

## **LIFE CYCLE COSTING IN PRODUCT SERVICE SYSTEM CONTEXT: A SIMULATION APPROACH**

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### **ABSTRACT**

The use of simulation in life cycle cost computation for Product-Service Systems have been limited in scope due to limited data availability at the concept design phase of PSS development. Case studies in the literature are context specific and focus on specific PSS variant. This paper proposes a framework for the life cycle costing of Product-Service Systems based on discrete event simulation methodology using a combination of literature review findings and empirical research. Sensitivity analysis show the influence of varying activity levels on total life costs of different PSS alternatives.

### **1 INTRODUCTION**

Product Service Systems (hereafter PSS) are integrated solutions which integrates product, service and knowledge components into unique combinations to deliver value in use (Baines and Lightfoot 2013). As manufacturers move along the PSS spectrum from product-oriented services to result-oriented services, the underlying operational delivery systems and processes become complex to manage and the service provider assumes responsibility for the cost of delivering on contracted function and result. In view of this, it becomes imperative for the service provider to broaden cost evaluation over all lifecycle phases of integrated solution. However, the non-availability of data at the concept design phase of PSS development poses a challenge to life cycle cost computation. To navigate this challenge, most studies tend to focus on specific PSS variant or the in-service phase of the PSS life cycle. Traditional costing techniques like analogous method focus on point forecasts and parametric technique is difficult to implement when historical data is unavailable for computing cost estimating relationships. Evidence from the PSS literature shows the efficacy of simulation techniques (system dynamics, agent-based modelling) as decision support tools in the modelling and simulation of lifecycle costs of PSS (Kuo 2011; Kyösti and Reed 2015). The focus of this paper is discrete event simulation (DES). There is no unanimous reference framework for costing PSS lifecycle. A DES framework is developed and used to compared alternatives of PSS.

### **2 SCIENTIFIC QUESTION OF THE RESEARCH**

What methodological aspects of discrete event simulation should be considered for use in life cycle costing of product-service-systems? In view of this question, this paper a proposes a generic framework based on discrete event simulation methodology for cost evaluation of PSS variants.

### **3 METHODOLOGY**

A thorough review of the literature combined with empirical study (involving the use of semi-structured interviews to study industry practice in lifecycle costing of PSS types – maintenance contracts, leasing and advanced services) was employed to identify patterns of DES use in the PSS costing literature and to develop a framework.

#### 4 PRELIMINARY RESULTS

A DES framework is shown below (Figure 1). The challenge of life cycle costing is a problem situation and gaining insight into the problem requires the acquisition of information and knowledge about the system, which is used to define inputs and output for each phase of the system life cycle. A common challenge is how to manage uncertainty (centered around the use phase) on cost estimation calculated during the design/bidding phase. Probability theory, possibility theory and fuzzy logic are some of the methods identified for modelling uncertainties in PSS cost estimation.

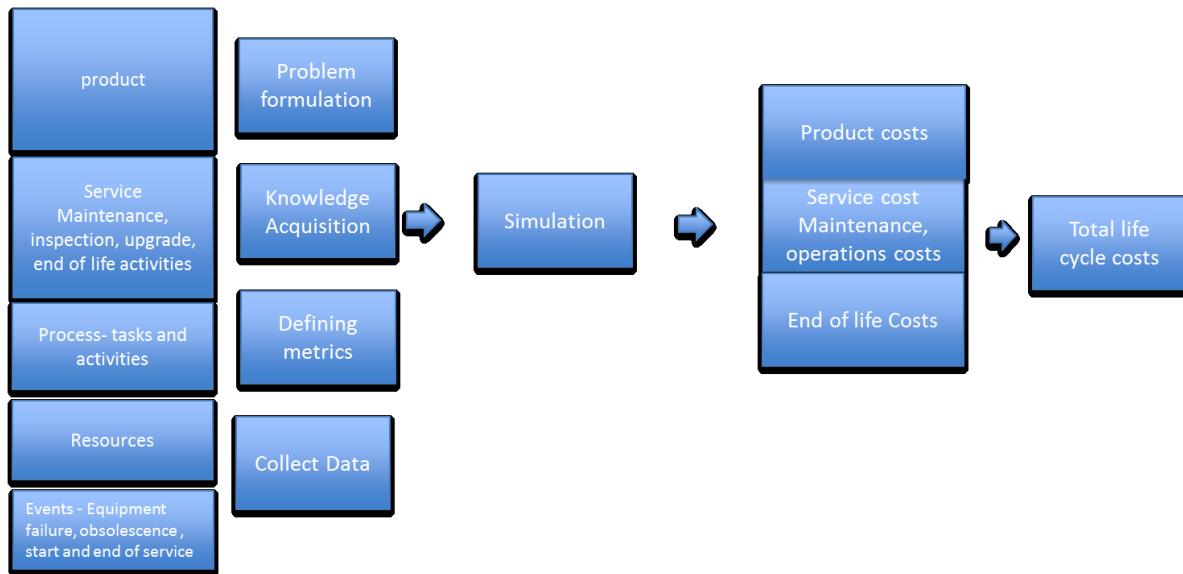


Figure 1: A DES-based lifecycle costing framework for product-service-system.

The framework was tested using three alternatives/variants of a PSS and four-way sensitivity analysis was conducted by varying activity frequency and levels to assess the impact of risks on the total life cycle costs. Result shows the sensitivity of total life cycle cost to activity levels (Table 1).

Table 1: Sensitivity analysis for PSS life cycle costs.

% Activity levels	Lifecycle cost (£)
20	25,000
50	45,000
75	60,000
100	90,000

#### REFERENCES

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