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Development and Testing of a Boolean Obsolescence Assessment Tool for Built Environment Asset Systems

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Abstract

Obsolescence is an economic phenomenon that is driving significant lifecycle investments into long life assets when managed reactively. There is an abundance of research literature aimed at the forecasting of obsolescence and the management of lifecycle mismatches. However, no literature primarily focuses on the Built Environment and the typical long life assets that exist within built structures across the globe. The aim of the tool designed and empirically tested within this paper is to interpret and visualise component data to aid monitoring of obsolescence and hence aid decision-making and mitigation strategies. This paper evidences that obsolescence driven investments can exceed hundreds of thousands of pounds in annual capital expenditure to keep assets operational throughout their expected life. To tackle these additional expenditures a Boolean model was adapted, tested within a case study and then further developed in preparation for further testing. The featured model contains internal weighting mechanisms, which aid the strategic prioritisation of resources, highlighting the most vulnerable systems to obsolete components. The major findings of this paper include real world evidence of the cost of obsolete parts to Facilities Managers along with the empirical testing and development of a decision-aiding tool. This paper targets a gap within current research and creates a starting point for further research into the field of obsolescence mitigation for stakeholders within the Built Environment.

Keywords

Decision support systems, Maintenance, Lifecycle, Obsolescence, Asset Management

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Introduction

Obsolescence has existed within literature since Dyckman's (1961) paper on obsolete job skills but it wasn't until Cowan et al. (1970) and Warmington (1974) that the term was used in regards to the Built Environment and assets. The use of the term and its agreed definition has changed, along with the introduction to whole life or lifecycle approaches to Asset Management. The British Standard Institute (BSI) describes obsolescence as 'inevitable' and 'unavoidable' whilst defining it as when an item is 'no longer suitable for current demands, or is unsupportable/no longer available from manufacturers' (BSI 2007). Obsolescence has affected advanced, fast moving industries such as Defence, Oil and Gas, Aerospace and Avionics in recent history, with Abili et al. (2013) and Rojo & Roy (2009) giving good examples. A recent public example of how modern systems within the Built Environment can contain obsolescence driven investments, would be the UK NHS along with the Dutch Health services requiring large payouts (£5 million for the NHS for a year extension) to Microsoft, extending support for the now obsolete Windows XP, despite the publicly available support dates via their website. This exemplifies the current approach to obsolescence management as depicted recently by several authors (Smith 2000; Myers 2007; Sandborn 2013). Through Gap Analysis of the current literature surrounding obsolescence, it was identified that there were the following issues:

- The majority of recent research focuses upon manufacturers and the prediction of obsolescence to optimise sales strategies and continuity planning
- The primary focus is upon consumer electronics and little on assets typical of the Built Environment
- There are no clear guidelines or explicit tools easily available to aid the mitigation of obsolescence

This paper develops a tool that can be used to aid obsolescence mitigation for end users. This constrains the scale and scope of data required in order to improve the applicability and feasibility of such a tool to users as opposed to manufacturers. The case study used to develop the model will be of a large scale, multipurpose office building in Central London, featuring asset systems which are transferrable to other building types (e.g. Security Systems).

To further illustrate the effects of obsolescence, the featured case study had experienced an expenditure of £1.7 million over a 37-month period (≈ £0.5 million annually) across all asset systems between 2012 and 2015. Applying the 80:20 rule, £1.1 million were concentrated in three systems alone, an important point for any Facility Managers looking to prioritise obsolescence mitigation. To add another layer of context, this case study is a private finance initiative funded building, with a contract length of 30 years. As a conservative projection, the remainder of the contract will witness £10 million worth of lifecycle capital expenditure driven or associated with obsolescence to sustain the asset systems. Depending on the unforeseen nature of these potential investments, it is possible for the planned lifecycle budget to be exceeded or additionally the lifecycle profile to become 'lumpy'. This poses a considerable challenge for Facilities Managers, one that will only increase (Myers 2007; Gravier & Swartz 2009).

Background

Figure 1 illustrates how the obsolescence phase of a components lifecycle is initiated by an end of life notification (EOL), these are released by manufacturers to suppliers and the wider market – the first issue is the distribution and recording of such information. Add to this scenario the likelihood of an organisation having an updated obsolescence management plan (OMP) and it isn't difficult to understand how unforeseen obsolescence driven investments occur.

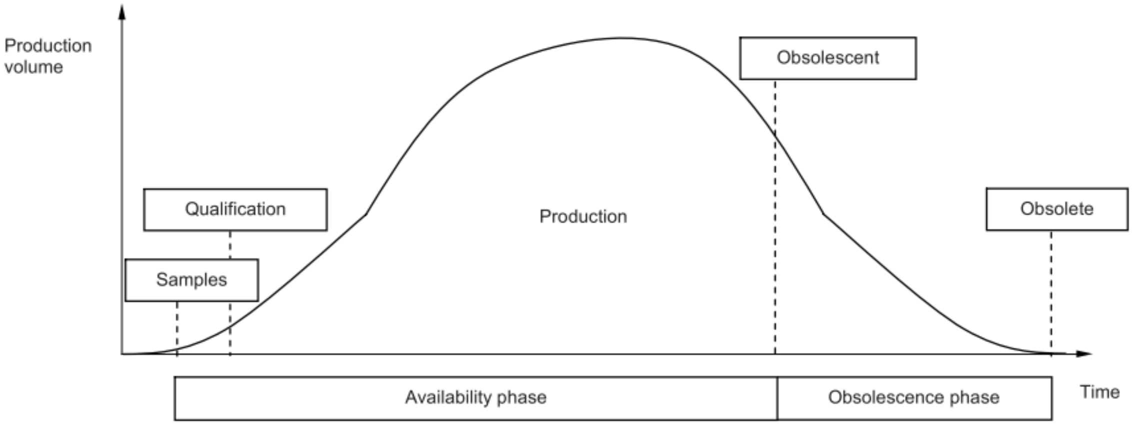

Figure 1 Asset lifecycle and the introduction of an 'Obsolescence Phase' (BSI 2007)

Bartels et al. (2012) explicitly displayed how obsolescence indexing could work and is shown below in its original form.

$$PI = 100\frac{(G + Y_1)}{(G + Y_1 + R + Y_2 + B)}$$

G = two or more suppliers

Y_1 = one supplier and funded solution

Y_2 = one supplier and no funded solution

R = obsolete part and no solution

B = unknown status

Literature illustrated that the use of alternative components from the market was a reputable mitigation strategy and a spares strategy is still the most widely used and referenced technique. The first development stage of the obsolescence assessment tool involved the adapting of Bartels et al.'s (2012) indexing technique and a change in nomenclature, resulting in the following iteration:

$$AH = 100\frac{(S + Y_1 + A_1)}{(S + Y_1 + Y_2 + O + U + A_1 + A_2)}$$

AH = Asset Health

S = Two or more suppliers and no EOL

Y1 = One supplier and no EOL notice

A1 = Alternative part and no EOL notice

Y2 = Alternative Supplier, no alternative part and EOL

O = Obsolete part with no solution

U = Unknown status

A2 = Alternative part with EOL notice

Finally, the drivers of this research are geared around the need to better understand the behaviour of obsolescence within asset systems from the Built Environment and to develop a tool that was usable in the improvement of mitigation techniques. In addition, through creating a link between obsolescence and the bathtub behaviour of the cost of components (Herald et al, 1998), there is a cost prevention element to research of this type.

Figure 2 demonstrates how a conceptual adoption of the bathtub curve theory to show the increase and decrease of obsolete components (Herald et al. 2008), can illustrate how the financial implications initiated by obsolescence can be simplistically represented. The bathtub curve represents component cost, as opposed to reliability, driven by the assumption that at time 0 the component is 'cutting edge', deteriorating as the market matures and then becoming a 'trailing edge' or scarcity component within the obsolescence phase (Herald et al. 2008). It is the synergy of these two concepts that the crux of the obsolescence problem can be visualised – keeping assets operational and serviceable throughout their expected life and beyond.

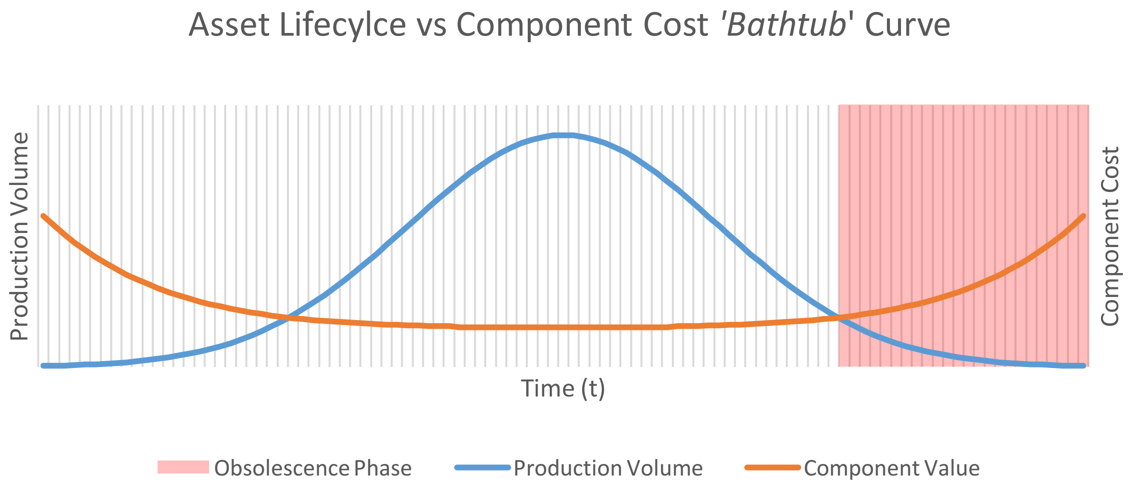

Figure 2 Asset Lifecycle vs Component Cost 'Bathtub Curve'

Literature Summary

Obsolescence

There have been a number of earlier studies in this area (Sandborn & Singh 2002; Singh 2004; Singh & Sandborn 2005; Singh, Peter Sandborn, et al. 2004; Singh & Sandborn 2002; Singh & Sandborn 2006; Singh, P. Sandborn, et al. 2004, Solomon et al. (2000) and Rojo & Roy 2009). This paper will contrast the approach taken by the above by viewing/tackling this issue from a different angle and taking a user centric approach to designing a methodology to best mitigate obsolescence. In addition, some of the earlier research has been funded by large organisations from the semi-conductor and consumer electronics industries, which brings access to the large data sets i.e. sales data, allowing for more data driven analysis.

The major benefit of research in partnership with large organisations with big data sets, is the mitigation of sample bias created by the low volume and slow pace of which obsolescence would typically have an impact. To clarify, the long life asset systems that feature within this paper have life expectancy predictions which enter the 10-20 year time frame and hardware components which can exist within the marketplace for even longer. Software has a different behavioural pattern. However, when looking to use a live case study (such as the one featured within this paper), it is difficult to extract the bias created by few changes over a short time frame, as opposed to a database of historical sales records that can date several decades and include millions of transactions.

Whist the approach within this paper may contrast that of the above, there are clear unifying themes and messages, such as the statement that ‘whilst obsolescence is unavoidable, the spiraling additional costs are not’ (Solomon et al. 2000). In addition, the universal agreement that proactive management techniques are required to effectively mitigate obsolescence (Bartels et al. 2012; Sandborn 2013; Zheng 2011), however how to explicitly do so or what methodology to use is unclear. To summarise the current stance upon obsolescence management, a reference must be made to the current BSI on Service Life Planning, which contains the statement ‘[This document]…does not cover limitation of service life due to obsolescence or other non-measurable or unpredictable performance states’ (BSI 2012). It is the ‘unpredictable’ and ‘non-measurable’ nature of obsolescence that is aim of this research.

Obsolescence Indexing

The obsolescence indexing technique featured within this paper originated from Bartels et al. (2012), generically, obsolescence indexing involves the assignment of a status to a component of an asset in reflection of certain characteristics i.e. age, type, EOL notification. This is a rather elementary measure to undertake, but an essential step to consolidating the relevant pieces of information regarding assets and their components when looking to mitigate obsolescence.

Figure 3 illustrates how conceptually, an indexing technique could be used in conjunction with a predefined threshold limits. It is speculatively possible to then use this visualisation to formulate a mitigation strategy, targeting specific components and cause and effect analysis to taper mitigation strategies.

Figure 3 Suggested Asset Health Score Threshold adapted from Bartels et al. (2012)

In theory, this method could be very useful for Facilities Managers and the often large asset registers they're responsible for, however, an identified gap within the literature highlighted a need for empirical testing and publishing of results.

Boolean Decision Making Models

Boolean methods are commonly used for modeling and have proven to be an effective technique for representing probabilistic relationships. Dubos (2011) and Dubois & Prade (2011) both explain the use and benefits of using a Boolean structure in comparison to a Fuzzy Logic architecture. The clear and structured nature of Boolean models improves their applicability to modeling, however there are weaknesses as well, such as the requirement to break relationships down into simple orthogonal processes. In regards to obsolescence indexing, certain characteristics are distinct and therefore a Boolean model is an appropriate fit, allowing for clear assignment of statuses to components.

Research Stance

The current research on obsolescence management has failed to address the topic from the perspective of the most vulnerable member of the supply chain, the end user. In addition, there has not been enough research within the confines of the Built Environment, which installs a wide range of long life assets (20+ years) containing rising levels of short life components (2-5 years). This paper addresses this issue, beginning with how to identify and monitor obsolescence levels within typical low volume, long life assets found across the Built Environment. Finally, due to advancements in research techniques and the level of computational power now readily available, research of this type is now more feasible, allowing for the Built Environment to learn and test ideas and methodologies from adjacent industries.

Most of the latest research around obsolescence focuses upon forecasting or predicting obsolescence within components, therefore allowing a manufacturer or supplier to supersede a design or equally reduce stock levels to meet demand. Solomon et al. (2000) shows how sales data of sequential products were used and then their historical sales distribution mapped, considering the trend - if present to then forecast the project lifecycle of future iterations of the product. Figure 4 illustrates how the lifecycle of 16M memory chips (DRAM) has been mapped and then used to predict the expected lifecycle and obsolescence phase, such projections would then be used to optimise manufacturing and stock holding in anticipation of a decrease of demand.

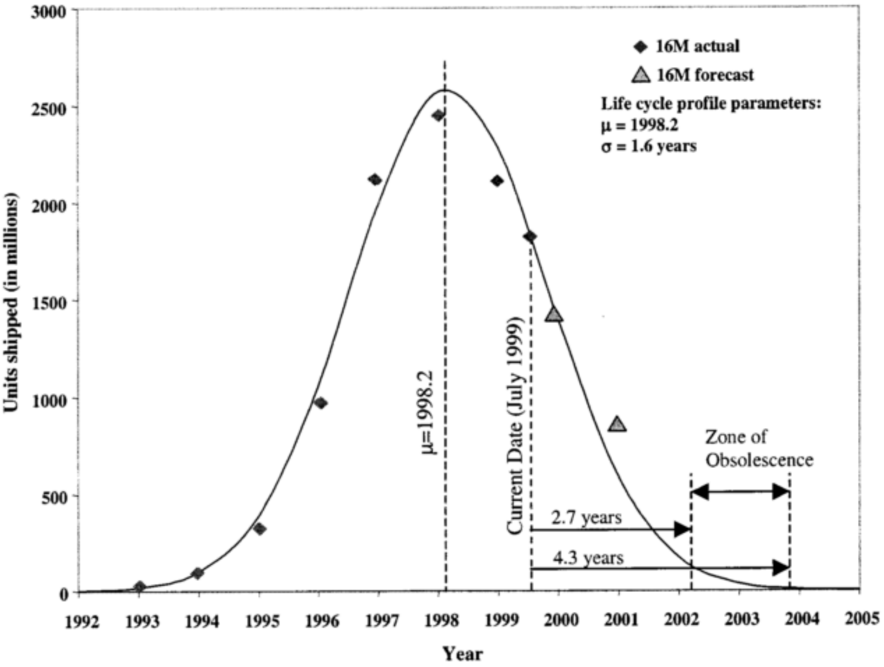

Figure 4 Prediction of the Obsolescence Phase for 16M DRAM by Solomon et al. (2000)

In contrast, Bartels et al. (2012) and Prabhakar (2011) take slightly different approaches and use a quantifiable characteristic of a component, in this case memory capacity. The rate of increase of memory for semi conductors was then trended, which can then be used predict when the current chips on the market would be superseded. These types of techniques are beneficial for several stake holders, for example a manufacturer within the consumer electronics market would use this type of information when designing new product lines that contain these components. To avoid supportability and maintenance issues, the lifecycle of internal components must align in order to maximise the length of time before components are deemed obsolete.

The methodologies that feature within the above papers require large data sets, which have been produced over significant periods of time. The results from these papers are highly valuable. As mentioned earlier, however, the usability of such information or techniques is debatable for end users, who do not have the power of economy of scale.

Methodology

The methodology presented in this paper contains a case study to empirically test an adapted obsolescence indexing technique and investigate its applicability within the Built Environment. In addition to the adaptions made to the original model, further internal weighting was applied to incorporate the total value (Total Lifecycle Cost) and criticality (criticality to the case study contract). The narrative being, through considering these additional two characteristics further accuracy can be applied on the results when seeking to identify which components, within which system should be prioritised for obsolescence mitigation.

Case Study

The case study used features a multi-storey office building, with a floor space of 100,000 m^2 and a total lifecycle cost of £56 million worth of assets in central London. This building will be referred to as *Building A* and after reviewing historical procurement records, it was decided that the following BCIS Code 5 – Service Assets would be appropriate for the case study:

- Fire Alarm System
- Building Management System
- Security System

These systems equated to an accumulative lifecycle investment of £1.1 million across a 37-month period. Examples of the investments made include compatibility/functionality issues with upgrades, unsupportable control panels and compliance driven investments.

Finally, *Building A* is a private finance initiative building (PFI), which adds a further dimension to the emphasis on lifecycle and asset management with regards to the above asset systems. Unforeseen investments of this nature impact both the service delivery and the planned lifecycle expenditure over the tenure of the contract. There are also contractual financial deductions built into PFI's, which add a further driver to gaining a better understanding of how obsolescence behaves and how it could be monitored and then mitigated.

Building of the Obsolescence Assessment Tool [OAT]

The mechanics behind the model is Boolean in the selection of statuses for each component, which then feeds into the adapted Bartels et al. (2012) formula. The data collection of the three independent asset systems was carried out over a period of a year with continual communication with distributors and suppliers to gather further background information. Anonymity was given to all suppliers to encourage the open sharing of such product information.

Weighting mechanisms

Inside OAT there are two weighting mechanisms applied, the narrative being; if two assets showed the same levels of obsolescence, then these two mechanisms could be used either independently or collectively to identify priority assets. Through this wider consideration OAT will be able to identify which asset systems, if un-operational will have potentially the largest impact due to obsolescence.

Initially, a list of all BCIS code 5 assets were sorted value and then dissected into four equal zones, which in turn would receive individual weightings. Meanwhile, a survey was undertaken on the same list of assets by senior management to ascertain their ‘criticality’ in regards to impact of un-operational status. The survey involved ranking assets from most to least critical, an exercise that would have to be repeated for calibration due to the perception of criticality being a site by site specific category.

In order to justify the weightings applied a form of sensitivity analysis was applied to gauge the impact on the resultant Asset Health scores with a range of weightings on the fixed inputs. The desired impact range of OAT’s output was half of a threshold range (shown in Figure 3), which is 12.5%. Therefore, a range of weightings was used to influence the output between 0 – 12.5%, this was run independently (i.e. by asset systems), in reflection however they produced suggested weightings that were very similar. Figure 5 and Figure 6 illustrate the range of weightings used and how they impacted OAT’s output with a set of asset data that was unchanged.

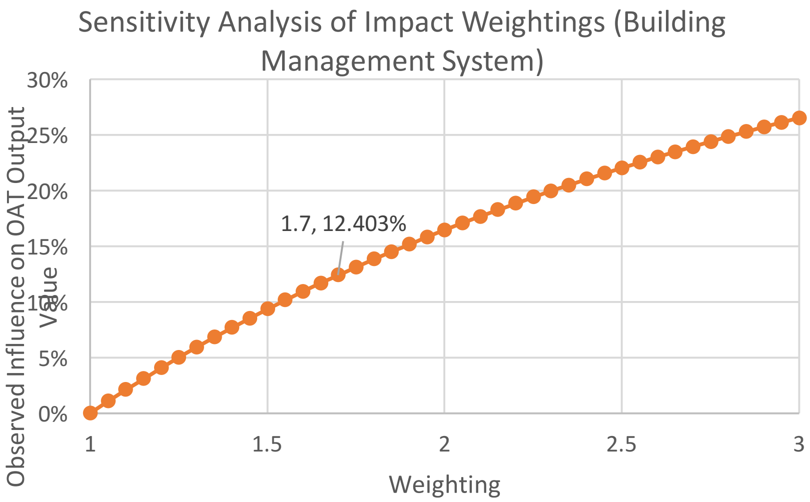

Figure 5 Sensitivity Analysis for BMS OAT Output

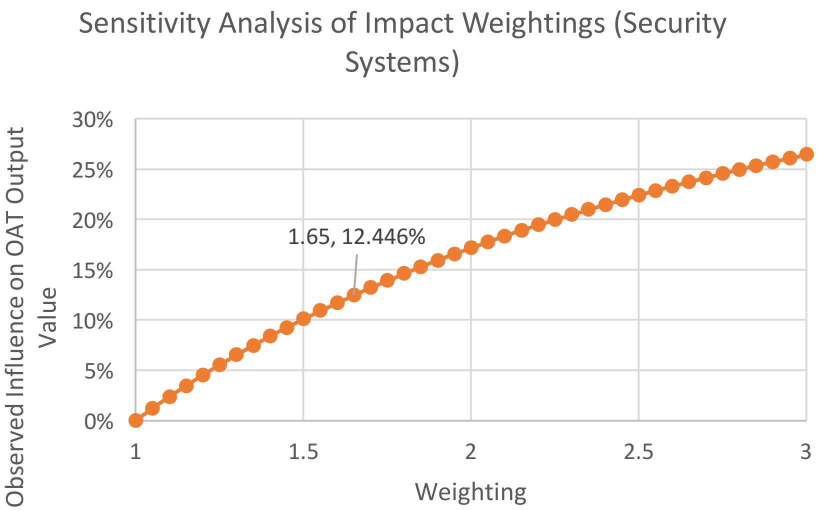

Figure 6 Sensitivity Analyses for Security Systems OAT Output

From Figure 5 and Figure 6 it is clear that a maximum weighting of 1.7 will cause the Asset Health score to decrease by a range of ≈ 12.5%, which is half of a threshold level. The narrative being, an asset that is classed as ‘critical’ lying within the lower half of the ‘medium threshold’ would be weighted down into the ‘low threshold’ (representing a high number of component parts that are obsolete or within their obsolescence phase) and therefore a larger risk.

Note the third asset system was not used for the sensitivity analysis, due to the unique business model used by the supplier it produces perfect results from OAT and is therefore not appropriate. This will be explained further in the findings section.

In line with the methodology for the creation of weighting zones, the weighting range was equally divided into four segments, resulting in the following weightings:

- Zone 1 – 1.0 (least critical or valuable)
- Zone 2 – 1.23
- Zone 3 – 1.46
- Zone 4 – 1.70 (most critical or valuable)

In summary, Building A represents a case study of significant size that contains assets which are transferrable across the Built Environment and provides first hand evidence of the effects of obsolescence driven investments. Through adapting and extending an existing obsolescence indexing technique this paper has the opportunity to test the applicability of such a tool and investigate the use of its results. This has not been previously published.

Results

The findings illustrate that the three asset systems have contrasting levels of obsolescence amongst the components with varying peripheral factors such as alternative suppliers. The reaction to such findings will vary on an asset-by-asset situation, however, OAT will identify which components within an assets system to review and therefore which suppliers should you immediately contact.

The following figures illustrate the types of graphic illustration possible from OAT, exploring both the assets health score and directly components that are either obsolete or within their obsolescence phase.

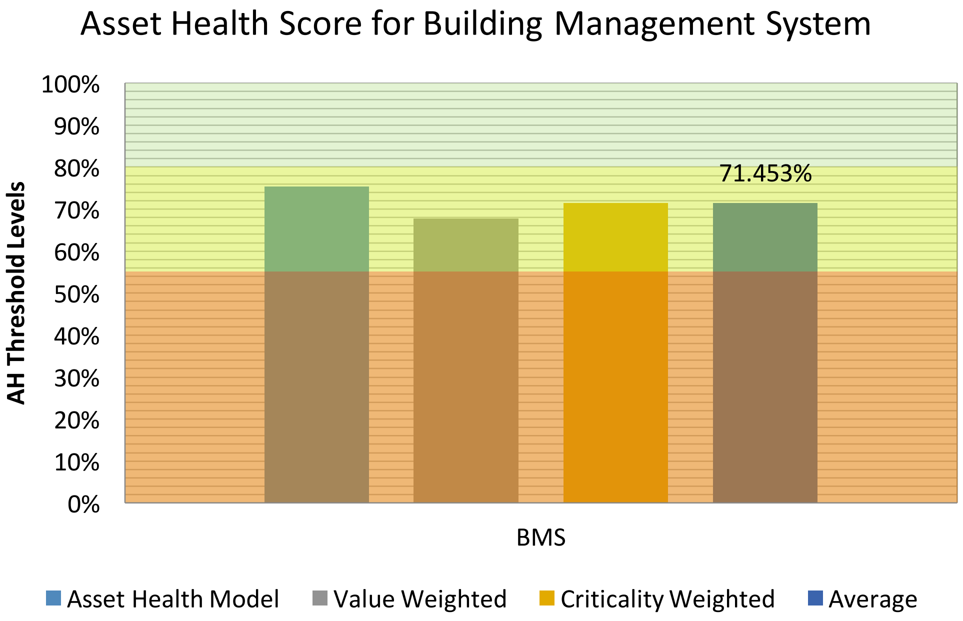

Figure 7 OAT Asset Health Findings for the BMS

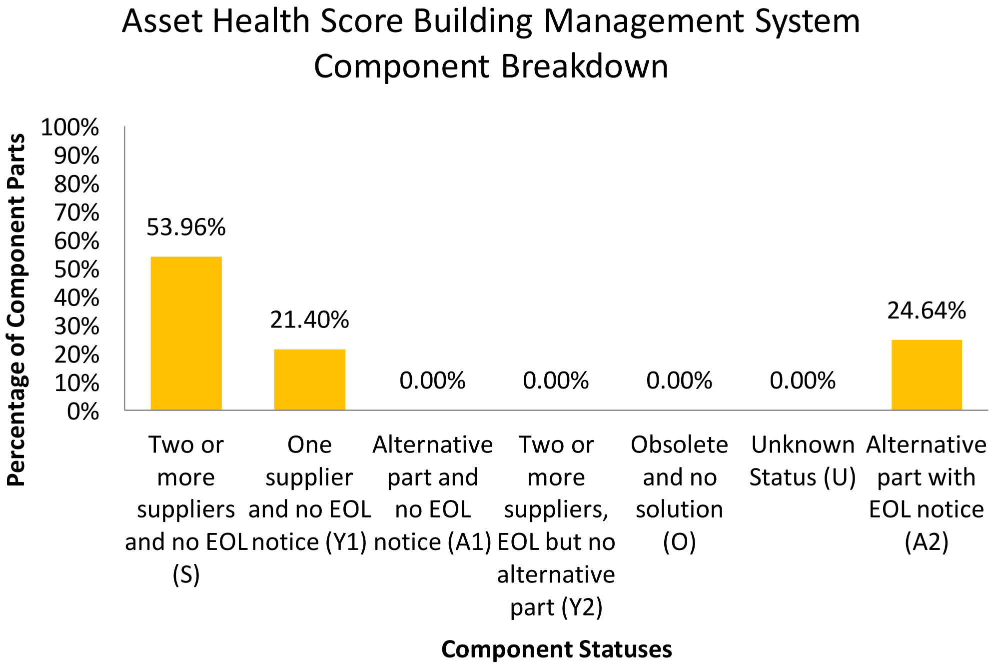

Figure 8 Asset Health Score Component Breakdown for BMS

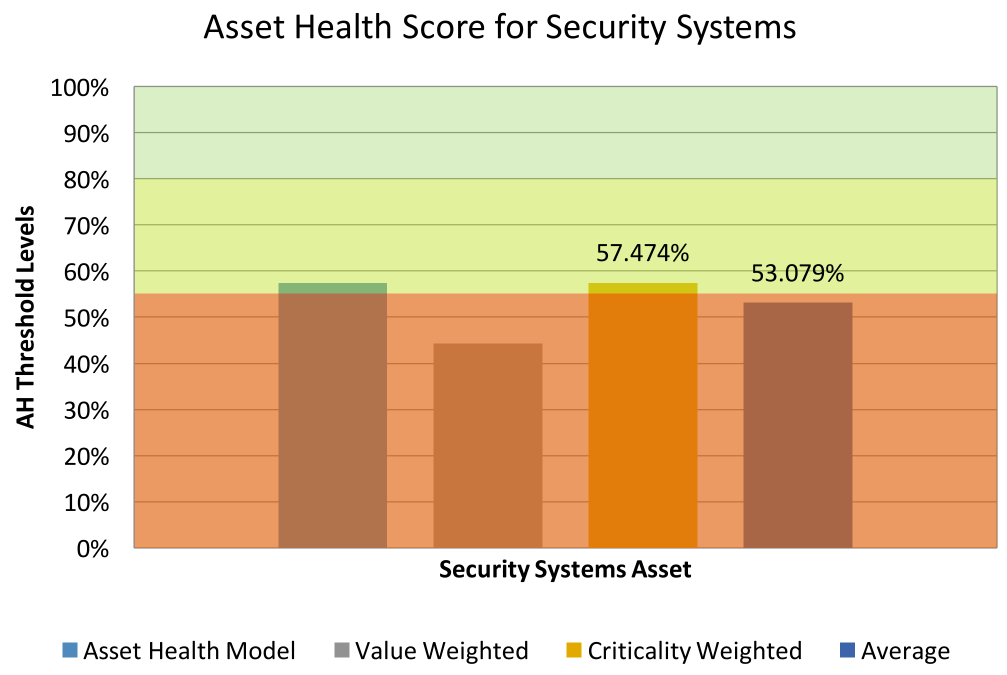

Figure 9 OAT Asset Health Findings for the Security System

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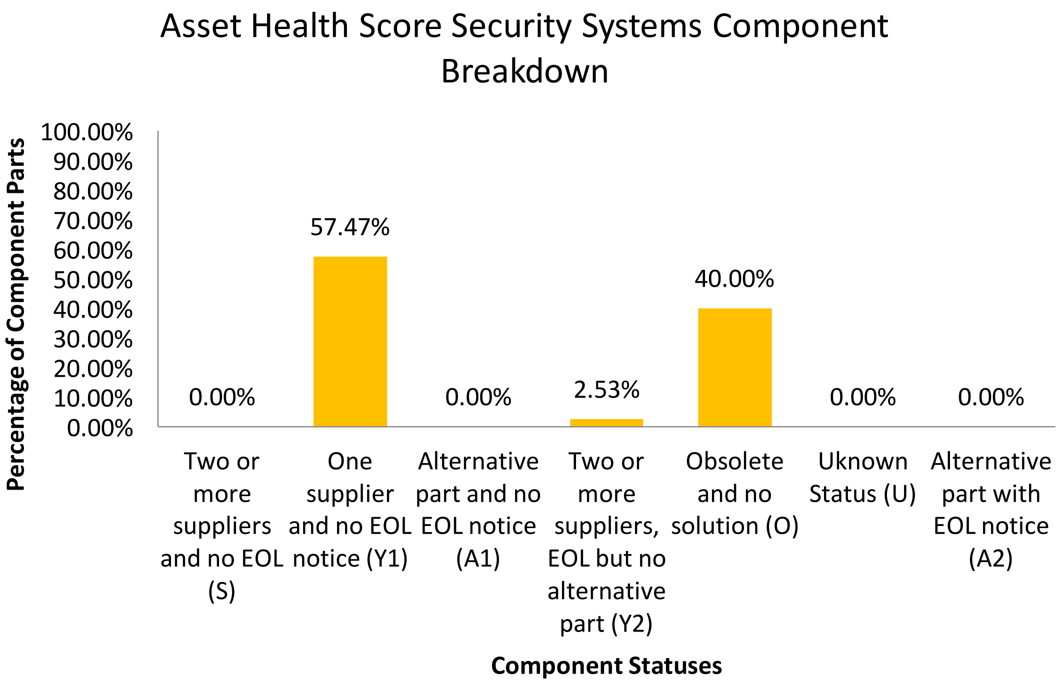

Figure 10 Asset Health Score Component Breakdown for Security System

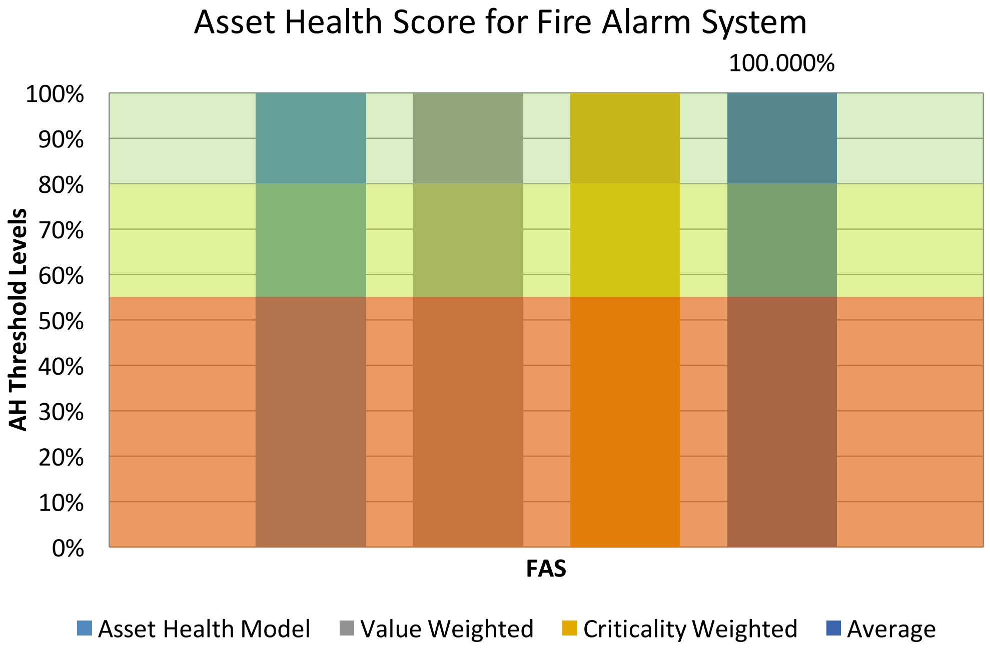

Figure 11 OAT Asset Health Findings for the Fire Alarm System

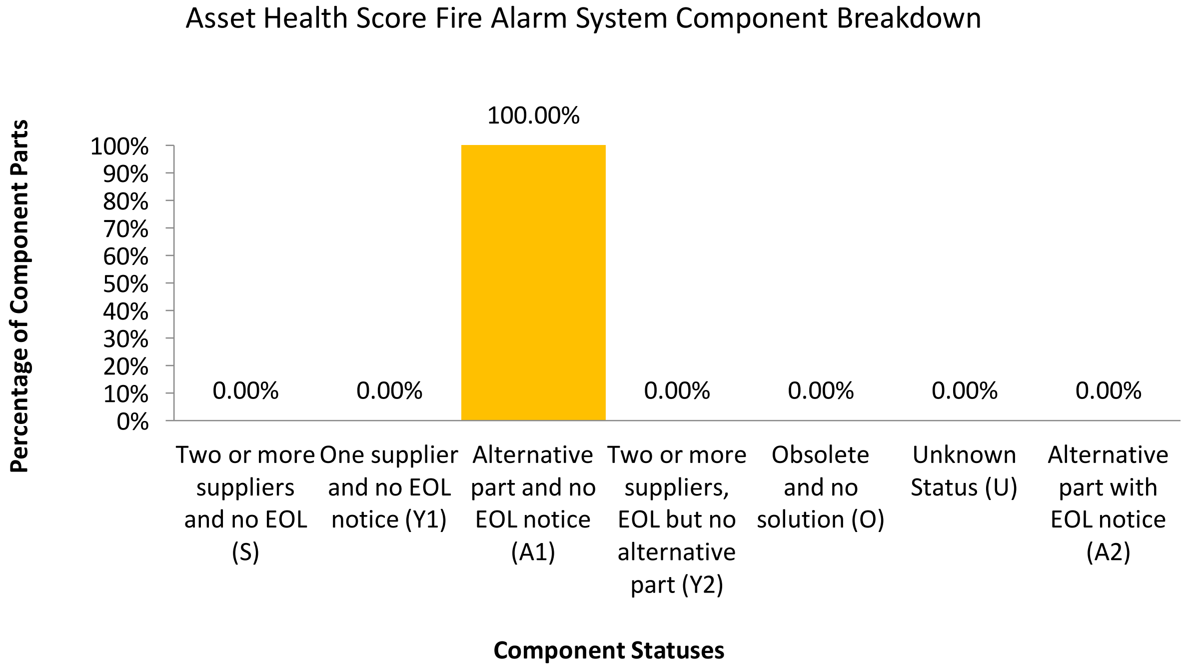

Figure 12 Asset Health Score Component Breakdown for Fire Alarm System

The manufacturers of the Fire Alarm System have a business model where all historical and future products are backwards compatible and are still supported. This is unique and is reflected in a perfect asset health score as all components both currently and in the near future are procurable which completely avoids obsolescence driven investments.

By comparing the results from the Building Management System (BMS) and Security System it is possible to get an insight to the variety of component statuses that can have operational impacts. The BMS contains medium levels of components (71.4%) that are in a strong position in regards to obsolescence. However, almost a quarter of the components within the system (≈25%) have an End of Life (EOL) notice against them, but with alternative substitute parts on the market. A possible operational response to these results could be, to undertake either a lifetime buy (if still possible) of the current components and store on site. Alternatively, investigate whether the alternative part is appropriate as a replacement for continued maintenance of the aforementioned components. Both would mitigate obsolescence and avoid a situation of potentially obsolescence driven investments at a later date.

In contrast, the Security System contains low levels of components (53.1%) that are in a strong position in regards to obsolescence. This system contains a rather large number of obsolete components (40% of total components), which pose an immediate risk of an obsolescence driven investment. In addition, there are few components (2.5%) that have more than one current supplier but with an EOL notice against them and no substitute part on the market. A possible response to these results could be to further investigate the components that have been identified as obsolete, this could lead to a lifetime buy (if still possible) or a slight system redesign. Both of which are likely to be highly expensive and if not aligned with planned lifecycle replacement of this system can have large financial impacts upon the budgetary planning within the business. It would be suggested that a cost benefit analysis (CBA) be undertaken to assess the need to mitigate or redesign the asset system.

In summary, through the use of a visualisation tool such as OAT, the analysis of an assets health in regards to obsolescence is far more efficiently digested. OAT will identify which parent assets to investigate, in which order and then which components specifically require attention, when considering lifecycle budgetary planning or obsolescence mitigation strategies. Research into this field along with management frameworks for addressing obsolescence is required by industry to reduce the level of unforeseen obsolescence driven lifecycle investments. It is the shift from a reactive to proactive stance when facing obsolescence, which will both aid this cost reduction whilst encouraging sustainable development within the Built Environment.

Conclusion

Both the literature reviewed as part of this paper and the feedback from industry experts highlight a distinct need for more to be done to identify and manage obsolescence within long life assets from the Built Environment. It is a phenomenon that is not new, rather the contrary, however the impact has grown and will continue to do so as the levels of technology imbedded within the aforementioned assets continue to rise.

This paper has documented the financial impacts unforeseen obsolescence driven investments have had upon a lifecycle budget, without considering the attached operational impacts. The Obsolescence Assessment Tool (OAT) developed within this paper was tested for its applicability to the above problem and the insights that the outputted results could provide for Facility Managers across the industry. The research stance of this paper is unique in the sense that it targets the end user and the level of asset data that is likely available. This paper therefore does not seek to predict obsolescence or forecast its eventuality (a common research topic for obsolescence), but rather provide a mechanism for monitoring it and help identify how it could impact your business.

Future Research

Obsolescence is a broad multidisciplinary topic, which has evolved as technology continues to innovate and advance. It is now a challenge to find fixed assets that do not contain or rely upon some form of technology within the Built Environment. In reflection to how the research problem has evolved, there is a plethora of research areas attached to this paper, which are worthwhile investigating. By solely considering OAT; there could be greater consideration for the importance of specific components within a system to the assets primary function. In addition, further inputs such as component availability in the form of spares and other mitigation methods could be incorporated, as they will influence the impact that obsolescence will have on an assets operational status. An improvement to the data collection would be to record the date of when an EOL notification was released for example, allowing for the plotting of Asset Health scores of a system over time and observe the impacts of certain lifecycle investments. Finally, the evolution of OAT will become more of a risk orientated tool under an existing research project, allowing for end users (Facility Managers) to quantify the financial impact that obsolete components within an asset register could have upon business continuity and resilience.

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