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ORIGINAL ARTICLE

Managing legacy system costs: A case study of a meta-assessment model to identify solutions in a large financial services company

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Abstract Financial services organisations spend a significant amount of their IT budgets maintaining legacy systems. This paper identifies the characteristics of legacy systems and explores why such systems are so costly to maintain and support. Three models for the assessment and management of legacy system costs are examined and a new meta-model that addresses differences between the existing models is proposed. The new meta-model is then applied to a large UK financial services company - FinCo. Input data for the new meta-model are provided by the company's senior business and IT executives and the results compared with the firm's actual legacy system management plans. The paper concludes by identifying improvements the company should make to these current legacy system management plans and its longer-term strategy for managing legacy systems.

1. Introduction

The financial services industry is one of the biggest spenders on IT but the majority of this spend is on maintenance activities required to keep legacy systems operational [1]. By some estimates, seventy-five per cent of the IT budgets of banks and insurance companies are consumed maintaining existing systems [2,3]. Consequently, identifying and implementing appropriate solutions to contain the maintenance cost of legacy systems is a significant requirement for many organisations.

Over fifteen years ago Bennet et al. [4] observed that research into legacy system assessment approached the subject as a technical issue rather than as a broader business problem. More recently Alkazemi et al. [5] recognise this technical "bias", noting the need for tools for senior management to be able to make informed decisions about legacy systems, while Plant [6] identifies the difficulty of engaging senior management in such decisions.

Extant literature proposes a number of models for use in assessing legacy systems and recommending approaches for how these systems should be managed to minimise their

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maintenance costs [5,7,8]. However, while the earlier published models include a wide range of assessment criteria they do not include more contemporary architectural considerations such as extensibility and interoperability. Conversely, a recent model by Alkazemi et al. [5] lacks recognition of detail such as lines of code and control flow as proposed by De Lucia et al. [7]. In an attempt to address these anomalies and unify the positive features of the varying approaches, this paper proposes a new meta-model derived from a range of existing models. The utility of the meta-model is then assessed through its application to FinCo - a large UK financial services company. By using a case study we seek to answer the following research questions: is the meta-model effective for analysing the company's core IT system, Customer Service System (CSS), to assess whether it is a legacy system? And, if so, does the meta-model identify appropriate solutions to contain the maintenance costs for CSS? Further details of our research methodology, findings and conclusions are discussed below.

2. What is a legacy system?

In 2001, Brooke and Ramage [9] concluded that no standard definition of a legacy system exists. Some of the current suggestions include the following:

- old information systems that remain in operation within an organisation [10, p. 314].
- any business critical software systems that significantly resist modification and their failure can have a significant impact on the business [11, p. 36].
- a legacy application or system may be based on outdated technologies, but is critical to day-to-day operations [12].

Many of today's legacy systems were built in a time when computer processing and storage capacity were far more expensive than they are today [15]. Consequently, efficiency frequently took precedence over a system being understood or maintainable, with the inevitable consequences in terms of degradation [13]. System degradation can also be caused by poor documentation and version control amongst other factors, but as De Lucia et al. [7] observe, whatever the cause such deterioration inevitably increases maintenance costs. This largely explains the high proportion of total IT expenditure organisations commit to system maintenance. Furthermore, Alkazemi et al. [5] contend legacy systems do not reflect contemporary architectural advances such as the emphasis on program reuse and construction of component libraries. These more recent approaches facilitate the constant evolution of systems and help prevent systems becoming legacy with their resultant high maintenance costs.

The definition of a legacy system adopted in this paper is a system that is business critical and demonstrates one or more of the following additional characteristics: old age, obsolete languages, poor if any documentation, inadequate data management, a degraded structure, limited support capability and capacity, changed to meet business needs, increasing maintenance costs, and lacking the necessary architecture to evolve [14,10,9,17]. It is this definition of a legacy system that is applied to FinCo to determine whether the company's system can be identified as legacy.

3. Legacy system cost management solutions

A number of solutions to minimise the cost of maintaining legacy systems have been proposed. For example, De Lucia et al. [7, p. 642] refer to "ordinary maintenance, reverse engineering, restructuring, reengineering, migration, wrapping, replacement with commercial off-the-shelf software and discarding". These authors acknowledge that there is confusion in the use of some of these terms in the literature, noting reengineering and migration as examples.

Bennet et al. [4] are more concise in proposing, "discard", "wrap", "outsource", "freeze", "carry on" and "reverse engineering" as potential solutions. As it is unlikely that outsourcing would negate the need to implement one of the other solutions proposed, the suggestion that outsourcing offers a solution for managing legacy systems must be questioned. The viability of carry on as a solution for an indefinite period also seems questionable for a business critical system. Additionally, it is highly likely that even a very stable old system will need some form of remediation at some point. For example, if the availability of people with the skills required to support an obsolete language is in decline this will require some form of corrective action.

Where there is consistency in the legacy system literature is in recognising that a decision on the best option to manage such systems should be based on a structured assessment incorporating economic and quality factors. These decisions must be taken and supported by a broad range of stakeholders within the organisation and not limited to technical considerations alone [14,18–20]. Additionally, research by Khadka et al. [11] suggests that the characteristics of an organisation operating and supporting the legacy system must be considered. It is essential that organisational factors such as resistance to change and/or weakness in systems support be reflected in any proposed system solution.

4. A new legacy system assessment model

Ransom et al. [8], De Lucia et al. [7] and Alkazemi et al. [5] each propose models that assess a legacy system based on defined business and technical attributes and then propose solutions to manage the system. Each model emphasises different attributes. De Lucia et al. provide more detail than the others on business value and technical quality. However, Ransom et al. offer important insights into gaps in organisational capability and culture that must be mitigated in an implementation plan. Alkazemi et al., in turn, add a number of contemporary architectural considerations. Each model therefore incorporates valuable features but without being as comprehensive as it could be. To address this issue we propose a new meta-model derived from the three existing models combining business and technical factors with contemporary architecture attributes and organisational considerations to produce a more extensive, unified approach that recognises the real-world complexity of legacy systems (Fig. 1).

The model output can then be plotted on a decisional matrix [14] that indicates a recommended solution (Fig. 2). In the case of FinCo the model's output was compared with the company's actual legacy system management plans to identify areas of divergence and thus potential improvements in these plans.

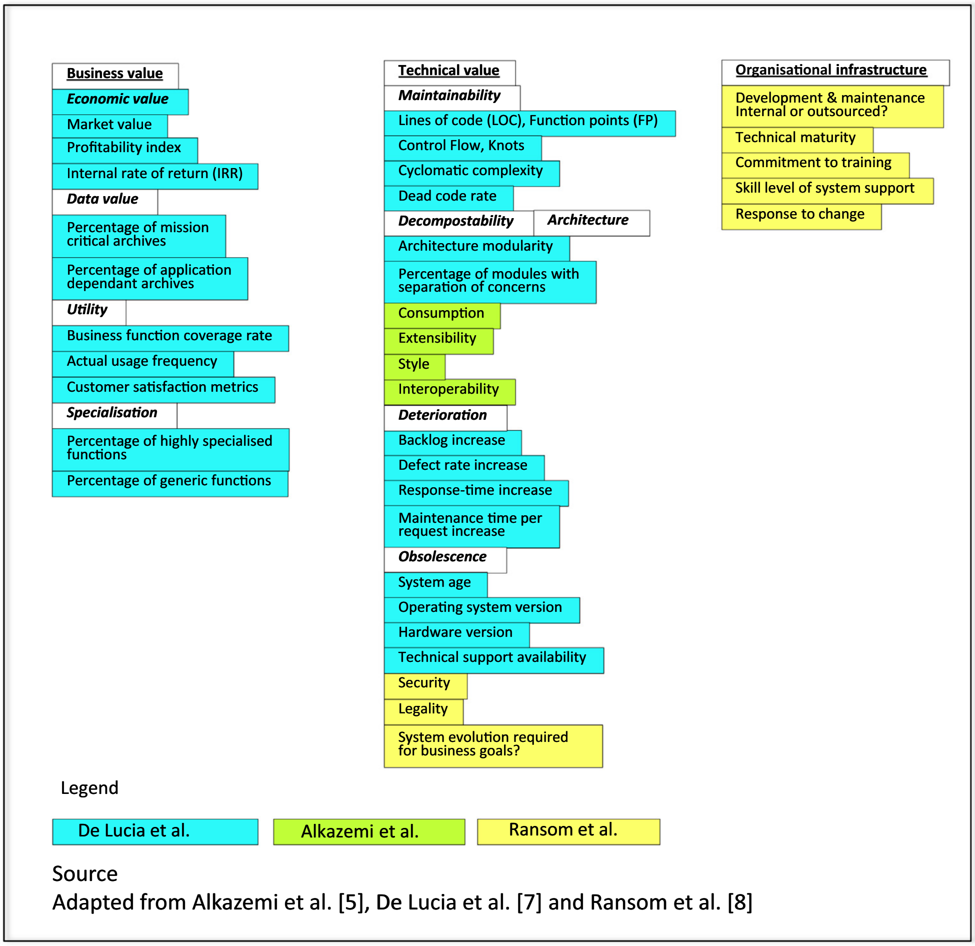

Figure 1 New legacy system assessment meta-model attributes.

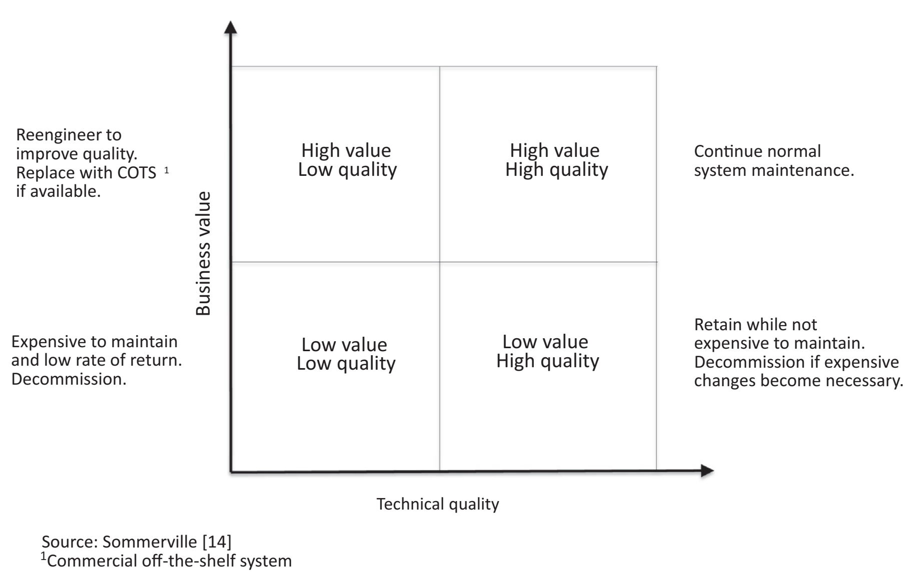

Figure 2 Legacy system decisional matrix.

5. Research methodology

Given the organisational nature of the subject under investigation and the design of the meta-model it was clear that a case study that provided the basis for situational analysis was an appropriate research approach [21,22]. Time and resource constraints combined with access opportunities meant a single case study was both a pragmatic course of action while also providing the necessary exploratory device/pilot study to test the utility of the meta-model [23]. As a large financial services company with four million accounts FinCo was identified as a highly relevant case study, not least because in common with many other similar companies FinCo estimates that maintenance of its core system, CSS, which supports the majority of the firm's business operations, accounts for 75–80% of the annual IT budget.

A questionnaire administered face-to-face to ten of FinCo's senior business and IT executives was chosen as the main method for data collection (see Appendix A for details of participants). The questionnaire focused on the following:

- The applicability of the proposed definition of legacy systems to FinCo's CSS system.
- The applicability of the proposed meta-model's business and technical attributes to FinCo.
- An estimated measure of each business and technical attribute for FinCo's core system.
- The applicability of the proposed meta-model's organisational attributes to legacy system solution selection for FinCo.
- An estimated measure of each organisational attribute for FinCo.

Documentary analysis was also conducted on FinCo's current IT plans to determine the actual decisions FinCo had made about its core system, CSS. The research data were analysed using the meta-model proposed in Section 4, and the results applied in the decisional matrix. The model's output was then compared with the company's actual legacy system management plans to identify areas of divergence and thus potential improvements in these plans.

6. Analysis and findings

6.1. Is CSS a legacy system?

This section examines whether CSS is a legacy system or not in accordance with the definition presented in Section 2.

Eleven of the characteristics associated with legacy systems discussed in Section 2 were investigated (Table 1). Respondents were asked to indicate which, if any, of these characteristics they would associate with FinCo's core system, answering *yes*, *no*, *maybe* or *don't know* for each characteristic.

With 11 system characteristics and 10 respondents there were a total of 110 responses for this part of the questionnaire. 75 of the 110 responses agreed the characteristics were applicable to CSS and 29 said they may be. Six of the responses were negative and none answered, *don't know*. The high proportion of positive responses to these questions suggests that FinCo's CSS platform conforms to the definition of legacy systems proposed in Section 2 and should be treated as such. No legacy system attributes other than those already identified in the literature were proposed in response to the open question asking for suggestions of new attributes that should be considered.

6.2. Use of business value attributes and calculation of business value index in legacy system assessment

The meta-model has ten business value attributes. When asked whether the 10 business attributes are used in assessing the CSS legacy platforms in FinCo, 71 of the 100 responses were positive, nine were negative and two were *don't know* (Table 2).

For each individual business attribute, the *very low* to *very high* and *don't know* answers by respondents were re-coded as values from 1 to 5 and 0 respectively, to facilitate plotting on the decisional matrix. Questionnaire responses with the same value for each of the business value attributes were aggregated across the ten FinCo respondents and results tabulated in Table 2. 66% of the 100 attribute values were recorded as *high* or *very high*. Only 5% were rated *low* or *very low*.

Table 1 Legacy system characteristics applicable to CSS.

System characteristics	Applicable to FinCo platform?			
	Yes	No	Maybe	D/K[a]
Business critical	8		2	0
Old	8	1	1	0
Has been changed to meet organisational needs	9		1	0
The system degrades as changes are made	5	1	4	0
Maintenance costs increase as changes are made	8	1	1	0
Obsolete languages	10			0
Poor, if any, documentation	6		4	0
Inadequate data management	5	2	3	0
Limited support capability	5	1	4	0
Limited support capacity	6		4	0
Lacks the architecture to evolve to meet emerging requirements	5		5	0
Total responses	75	6	29	0

[a] D/K = Don't know.

Table 2 Use of business value attributes in legacy system assessment and derived value index.

	Used in legacy system assessment in FinCo?			Number of responses for each re-coded attribute value for FinCo's CSS system						Value index derived from re-coded attribute values
Business value attributes	Y	N	D/K[a]	1	2	3	4	5	0	
Economic value										
Market value	8	1	1				1	9		4.90
Profitability index	7	1	2		1	4	2	1	2	3.38
IRR	4	3	3		1	4		1	4	3.17
Data value										
Percentage of mission critical archives	8	1	1		1		3	6		4.40
Percentage of application dependant archives	7	1	2		1	1	1	6	1	3.90
Utility										
Business function coverage rate	8		2			1	3	6		4.50
Actual usage frequency	8		2			1	1	9		4.90
Customer/user satisfaction metrics	7	1	2		1	3	1	2	3	3.57
Specialisation										
Percentage of highly specialised functions	8		2			1	3	6		4.50
Percentage of generic functions	6	1	3			2	3	2	3	4.00
Total FinCo	71	9	20	0	5	16	18	48	13	4.12

[a] D/K = Don't know.

$$individual\ business\ attribute\ value = \frac{\sum(recoded\ responses\ for\ the\ individual\ business\ attribute)}{\sum(number\ of\ recoded\ responses\ for\ the\ individual\ business\ attribute \neq 0)}$$

$$value\ of\ business\ attribute = \frac{\sum(value\ of\ individual\ business\ attributes)}{\sum(number\ of\ recoded\ responses\ for\ the\ individual\ business\ attributes \neq 0)}$$

Figure 3 Business attribute value calculation.

The business value for each attribute is calculated from respondents' re-coded answers and then a consolidated business value is determined as shown in Fig. 3.

The results of these calculations are presented in Table 2. The consolidated business attribute value for FinCo's CSS is 4.12. This compares with a maximum value of 5 and places CSS in the top two quadrants of the decisional matrix. The high business value indicates that the solution recommended by the assessment will be to conduct extensive re-engineering, replacement by a commercial off-the-shelf system (COTS) if available, or continue normal system maintenance. The technical value is required to complete the assessment and identify a recommended solution.

6.3. Use of technical value attributes and calculation of technical value index in legacy system assessment

The meta-model has 23 technical value attributes. When asked whether these are used in assessing the legacy systems in FinCo, 60% of the 230 responses were positive and 13% were negative (Table 3). The highest concentration of *don't know* responses was in the maintainability category. The 18 negative responses were distributed across 17 attributes.

As for the business attributes, the technical attribute measure answers were re-coded to provide an attribute value. The common re-coded values for each of the 23 technical attributes were aggregated across the FinCo respondents and are tabulated in Table 3.

6.4. Application of decisional matrix

When plotted in the decisional matrix the consolidated business attribute and technical attribute value for FinCo is in the High Business Value - Low Technical Value (HBV-LTV) quadrant (Fig. 4).

Maintainability attributes account for 72% of all *don't know* responses by FinCo. To explore the impact of this concentration of *don't know* responses on the overall results, the analysis was rerun excluding all the maintainability responses. Though the outcome is an increase in the technical value for FinCo's CSS from 2.32 to 2.63, the combined business and revised technical value remains in the same quadrant when plotted in the decisional matrix.

Table 3 Use of technical value attributes in legacy system assessment and derived value index.

Technical value attributes	Used in legacy system assessment in FinCo?			Number of responses for each re-coded attribute value for FinCo's CSS system						Value index derived from re-coded attribute values
	Y	N	D/K[a]	1	2	3	4	5	0	
Maintainability										
Lines of code	4	2	4	7	1				2	1.13
Function points	4	1	5	5					5	1.00
Control flow	2	1	7	2	1	1			6	1.75
Knots	2	1	7	2		1			7	1.33
Cyclomatic complexity	2	1	7	2		1			7	1.67
Dead code rate	1	1	7	1	2				7	1.67
Decompostability/architecture										
Architecture modularity	7	1	2		6	3			1	2.33
Per cent of modules with separation of concerns	6	1	3	1	5	1	1		2	2.25
Extensibility	7	1	2		6	2	1		1	2.44
Interoperability	7	1	2		3	5	1		1	2.78
Architectural style	6	1	3		5	2	1		2	2.5
Consumption	6	1	3		5	1	2		2	2.63
Deterioration										
Backlog increase	7	1	2		7	2	1			2.40
Defect rate increase	6	1	3		4	4	1		1	2.67
Response-time increase	6	1	3		3	3	4			3.10
Maintenance time per request increase	5	1	4		6	2	1		1	2.44
Obsolescence										
System age	8		2	1	5	4				2.30
Operating system version	8		2	1	2	6			1	2.56
Hardware version	8		2	1	2	5	1		1	2.67
Technical support availability	9		1		4	5	1			2.70
Security	9		1		3	3	4			3.10
Legality	8	1	1			3	5	2		3.90
System evolution required for business goals	9		1	3	4	3				2.0
Total FinCo	138	18	74	26	74	57	24	2	47	2.32

[a] D/K = Don't know.

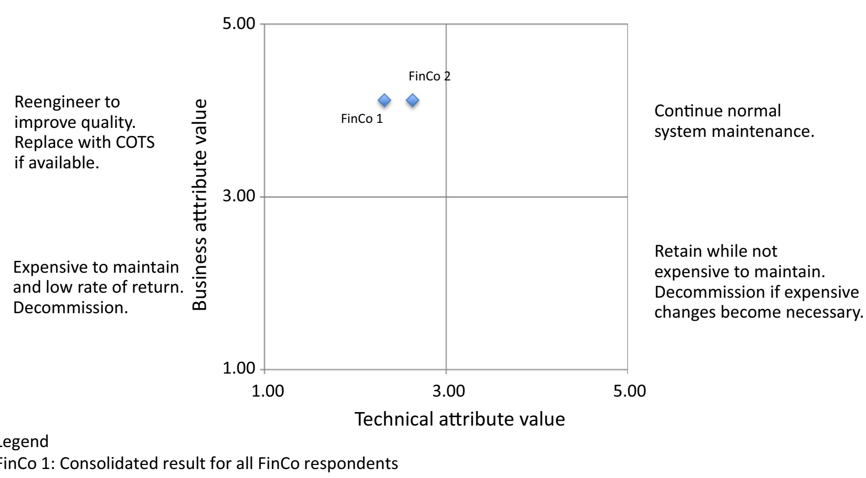

Figure 4 Legacy system assessment results applied to decisional matrix.

To examine the dispersion of results across respondents, business and technical values were calculated for the input of each of the ten respondents and plotted together with the aggregated value for FinCo in the decisional matrix (Fig. 5).

This chart shows a concentration for nine of the results. Ten of the data points are inside the HBV-LTV quadrant and the eleventh is only marginally outside.

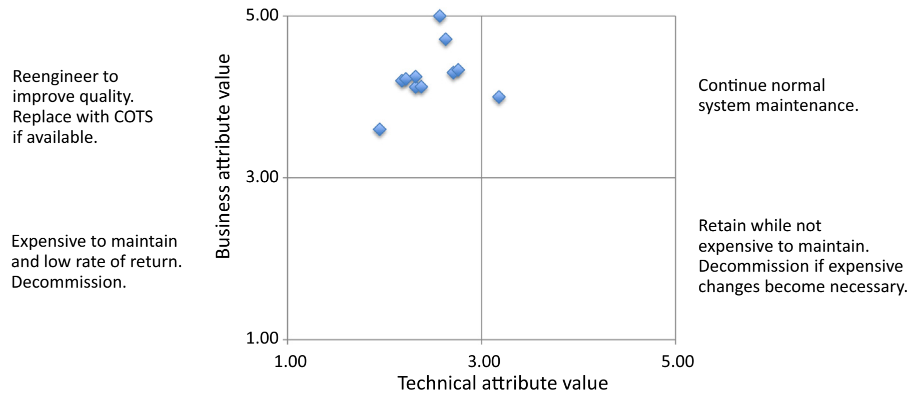

Figure 5 Mapping of individual and aggregated legacy system assessment results.

Table 4 Organisational attribute influences in legacy system solution selection and derived value index.

Organisational attributes	Influences legacy system solution selection in FinCo? Y	N	D/K[a]	Number of responses for each re-coded attribute value for FinCo's CSS system 1	2	3	4	5	0	Value index derived from re-coded attribute values
Development & maintenance internal	7	1	2				6	4		4.40
Development & maintenance outsourced	7	1	2		1	3	4	2		3.70
Technical maturity	6	1	3			4	4		2	3.50
Commitment to training	6	1	3		1	6	2		1	3.11
Skill level of system support	7	1	2		1	5	3		1	3.22
Response to change	6	1	3		1	4	3		2	3.25
Total FinCo	39	6	15	0	4	22	22	6	6	3.53

[a] D/K = Don't know.

6.5. Influence of organisational attributes on legacy system solution selection

More than a third of respondents demonstrate uncertainty about the six organisational attributes identified in the literature influencing legacy system remediation plans in FinCo (Table 4). This doubt is reinforced by FinCo's IT plans which show limited signs of these factors being considered. The internal development and maintenance value index is 4.4 compared with a maximum value of 5 and lower index values for all of the other attributes. This suggests that FinCo may have a gap between its emphasis on internal development and maintenance and its organisational capability to deliver its legacy system management plans through these means.

6.6. Legacy system management actions proposed by FinCo

The remediation actions planned by FinCo for its legacy system were identified by reviewing the company's IT plans. These plans conclude that no suitable COTS is available to replace FinCo's CSS platform. This finding is consistent with the high business value placed on the specialist functions performed by CSS.

The remediation plans involve major reengineering of FinCo's legacy platform including addressing architectural style and consumption constraints, source code translation, operating system and hardware replacement and outsourcing of data centre management. These extensive plans are consistent with the recommendations made by Sommerville [14] for systems mapped in the HBV-LTV quadrant when no COTS is available. While the plans involve outsourcing of the data centres to capitalise on external expertise in this area, there is little evidence of any other limitations in FinCo's organisational attributes influencing the legacy system remediation plans or being addressed as part of these plans.

7. Conclusions and recommendations

In this paper we set out to construct a legacy system assessment meta-model and then carry out situational analysis of the utility of this device by applying it to a real case – FinCo. In so doing we accept the argument that one rationale for using a single case study is that it can confirm or challenge whether a theory's or model's propositions are correct [22,23]. Our aim was therefore to use FinCo to examine the effectiveness of the meta-model for analysing IT systems and assessing whether these are legacy systems, and, if so, the utility of the meta-model for identifying appropriate solutions to contain legacy system maintenance costs.

As the analysis in the previous section demonstrates, FinCo's core operating platform, CSS, is business critical and exhibits a very high proportion of the characteristics attributable to legacy systems. It therefore conforms to the legacy system definition we proposed in Section 2 and should be assessed as such. The high proportion of positive questionnaire responses also indicate that the business and technical value attributes proposed in the meta-model are valid for use in legacy system assessment. We would add, however, that this is not a particularly surprising finding given our meta-model combines business and technical factors with contemporary architecture attributes and organisational considerations from three existing, research based, models – as discussed in Section 3. The value of the unified meta-model is therefore that it provides a holistic approach that recognises the real-world complexity of legacy systems. Thus, while we accept the widely held view that generalising from a single case study is difficult, our view is that given the meta-model's construction it could prove a useful analytical device for any organisation in a similar situation to FinCo.

That said, there are several important observations to make on the meta-model by way of concluding this paper. The first is to note that despite the disparate knowledge of the FinCo respondents all but one of the individual outcomes plot into the HBV-LTV quadrant when mapped onto the decisional matrix. This is also true for the mapping of the consolidated response and the consolidated response excluding all answers from the maintainability section. Thus we conclude that although the technical knowledge of the assessment participants varied considerably the results show a high degree of consistency in the output of the meta-model.

Second, given our knowledge of the FinCo respondents we attribute the high number of *don't know* responses to the maintainability section of the technical attribute list compared with business attributes as due to the limited technical knowledge of the senior business respondents. By comparison, members of FinCo's technical team were better placed to offer a view on both business and technical attributes. This suggests that biasing the assessment participant selection in favour of senior technical representatives may lead to a more informed analysis. However, such an approach would serve to perpetuate the concerns discussed earlier in the paper about the lack of broad business participation in such important and potentially very expensive decisions for FinCo, as well as ownership of the outcome [4–6]. An alternative approach would be to share the output of the meta-model and decisional matrix with all the FinCo respondents in a group meeting to help foster discussion on the results and build greater common understanding and ownership across the institution. Another approach might be for respondents to complete the questionnaire in a joint forum where all of the participants have the opportunity to gain a greater understanding of the questions and foster debate about potential concerns.

Finally, we note that FinCo's IT plans to reengineer to improve quality are consistent with the actions expected for a system assessed as being in the HBV-LTV quadrant of the decisional matrix when no COTS is available. This indicates that the meta-model has identified an appropriate solution for FinCo to contain its CSS maintenance costs, as asked in the research questions. However, these plans do not reflect the organisational constraints identified through the comprehensive, real-world assessment provided by the meta-model. While a very high percentage of FinCo responses indicate the legacy system solutions selected are influenced by the organisational attributes explored, there is only limited evidence of this actually happening in FinCo's IT plans. This weakness in the proposed plans may have become evident and constructively debated had the questionnaire been completed in a joint forum or the results of the questionnaire discussed in such a forum. They were not. Our view is, therefore, that failure to consider organisational constraints when formulating legacy system solutions is likely to have a significant detrimental impact on FinCo's ability to execute its plans – as it would for organisations more broadly, we would argue. Ultimately, then, we would argue that the meta-model based assessment of FinCo's CSS legacy system suggests the company re-examine its plans to ensure it has the organisational capabilities to deliver on them. Furthermore, by applying the meta-model to each of the platforms in its portfolio of systems, FinCo has the opportunity to establish an understanding of the relative needs of its platforms from a legacy system management perspective and incorporate this portfolio assessment into its long-term IT strategy.

Appendix A

The questionnaire was administered face-to-face to ten of FinCo's senior business and IT executives. The FinCo participants were as follows:

– CEO
– CIO
– Senior Business Data Steward
– Head of Business Change Management
– Head of IT Strategy & Architecture
– Head of Business Management for IT
– Head of IT Development
– Head of IT Change Delivery
– Head of IT Governance & Security
– Head of IT Production Services

References

[1] P. Jenkins, 'Start-ups threat to creaking banks', Financial Times, October 14, 2015 [Online]. Available at <http://www.ft.com/cms/s/0/481671a4-61ca-11e5-9846-de406ccb37f2.html#axzz3todieGia> (accessed December 2015).
[2] M. Arnold, T. Braithwaite, 'Banks' ageing IT systems buckle under strain', Financial Times, June 18, 2015 [Online]. Available at <http://www.ft.com/cms/s/0/90360dbe-15cb-11e5-a58d-00144feabdc0.html#axzz3tFTKBd00> (accessed December 2015).
[3] G.R. Gangadharan, E.J. Kuiper, M. Janssen, P.O. Luttighuis, 'IT Innovation Squeeze: Propositions and a Methodology for Deciding to Continue or Decommission Legacy Systems, Grand Successes and Failures in IT', Public and Private Sectors, International Federation of Information Processing, Springer Link, 2013, pp. 481–494 [Online]. Available at <http://link.springer.com/chapter/10.1007/978-3-642-38862-0_30> (accessed March 2016).
[4] K.H. Bennett, M. Ramage, M. Munro, Decision model for legacy systems, Softw IEEE Proc. 146(3) (1999) 153 [Online]. Available at <http://ieeexplore.ieee.org.libezproxy.open.ac.uk/search/searchresult.jsp?newsearch=true&queryText=Decision%20model%20for%20legacy%20systems> (accessed December 2015).
[5] B.Y. Alkazemi, M.K. Nour, A.Q. Meelud, Towards a framework to assess legacy systems, in: IEEE International Conference on Man and Cybernetics, IEEE Conference

Publications, 2013, pp. 924–928. [Online] Available at < http://ieeexplore.ieee.org.libezproxy.open.ac.uk/search/searchresult.jsp?queryText = Towards%20a%20framework%20to%20assess%20legacy%20systems&newsearch = true > (accessed December 2015).

[6] R. Plant, A system for speaking IT truths to CEOs, Harvard Business Review, 2011 [Online]. Available at < https://hbr.org/2011/02/how-i-learned-a-system-for-spe > (accessed March 2016).

[7] A. De Lucia, A.R. Fasolino, E. Pompelle, A decisional framework for legacy system management, in: IEEE International Conference on Software Maintenance, IEEE Conference Publications, 2001, pp. 642–651 [Online]. Available at < http://ieeexplore.ieee.org.libezproxy.open.ac.uk/search/searchresult.jsp?queryText = A%20decisional%20framework%20for%20legacy%20system%20management&newsearch = true > (accessed December 2015).

[8] J. Ransom, I. Sommerville, I. Warren, A method for assessing legacy systems for evolution, in: Proceedings of the Second Euromicro Conference on Software Maintenance and Reengineering, IEEE Conference Publications, 1998, pp. 128–134 [Online]. Available at < http://ieeexplore.ieee.org.libezproxy.open.ac.uk/search/searchresult.jsp?queryText = A%20Method%20for%20Assessing%20Legacy%20Systems%20for%20Evolution&newsearch = true > (accessed December 2015).

[9] C. Brooke, M. Ramage, Organisational scenarios and legacy systems, Int. J. f Inform. Manage. J. Inform. Professionals 21(5) (2001) 365–384 [Online]. Available at < http://oro.open.ac.uk/2667/1/IJIM2001.pdf > (accessed February 2016).

[10] H.K.A. Bakar, R. Razali, A preliminary review of legacy information systems evaluation models, in: International Conference on Research and Innovation in Information Systems (ICRIIS), IEEE Conference Publications [Online], 2013, pp. 314–318. Available at < http://ieeexplore.ieee.org.libezproxy.open.ac.uk/search/searchresult.jsp?queryText = A%20preliminary%20review%20of%20legacy%20information%20systems%20evaluation%20models&newsearch = true > (accessed December 2015).

[11] R. Khadka, B.V. Batlajery, A.M. Saeidi, S. Jansen, J. Hage, How do professionals perceive legacy systems and software modernization, in: Proceedings of the 36th International Conference on Software Engineering, ACM, 2014, pp. 36–47 [Online]. Available at < http://dl.acm.org.libezproxy.open.ac.uk/citation.cfm?doid = 2568225.2568318 > (accessed July 2016).

[12] Gartner, Legacy application or system, Gartner IT Glossary, 2015 [Online]. Available at < http://www.gartner.com/it-glossary/?s = legacy + system > (accessed March 2016).

[13] M.M. Lehman, Laws of Software Evolution Revisited, Software Process Technology, vol. 1149, Springer, 2005, pp. 108–124 [Online]. Available at < http://link.springer.com/chapter/10.1007/BFb0017737 > (accessed January 2016).

[14] I. Sommerville, Software Engineering, 10th ed., Pearson Education, Harlow, 2015.

[15] Economist, After Moore's Law, The Economist Technology Quarterly, 2016, [Online]. Available at < http://www.economist.com/technology-quarterly/2016-03-12/after-moores-law > (accessed April 2016).

[17] L. Erlikh, Leveraging legacy system dollars for e-business, IT Professional, IEEE J. Mag. 2(3) (2000) 17–23 [Online]. Available at < http://ieeexplore.ieee.org.libezproxy.open.ac.uk/stamp/stamp.jsp?tp = &arnumber = 846201 > (accessed December 2015).

[18] R.A. Salama, S.G. Aly, A Decision Making Tool for the Selection of Service Oriented-Based Legacy Systems Modernization Strategies, Software Engineering Research and Practice, 2008 ResearchGate [Online]. Available at < https://www.researchgate.net/profile/Rafik_Salama/publication/221610608_A_Decision_Making_Tool_for_the_Selection_of_Service_Oriented-Based_Legacy_Systems_Modernization_Strategies/links/00b7d529e0be8e8630000000.pdf > (accessed January 2016).

[19] L. Aversano, M. Tortorella, An assessment strategy for identifying legacy system evolution requirements in eBusiness context, J. Softw. Maintenance Evol.: Res. Practice 16 (2004) 255–276 (John Wiley & Sons, Online). Available at < http://onlinelibrary.wiley.com.libezproxy.open.ac.uk/doi/10.1002/smr.296/epdf > (accessed April 2016).

[20] H.M. Sneed, Planning the reengineering of legacy systems, IEEE Software 12(1) (1995) 24–34 [Online]. Available at < http://ieeexplore.ieee.org.libezproxy.open.ac.uk/stamp/stamp.jsp?tp = &arnumber = 363168 > (accessed December 2015).

[21] R.B. Burns, Introduction to Research Methods, Sage, Thousand Oaks, 2000.

[22] D. Silverman, Doing Qualitative Research, Sage, Thousand Islands, 2013.

[23] R.K. Yin, Case Study Research: Design and Methods, fifth ed., Sage, Thousand Oaks, 2014.