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# Development and testing of a Boolean obsolescence assessment tool for built environment asset systems

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## Abstract

**Purpose** – The purpose of this paper is to address the need for further development of tools that could be used to mitigate obsolescence within the built environment. Literature reviewed within this paper indicates a distinct gap in research, allowing for rising obsolescence-driven investments within asset systems. In addition to further conceptual development, case study testing is required to validate the use of certain existing methods.

**Design/methodology/approach** – This paper has developed a Boolean obsolescence assessment tool, which was then tested within a case study environment. This year-long case study provided real world data across three asset systems within an operational building.

**Findings** – The findings from this preliminary case study indicate that a Boolean tool of this type has the potential to provide significant insight into obsolescence mitigation. Such a tool, implemented in accordance with onsite asset management processes, has the ability to mitigate and avoid obsolescence-driven investments.

**Research limitations/implications** – This case study is limited because of its length and size. To mitigate the effects that may have been captured, this research project has been developed and continued.

**Originality/value** – The model featured within this paper originated from an untested obsolescence indexing technique. This model was adapted and extended to improve its accuracy and functionality, which also involved adding weighting mechanisms, resulting in not only an original model but a novel set of results because of the current lack of explicit testing of similar models.

**Keywords** Risk, Asset management, Lifecycle, Private finance initiative, DMSMS, Obsolescence

**Paper type** Case study

## Introduction

Obsolescence has existed within literature since [Dyckman's \(1961\)](#) paper on obsolete job skills, but it was not until the studies by [Cowan \*et al.\* \(1970\)](#) and [Warmington \(1974\)](#) that the term was used with 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 and 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 National Health Service (NHS) along with the Dutch Health services requiring large payouts (£5m for the NHS for one-year extension) to Microsoft, extending support for the now obsolete Windows XP, despite the publicly available support dates via their websites. 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 the following issues exist:

- 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 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, multi-purpose 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 £1.7m over a 37-month period (approximately £0.5m annually) across all asset systems between 2012 and 2015. Applying the 80:20 rule, £1.1m 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 (PFI)-funded building with a contract length of 30 years. As a conservative projection, the remainder of the contract will witness £10m 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”. Posing a considerable additional challenge for Facility Managers and one that is believed to only increase (Myers, 2007; Gravier and Swartz, 2009).

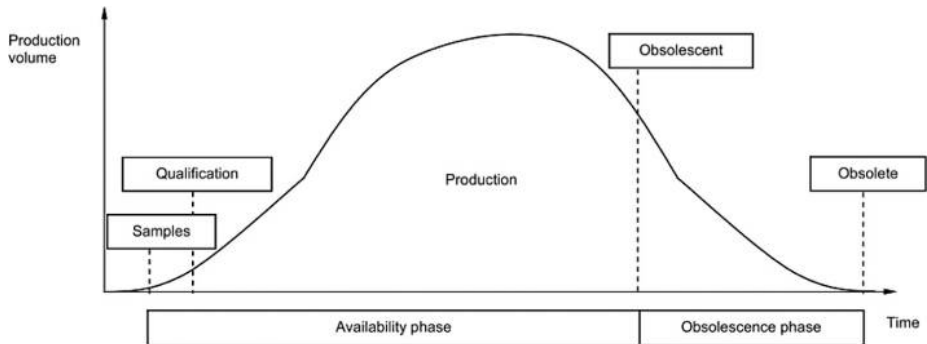
## Background

Figure 1 illustrates how the obsolescence phase of a components lifecycle is initiated by an end-of-life notification (EOL); this is 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 and it is not difficult to understand how unforeseen obsolescence-driven investments occur.

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

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

**Figure 1.**  
Asset lifecycle and  
the introduction of an  
“Obsolescence  
phase”



**Source:** BSI (2007)

where:

- $G$  = 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; and
- $B$  = 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 (OAT) involved the adapting of *Bartels et al.'s (2012)* indexing technique and a change in nomenclature, resulting in the following iteration:

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

where:

- $AH$  = asset health;
- $S$  = two or more suppliers and no EOL;
- $Y_1$  = one supplier and no EOL notice;
- $A_1$  = alternative part and no EOL notice;
- $Y_2$  = alternative supplier, no alternative part and EOL;
- $O$  = obsolete part with no solution;
- $U$  = unknown status; and
- $A_2$  = 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 is 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., 2008*), 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 in 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 zero, 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.

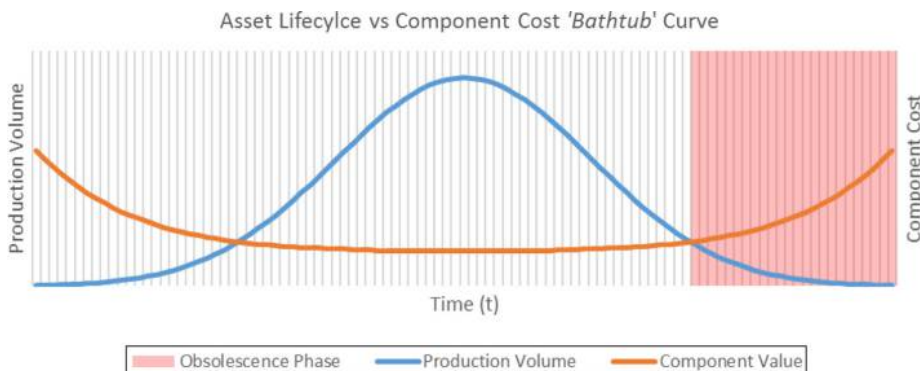
### Literature summary

#### Obsolescence

There have been a number of earlier studies in this area (Sandborn and Singh, 2002; Singh, 2004; Singh and Sandborn, 2005, 2002, 2006; Singh *et al.*, 2004a, 2004b; Solomon *et al.*, 2000; Rojo and Roy, 2009). This paper will contrast the approach taken by the aforementioned researchers 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 large data sets, for example, 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 to 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.

Although the approach within this paper may contrast that described above, there are clear unifying themes and messages, such as the statement that “whilst obsolescence



**Figure 2.**  
Asset lifecycle vs  
component cost  
“bathtub curve”

is unavoidable, the spiraling additional costs are not” (Solomon *et al.*, 2000). In addition, there is 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 the aim of this research.

### *Obsolescence indexing*

The obsolescence indexing technique featured within this paper originated from Bartels *et al.* (2012) study. Generically, obsolescence indexing involves the assignment of a status to a component of an asset in reflection of certain characteristics, such as age, type and EOL notification. This is a rather elementary measure to undertake but an essential step for 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 limit. It is speculatively possible to then use this visualisation to formulate a mitigation strategy, targeting specific components, and a cause and effect analysis to taper mitigation strategies.

In theory, this method could be very useful for facilities managers and the often large asset registers they are 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 modelling and have proven to be an effective technique for representing probabilistic relationships. Dubos (2011) and Dubois and Prade (2011) 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 modelling; however, there are weaknesses as well, such as the requirement to break relationships down into simple orthogonal processes. With 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.



**Figure 3.**  
Suggested asset  
health score  
threshold

**Source:** Adapted from Bartels *et al.* (2012)

*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, because of 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) show how sales data of sequential products were used, and then their historical sales distribution was mapped considering the trend – if present, then forecast the project lifecycle of future iterations of the product. Figure 4 illustrates how the lifecycle of 16M memory chips [dynamic random access memory (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 in demand.

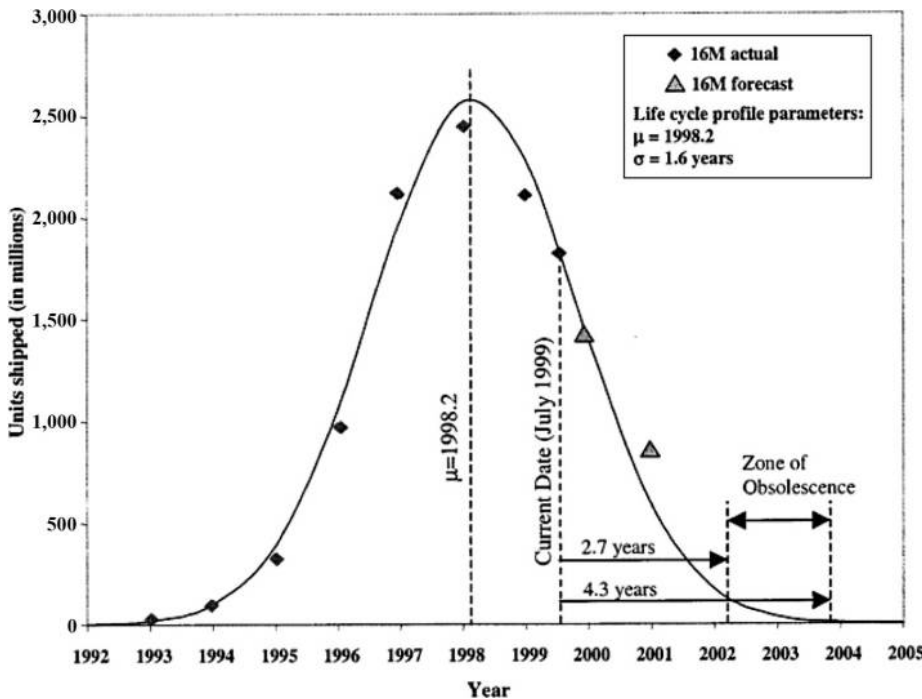


Figure 4.  
Prediction of the  
obsolescence phase  
for 16M DRAM by  
Solomon *et al.* (2000)



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 in memory for semi-conductors was then trended, which can then be used to predict when the current chips in 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 be aligned to maximise the length of time before components are deemed obsolete.

The methodologies that feature within the aforementioned researches require large data sets, which have been produced over significant periods of time. The results from these studies 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 adaptations 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<sup>2</sup> and a total lifecycle cost of £56m 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 building cost information service (BCIS) code 5 – service assets – would be appropriate for the case study:

- fire alarm system;
- building management system; and
- security system.

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

Finally, Building A is a PFI building, 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 PFIs, which add a further driver for gaining a better understanding of how obsolescence behaves and how it could be monitored and then mitigated.

*Building of the obsolescence assessment tool*

The mechanics behind the model is Boolean in the selection of statuses for each component, which then feeds into the adapted *Bartels et al.'s (2012)* formula. The data collection of the three independent asset systems was carried out over a period of one 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.

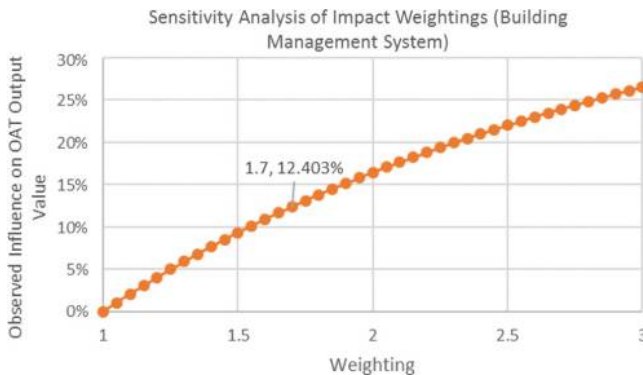
*Weighting mechanisms*

Inside the 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, the 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 by 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” with regards to the 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 because of the perception of criticality being a site-by-site specific category.

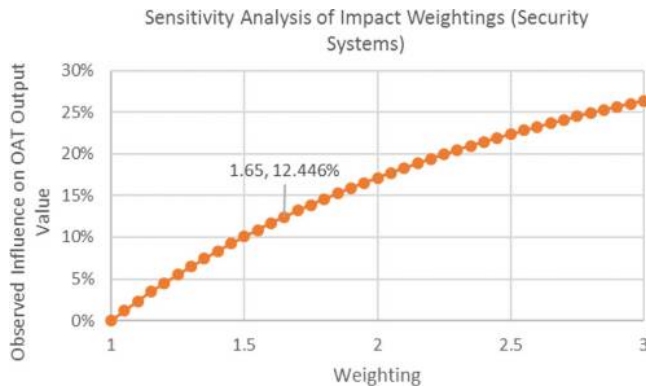
To justify the weightings applied, a form of sensitivity analysis was applied to gauge the impact on the resultant asset health scores with a range of weightings on the fixed inputs. The desired impact range of the OAT’s output was half of a threshold range (Figure 3), which is 12.5 per cent. Therefore,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

From Figures 5 and 6, it is clear that a maximum weighting of 1.7 will cause the asset health score to decrease by approximately 12.5 per cent, which is half of the 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”



**Figure 5.**  
Sensitivity analysis  
for BMS OAT output

**Figure 6.**  
Sensitivity analyses  
for security system  
OAT output



(representing a high number of component parts that are obsolete or within their obsolescence phase) and, therefore, a larger risk.

Note that the third asset system was not used for the sensitivity analysis because of 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 Results 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:

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

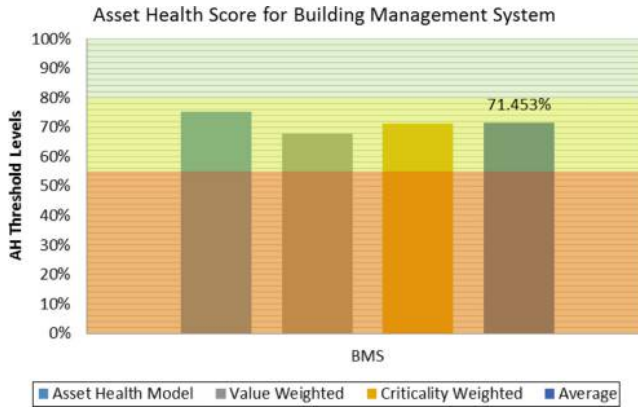
In summary, Building A represents a case study of a significant size that contains assets which are transferrable across the built environment and provides first-hand evidence of the effects of obsolescence-driven investments. Through adapting and extending an existing obsolescence indexing technique, 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

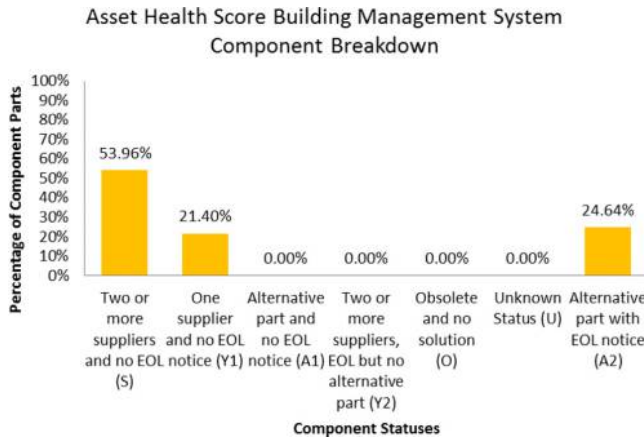
The findings illustrate that the three asset systems have contrasting levels of obsolescence amongst the components with varying peripheral factors such as alternative suppliers. The reaction to such findings will vary on an asset-by-asset situation; however, OAT will identify which components within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

Figures 7-12 illustrate the types of graphic illustration possible from OAT, exploring both the asset health score and direct components that are either obsolete or within their obsolescence phase.

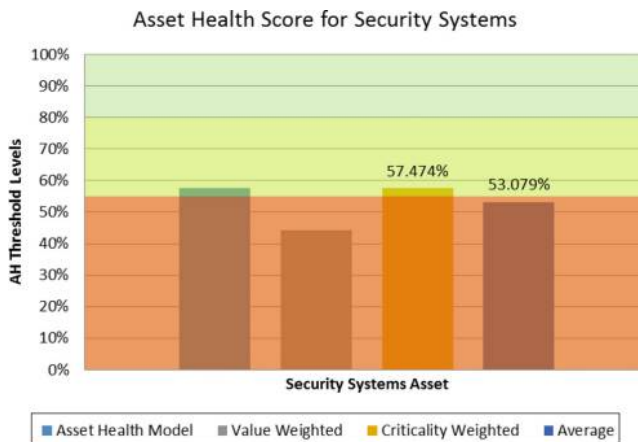
The manufacturers of the fire alarm system have a business model where all historical and future products are backwards compatible and are still supported. This is unique and is reflected in a perfect asset health score as all components both currently



**Figure 7.**  
OAT asset health  
findings for the BMS

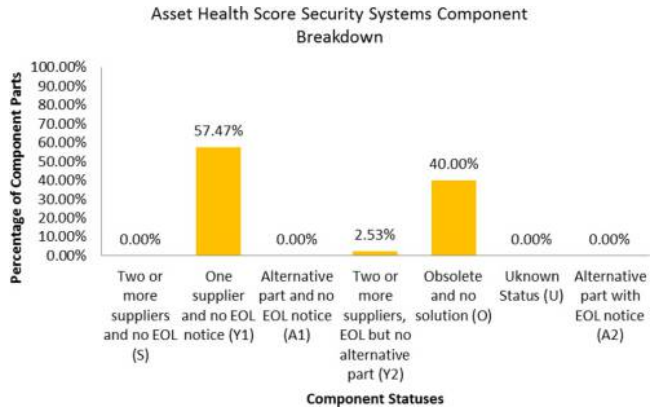


**Figure 8.**  
Asset health score  
component  
breakdown for the  
BMS

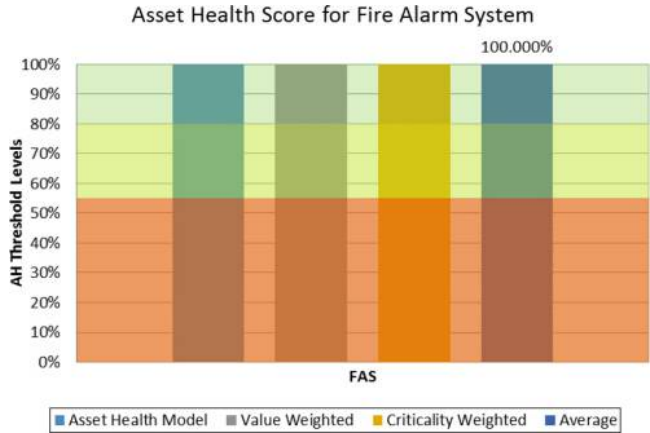


**Figure 9.**  
OAT asset health  
findings for the  
security system

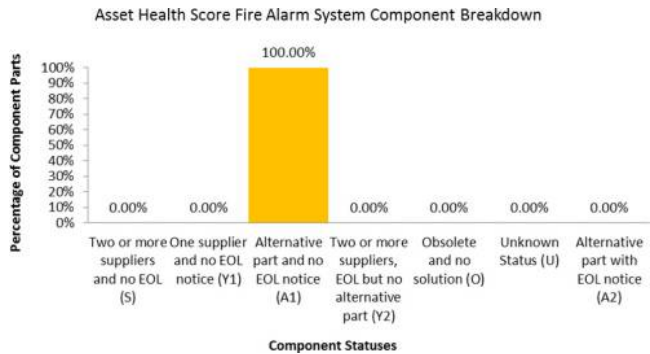
**Figure 10.**  
Asset health score component breakdown for the security system



**Figure 11.**  
OAT asset health findings for the fire alarm system



**Figure 12.**  
Asset health score component breakdown for the fire alarm system



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 into the variety of component statuses that can have operational impacts. The BMS contains medium levels of components (71.4 per cent) that are in a strong position with regards to obsolescence. However, almost a quarter of the components within the system (approximately 25 per cent) have an 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 the 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 per cent) that are in a strong position with regards to obsolescence. This system contains a rather large number of obsolete components (40 per cent of total components), which pose an immediate risk of an obsolescence-driven investment. In addition, there are few components (2.5 per cent) 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 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 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 asset health with regards to obsolescence is far more efficiently digested. OAT will identify which parent assets to investigate and in which order and 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 the 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 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 OAT developed within this paper was tested for its applicability to the aforementioned problem and the insights that the output 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 provides a mechanism for monitoring it and helps identify how it could impact your business.

#### *Future research*

Obsolescence is a broad multi-disciplinary 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 that are worthwhile investigating. By solely considering OAT, there could be greater consideration for the importance of specific components within a system to the asset's 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 asset's operational status. An improvement to 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 observing 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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