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Medical Devices Service Life Cycle Cost Management in Al Karak Hospital as a Case Study

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Abstract

This study implemented the concept of LCC to select between two alternative models from three different sets of medical devices, including two electrolyte models, two X-ray models and two infant incubator models as case studies. For LCC calculations, Kaufmann approach was used, which defines the operating profile, utilizing factor, the most critical cost parameters (i.e. failure rate and repair rate) and any related cost component (i.e. operating cost and maintenance cost). Our results showed that LCC could improve the range and quality of information available for decision-making when a comparison is performed between two alternatives. When comparing the annual LCC values for each two alternative models, the key effective cost categories affecting LCC were the consumable power cost and/ or consumables costs and the maintenance cost. Results showed that LCC and device age are linearly related indicating the increase of the cost to maintain the device in service by increasing the device age. Paired t-test showed significant differences between each two alternative models in annual LCC estimates. In this study, for the electrolyte devices (Model 2) displayed 25% lower annual LCC as compared with (Model 1). Higher annual LCC value (4.4%) was found for the X-ray device (Model 1) than (Model 2) suggesting that (Model 2) is better alternative than (Model 1), even though foe the infant incubator devices (Model 2) has higher capital cost. The annual LCC estimate for (Model 1) was 5% lower than (Model 2) due to lower initial cost and maintenance cost. In conclusion, LCC analysis used in this study is vital for decision making for justifying certain model selection among a group of alternatives based on total costs rather than on the initial purchase price of a device.

Keywords: Medical devices; Life cycle cost; Net present value; Discounting back factor

Introduction

One of the most common important issues for decision-making is to select the suitable model among a group of alternatives. Selecting the best alternative is crucial for an efficient budget management. In governmental health sector in Jordan, criteria for the selection and purchase of medical devices focused on the safety properties, and the initial purchase price. Many decisions concerning the purchase of a medical device is usually relying on personal opinions rather than on the basis of life cycle costing information. The continuous evolution and life cycle cost (LCC) analysis of medical devices have an impact on health services quality, and financial efficiency of the hospital long run costs. Planning for this evolution and its subsequent implications became a major challenge in most decisions of health care organizations and their related industries [1]. Therefore, there is a need to apply adequate management tools which optimize the development of medical technology that takes into account life cycle costs and improves health care services [2].

Various definitions could be found in literature for LCC analysis. According to Bronzino [3], LCC analysis is an economic measure that is used to evaluate competing alternatives based on the estimated total cost of decision makers. Life cycle cost is "a tool used during technology planning, assessment or acquisition either to compare high-cost, alternative means of providing a service or to determine whether a single medical device or technology has a positive or negative economic value" [3]. The strength of the LCC analysis is to monitor the cash flow impact of an alternative over its life span, instead of focusing solely on initial cost of the medical device. Another definition of life cycle cost stated by Barringer and Weber [4] where they defined LCC as summations of cost estimates from inception to disposal for devices as determined by an analytical study and estimate of total costs experienced during their life. Industry competitiveness depends on the cost, performance, and timely delivery of the product. Thus, an accurate, rapid, and robust product cost estimation model for the entire product life cycle is essential [4]. In view of resources could be obtained for the healthcare system (i.e. hospitals or health care centers), the effectiveness of the cost of new technology or purchasing new devices will be a key factor in its adoption. The life cycle cost of a medical device is based on its accumulated cost during its life cycle. Usually the cost of the medical device is closely associated the benefits: cost ratio obtained from one device as compared to other new or best alternatives (i.e. different sources and new technology to achieve the same purpose). Having an idea about cost effectiveness will be helpful for the decision makers and/or investment decisions which products (model) and sources will be most cost effective.

The presence of sophisticated healthcare systems needs to give more effort on select convincing and sophisticated application for the medical device that meets patient needs with minimum cost. The customers do not need elegant technical solutions but also a device with the greatest 'value proposition' [1]. In general, it was estimated that the purchase price represents only 20% of the LCC of ownership [1,5]. Other research estimated the acquisition cost is equal to 15% of the total cost of ownership for a device. That means the bulk of the life-cycle costs comes after the purchase, including 45% energy-related

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costs, 35% maintenance costs, and the remaining 5% for what is classified as other [6].

LCC uses Net Present Value (NPV) concepts. NPV is an important economic measure for projects or devices taking into account discount factors, cash flow, and time. Net present value calculations start with a discount rate, followed by finding the present value of the cash proceeds expected from the investment, then followed by finding the present value of the outlays, the net of this calculation is the net present value. Cash availability and strategies aside, when competing projects are judged for acceptance, projects with high NPVs usually win [7]. The selection and purchase of a medical device depends on the price and any probable risk to patients and/or staff during the using of the device. In addition, usually the basis for taking such decisions would be a personal opinion, or shallow understanding of the device and its implementation or poor information regarding life cycle cost. From this point view, the utilization of the LCC is a key factor to be a framework for making a wise decision related to suitable device purchasing. LCC would play a supportive element for the healthcare managers in motivating a strong evidence-based decision-making [8]. One other purpose of LCC is to help decision makers to select a medical device based on available alternatives in order to achieve the most economical option from inception to decommissioning. LCC takes into consideration the design, device selection, operation, maintenance and final disposition costs of a device over its lifespan. In the short run, LCC approach can increase the department efficiency. However, the lower initial capital costs may be combined with high maintenance or operation costs over the device working years. LCC can help avoid unnecessary downtime and help make the medical device more profitable. At the very least, an LCC may prompt decision makers to consider a wider range of possibilities [9]. The purpose of this article is to implement the concept of LCC to select between two alternative models from three different sets of medical devices, including two electrolyte models, two X-ray models and two infant incubator models as case studies.

Materials and Methods

The operating cost was obtained from technical operators who have full responsibility to operate the medical device, and the historical reports. The data collected from the historical maintenance recodes focused on the initial cost (purchasing and installation costs), maintenance costs related to the corrective and preventive maintenance, the installation date of the device, and number of failures. This information was invested in calculating the critical cost parameters as well as the LCC values.

The target medical devices used in this study include devices from three main groups:

- Two different models of Electrolyte device: Model 1 and Model 2

- Two models of X-rays devices Model 1 and Model 2

- Two models of Infant incubator devices were selected including Model 1 and Model 2

Area of Study

Our study site is Al Karak Public Hospital, Al Karak district, Jordan. Karak Public Hospital has 370 beds and a suite of 7 operating theatres. The hospital was established in 1992 in an area of 13.2 hectare and total building area of 6500 m^2. The hospital contains hospital clinics with an area of 2950 m^2. The buildings are divided into sections (i.e. departments).

LCC Estimation Procedure

LCC was estimated for two different alternative models from two different manufacturer sources that have the same function. These data were collected from the operator, the value of this category expected to be very close for the two alternative models, as they have the same load and the same number of served patients or samples per day. This will lead to unbiased comparison between the two alternatives.

All required data were obtained from historical maintenance reports, historical operator reports and other information from the site engineers if required.

To estimate the LCC for the selected medical devices, the Kaufman approach for LCC analysis was used. LCC estimation steps are listed below:

(i) Defining the operating profile: the operating time profile per day was estimated by the operator for each device.

(ii) Establishing the utilization time(UT) of the device as follows [10]:

$$UT = N \times T,$$

Where,

N=Average number of served patients per day according to the operators

T=Time required for each service

(iii) Identifying the cost elements, including initial cost, total operating cost, total maintenance cost (corrective and preventive maintenance), the income from the device, and the salvage value.

(iv) Estimating the total operating costs, which is the sum of the required costs to put the device in service including operator man-hour cost, materials (reagents) costs, and the electrical power cost? All these data were collected from the operator.

(v) Estimating the total maintenance cost, which consists of the cost related to the corrective maintenance and to the preventive maintenance taking into consideration the man-hour cost and the spare parts cost. It was collected from the historical maintenance records.

(iv) Estimating the device income (DI) as follows [11]:

$$DI = N \times T \times C$$

Where,

N= the number of operating days

T=the number of performed services

C=the cost of the service

(v) Salvage value estimation: The last cost category is the salvage value (S), which was calculated using the following specific equation [12]. Taking into consideration linear depreciation of 10%:

$$S = C(1 - D)^n$$

Where,

S: salvage value

C: original price

D: depreciation rate

n: age in years.

(vi) Inclusion of inflation rate: Kaufman approach concedes

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the inflation rate in the LCC calculation, so it was important to concede it in NPV calculations. The Jordanian central bank reports were the source of such information over the previous ten years, discounting back all costs to the base period. It is known that money which has a time value and the cash flows developing in different time periods are discounted back to the main period to warrant equitability using a discount factor.

Estimation of LCC based on Collected Data

LCC could be estimated by summing the discounted costs to establish the NPV. Integrating all of these cash flow categories at a specific year will produce the yearly LCC for each device.

Our LCC model is:

$$LCC = C + O + M - S$$

Where,

C=the capital cost

O=the operation cost (man - hour cost, reagents, disposables cost and power cost)

M=the maintenance cost (corrective and preventive maintenance)

S=the salvage value

The comprehensive equation used to calculate the total LCC value at the determined base year includes the cost categories and the discounting factor is:

$$LCC = C + \left(\frac{1+f}{1+i}\right)^n \sum_{1}^{n} O + M - \left(\frac{1+f}{1+i}\right)^n \times S$$

Where,

C=the capital cost

O=the operation cost (man-hour cost, reagents, disposables cost and power cost)

M=the maintenance cost (corrective and preventive maintenance)

S=the salvage value

f=inflation rate

i=interest rate.

The deterministic model was obtained for each model to forecast the LCC values for five years more in future. Based on LCC estimates, the decision is made to determine which model is better to be purchased and maintained over its physical life.

Statistical Analysis

The Pearson correlation coefficient (r) was used to measure the strength of the relationship between LCC and the device age. The correlation values (r) could be ranged from -1 to1. r value less than zero indicates negative linear relationship between variables, and when r value more than zero indicates a positive linear relationship between variables.

A simple linear regression was used to estimate the regression coefficient (b), the coefficient of determination (R^2) and the standard error. Linear regression was used to investigate the relationship between LCC (the response variable) and device age (the explanatory variable). Also, the regression equation was used to predict the future life cost based on the available historical data.

A paired t-test was used to look at the difference between paired LCC values came from the two alternative models. For paired t-test, the null hypothesis was tested that the true mean values of LCC differences between two models over yeas are zero, against the alternative hypothesis that the mean differences in LCC values between the two alternative models are significantly different.

For the comparison between the two models in each group, the device income was omitted since the both models assumed to perform the same number of tests, and after calculations it was clear that the both models have the same income values. Omitting the income from LCC calculations did not affect the final decision regarding the best alternative. Moreover, including the device income make the decision even harder.

Results

LCC comparison for electrolyte models

Model 1, yearly LCC values ranged from 6680.71 to 12518.32 JD/year, with equalized average of 8609.21 JD/year. The summing of all LCC values over the device life span after discounting them to the installation year release the total LCC values at the year of installation, which is 76510.32 JD.

Model 2, LCC yearly values ranged from 5399.67 to 9480.93 JD/year, with an average of 7118.98 JD/year. The total LCC of the device from 2008 to 2013 is 38426.74 JD.

Figure 1 shows the LCC values for each model from 2008 to 2013 taking in consideration a discount factor based on year 2008 as a base year. The base year is the first year of having both models in service. This makes the comparison more logical since the money value for each model in the period from 2008-2013 will be discounted back to the same year.

On average, Model 1 displayed 25.45% higher LCC than Model 2 when comparing LCC discounted values. Model 1 values ranged from 7771.69 to 12518.31 JD/year (LCC average=9597.99 JD/year) and from 5399.67 to 9626.33 JD/year (LCC average=7154.59 JD/year).

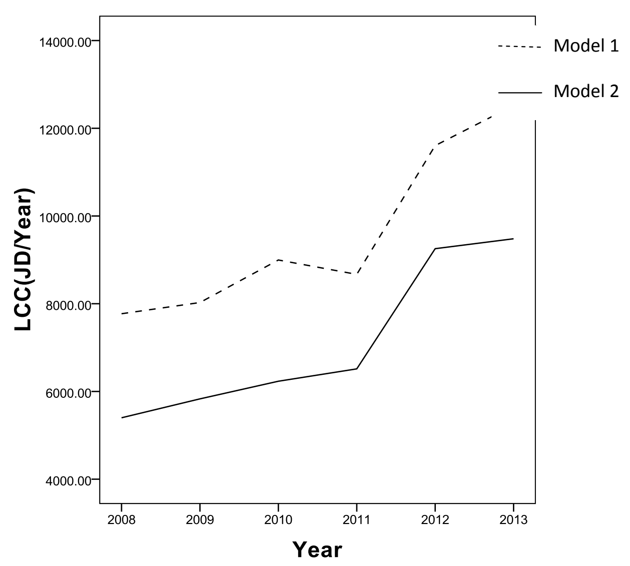

Figure 1: The LCC for the two electrolyte devices: Model 1 and Model 2.

Also comparing the LCC values for the first four years (from 2004 to 2008) of the Model 1 to the first four year of Model 2 shows the same trend where the former LCC values were 25.5% higher than the later. This bright the fact that the LCC values for Model 1 is higher than Model 2 from the years extended from 2008 to 2013 where both models were in service and regarding to the device age. This indicates that Model 1 is less efficient alternative for decision makers from LCC point view, even though it displayed lower failure rate and longer period of availability in service as compared with Model 2. However Model 2 showed lower initial purchasing cost and less operating and maintenance costs as compared to Model 1.

Pearson correlation coefficients (r) were 0.998 and 0.928 between years and LCC values for Model 1 and Model 2, which was significant at α=0.01. This indicates that the LCC increases with increasing the device age. Linear regression was used to investigate the relationship between LCC (the response variable) and device age (the explanatory variable). The slope directly tells us about the relation between the mean LCC and the device age. When the true sample slope does not equal 0, the variables LCC and device age are linearly related. When the slope is 0, there is no linear relationship because the mean of LCC does not change when the device age is changed. The null and alternative hypotheses for a hypotheses test about the slope are written as follows:

$H_0 : \beta_1 = 0$

$H_A : \beta_1 \neq 0.$

The regression equation was estimated for the available working years ranging from 2004 to 2013 for Model 1 and from 2008 to 2013 for Model 2. Results showed that significant regression between LCC and the device age at α=0.0001 and 0.008 for Model 1 and Model 2, respectively.

A straight line regression model was fitted to the data. The α-value for testing that the true value of the slope is <0.008, so we reject the null hypothesis that LCC is not related to device age. The two variables are statistically significantly related: as the device age increases, so does the LCC. Regression (R^2) for the straight line regression model is 0.811 and 0.861 for Model 1 and Model 2, respectively. This means that just over 81.1% and 86.1% of the total variability in LCC has been explained by the straight line regression model. A scatter plot of LCC against the device age, together with a straight line regression for Model 1 and Model 2 (Figures 2 and 3) suggest that the LCC increases linearly with increasing the device age.

The two representative equations of LCC for both models are:

- LCC equation for Model 1 :

$$LCC(\text{Model1}) = 5398.78 + 583.72\ x$$

- LCC equation Model 2:

$$LCC(\text{Model2}) = 4022.98 + 884.57\ x$$

Where, x represents device age in year(s).

These two equations can be used to predict and evaluate the LCC values over the device future physical life. Applying the device age (x) in these functions for the next five years will give an idea about the devices behavior over years.

For Model 1, the LCC values would slightly decreased for small amount for the two next year's due to major maintenance actions carried out during the year 2013, then increased again for the last three years by increasing the device age as some of the device parts would be

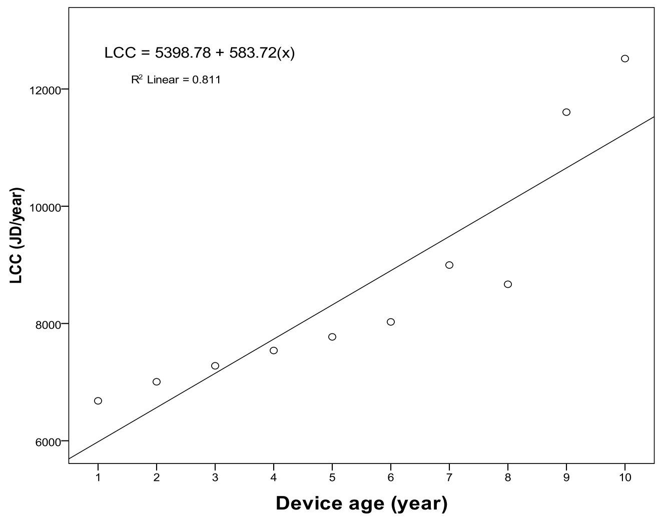

Figure 2: Scatter plot of LCC against the device age, together with a straight line regression for the electrolyte device, Model 1.

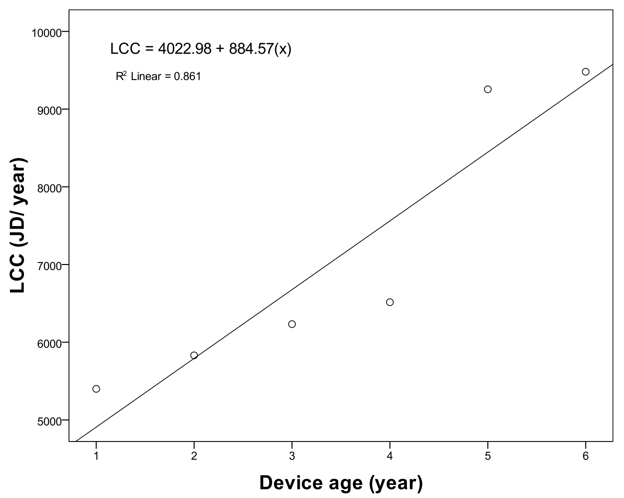

Figure 3: Scatter plot of LCC against the device age, together with a straight line regression for the electrolyte device, Model 2.

expired after that and new maintenance actions might be required. The expected average LCC value for the next five years would be 12987.14 JD/year, where LCC expected values would reach the maximum by the year 2018 (LCC=14154.58 JD/ year); and the minimum value by 2014(LCC=11819.7 JD/ year). Figure 4 shows the previous LCC values from 2004 to 2013 and the future expected values from 2014 to 2018.

Model 2 LCC expected values for the next five years would range from 10214.97 JD/year to 13753.25 JD/year with an average would equal 11984.11 JD/year. LCC values would substantially increase for this model reaching the maximum value after four years and slightly decrease again in the fifth year. Figure 5 shows the previous LCC values from 2008 to 2013 and the future expected values from 2014 to 2018. For paired t-test, the null hypothesis was tested that the true difference mean values of LCC for Model 1is the same as that for Model 2, against the alternative hypothesis that the true mean LCC value of differences is different for the two Models, i.e. we tested:

H_0: μ for Model 1 − μ Model 2=0

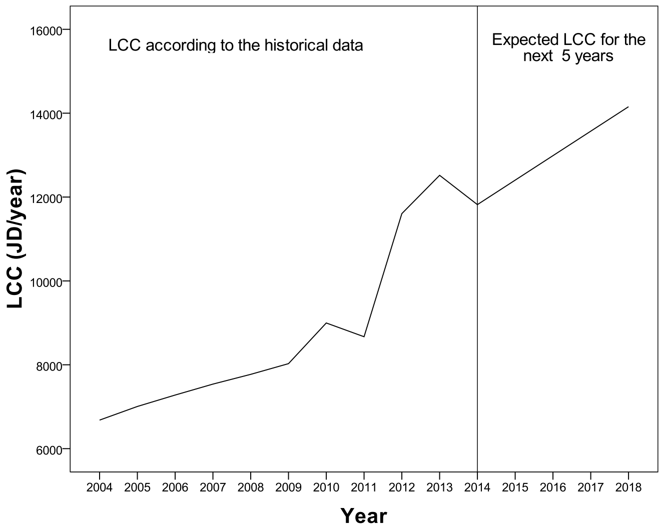

Figure 4: The previous LCC values from 2004 to 2013 and the future expected values from 2014 to 2018 for the electrolyte device, Model 1.

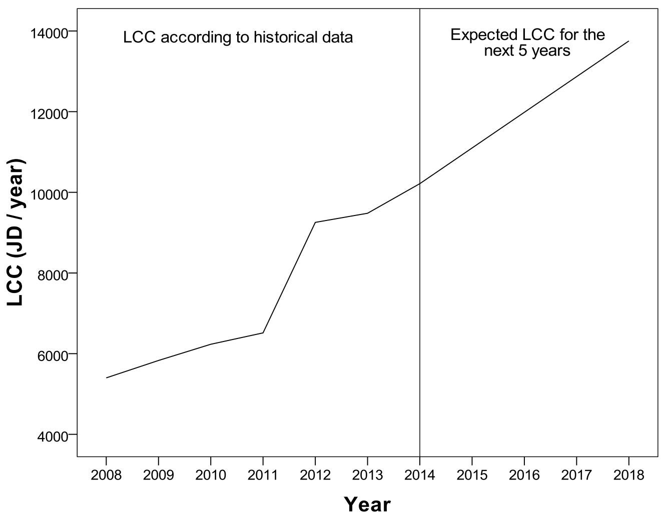

Figure 5: The previous LCC values from 2004 to 2013 and the future expected values from 2014 to 2018 for the electrolyte device, Model 2.

Against

HA: μ for Model 1 − μ Model 2 ≠ 0,

Where, μ denotes the true mean LCC for Model 1 and Model 2, respectively. The two-sample paired t-test for testing the null hypothesis stated above gives α<0.01. So we reject the nullhypothesis in favor of the alternative. This suggests that the mean LCC values for the two devices are significantly different. The observed difference between the LCC mean of the two models is2489.83 JD with standard error of the difference of 156.51. t-calculate was significant at α=0.0001, suggesting thatthe true mean LCC value of the differences for Model 1 (LCC=9644.43) is higher than that for the Model 2 (LCC=7154.59).

LCC comparison for X-ray devices

For the X-ray devices over the period extended from 2003 to 2013, the average LCC for Model 1 is 51,034.77 JD/year, ranging from 37,593.34 to 79,639.59JD/year. Summing up all LCC values over the device service years after discounting them to the installation year released the total LCC values at the year of installation, which is 613,364.7 JD.

Model 2 LCC yearly values ranged from 38,046.77 to 69,665.74JD/year, with an average of 54,964.57JD/year. The total LCC of the device over its life span (from 2007 to 2013) is 412,722.6 JD/year. Model 1 displayed 4.4% higher LCC values than Model 2 when LCC discounted back to 2007. Figure 6 shows yearly LCC values for both models. Comparing the LCC values for the first four years for both models shows that the LCC values of Model 1 was relatively lower than the LCC values of Model 2 over the first 4 years of their service because of the differences in power (electrical) costs between the installation years for both models. These results indicate that Model 2 is more preferable alternative for decision makers depending on the LCC values, even though it displayed higher initial cost but lower maintenance cost as compared to Model 1.

The released deterministic model for this study case shows that the historical data can be exploited to estimate the LCC values for the coming (x) years of its life. Some statistics were performed for LCC values over years for both models including:

Pearson correlation coefficients (r) were 0.929 and 0.870 between years and LCC values for Model 1 and Model 2, respectively. The relation was highly significant at α=0.01. The positive correlation between LCC and device age indicate that LCC is increasing with the increase of the device age.

Linear regression showed significant relationship between LCC and the device age. The regression equations were established for both models and results showed the significant regression between LCC and the device age at α=0.0001 for both models.

A straight line regression model was fitted to the data (Figures 7 and 8). Regression (R^2) for the straight line regression model is 0.864 and 0.922 for Model 1 and Model 2, respectively. This means that just over 86.4% and 92.2% of the total variability in LCC has been explained by the straight line regression model for Model 1 and Model 2, respectively. The two representative equations of LCC for both models are:

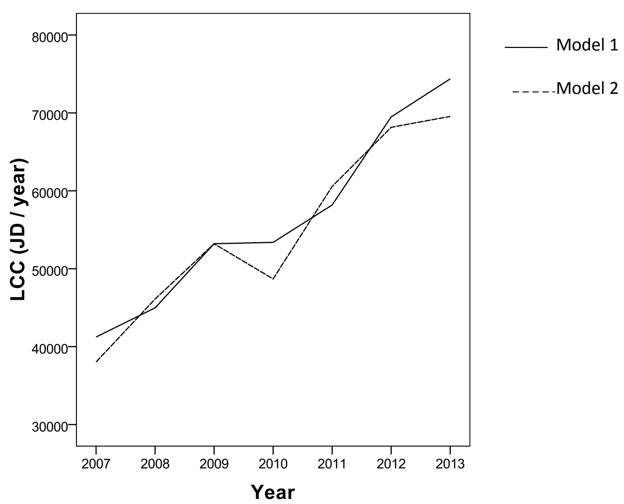

Figure 6: The LCC for the two X-ray devices: Model 1, and Model 2.

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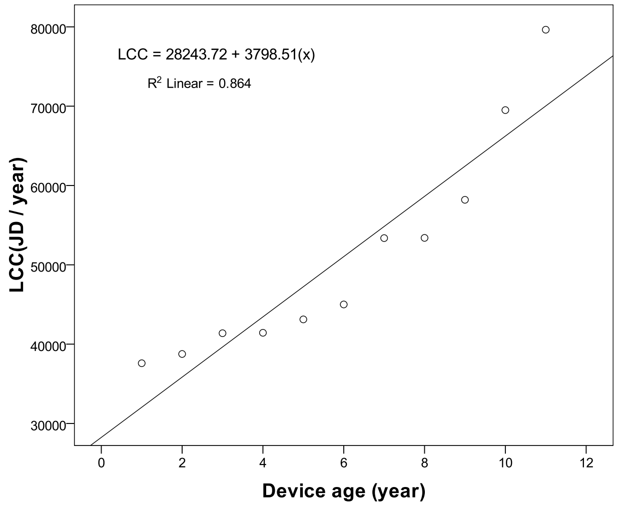

Figure 7: Scatter plot of LCC against the device age, together with a straight line regression for the X-ray device, Model 1.

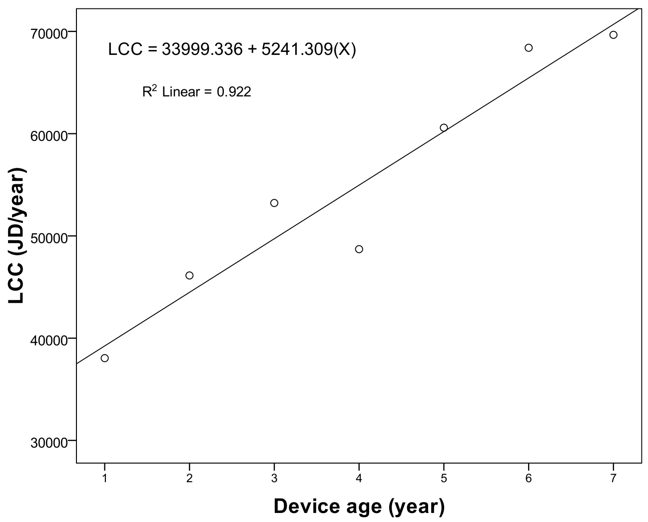

Figure 8: Scatter plot of LCC against the device age, together with a straight line regression for the X-ray device, Model 2.

- LCC equation for Model 1:

$$LCC(\text{Model1}) = 28243.72 + 3798.51\ x$$

- LCC equation for Model 2:

$$LCC(\text{Model2}) = 33999.34 + 5241.309x$$

Where, x represents device age in year(s). These two equations can be used to estimate and evaluate the LCC values over the device future physical life. Applying the device age (x) in these functions for the next five years will give an idea about the devices behavior over years.

For Models 1 and 2, respectively. LCC values are steadily increased by increasing the device age for both models. The expected average LCC value over the next five years for Model 1 would be 81,422.72 JD/year, whereas LCC expected values would reach the maximum by the year 2018 (LCC=89,019.72 JD/year); and the minimum value by 2014(LCC=73,825.72 JD/year).

Model 2 LCC expected values for the next five years would range from 75,929.81JD/year to 96,895.04JD/year with an average would equal 86,412.43JD/year. Figures 9 and 10 shows the previous LCC values and the future expected values from 2014 to 2018 for Models 1 and 2, respectively.

Paired t-test indicates significantly higher LCC value for Model 1 than Model 2 suggesting that Model 2 is better alternative than Model 1.

The LCC values showed that the total costs for Model 1 over its service life from 2003 to 2013 as calculated from the historical data were higher than in Model 2. Moreover, the LCC values expected from the deterministic model would be higher for the next 5 years (Figure 11). Model 2 would need spare parts replacement as its parts would be expired with time and major maintenance actions might be needed as expected from the future LCC values resulted from the deterministic

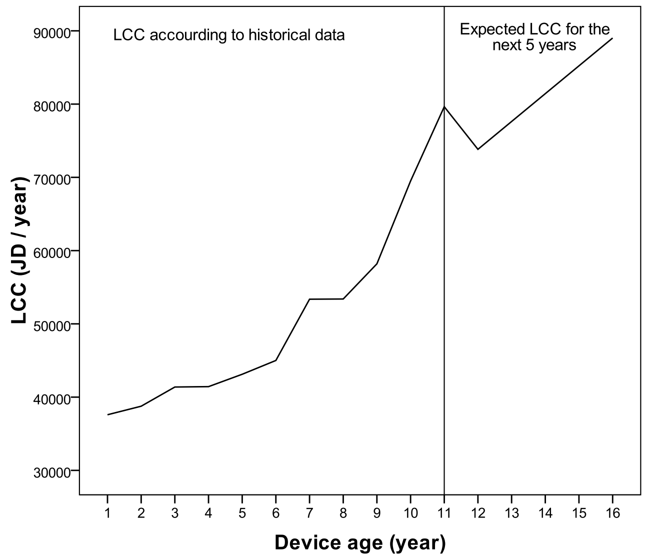

Figure 9: The previous LCC values from 2004 to 2013 and the future expected values from 2014 to 2018 for the X-ray device, Model.

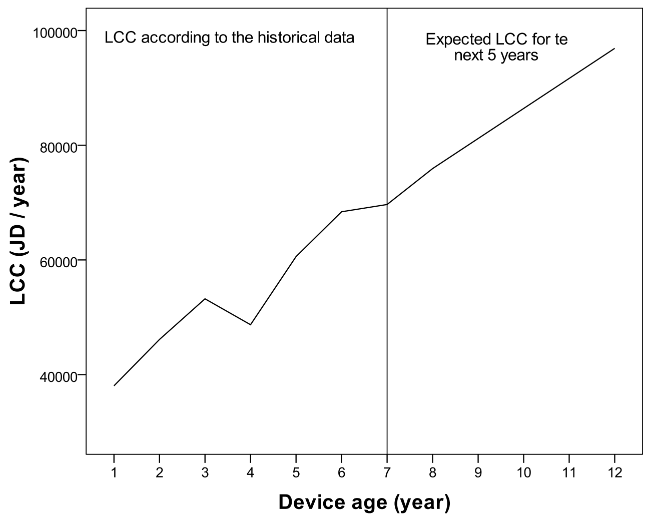

Figure 10: The previous LCC values from 2004 to 2013 and the future expected values from 2014 to 2018 for the X-ray device, Model 2.

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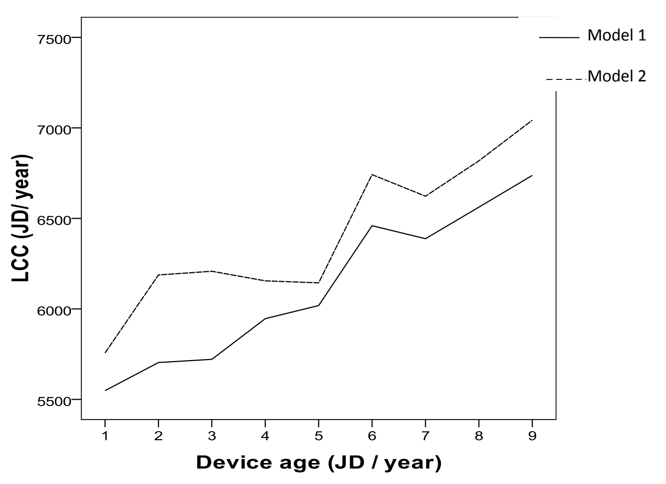

Figure 11: The LCC for both infant incubators devices; Model 1 and Model 2.

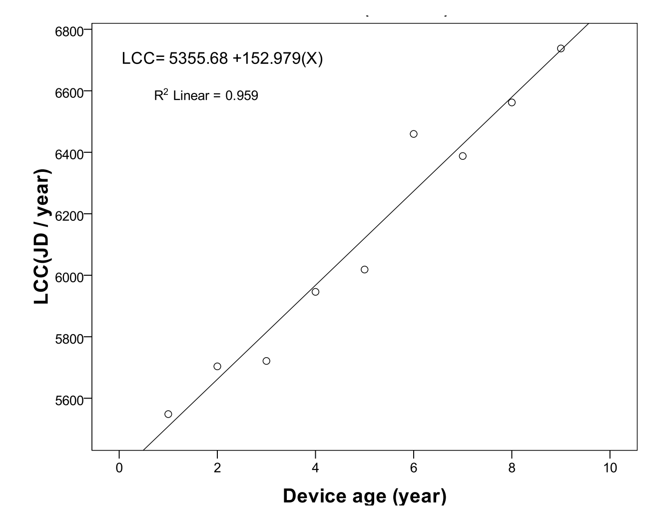

Figure 12: Scatter plot of LCC against the device age, together with a straight line regression for the infant incubator, Model 1.

model. The LCC values resulted from the historical data enhances the preference of Model 2 over Model 1 even though Model 1 displayed lower initial, but model higher maintenance cost over its service year. Therefore it could be concluded that Model 2 is economically preferred than Model 1 and it is highly recommended for future tenders.

LCC comparison for infant incubators models

Over the period extended from 2005 to 2013, the average LCC for Model 1 is 6120.58 JD/year, ranging from 5548.41 to 6737.64 JD / year. The total LCC over its service years (for 9 years) is 60,255.92 JD. Model 2 yearly values ranged from 5338.52 to 7042.46 JD/year, with an average of 6241.62 JD/year. The total LCC of the device over its service (2003-2013) is 75,987.1. These results indicate that Model 1 is more preferable alternative for decision-making depending on the LCC values, with lower initial and lower maintenance cost as compared to Model 2 and 5% lower in LCC values.

Similarly, the regression analysis can be exploited to estimate the LCC values for the two infant incubator devices for the coming (x) service years. Some statistics were performed for LCC values over years for both models including:

Pearson correlation coefficients (r) were 0.98 and 0.961 between years and LCC values for Model 1 and Model 2, respectively. This positive significant correlations (α=0.01) indicate that LCC is increasing with the increase of the device age.

The regression between LCC and device age were significant (α=0.0001) for both models. Regression (R^2) for the straight line regression model is 0.959 and 0.923 for Model 1 and Model 2, respectively (Figures 12 and 13).

The two representative equations of LCC for both models are:

- LCC equation for Model 1:

$$LCC\left(Model1\right) = 5355.68 + 152.98x$$

- LCC equation for Model 2:

$$LCC\left(Model2\right) = 5321.84 + 153.29x$$

The expected ranged LCC values over the next five years for Model 1 would be 6885.47 in 2014 to7161.39 JD /year in 2018. Similarly, the expected LCC values for the next five years for Model 2 will be continuously increased from 7497.39 JD/year in 2014 to 7774.58 JD/ year in 2018 (Figures 14 and 15).

Paired t-test indicates significantly higher LCC value for Model 2 than Model 1 pointing that Model 1is better alternative than Model 2.

The LCC values showed that the total costs for Model 2 over its service were higher than Model 1. Moreover, the LCC values expected from the deterministic model would be higher for the next 5 years. Therefore it could be concluded that Model 1is better economic alternative as compared to Model 2.

Conclusions

Efficient budget management of medical devices includes selection of better alternative with low maintenance and operation costs, which will lead in consequence to low LCC during the device lifespan. LCC data base provides basic information essential for decision making when a group of alternatives are available. Lack of LCC implementation might lead to select less economic medical device model which have difficulties in acquiring their spares parts and/or those devices with

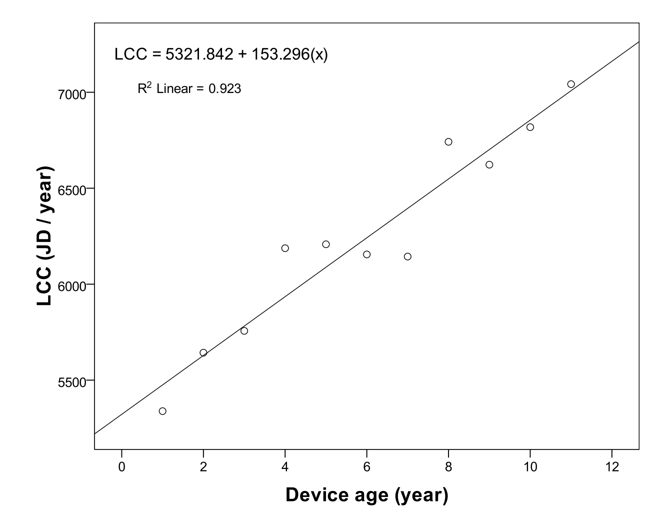

Figure 13: Scatter plot of LCC against the device age, together with a straight line regression for the infant incubator, Model 2.

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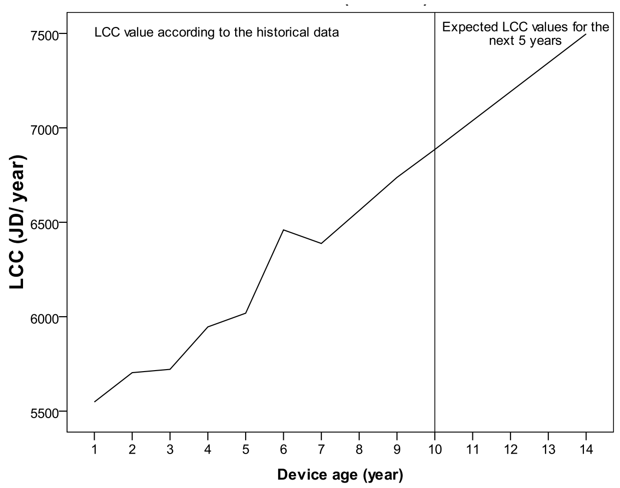

Figure 14: The previous LCC values from 2005 to 2013 and the future expected values from 2014 to 2018 for the infant incubator, Model 1.

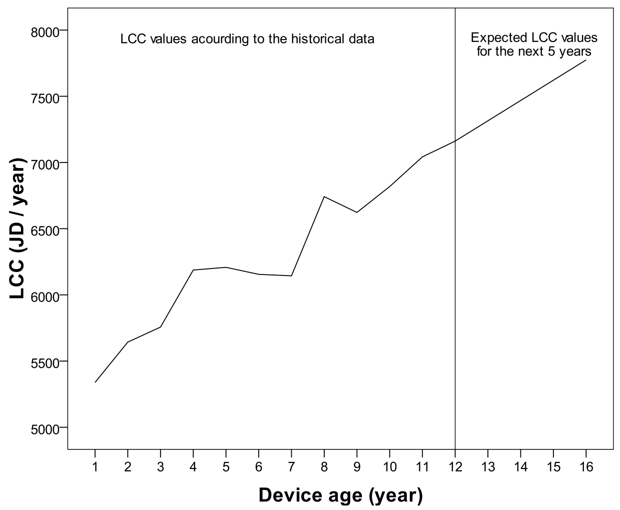

Figure 15: The previous LCC values from 2003 to 2013 and the future expected values from 2014 to 2018 forthe infant incubator, Model 2.

high maintenance cost and consequently high LCC during the device life span. The findings from the data collected in this study revealed that LCC could be implemented efficiently to maintain the hospital medical devices assets in a cost effective manner which is aimed at long-term preservation of the asset value. The major outcomes of the current study include:

a. Results showed that LCC and device age are linearly related indicating the increase of the cost to maintain the device in service by increasing the device age. From the regression equation, the expected LCC values for the next five years were estimated. LCC values would substantially increase during the following years indicating the need for more maintenance costs during the following years.

b. The high initial cost is not necessarily indicating the best or the worst alternative. In the electrolyte case and the infant incubator the best alternative were those with lower initial cost. However in the X-ray case study the best alternative was with the higher initial cost. Therefore, the availability of LCC information for particular devices is vital for decision-making to justify devices and process selection based on total costs rather than the initial purchase price as the cost of operation, maintenance, and disposal costs might exceed the initial cost of the medical device.

c. Most commonly, consumable power cost and the maintenance cost are the main cost factor in life cycle cost of the medical device Therefore, when comparing the annual LCC values for each two alternative models, the key effective cost categories affecting LCC were the consumable power cost and the maintenance cost. If these factors are minimized, it will improve the life time performance of the medical device and will substantially reduce the LCC.

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