THROUGH-LIFE MANAGEMENT OF BUILT FACILITIES: TOWARDS A FRAMEWORK FOR ANALYSIS

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ABSTRACT

Although built facilities are required to cater to changing requirements over time, effective through-life management is absent as an in-process activity from most large scale procurements. Through a review of key literature, several approaches which address aspects relevant to through-life management are discussed. An attempt is made to create a unified framework of understanding of what constitutes through-life management. Furthermore, an initial diagnostic style checklist is provided as a way of identifying the absence of through-life management.

KEY WORDS

Through-Life Management, Built Facilities, Product-Service

INTRODUCTION

Built facilities such as buildings, roads, and infrastructure are expected to last for a long time. Although they are primarily built products, they are demanded due to the need for servicing a particular need of the society. For example school buildings are intended to provide education services, and hospitals are part of the healthcare infrastructure. However, the changing nature of the end-user needs, financing arrangements, government / client policies and business needs, mean that managing built facilities to continually perform effectively and efficiently becomes a challenging endeavour.

However, our initial observations, suggest that through-life management as an in-process feature is absent from most large-scale procurements in the built environment. For example, the UK National Audit Office (2003) report on through-life management in the defence sector, referring to the Ministry of Defence's strategic defence review (1998) states "Historically, the functions of requirement definition, procurement management and through-life support have been organisationally separated [...] which makes it difficult to get the right balance between risk, cost performance and through-life support". The 4ps PFI / PPP (Private Finance Initiatives / Public Private Partnerships) operational project review (2006) for the UK schools sector has reported problems at the handover stage of the newly built schools, and

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also the lack of schemes to facilitate continuous improvement of the performance in-use. It must be noted that such observations are reported despite the presence of procurement models such as PPP / PFI, the use of life cycle costing, and the like.

In this paper we argue that one of the root causes for non-achievement of through-life management is due to two key theoretical weaknesses in its understanding. Firstly, although there are several approaches and techniques such as life cycle costing, whole life value, life cycle assessment, there isn't a unified view of what is meant by through-life management. Secondly, there isn't a framework / benchmark, which can be used to analyse the presence (or the absence) of through-life management.

In an attempt to address the above mentioned issue, this paper will be structured as follows. Firstly, a brief introduction of the concept of through-life management and its importance is presented. Secondly, the various approaches to through-life management are presented and discussed. This will be followed by a framework for the understanding of through-life management, based on a flow conception. Finally, the paper presents a checklist style guide to assessing the existence of through-life management in built facilities. Throughout the paper, references and evidence from reported studies in the built environment and other sectors will be presented as necessary to justify the arguments.

THROUGH-LIFE MANAGEMENT

Through-Life Management refers to the management of artefacts, often large and complex, such as buildings, plants, ships, airplanes through their life time. It is thus basically referring to designing and producing those artefacts, as well as to producing services through those artefacts, and finally to the deconstruction (or disposal otherwise) of those artefacts. Of course the central idea is to see all those stages as one unit of analysis and as one integral object of management.

Thus, one of the hallmarks of through-life management is that the total unit of analysis consists of a number of mutually differing stages which affect each other. It is understandable that process models, depicting stages and their interactions, have emerged as a popular way of improving through-life management. However, their practical benefits have not yet been proven.

It is useful to note the dynamic environment in the framework of which through-life management is carried out. First, the phenomenon of physical decay is affecting all technical systems, and must be counteracted through maintenance and periodic overhaul. Second, the phenomenon of technical obsolescence may lead to a situation where the artefact is not competitive. Again, this may be counteracted through partial rebuilding of the artefact. Third, the customer requirements change over time, and this may necessitate an overhaul (refurbishment).

APPROACHES TO THROUGH-LIFE MANAGEMENT

The starting point for any discussion on through-life management is the traditional way of product realization, where the focus is on the situation of the handover of the product to its user. Surely, requirements for use and maintenance have been taken into account, but not in a systematic and integrated manner, as shown by the plethora of initiatives trying to extend that approach.

Some of such initiatives are listed and briefly explained below.

- From investment cost to life cycle costs
- From cost to value
- From design focus to life cycle focus
- From black box to open box understanding of production
- From static analysis to dynamic analysis
- From financial flows to capital
- From management as decision-making to management as designing

FROM INVESTMENT COST TO LIFE CYCLE COSTS

The first extension is towards minimization of life cycle costs of an artefact under design and construction, the performance specifications of the artefact being given.

Regarding life cycle assessment of products, the seminal initiatives were taken by the US Department of Defense in the 1960s (Asiedu & Gu, 1998). The basic idea is to focus, instead of acquisition costs, on the total product costs over its life cycle, covering thus R & D expenses, design costs, production costs, operation and maintenance costs as well as disposal costs. Now, the basic principles of life cycle costing (LCC) are widely known and agreed upon, but at least in Europe, LCC is not commonly applied in practice (Häkkinen & Pulakka, 2007). Buildings, representing a very common product with a long life cycle, have been especially addressed in the implementation of LCC. An ISO standard (ISO-DIS 15686-5) for LCC analyses of buildings is currently under preparation.

Life cycle assessment (LCA) can be seen as an extension of LCC. It is a technique for assessing the environmental aspects and impacts of a product by compiling an inventory of relevant input and outputs of a products system, evaluating the potential environmental impacts associated with those inputs and outputs and interpreting the results in relation to the objectives of the study (ISO 14040). The methodology, principles and guidelines of LCA are presented in ISO standards 14040 and 14044.

Besides an active international standardization process in relation to LCC and LCA, the life cycle approach is especially being promoted by the European Community, as exemplified by the Directive 2002/91/EC on Energy Performance of Buildings, which has then been implemented in national legislations.

Total cost of ownership (TCO) is a related methodology for assessing the life cycle costs of products of shorter life time, such as cars and software (Ellram, 1995).

FROM COST TO VALUE

The second extension is obvious: it is not enough to look at the costs, but also the value provided by the artefact should be taken into account. Thus, the move is towards the optimization of the value/cost relation over the life time of the artefact. The method of Whole Life Value (WLV) (Bourke et al., 2005; Saxon R, 2005) has been proposed with this in mind, with the aim of supporting investment decisions at any stage in the life of an infrastructure or building asset. This has led to much discussion of the ratios between the costs of producing, maintaining and operating buildings, with the implication that relatively small increases in production costs can leverage much larger savings in maintenance and operation. (Ive, 2006 ; Saxon, 2005 ; Hughes, et al, , 2004, Evans, et al, ;1998). There is evidence, for instance, of improved health care outcomes arising from improved hospital design (Choi, 2005). It has also led to a recognition of the subjective aspects of value and an emphasis on value exchanges between the wide range of stakeholder groups (Choi, 2005; Loftness et al, 2006)

From design focus to life cycle focus

However, in all previous approaches the arena of managerial action has been in investment or design decisions. Obviously, the outcome is dependent on managerial action throughout the life cycle. Thus, the next switch of focus is from (optimization in) design to the whole life cycle. Here, methodological approaches such as whole life systems engineering (Boardman et al, 2005; Boulding, 1956; Churchman, 1968) and total asset management come into the picture. On the other hand, with origins in marketing, strategy and product development, such approaches as product service systems (Roy, 2000; Mont, 2002; Manzini, Vezzoli & Clark, 2001) and integrated solutions (Oliva & Kallenberg, 2003; Levis, 2005, Brady et al. 2005) come into the play. There is also a related switch of focus from manufacturing to service underway, incentivized by high revenues from maintenance and upgrading; high margins and stable income streams from providing services.

Managing production: from static black box to dynamic open box

Operations management has traditionally subscribed to static view of the managerial situation (Jaikumar & Bohn, 1992). However, a more dynamic view is gaining ground, in which learning and improvement are seen to take place. This can be seen as part of a broader movement away from a simple transformation view of production, in which it is modelled as an input-output relation, to one which in which transformation is supplemented by the concepts of temporal flow and customer value. The temporal flow view highlights the problem of waste, which can be reduced or eliminated by implementing appropriate production control mechanisms (especially the pull method of production control) and continuous improvement based on empirical observations in production itself, as demonstrated in the Toyota Production System (TPS). The value concept places customer requirements at the centre of the analysis, tracing the processes necessary to fulfil them (Koskela 2000).

In production management terms, through life management is about producing an artefact and then producing services which accompany it. The static transformation model, in which the task of management is to plan, (managerially) execute and monitor, is particularly inadequate to capture through life processes which, rather that ending in the delivery of a discrete saleable product, involve a continuous and developing flow of value generation among a variety of stakeholders (Saxon, 2005). Thus, a production view on through-life management identifies three generic tasks:

- designing and realizing the production system
- operating the production system
- improving the production system.

Of course, the longer the life cycle, the more important is the dynamic aspect. It is a view which underpins the TPS (also known as lean production). Here, the continuous pursuit of waste elimination and value maximization is perhaps the central feature. Thus, calls for lean life cycle management have been presented (Hines et al, 2006).

FROM FLOWS TO CAPITAL

The approaches hitherto have implied that the focus is on the summed flows of costs, materials and value, which one endeavours to optimize. With origins in sustainability economics and company valuation, an alternative approach has recently been proposed. For Pearce (2003), the central issue for sustainability is the preservation and increase of wealth, in the sense of real capital value. This capital approach can be implemented at different levels, ranging from global to company. One important issue that arise is “which are different capitals in play, and how do they possibly substitute for each other?”.

In the case of through-life management, it is suggested that the following types of capital accentuate:

- the (physical) artefact itself.
- codified information about the artefact (in form of drawings, instruction manuals, maintenance history, etc.)
- uncodified knowledge and skills required for using and maintaining the artefact
- (influences on) the natural capital (depletion of minerals, pollution).

The merit of this approach is that it brings hitherto disparate aspects of sustainability, information and learning into the same conceptual framework.

FROM DECISIONS TO DESIGNING

It is common to see management as consisting of decision making, at least as its dominating ingredient. Through-life management is often conceptualized as decision making, which is supported by the classical decision making theory. In this framework, the attractive idea of the identification of key decisions in through-life management arises. The hope is that perhaps we can cover a major part of through life management by focusing on a few key decisions. This line of argument has been adopted, for example, by Krishnan & Ulrich (2001). They suggest the decision perspective is suggested as a unifying perspective within which other perspectives can be subsumed. According to them, the nature of the decisions made remain constant across organisations and time; identifying them “helps us get a glimpse inside the 'black box' of product development”. They provide a comprehensive decision perspective model of the product development process and identify 35 questions which they claim are generic to all product development processes.

It would be tempting to extend the Krishnan & Ulrich model to through-life management. The key decisions are related to i.e.: (a) life cycle costs (b) energy efficiency; (c) continuous improvement; (d) ease of maintenance; (e) flexibility of use; (f) design for decommissioning.

However, the decision making model represents a static atemporal model in which several critical features have been abstracted away in order to facilitate the clear enumeration of decisions. If we are to relate these decisions to the life-cycle, we need to re-introduce the element of time. Here, naturalistic decision making (NDM) offers itself as an alternative concept. According to Klein (1998) this type of decision making has the following qualities: it occurs in dynamic and turbulent situations; it is fast; it is concerned with ill-defined tasks; it is a process guided by previously acquired knowledge; the emphasis is on the evaluation of a single solution, rather than choosing between alternatives; solutions are satisficed (found to be adequate) rather than optimised. This amounts to a recognition that time is a design resource, the cost of which must be measured against the value of achieving an optimum solution.

Moreover, Thagard (2000) has attempted to analyse the sense making process in which alternatives are constructed as a problem of coherence. The production of a coherent account of a situation can, he argues, be understood as a process of “satisfying multiple constraints” (p. 17) such that representational elements are to be assessed as to whether or not they fit together. Those that fit together can be included in the same account, those that do not, can not. Schön (1991) treats design as “a reflective conversation with the situation, equating it with other professional practices, such as psychotherapy. These reflective practices are processes of active sense making, in which actions are shaped to respond to a perceived situation and, in turn, reveal further knowledge of that situation.

These developments suggest that improving management processes involves something more than simply improving decision making processes, as narrowly conceived in conventional decision theory. That is to say, it involves more than developing better procedures for assembling information and choosing between alternatives. Similarly, Boland and Collopy (2004) argue that management has too long been seen as consisting of decision making, whereas the alternative conceptualization of management as design has been neglected. They argue that making a decision from alternatives is not the difficult part in management, but rather designing those alternatives. And if a superior alternative is designed, the decision making itself is trivial. Another aspect of the suggested design attitude is that in design, all aspects have to be taken into account, whereas managerial decision making tends to concentrate on the “key decisions”, leaving other decisions for others and later stages.

Then, how would through life management seem from a design perspective? The key design tasks would be to design the whole life cycle of the artefact, related organization as well as managerial and information systems to allow for the realization of through-life management goals, especially

- the (artefact) design project organization to take life cycle costs into account (and generally design for production/construction use, maintenance and decommission)
- the organizational system for continuous improvement, especially during use and maintenance
- the information infrastructure for capture, storage and access of information and knowledge along the life cycle

Framework of understanding for through-life management

Analysis of the initiatives towards through life management reveal that the question is about a multi faceted and complex phenomenon, which still lacks a robust, unified conceptual and theoretical foundation, although several ingredients for that can be pinpointed (Box 1).

Box 1: Approaches to through-life management

- ***From investment cost to life cycle costs*** - minimization of life cycle costs of an artifact under design and construction, the specifications of the artefact being given
- ***From cost to value*** - it is not enough to look at the costs, but also the value provided by the artefact should be taken into account
- ***From design focus to life cycle focus*** - from (optimization in) design to the whole life cycle
- ***From static black box to dynamic open box*** - understanding of production from a static view of managing the design and production to a dynamic view (where learning and improvement is fostered; continuous focus of waste elimination and value maximisation)
- ***From flows to capitals*** – from looking narrowly at the flows of value and costs to a broader view that acknowledges the need to preserve and increase associated capitals
- ***From understanding of management as decision making to a design approach*** – from looking narrowly on decisions to embracing the broader view of management as design

Thus, tentatively we may define through-life management as an approach, where

- at each stage, activity and decision, the impacts on later stages, activities and decisions are taken into account for the sake of through-life optimisation regarding cost, value and material flows
- the unavoidable uncertainty is appropriately counteracted
- the relevant real asset capitals are preserved and increased
- production system design and control are geared towards elimination of waste and increase of value
- continuous improvement regarding cost and value is aggressive pursued.

However, for several reasons, it is easier to recognize when through-life management has failed than to define what through-life management should be. Table 1 represents an initial attempt to characterize commonly perceived failures of through-life management. It is acknowledged that all theoretical failures are not yet adequately represented. The development of a diagnostic list of failures informed both by theory and practice is targeted in further research.

Table 1: Failing mechanisms of through-life management and their impacts

Failure of through-life management	Impact
Dominating focus on first cost during design and construction	Increased life-cycle costs
Relative neglect of design for constructability	Increased construction costs
Relative neglect of design for usability	Increased use costs or reduced use value
Relative neglect of design for maintainability	Increased maintenance costs
Relative neglect of design for decommission	Increased decommission costs
Neglect of design for flexibility and robustness	Difficulty of accommodating changing user requirements or technology
Loss of information and knowledge over time	Increased costs over the life cycle due to missing information and knowledge
Failure to act on repeating problems	Increased costs due to neglected learning
Suboptimal maintenance effort	Accelerated physical decay of the facility and reduced use value
Overhaul destroying the integrity and merits of the original design concept	Decreased use value, increased life-cycle costs

CONCLUSIONS

The absence of through-life management as a key consideration in large scale procurements has been highlighted. As a result this paper has brought together several approaches that discuss relevant strands of through-life management. These approaches range from focusing on investments costs to life cycle costs, to calls for a deeper and a broader view of design and production sciences. This paper presents through-life management as an approach, where

- at each stage, activity and decision, the impacts on later stages, activities and decisions are taken into account for the sake of through life optimum regarding cost, value and material flows
- the unavoidable uncertainty is appropriately counteracted
- the relevant real asset capitals are preserved and increased
- production system design and control are geared towards elimination of waste and increase of value
- continuous improvement regarding cost and value is aggressive pursued.

As an offering to facilitate through-life management, an initial diagnostic style checklist has been provided.

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