience of rolling stocks transport in comparison to the increasing traffic densities and delays of traditional transport [1]. Meantime, rolling stocks production and design is a long-term and complex activity with high investment costs. After produced, it is difficult and expensive to modify the initial solution.

The main goal of the life cycle studies is to support the product development by predicting the LCC impact and taking engineering actions [2]. Therefore, the design solution of the rolling stocks shall be detail evaluated in the very initial phase. The customers of rolling stocks take the quality of rolling stocks into consideration during rolling stocks procurement as in other filed. Furthermore, they gradually pay more attention on LCC for rolling stocks requiring the reliability, availability, maintainability and safety (RAMS) in the last decade. The LCC evaluation is one aspect of RAMS evaluation. With the precondition of ensuring the normal operation of rolling stocks, the LCC shall be minimized during each phase of rolling stocks. LCC involves the evaluation of all future costs related to the life cycle of the system [3]. In addition, strategies and technologies shall be developed to evaluate rolling stocks' LCC. LCC is the cumulative costs of rolling stocks procurement and operation with the period from the conceptual phase to the disposal phase. How to reduce LCC with precondition of ensuring the rolling stocks' performance has become customers and producers mutual

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concern. Because operating and maintenance costs accounted for more than 66% of the LCC [4], it is necessary to carry out effective prediction, analysis and evaluation of LCC during the maintenance phase.

Currently the world has carried out research on rolling stocks' LCC and had remarkable achievements, but LCC studies in China still in the preliminary phase. Lin exposited the definition of LCC, system modeling, data collection, costs characteristics research and evaluation to describes the LCC analysis [5]. Wang proposed the LCC model with six main costs items for electric locomotives, and developed the analysis software for the electric locomotives [6]. Jun and Kim presented a life cycle costs model of railway vehicle based on the UNIFE LCC model for evaluation the life cycle costs of total railway system [7]. Xu proposed the LCC model in the means of costs elements breakdown for the 25-style railway passenger vehicles [8]. Zhou and Xie described the basic process of software development for the LCC of rolling stocks, provided the basic principle and framework for software development [9]. According to the investigation from Yu, rolling stocks design philosophy for abroad modern companies have transferred from the core aim of function design to the RAMS and LCC engineering design, the ideas extended from solid rolling stocks products' design to the virtual design rolling stocks services [10]. Liu proposed the concept of optimal LCC, identified five main costs items and verified via the empirical analysis [11]. Dina et al. proposed an activity-based life cycle costing model and stress the importance of AB-LCC costs systems [12].

According to existing literature, the research of product LCC is mainly on the model creation. There are only a few studies as regarding to software development. Therefore, in order to meet the requirements of the customer and ensure the reliability, availability, maintainability and safety of the rolling stocks, the software is developed for LCC prediction, analyze and compare the maintenance phase costs. This software is created with VBA (Visual Basic for Applications) program language based on Excel spreadsheet.

In the design phase, the focus is usually on minimizing the rolling stocks' procurement costs whilst often little attention is paid to rolling stocks' maintenance costs. In addition, it is extensively recognized that the costs related to the operation and maintenance of the system during the life cycle could be many times higher than the procurement costs [13]. In order to solve this problem, LCC predictor software is developed majorly covering the LCC predication for rolling stocks during maintenance.

2. LCC Prediction for Rolling Stocks

In normal LCC prediction, LCC's practical application is limited by the lack of reliable data, complexity of the development process and conceptual confusions [14]. Therefore, it is essential to create a practical LCC model based on the reliable input. The LCC modeling is the precondition and base for calculating and analyzing the LCC costs. The success of a project mostly depends on the accurate analysis of the initial prediction costs from the phases of design covering construction costs, operating costs and operation and maintenance costs [15]. Studies reported in Dowlatshahi and by other researchers suggest that the design of a product influences between 70% and 85% of the LCC [16]. Designers can substantially reduce the LCC of a product by taking proper consideration to life cycle impact of their design solutions [17]. While such a LCC analysis requires the experience for different systems and a significant base of performance data. We adopt the breakdown method to analyze and calculate the LCC, so the primary work is to establish the LCC breakdown structure. According to IEC 60300-3-3, the LCC breakdown structure is illustrated in Figure 1.

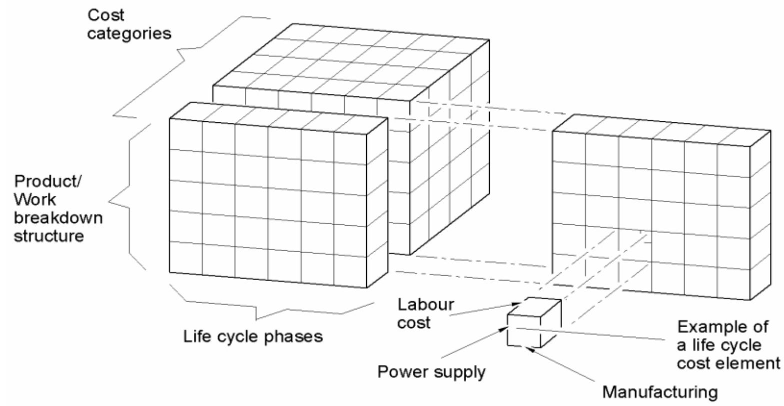

Figure 1. LCC Breakdown Element Concept

2.1. LCC Breakdown Structure for Rolling Stocks

The product structure tree (PST) is used to show the hierarchical relations between product and its systems, parts. The PST shows the hierarchical relations in both function and installation relations between parts and systems.

Accordingly, the structure of the rolling stocks can also be breakdown in the product structure tree format. The root node of the PST for rolling stocks is marked with the identification code “0”. Based on the structure features and function of rolling stocks, it can be breakdown into secondary layer with car body, gangway, bogies, propulsion, drive, brake, TCMS, PIS, passenger doors, cab doors, detrainment device, HVAC and so on systems. Each system can be marked with the secondary layer with identification code “1”, “2”, “3” and so on. Each system can also be subsequently breakdown into the third layer structure. In this layer, the parts will be detailed down to the work of minimum repairable units (MRU) in principle. Take passenger door system as an example, it can be breakdown into threaded rod clean and grease, sealing rubber replace, threaded rod replace and so on. Then each maintenance work can be allocated with one specific identification code. The work for threaded rod clean and grease, sealing rubber replace, threaded rod replace is subsequently marked with the identification code “1-1”, “1-2” and “1-3”. The PST modeling of the rolling stocks is illustrated in Figure 2.

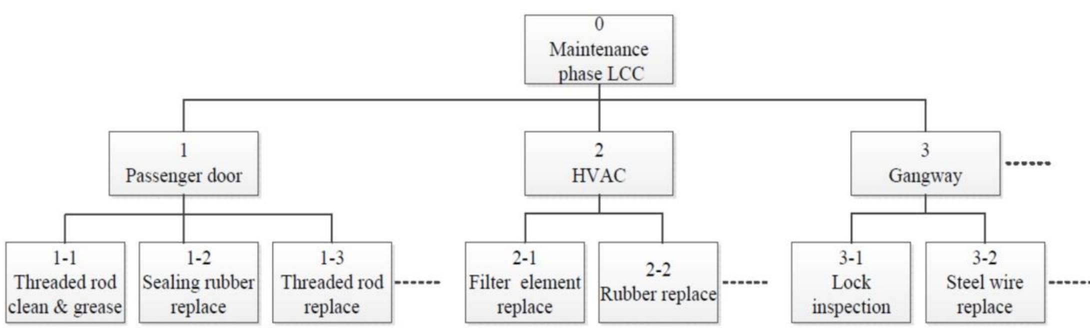

Figure 2. Product Structure Tree

If we consider it from the point view of maintenance and repair, the systems and parts can be divided into free maintenance systems/parts and maintenance systems/parts. For example, car body, bogie frame, window panes are contractual with the same life span of the rolling stocks, so they shall be designed and produced free of maintenance within the life span of the rolling stocks. For this kind of parts, it will not appear in the PST of rolling stocks for LCC prediction. Other systems/parts may get aged, worn out, damaged or performance degradation, therefore, maintenance, repair or replace work is necessary.

2.2. Phase of Life Cycle

The life cycle of normal production can be divided into 6 phases: concept and definition, design and development; production; installation; operation and maintenance; disposal. The LCC predication, analysis and evaluation can be carried out in different phase according to different rolling stocks life cycle phase and different costs elements. The LCC for the maintenance phase depends on the overall aim: (1) Contractual requirements; (2) To minimize the maintenance costs; (3) Promote the maintenance efficiency of the maintenance and repair; (4) Reasonable design for minimizing the materials costs. The work of maintenance and repair phase is the most complicated. On one hand, the train sets shall be operated normally, on the other hand, various maintenances and repair work is required. Therefore, the maintenance and repair work should be detailed. For calculation and compare easy purpose, the LCC of rolling stocks is calculated based on one year interval. The predicated life span is about 30 years to 35 years for rolling stocks. During this period, several maintenances and overhauls are required.

3. LCC Breakdown for Maintenance Phase

The costs items breakdown is an important task. The procedure is to breakdown the LCC to several main costs units to establish main costs model. And then breakdown the main costs units into several sub costs units. The sub costs units can be subsequently breakdown to the next level until the sub costs units is the minimum evaluable unit. All the sub costs units can be combined to the LCC model.

The LCC costs for rolling stocks can be divided into several phase: concept and definition phase costs; design and development phase costs; production phase costs; installation phase costs; operation and maintenance phase costs; disposal phase costs.

3.1. Full LCC Model for Rolling Stocks

The full LCC for rolling stocks can be divided into the following items according to different phase:

$$LCC = C_{CD} + C_{DD} + C_P + C_I + C_{OM} + C_D \quad (1)$$

LCC – life cycle costs

C_{CD} – concept and definition phase costs

C_{DD} – design and development phase costs

C_P – production phase costs

C_I – installation phase costs

C_{OM} – operation and maintenance phase costs

C_D – disposal phase costs

3.2. LCC Model for Operation and Maintenance Phase Costs

The LCC model for operation and maintenance phase costs can be breakdown to operation phase costs and maintenance costs.

$C_{OM=} C_O + C_M$ (2)

C_O – operation costs

C_M – maintenance costs

Operation and maintenance phase costs takes large portion of rolling stocks full LCC, and maintenance costs is the most complicated item within it. Maintenance is commonly divided into preventive maintenance (scheduled, on-condition and predictive) and corrective maintenance [18]. Therefore, maintenance costs can be split into preventive repair costs and corrective maintenance costs. According to regular rolling stocks maintenance stipulation, preventive repair costs include regular repair costs and overhaul costs. Because overhaul takes long time, covers most of the parts, so the costs are very high. Therefore, we set it as independently as important costs during modeling the rolling stocks LCC.

$C_M = C_{MC} + C_{MP} + C_{MO}$ (3)

C_{MC} – corrective maintenance costs

C_{MP} – preventive maintenance costs

C_{MO} – overhaul costs

The costs composition of preventive maintenance costs, corrective maintenance costs is the same, so the model can be illustrated as following (taking preventive maintenance costs as an example)

$C_{MC} = C_{MCL} + C_{MCF} + C_{MCC} + C_{MCS}$ (4)

C_{MCL} – labor costs

C_{MCF} – materials costs

C_{MO} – overhaul costs

C_{MCC} – costs for contract suppliers' service

C_{MCS} – software maintenance costs

The employment costs could be split into three major sub items: Recruitment costs, additional production costs and training costs [19]. The costs for contract suppliers' service and software maintenance only have labor costs, so we simplify this model putting them in the labor costs C_{MCL}.

4. VBA Software Development

4.1. Concept Design of the VBA Software

4.1.1. General Description for VBA Software in Excel: Both VBA and VB (visual basic) are object-oriented, visualization and event-driven programming advanced language. VBA is a macro programming language under VB framework. Compared to VB, VBA is applicable to various application programs in Microsoft Office. Via VBA program, the users can freely access the text with Microsoft Office format. Furthermore, the operation can realize automation, universality and interaction [20]. In this paper, it is integrated in Excel software with excel function and suitable for dealing with mass data.

4.1.2. Structure of the VBA Software: In order to realize different function, the LCC predication software for rolling stocks' maintenance phase is developed with the following 5 function model: Basic information management model, data input model, maintenance materials costs prediction model, maintenance labor hours prediction model and user guide model.

1) Basic information management model

The basic information management model includes the general information for the project and the rolling stocks. For example, project name, service lifespan, rolling stocks' configuration, failure category, annual operation distance and so on. During the computing, the evaluation time span should be considered first [21]. The basic information is the input for the final LCC calculation. It is finalized after the very preliminary conceptual design phase. Therefore, it can be filled by the LCC engineer only. After input, this model shall lock the information and the area for any unintended change by any suppliers or engineers in the following procedure: go to Tools of Excel menu, Protection, Protect the Sheet and select all of the options with a check mark.

2) Data input model

The LCC of rolling stocks' maintenance phase target shall be fulfilled with the precondition of ensuring the performance of rolling stocks meet the requirements of RAMS. The relevant data from observation of rolling stocks operational reliability can be applied successfully for optimization of conditions of the maintenance [22]. The accuracy of LCC model depends on the reality of simulation model and data for the calculation. In order to make the information collection more practical, effective, and efficient, there needs to be in place information collection system that makes it possible to integrate information from various sources and different product life cycle phases [23]. The function of this model is inputting the data for maintenance the rolling stocks. All input data is inherited from the history data of similar system or from FTA (Fault Tree Analysis), FMECA (Failure Mode, Effects and Criticality Analysis), CCA (Cause Consequence Analysis) FBDA (Failure Block Diagram Analysis), and HAZOP (Hazardous Operability Analysis). The data includes component name, type of maintenance, task description, elapsed time hours, quantity of parts required for maintenance, price for repairing or replacing, frequency of maintenance and so on. All information related to a certain system rather than the project or the rolling stocks' characteristics are input in data input model only. This model also integrates an automatically error check function which can identify the input error timely.

3) Maintenance materials costs prediction model

The maintenance materials costs prediction model is one of the output models. Since a part can be either repaired or replaced at different costs, the supplier has to estimate the probability for a part to be repaired and replaced based on design knowledge and in service experience. The suppliers also have to include a replacement price and/or a repair price. Based on the input data in the input model, the maintenance materials costs is automatically calculated and showed in this model. It includes the following information: preventive maintenance costs, overhaul costs and corrective maintenance costs for each year in the lifespan of the rolling stocks. It can also automatically accumulate the materials costs for defined years. The costs of the unscheduled maintenance materials needed during the warranty period is not included in the sheet calculation results since it's costs is included in the rolling stocks' warranty already.

4) Maintenance labor hours prediction model

The structure of the maintenance labor hour prediction model is the same with that of maintenance materials costs prediction model. The maintenance labor hours are automatically calculated and showed in this model. It includes the following information: preventive maintenance labor hours, overhaul labor hours and corrective maintenance labor hours for each year in the lifespan of the rolling stocks. It can also automatically accumulate the labor hours for defined years.

5) User guide model

This model can provide the support and help for the users, including the overview and operation procedure of the software. Based on the software's requirements concept, the workflow brief chart is showed in Figure 3.

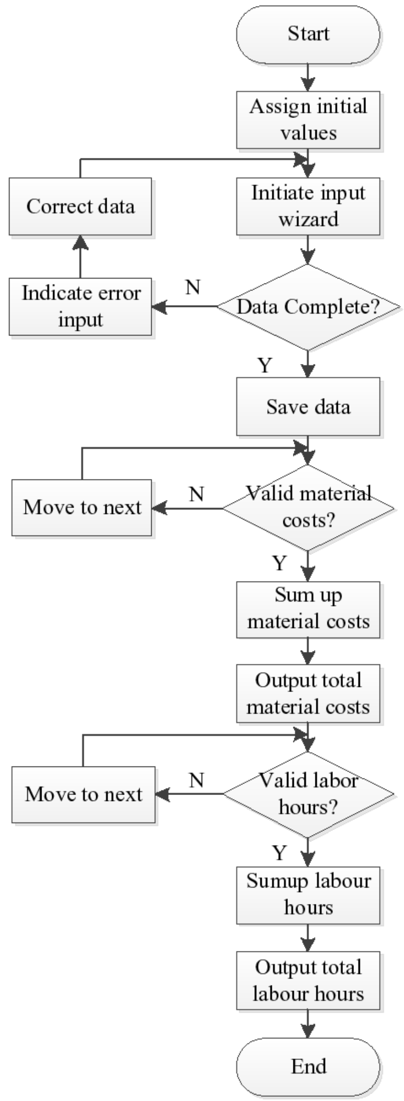

Figure 3. Workflow for LCC Predictor

4.2. Software Detail Design

The excel spreadsheet includes four worksheets, which is project description, input sheet, annual materials costs and annual labour hours separately. Correspondingly, each worksheet relates to a software model. The VBA program editor can be accessed by the following path in Excel 2003: select Tools menu in excel, then click Macro, finally click Visual Basic Editor, or just press shortcut keys Alt + F11. Input the name of the macro in the pop-up window.

Variable data can be deemed as a single event or a series of smaller event subsets based on the grouping information. In order to ensure the required data is correctly input in the input sheet, a Wizard is developed to help the users. The interface of the wizard is showed in Figure 4.

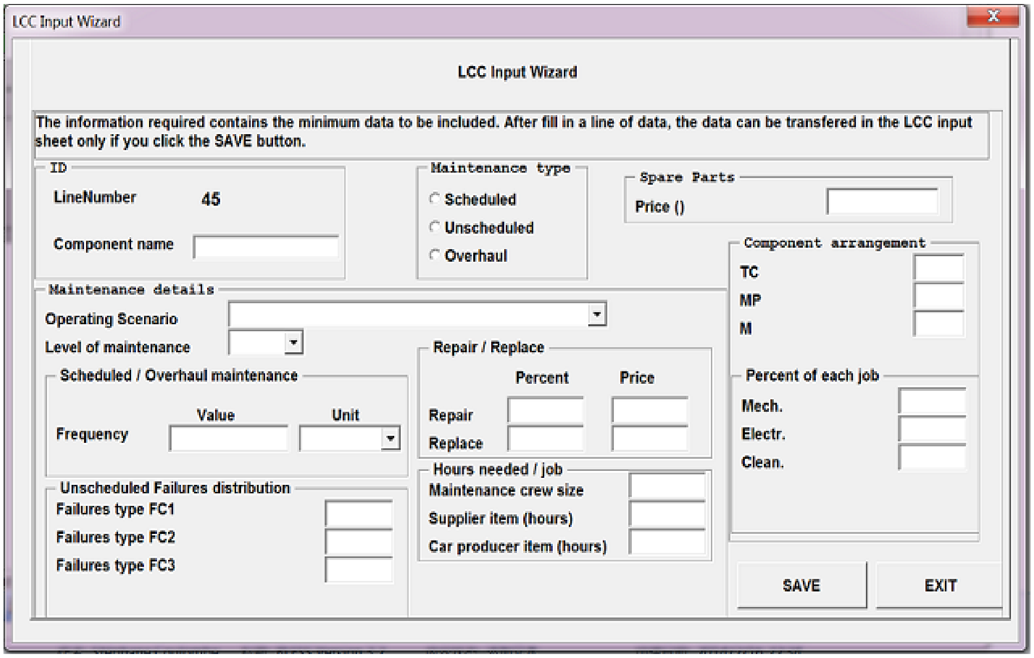

Figure 4. Interface of Inputting Wizard

In order to create the wizard, the first step is to create user windows which include a series of command buttons, right-click the command button, and then click View Code on the shortcut menu. Visual Basic Editor is activated. Enter the code between the Private Sub CommandButton1 statement and the End Sub statement to create the required command for each command buttons. The wizard window can be disappear in the display and remove from the memory with the Unload method after finish data inputting. After being unloaded, all the relevant memory is withdrew, so the user cannot communicate with the window anymore. One section of the program for SAVE function is showed below:

```
Private Sub SaveWizard_Click()
Dim mes As Integer
   If Checkdata Then
      Writedata
      Mes = MsgBox("Save finished", vbOKOnly, "Save confirmation")
      If Not inline Then
         InputLine = InputLine + 1
         Linenumber.Caption = InputLine - 12
      Else
         WizNewLine
         ActiveWorkbook.Sheets("Input Sheet").Cells(inputLine, "A") = Empty
         Unload InputWizard
      End If
   Else
      Mes = MsgBox("Error in the data, change the data in red and try saving again", vbOKOnly, "Unable to save, error in data")z
   End If
End Sub
```


5. Practical Application

To prepare a LCC Analysis we refer to reports such as Preliminary Maintenance Analysis, Preliminary Maintenance Plan, Preliminary Reliability Analysis and the Subdivided Equipment List from each supplier, which presents the basic data for LCC costs information per system.

What if some parts are impacted by both normal preventive maintenance and overhaul? Here is an example below: A filter is replaced on a HVAC every two month and the HVAC overhaul is done every 5 years. During the HVAC overhaul, the filter will also be replaced. How can the filter replacement be cancelled at the 5 years period since it is already done as part of the overhaul? On the first line, the filter is replaced every two month. On the second line, the HVAC is replaced in 5 years overhaul and on the third line a filter change with a frequency of 5 years and a negative man-hour and negative parts costs (Table 1). This will cancel the filter change at 5 years that is included in the second line already.

Table 1. A Maintenance Example

Component	Level of maint(R)	Crew size(U)	Hours(V + W)	Mat. Costs (AH)	Freq(AV)
Filter change	1	1	0.5	80 RMB	2 month
HVAC Overhaul	1	1	10	40000 RMB	5 years
Filter adjustment	1	1	-0.5	-80 RMB	5 years

The prediction of the vehicle life cycle costs was created according to the suggested maintenance requirement of the vehicle and system device, and the main maintenance content of each procedure. Take Shanghai Metro Line 13 for example, all the relevant parameters for this project is as following:

- Annual running distance 125,000 km per 6-cars configuration train
- Annual operation time 6,935 hours
- Annual power-on time 8,760 hours
- Lifetime 30 years
- Round trip 80 km
- Man-hours rate 40 RMB/hour/man
- Electric costs 0.8 RMB/kilowatt-hour

This system can calculate the LCC system by system, take the passenger door system as an example, we get all the input data such as components' name, replace price, maintenance frequency and so on from a door supplier and confirmed by the responsible engineer. For details of the original input data for door system, please refer to Table 2. All the data is input into the Input Sheet via the Input Wizard line by line. After input, we click the calculate button in the upper side, the maintenance materials costs and Maintenance labor hours is automatically given in the relevant excel sheets, which is 469110 RMB and 387.54 hours separately in the first ten years. When all the information input, the following LCC prediction result was obtained for each system separately in Table 3.

Table 2. Door System Maintenance Data

Breakdown structure	Components	Scheduled (SM)	Unscheduled(UM)	Overhaul(OH)	Task Description	Mainten. crew size	Replace Price per piece (RMB)	% Replace	Frequency	Frequency Unit of measurement
1-1	Electric	1			Safety	1			3	Month

	driven passenger door				inspecti on					
1-2	Electric driven passenger door	1			Inspect ion	1			1	Years
1-3	Threaded rod	1			Clean and grease	1			1	Years
1-4	upper rail cpl.	1			Clean and grease	1			1	Years
1-5	Bearing wheel cpl.			1	Replac e	1	90	100%	10	Years
1-6	Anti-jiggle cpl.			1	Replac e	1	78	100%	10	Years
1-7	Sealing rubber	1			Replac e	1	416.1	100%	5	Years
1-8	Sealing rubber	1			Clean and grease	1			2	Years
1-9	Finger protection rubber	1			Clean and grease	1			2	Years
1-10	Finger protection rubber	1			Replac e	1	326.0 4	100%	5	Years
1-11	Release door switch cpl.			1	Replac e	1	388.8	100%	15	Years
1-12	Isolated door switch cpl.			1	Replac e	1	337.0 9	100%	15	Years
1-13	Door position switch cpl.	1			Replac e	1	259.6 4	100%	5	Years
1-14	Nuts cpl.			1	Replac e	1	392.7 2	100%	10	Years
1-15	Damper			1	Replac e	1	18.34	100%	10	Years
1-16	Stainless steel wire for opening doors	1			Replac e	1	65.46	100%	5	Years
1-17	Threaded rod		1		Replac e	2	1061	100%	0.5	Years
1-18	Finger		1		Replac	2	537.9	100%	0.5	Years

	protection rubber				e		7			
1-19	Sealing rubber		1		Replace	2	686.57	100%	0.3	Years
1-20	Emergency egress device		1		Replace	1	560.54	100%	0.2	Years
1-21	Door plate		1		Replace	2	6226	100%	0.5	Years
1-22	Motor		1		Replace	1	7286	100%	0.5	Years
1-23	Bearing wheel cpl.		1		Replace	2	148.5	100%	0.5	Years
1-24	Anti-jiggle cpl.		1		Replace	2	128.7	100%	0.5	Years
1-25	Nuts cpl.		1		Replace	2	648	100%	0.5	Years
1-26	Damper		1		Replace	1	30.27	100%	0.1	Years
1-27	Stainless steel wire for opening doors		1		Replace	1	108.01	100%	0.2	Years
1-28	upper rail cpl.		1		Replace	1	1349	100%	0.2	Years
1-29	Release wheel cpl.		1		Replace	1	1332	100%	0.5	Years
1-30	Stainless steel wire for opening doors		1		Replace	1	138.68	100%	0.5	Years
1-31	Bracket for threaded rod		1		Replace	1	106.21	100%	0.5	Years
1-32	EDCU		1		Replace	1	14355	100%	0.2	Years

Table 3. Materials and Persons Costs of Different Systems

Systems	Gangway		Semi-permanent couplers		Automatic couplers	
Interval	5 years	10 years	5 years	10 years	5 years	10 years
Man hours [h]	3.64	8364	57.83	69.04	37.29	42.79
Materials costs [RMB]	0	923070	172100	208000	80100	97000
Materials and persons costs [RMB]	137.2	923070	172100	208000	81505.8	98613.2

Systems	TCMS		PIS		Cab door	
Interval	5 years	10 years	5 years	10 years	5 years	10 years
Man hours [h]	8.9	12.9	451.2	1027.2	3.64	3.64
Materials costs [RMB]	34000	34000	565780	898900	1430	1430
Materials and persons costs [RMB]	34000	334000	582790.2	937625.4	1567.2	1567.2
Systems	Propulsion		Drive		Detrainment device	
Interval	5 years	10 years	5 years	10 years	5 years	10 years
Man hours [h]	19.76	59.6	99	403	456	456
Materials costs [RMB]	46880	244880	84000	113240	13600	13600
Materials and persons costs [RMB]	47625	247126.9	87732.3	128433.1	30014.6	30014.6
Systems	Brake		Passenger door		HVAC	
Interval	5 years	10 years	5 years	10 years	5 years	10 years
Man hours [h]	617.34	617.34	114.54	387.54	167.64	361.84
Materials costs [RMB]	357830	357830	191640	469110	192627.2	1174048
Materials and persons costs [RMB]	381103.7	381103.7	195958.2	483833.4	198947.2	1187689

6. Conclusion

The highest priority is to provide the costs at the decision-making and design phases for evaluation [24]. LCC predictor is proved to be user-friendly software incorporated in Microsoft Excel for the maintenance phase LCC prediction for rolling stocks. It was developed with VBA program language and run under Microsoft Excel version 2003 or later. First of all, the software can standardize the input for all the suppliers. According to the users' guide and input wizard, the data input can be preliminary analyzed to make it uniform and meet the requirements. Secondly, LCC predictor can be easily be modified to suit for users' purpose because it is programmed with easy VBA language. Finally, the data input and processing can be performed directly within Excel spreadsheet without the need for the critical data format required by most other available programs. All the above features make LCC predictor suitable prediction software for rolling stocks' LCC prediction.

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References

[1] S. C. Pascale, B. Isabelle, G. F. Marcel, E. Bastien, W. Martyn, M. Jan-Anders, E. Daniel, H. Seong-Ho, H. Jinglan and J. Olivier, J. Life Cycle Assess, vol. 14, no. 429, **(2009).**
[2] S. Wulf-Peter and B. Frank, J. LCA, vol. 11, no. 315, **(2006).**
[3] B. U. Ingrid, J. Cleaner Production, vol. 17, no. 335, **(2009).**
[4] Y. J. Xiao and R.D. Yang, J. Electric Locomotives & Mass Transit Vehicles, vol. 26, no. 17, **(2003).**
[5] X.Y. Lin, J. Urban Mass Transit, vol. 1, no. 41, **(2005).**
[6] H. S. Wang, L. Wen, E. F. Shen and Z. X. Zhao, J. Electric Locomotives & Mass Transit Vehicles, vol. 30, no. 52, **(2007).**
[7] H. K. Jun and J. H. Kim, Proceeding of International Conference on Electrical Machines and Systems, **(2007)** October 8-11, Seoul, Korea.
[8] X. Y. Xu, H. W. Zhou and H. S. Wang, J. Railway Locomotive & Car, vol. 28, no. 51, **(2008).**
[9] H. Zhou and S. C. Xie, J. Changsha Railway University, vol. 9, no. 222, **(2008).**
[10] X. H. Yu, J. Foreign Rolling Stock, vol. 46, no. 1 **(2009).**
[11] W. J. Liu and L. J. Liu, J. Mechanical Management and Development, vol. 129, no. 95, **(2012).**
[12] K. Dina, M. Tore and G. Behzad, J. Syst Assur Eng Manag, vol. 2, no. 218, **(2011).**
[13] B. Blanchard, in System engineering management, edited B. S. Blanchard, Wiley Publishers, Virginia, **(2004)**, pp. 126-129.
[14] G. Glucha and B. Henrikke, J. Building and Environment, vol. 39, no. 571, **(2004).**
[15] K. Gu-Taek, K. Kyoon-Tai, L. Du-Heon, H. Choong-Hee, K. Hyun-Bae and J. Jin-Taek, Automation in Construction, vol. 19, no. 308, **(2010).**
[16] S. Dowlatshahi, J. Production Research, vol. 3018, no. 1803, **(1992).**
[17] J. H. Park, K. K. Seo, D. Wallace and K. I. Lee, J. CIRP Annals - Manufacturing Technology, vol. 51, no. 421, **(2002).**
[18] A. Bracciali, S. Cervello and P. Gatti, J. Noise and Vibration Mitigation, vol. 99, no. 257, **(2008).**
[19] D. Per and S. B. Gunnar, J. Production Economics, vol. 46, no. 459, **(1996).**
[20] M. Q. Wang, J. Fujian Computer, vol. 12, no. 167, **(2012).**
[21] G. Zhang and W. Wang, J. Systems Engineering Procedia, vol. 4, no. 68, **(2012)**.
[22] V. Zdenek and H. Rudolf, 2003 Proceedings Annual Reliability and Maintainability Symposium, **(2003)** January 27-30, USA.
[23] M. Tore and K. Uday, 2003 Proceedings Annual Reliability and Maintainability Symposium, **(2003)** Janaury 27-30, USA.
[24] D. Lian and X.F. Zhao, J. Physics Procedia, vol. 25, no. 443, **(2012).**

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