



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

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Review

# 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

## Funding

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## 38 Introduction

39 Obsolescence has existed within literature since Dyckman's (1961) paper on obsolete job skills but it  
40 wasn't until Cowan et al. (1970) and Warmington (1974) that the term was used in regards to the Built  
41 Environment and assets. The use of the term and its agreed definition has changed, along with the  
42 introduction to whole life or lifecycle approaches to Asset Management. The British Standard Institute  
43 (BSI) describes obsolescence as 'inevitable' and 'unavoidable' whilst defining it as when an item is 'no  
44 longer suitable for current demands, or is unsupported/no longer available from manufacturers' (BSI  
45 2007). Obsolescence has affected advanced, fast moving industries such as Defence, Oil and Gas,  
46 Aerospace and Avionics in recent history, with Abili et al. (2013) and Rojo & Roy (2009) giving good  
47 examples. A recent public example of how modern systems within the Built Environment can contain  
48 obsolescence driven investments, would be the UK NHS along with the Dutch Health services  
49 requiring large payouts (£5 million for the NHS for a year extension) to Microsoft, extending support  
50 for the now obsolete Windows XP, despite the publicly available support dates via their website. This  
51 exemplifies the current approach to obsolescence management as depicted recently by several  
52 authors (Smith 2000; Myers 2007; Sandborn 2013). Through Gap Analysis of the current literature  
53 surrounding obsolescence, it was identified that there were the following issues:

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

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

65 To further illustrate the effects of obsolescence, the featured case study had experienced an  
66 expenditure of £1.7 million over a 37-month period ( $\approx$  £0.5 million annually) across all asset systems  
67 between 2012 and 2015. Applying the 80:20 rule, £1.1 million were concentrated in three systems  
68 alone, an important point for any Facility Managers looking to prioritise obsolescence mitigation. To  
69 add another layer of context, this case study is a private finance initiative funded building, with a  
70 contract length of 30 years. As a conservative projection, the remainder of the contract will witness  
71 £10 million worth of lifecycle capital expenditure driven or associated with obsolescence to sustain the  
72 asset systems. Depending on the unforeseen nature of these potential investments, it is possible for  
73 the planned lifecycle budget to be exceeded or additionally the lifecycle profile to become 'lumpy'.  
74 This poses a considerable challenge for Facilities Managers, one that will only increase (Myers 2007;  
75 Gravier & Swartz 2009).

## 76 Background

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

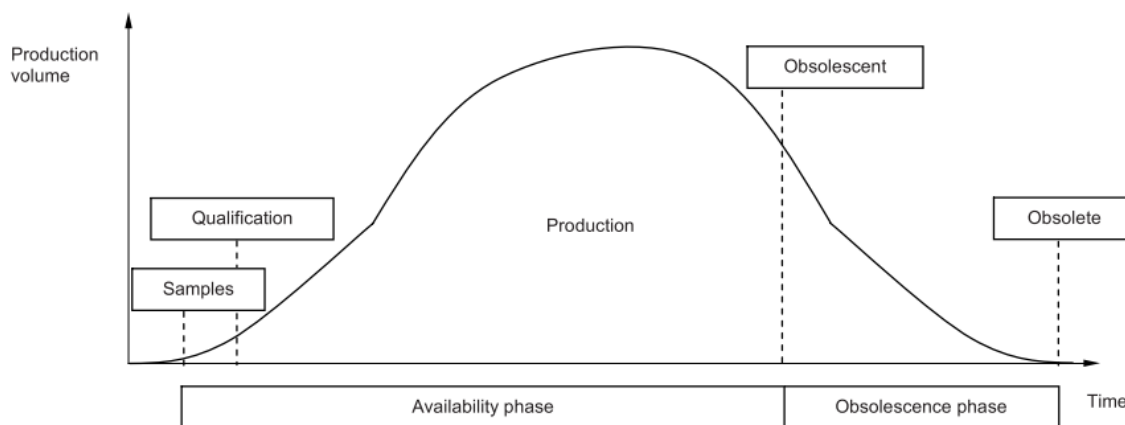


Figure 1 Asset lifecycle and the introduction of an 'Obsolescence Phase' (BSI 2007)

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

$$84 \quad PI = 100 \frac{(G + Y_1)}{(G + Y_1 + R + Y_2 + B)}$$

85 G = two or more suppliers

86 Y<sub>1</sub> = one supplier and funded solution

87 Y<sub>2</sub> = one supplier and no funded solution

88 R = obsolete part and no solution

89 B = unknown status

90 Literature illustrated that the use of alternative components from the market was a reputable  
91 mitigation strategy and a spares strategy is still the most widely used and referenced technique. The  
92 first development stage of the obsolescence assessment tool involved the adapting of Bartels et al.'s  
93 (2012) indexing technique and a change in nomenclature, resulting in the following iteration:

$$94 \quad AH = 100 \frac{(S + Y_1 + A_1)}{(S + Y_1 + Y_2 + O + U + A_1 + A_2)}$$

95 AH = Asset Health

96 S = Two or more suppliers and no EOL

97 Y<sub>1</sub> = One supplier and no EOL notice

98 A<sub>1</sub> = Alternative part and no EOL notice

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3 100 Y2 = Alternative Supplier, no alternative part and EOL

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5 101 O = Obsolete part with no solution

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7 102 U = Unknown status

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9 103 A2 = Alternative part with EOL notice

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12 105 Finally, the drivers of this research are geared around the need to better understand the behaviour of  
13 106 obsolescence within asset systems from the Built Environment and to develop a tool that was usable  
14 107 in the improvement of mitigation techniques. In addition, through creating a link between  
15 108 obsolescence and the bathtub behaviour of the cost of components (Herald et al, 1998), there is a  
16 109 cost prevention element to research of this type.

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19 110 Figure 2 demonstrates how a conceptual adoption of the bathtub curve theory to show the increase  
20 111 and decrease of obsolete components (Herald et al. 2008), can illustrate how the financial  
21 112 implications initiated by obsolescence can be simplistically represented. The bathtub curve represents  
22 113 component cost, as opposed to reliability, driven by the assumption that at time 0 the component is  
23 114 'cutting edge', deteriorating as the market matures and then becoming a 'trailing edge' or scarcity  
24 115 component within the obsolescence phase (Herald et al. 2008). It is the synergy of these two  
25 116 concepts that the crux of the obsolescence problem can be visualised – keeping assets operational  
26 117 and serviceable throughout their expected life and beyond.

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38 Asset Lifecycle vs Component Cost 'Bathtub' Curve

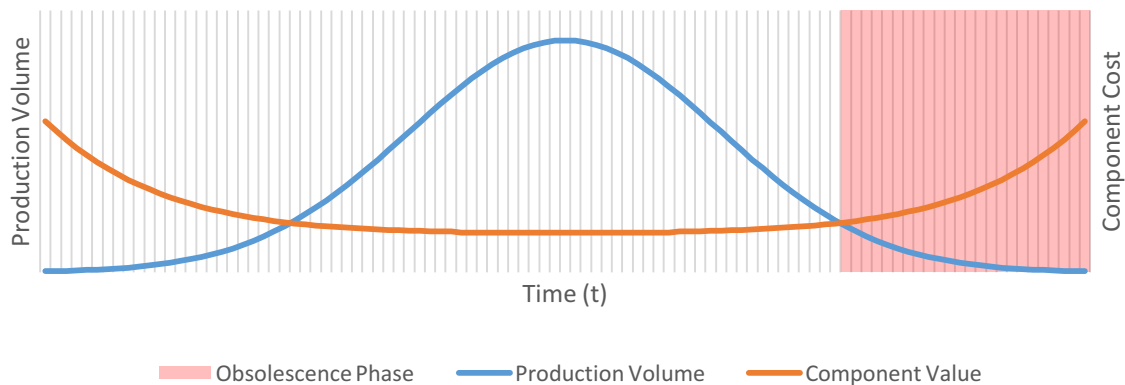


Figure 2 Asset Lifecycle vs Component Cost 'Bathtub Curve'

## 120 Literature Summary

### 121 *Obsolescence*

122 There have been a number of earlier studies in this area (Sandborn & Singh 2002; Singh 2004; Singh  
123 & Sandborn 2005; Singh, Peter Sandborn, et al. 2004; Singh & Sandborn 2002; Singh & Sandborn  
124 2006; Singh, P. Sandborn, et al. 2004, Solomon et al. (2000) and Rojo & Roy 2009). This paper will  
125 contrast the approach taken by the above by viewing/tackling this issue from a different angle and  
126 taking a user centric approach to designing a methodology to best mitigate obsolescence. In addition,  
127 some of the earlier research has been funded by large organisations from the semi-conductor and  
128 consumer electronics industries, which brings access to the large data sets i.e. sales data, allowing  
129 for more data driven analysis.

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

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

### 148 *Obsolescence Indexing*

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

154 Figure 3 illustrates how conceptually, an indexing technique could be used in conjunction with a  
155 predefined threshold limits. It is speculatively possible to then use this visualisation to formulate a

156 mitigation strategy, targeting specific components and cause and effect analysis to taper mitigation  
157 strategies.

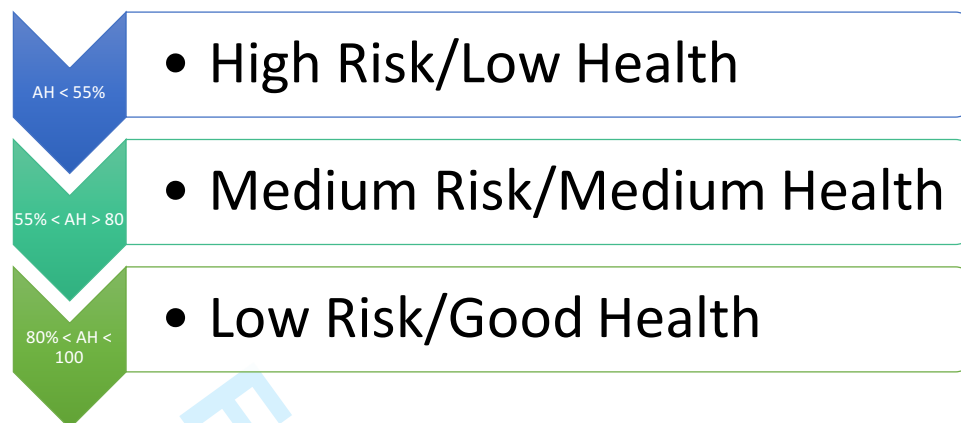


Figure 3 Suggested Asset Health Score Threshold adapted from Bartels et al. (2012)

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

### 162 *Boolean Decision Making Models*

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

### 170 *Research Stance*

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

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3 180 Most of the latest research around obsolescence focuses upon forecasting or predicting  
4 181 obsolescence within components, therefore allowing a manufacturer or supplier to supersede a  
5 182 design or equally reduce stock levels to meet demand. Solomon et al. (2000) shows how sales data  
6 183 of sequential products were used and then their historical sales distribution mapped, considering the  
7 184 trend - if present to then forecast the project lifecycle of future iterations of the product. Figure 4  
8 185 illustrates how the lifecycle of 16M memory chips (DRAM) has been mapped and then used to predict  
9 186 the expected lifecycle and obsolescence phase, such projections would then be used to optimise  
10 187 manufacturing and stock holding in anticipation of a decrease of demand.

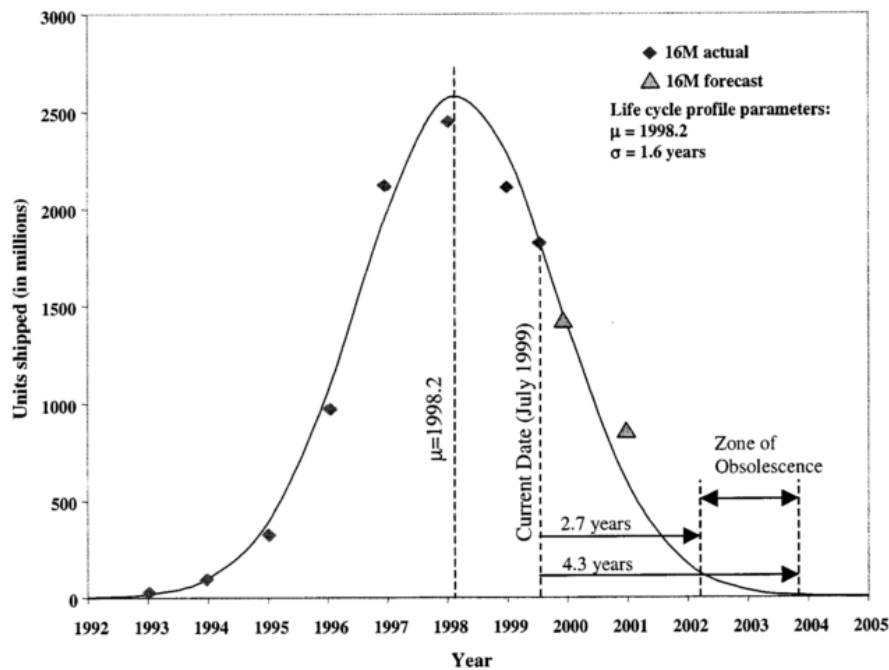


Figure 4 Prediction of the Obsolescence Phase for 16M DRAM by Solomon et al. (2000)

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

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



## 200 **Methodology**

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

### 208 *Case Study*

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

- 213 • Fire Alarm System
- 214 • Building Management System
- 215 • Security System

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

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

### 225 *Building of the Obsolescence Assessment Tool [OAT]*

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

### 231 *Weighting mechanisms*

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

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

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

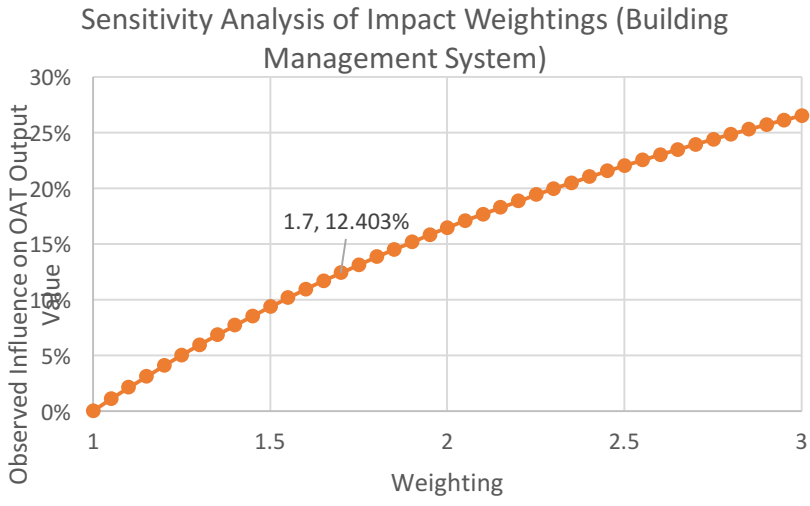


Figure 5 Sensitivity Analysis for BMS OAT Output

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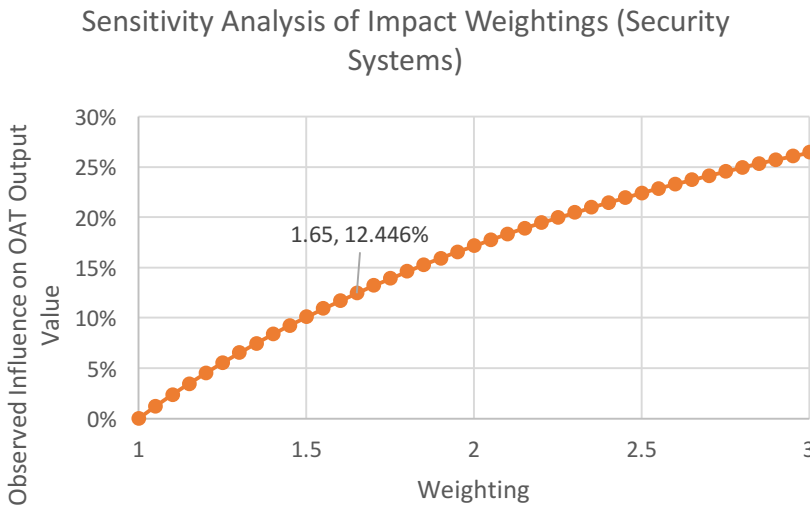


Figure 6 Sensitivity Analyses for Security Systems OAT Output

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3 249 From Figure 5 and Figure 6 it is clear that a maximum weighting of 1.7 will cause the Asset Health  
4 250 score to decrease by a range of  $\approx 12.5\%$ , which is half of a threshold level. The narrative being, an  
5 251 asset that is classed as 'critical' lying within the lower half of the 'medium threshold' would be  
6 252 weighted down into the 'low threshold' (representing a high number of component parts that are  
7 253 obsolete or within their obsolescence phase) and therefore a larger risk.

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11 254 Note the third asset system was not used for the sensitivity analysis, due to the unique business  
12 255 model used by the supplier it produces perfect results from OAT and is therefore not appropriate. This  
13 256 will be explained further in the findings section.

16 257 In line with the methodology for the creation of weighting zones, the weighting range was equally  
17 258 divided into four segments, resulting in the following weightings:

- 20 259 • Zone 1 – 1.0 (least critical or valuable)
- 21 260 • Zone 2 – 1.23
- 22 261 • Zone 3 – 1.46
- 23 262 • Zone 4 – 1.70 (most critical or valuable)

26  
27 263 In summary, Building A represents a case study of significant size that contains assets which are  
28 264 transferrable across the Built Environment and provides first hand evidence of the effects of  
29 265 obsolescence driven investments. Through adapting and extending an existing obsolescence  
30 266 indexing technique this paper has the opportunity to test the applicability of such a tool and  
31 267 investigate the use of its results. This has not been previously published.

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279 **Results**

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

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

**Asset Health Score for Building Management System**

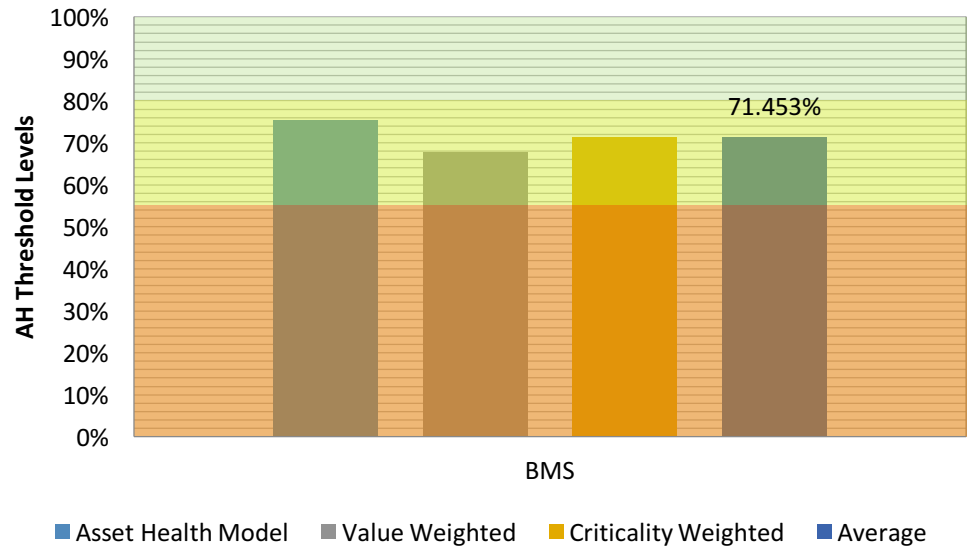


Figure 7 OAT Asset Health Findings for the BMS

**Asset Health Score Building Management System Component Breakdown**

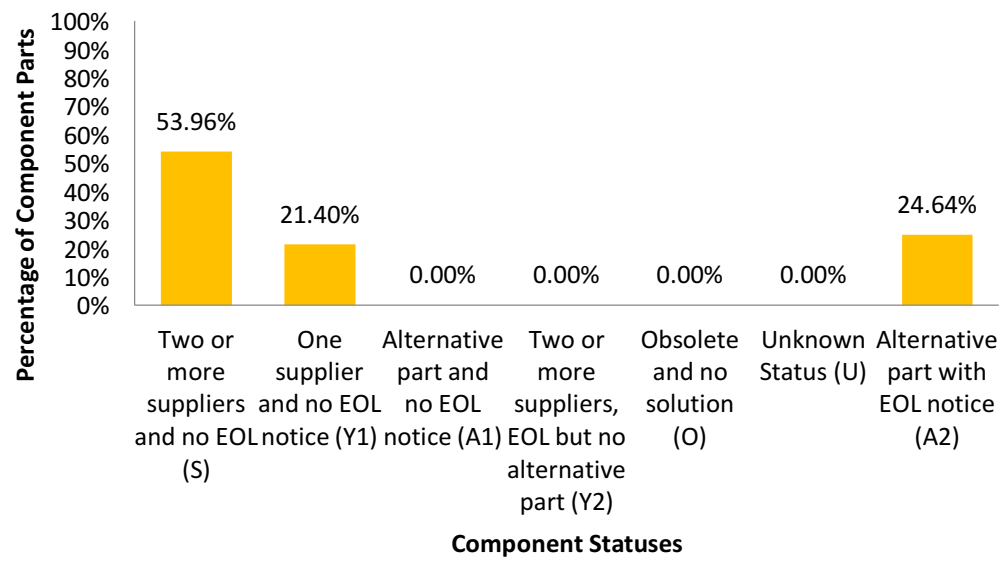


Figure 8 Asset Health Score Component Breakdown for BMS

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### Asset Health Score for Security Systems

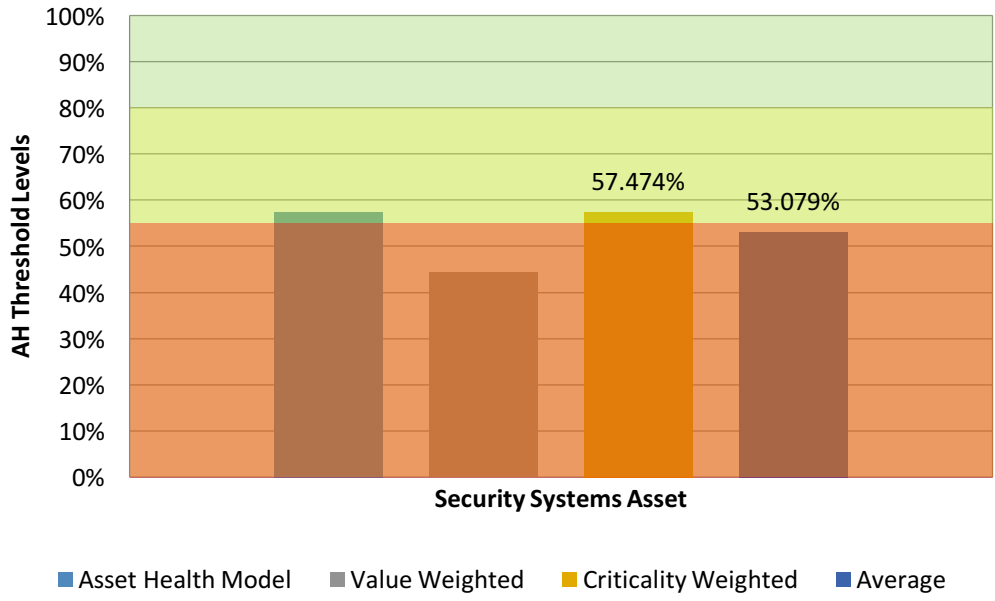


Figure 9 OAT Asset Health Findings for the Security System

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### Asset Health Score Security Systems Component Breakdown

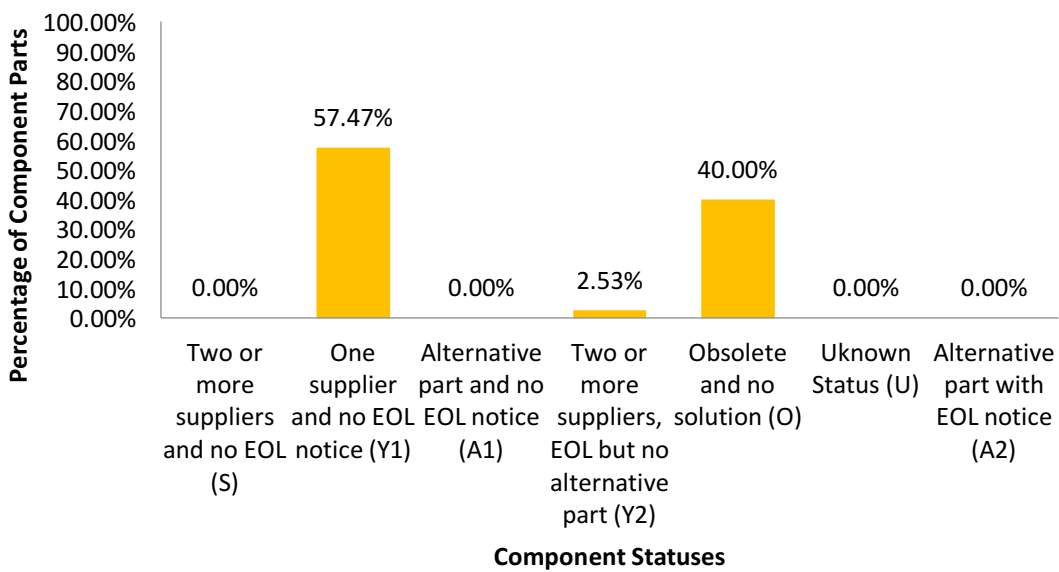


Figure 10 Asset Health Score Component Breakdown for Security System

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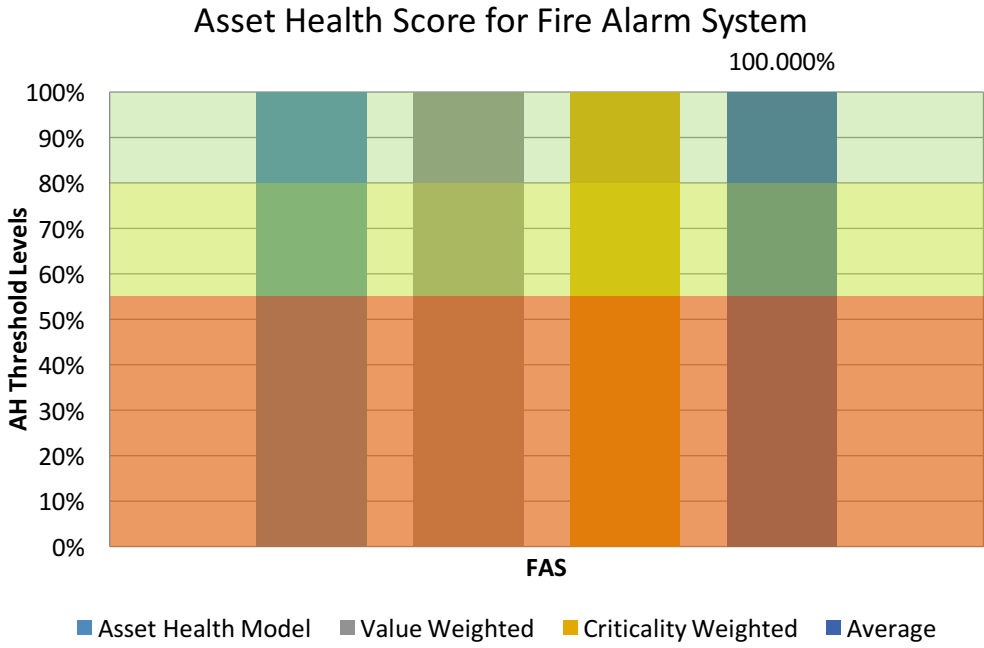


Figure 11 OAT Asset Health Findings for the Fire Alarm System

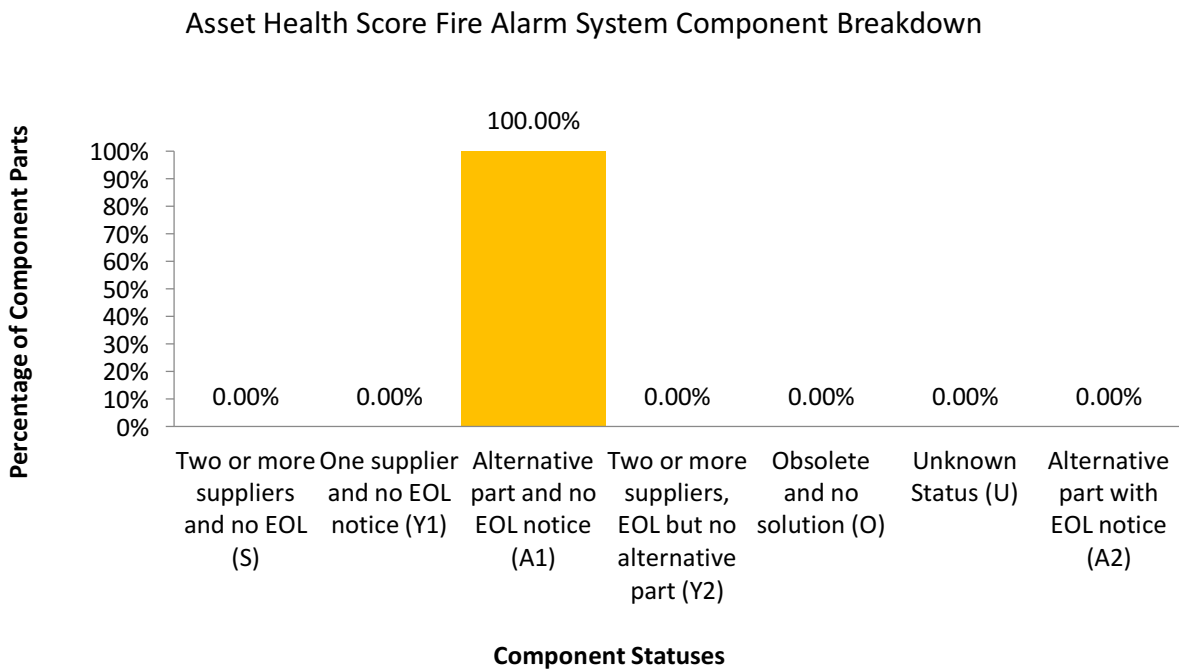


Figure 12 Asset Health Score Component Breakdown for Fire Alarm System

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

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

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

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

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## 330 **Conclusion**

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

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

### 344 *Future Research*

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

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365 **References**

- 366 Abili, N., Onwuzuluigbo, R. & Kara, F., 2013. Subsea controls future proofing: A systems strategy  
367 embracing obsolescence management. *Underwater Technology: International Journal of the*  
368 *Society for Underwater*, 31(4), pp.187–201. Available at:  
369 [http://openurl.ingenta.com/content/xref?genre=article&issn=1756-](http://openurl.ingenta.com/content/xref?genre=article&issn=1756-0543&volume=31&issue=4&spage=187)  
370 [0543&volume=31&issue=4&spage=187](http://openurl.ingenta.com/content/xref?genre=article&issn=1756-0543&volume=31&issue=4&spage=187) [Accessed February 10, 2014].
- 371 Bartels, B. et al., 2012. *Strategies to the Prediction, Mitigation, and Management of Product*  
372 *Obsolescence* 1st ed., New Jersey: John Wiley & Sons Inc.
- 373 BSI, 2012. *Buildings and constructed assets — Service life planning Part 2: Service life prediction*  
374 *procedures*, London BS ISO 15686 -2:2012.
- 375 BSI, 2007. *Obsolescence management — Application guide*, London BS EN 62402:2007.
- 376 Cowan, P. et al., 1970. *Obsolescence in the Built Environment*, London.
- 377 Dubois, D. & Prade, H., 2011. Possibility Theory and its Applications: Where Do we Stand? *EUSFLAT*  
378 *magazine*, pp.1–29. Available at: [http://www.irit.fr/~Didier.Dubois/Papers1208/possibility-](http://www.irit.fr/~Didier.Dubois/Papers1208/possibility-EUSFLAT-Mag.pdf)  
379 [EUSFLAT-Mag.pdf](http://www.irit.fr/~Didier.Dubois/Papers1208/possibility-EUSFLAT-Mag.pdf).
- 380 Dubos, G.F., 2011. *Stochastic modeling of responsiveness, schedule risk and obsolescence of C*  
381 *systems, and implications for design choices*. Ann Arbor: Georgia Institute of Technology.  
382 Available at: <http://search.proquest.com/docview/1221586145?accountid=14511>.
- 383 Dyckman, J.W., 1961. The Technological Obsolescence of Planning Practice. *Journal of the*  
384 *American Institute of Planners*, 27(3), pp.242–245. Available at:  
385 <http://www.tandfonline.com/doi/abs/10.1080/01944366108978464> [Accessed January 3, 2014].
- 386 Gravier, M.J. & Swartz, S.M., 2009. The dark side of innovation: Exploring obsolescence and supply  
387 chain evolution for sustainment-dominated systems. *The Journal of High Technology*  
388 *Management Research*, 20(2), pp.87–102. Available at:  
389 <http://linkinghub.elsevier.com/retrieve/pii/S1047831009000194> [Accessed February 11, 2014].
- 390 Herald, T. et al., 2008. An Obsolescence for System Baseline Evolution — Perspectives Through the  
391 System Life Cycle. , 12(1), pp.1–20.
- 392 Myers, J.L., 2007. *Integration of technology roadmapping information into DMSMS-driven design*  
393 *refresh planning of the V-22 Advanced Mission Computer*. Ann Arbor: University of Maryland,  
394 College Park. Available at: <http://search.proquest.com/docview/304843593?accountid=14511>.
- 395 Prabhakar, V.J., 2011. *Electronic part total cost of ownership and sourcing decisions for long life cycle*  
396 *products*. Ann Arbor: University of Maryland, College Park. Available at:  
397 <http://search.proquest.com/docview/1033323128?accountid=14511>.
- 398 Rojo, F.R. & Roy, R., 2009. Obsolescence challenges for product-service systems in aerospace and  
399 defence industry. *Proceedings of the ...*, (April), pp.1–2. Available at:  
400 <https://dspace.lib.cranfield.ac.uk/handle/1826/3845> [Accessed January 3, 2014].
- 401 Sandborn, P., 2013. Design for obsolescence risk management. *Procedia CIRP*, 00, pp.15–22.  
402 Available at: <http://www.sciencedirect.com/science/article/pii/S2212827113005477> [Accessed  
403 January 30, 2014].
- 404 Sandborn, P. & Singh, P., 2002. Electronic part obsolescence driven product redesign optimization.  
405 *Proceedings of the 6th Joint FAA/DoD/NASA ...*, pp.1–13. Available at:  
406 <http://www.enme.umd.edu/ESCML/Papers/AgingAircraft.pdf> [Accessed January 29, 2014].

- 1  
2  
3 407 Singh, P., Sandborn, P., et al., 2004. Electronic Part Obsolescence Driven Product Redesign  
4 408 Planning. *International Journal of ...*, 7(2). Available at:  
5 409 [http://www.enme.umd.edu/ESCML/Papers/MOCA\\_paper.pdf](http://www.enme.umd.edu/ESCML/Papers/MOCA_paper.pdf) [Accessed January 30, 2014].  
6  
7 410 Singh, P., 2004. *Forecasting technology insertion concurrent with design refresh planning for COTS-*  
8 411 *based obsolescence sensitive sustainment-dominated systems*. Ann Arbor: University of  
9 412 Maryland, College Park. Available at:  
10 413 <http://search.proquest.com/docview/305174518?accountid=14511>.  
11  
12 414 Singh, P. & Sandborn, P., 2002. Determining optimum redesign plans for avionics based on electronic  
13 415 part obsolescence forecasts. *Proceedings of the World ....* Available at:  
14 416 <http://enme.umd.edu/ESCML/Papers/02WAC-150.pdf> [Accessed January 30, 2014].  
15  
16 417 Singh, P. & Sandborn, P., 2005. Forecasting technology insertion concurrent with design refresh  
17 418 planning for COTS-based electronic systems. *Annual Reliability and Maintainability Symposium,*  
18 419 *2005. Proceedings.*, pp.349–354. Available at:  
19 420 <http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=1408387>.  
20  
21 421 Singh, P. & Sandborn, P., 2006. Obsolescence Driven Design Refresh Planning for Sustainment-  
22 422 Dominated Systems. *The Engineering Economist*, (December 2013), pp.37–41.  
23  
24 423 Singh, P., Sandborn, P. & Singh, P., 2004. Forecasting Technology Insertion Concurrent with Design  
25 424 Refresh Planning for COTS-Based Electronics Systems. *Logistics Spectrum*, pp.349–354.  
26 425 Available at: <http://www.enme.umd.edu/ESCML/Papers/solemocapaper.pdf> [Accessed February  
27 426 11, 2014].  
28  
29 427 Smith, T., 2000. *Future Initiatives for Obsolescence Mitigation Strategies Mitigation Strategies*,  
30 428 London.  
31  
32 429 Solomon, R., Sandborn, P. & Pecht, M., 2000. Electronic part life cycle concepts and obsolescence  
33 430 forecasting. *... , IEEE Transactions on*, 23(4), pp.707–717. Available at:  
34 431 [http://ieeexplore.ieee.org/xpls/abs\\_all.jsp?arnumber=888857](http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=888857) [Accessed January 13, 2014].  
35  
36 432 Warmington, A., 1974. Obsolescence as an Organizational Phenomenon. *Journal of Management*  
37 433 *Studies*, 11, pp.1–119.  
38  
39 434 Zheng, L., 2011. *Knowledge Representation and Decision Support for Managing Product*  
40 435 *Obsolescence*. Ann Arbor: Virginia Polytechnic Institute and State University. Available at:  
41 436 <http://search.proquest.com/docview/1020897067?accountid=14511>.  
42  
43  
44 437  
45  
46 438  
47  
48 439  
49  
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