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1 **Process digital twin: lessons learned from a construction case study**

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26 **Abstract**

27 This briefing paper reflects on an effort to create a digital twin of the work processes of a
28 construction company. The digital twin was to be used by the business to take advantage
29 of digital techniques like machine learning, artificial intelligence and data analytics in
30 optimising their activities. However, the effort to create the required process maps took
31 longer than expected. In capturing the lessons learned, a system dynamics approach was
32 used to reveal the structural and behavioural issues that prevented the timely completion
33 of the task. The issues identified include problems with planning, process documentation,
34 process standardisation, leadership and stakeholder engagement. From analysing the
35 results, good practices are recommended to ensure timely delivery of similar tasks in the
36 future.

37 **Keywords**

38 Business; Information technology; Planning & scheduling

39

40 **1. Introduction**

41 A factor in the successful delivery of construction projects is the timeliness and quality of
42 information (Dzokoto, 2015). Where the quality of shared information is poor or not retrieved in a
43 timely way, inadequate decisions may be made, which can damage project performance and
44 potentially lead to conflicts or even litigations (Sheng *et al.*, 2020). Presented here is the case of
45 a leading specialist construction business with a desire to radically turn around its information
46 management processes to achieve higher productivity. To achieve this goal, the organisation
47 took part in a UK-wide programme known as Knowledge Transfer Partnership (Howlett, 2010).
48 The programme helps businesses to improve their competitiveness and productivity through the
49 better use of knowledge, technology and skills that reside within the UK knowledge base,
50 namely universities, further education colleges and research institutions. In this case, the
51 business partnered with a university on a project.

52

53 The aim of the partnership project was to develop a bespoke, real-time data information portal
54 and dashboard for effective and efficient construction decisions. However, audit of the
55 organisation's work processes at the outset of the project revealed that the way information and
56 data was being applied across the business was inconsistent and causing inefficiencies and
57 errors. To revert this situation, an important objective of the project was to develop a digital
58 representation – in essence a 'digital twin' (Qiuchen *et al.*, 2019) – of the business processes
59 and IT systems across the organisation. This required generating process maps covering the
60 work processes and data flows in the company.

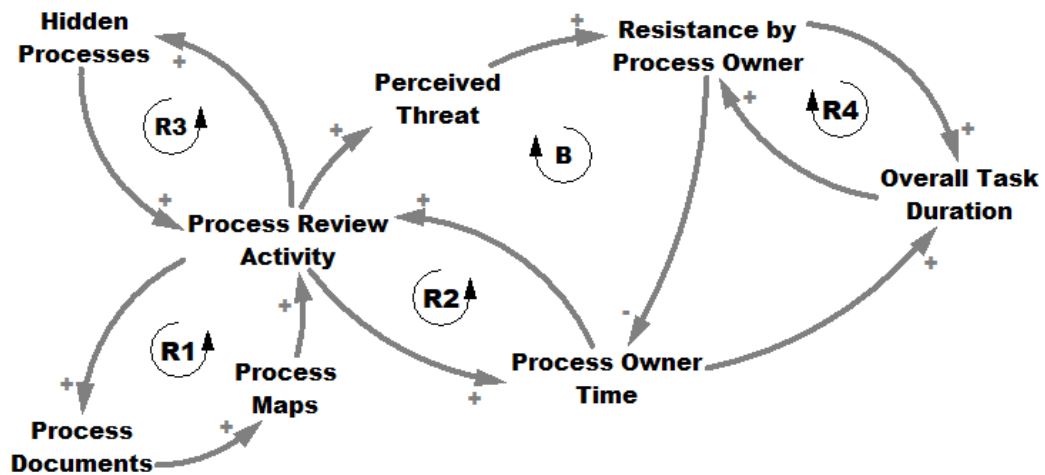
61

62 The effort to deliver the 'digital twin' took a lot longer than initially anticipated. Indeed, in the
63 initial project plan, the duration was estimated at 3 months; but it took 12 months to complete.
64 So, what happened and why the delay? This article evaluates the work that went into delivering
65 that 'digital twin', describes the challenges that were faced and makes recommendations for
66 future similar projects. We hope this experience and the lessons learned from it will be of benefit
67 to all organisations aiming to transform themselves to remain competitive in a digitalised
68 construction sector.

69

70 **2. Analysis of case study**

71 To support our discussion on the challenges faced, Figure 1 captures the dynamics of the effort
 72 using a causal loop diagram - a systems dynamics representation (Abdelbari and Shafi, 2017).
 73 Firstly, there was limited documentation of the organisation's processes that would help in
 74 creating the digital twin. As a result, there was a need for further elicitation activities. The more
 75 process documents were found, the more process maps were generated and the more the
 76 process review activities had to take place. The more review activities that took place, the more
 77 the process documents were found. This fact pattern is represented by the links in the
 78 reinforcing loop R1 in Figure 1, which indicates that change in one direction is compounded by
 79 more change.



80
 81 *Figure 1. Causal loop diagram showing the system that emerged from the digital twinning effort*

82 Secondly, getting the process owners and relevant stakeholders to participate in elicitation
 83 activities while contributing to their day-to-day live projects was a challenge. The fact that
 84 meetings had to take place at times most workable for the stakeholders extended the period for
 85 elicitation and reviews. The more the process review activities that took place, the more time of
 86 process owners was required. The longer process owners spent on process review, the more
 87 hidden processes were revealed, generating additional process review activities. This fact
 88 pattern is represented by the links in reinforcing loops R2 and R3 in Figure 1.

89

90 Thirdly, the business has multiple operational zones with functional teams that were found to
91 sometimes have dissimilar processes. While this, on one hand, is valuable to ensure project
92 teams are able to address the unique situations at their locations, on the other hand it created a
93 point of conflict. The differences that existed required additional time for resolution because of
94 the iterative process to get stakeholders to agree to a common standard. The more the process
95 review activities carried out, the more the differences between teams became apparent and the
96 fiercer the competition between them became, increasing the perceived threat amongst the less
97 influential stakeholders. The higher the perceived threat, the less receptive affected
98 stakeholders became to the effort and as a result spent lesser time engaging. Nonetheless, the
99 little they contributed still provided leads that resulted in more process review activities. The fact
100 that the disenchanted stakeholders gave little at each engagement significantly slowed the
101 review process. This fact pattern is represented by the links in balancing loop B – in Figure 1 -
102 which indicates that change in one direction is countered with change in the opposite direction.
103 Fourthly, the more resistant to the effort process owners became, the longer it took to complete
104 the task and vice versa. This fact pattern is represented by the links in reinforcing loop R4 in
105 Figure 1.

106

107 Finally, on hindsight “pre-project planning” appeared to have been overly optimistic. It is
108 possible to point to the fact that every project is unique. However, the risks were not adequately
109 assessed in this case. In particular, the lack of existing resources (process documents and
110 process owner time) was misjudged, and so was the challenge of delivering the task within a
111 live work environment.

112

113 Overall, the patterns in the system contributed to a significant increase in the overall task
114 duration as evidenced by the nine month increase to the planned duration. In taking stock of
115 what happened with the task, it is always easy to focus on the singular events - conflicts,
116 workshops, meetings etc. that took place during its execution. However, these events have
117 limited usefulness in fully understanding the delays to the task completion. Behind the delaying
118 events are patterns of behaviour that are sources of pressure and imbalance, causing things to
119 change. Behaviour is shaped by structure, both physical and informational, and the events are

120 snapshots of that behaviour (Ventana Systems, 2015). By representing our experience from a
121 causal perspective, the structural forces that produced the undesired behaviour have become
122 apparent. To mitigate against these forces in similar projects in the future, interventions need to
123 be made to counterbalance them.

124

125 **3. Recommendations**

126 Given the experience from this case study, the following are recommendations for similar efforts
127 in the future.

128 • Planning: rolling wave planning (Laufer *et al.*, 2018) should be used for similar efforts as
129 details will only become clearer as the project proceeds. In the discussed case, the pre-
130 project planning was overly optimistic because it made too many assumptions – in
131 particular with regard to information availability – that turned out to be flawed.

132 • Process documentation: The most up-to-date process documents covering all the
133 associated processes should be collated in a separate initial effort. In the discussed case,
134 relevant process documents that were incomplete or not mainstream resulted in additional
135 reviews which delayed the effort.

136 • Process standardisation: A separate effort should be dedicated to reconciling the different
137 views of relevant processes if standardisation is desired. This is important considering that
138 the duration is unpredictable given the complexities that may arise. The effort should also
139 precede the creation of any digital twin.

140 • Top level management: There must be clear top-down mandate that communicates the
141 goal and importance of the effort. The mandate should empower stakeholders to prioritise
142 the activities of the effort. This is important because any ambiguity is a leeway for
143 unnecessary competition between stakeholders.

144 • Stakeholder engagement: Irrespective of the engagement method, stakeholders must be
145 able to create suitable and proportional time for task. From the experience of this case
146 study, the methods of engagement didn't have much impact on the efficiency of producing
147 the process maps. In some cases, stakeholders preferred to have online meetings and
148 mark-up electronic documents. Although this method seemed efficient because they could
149 do it remotely and still benefit from interactive chats, they still needed to create time for the

150 task while engaging on their projects. In some other cases, stakeholders preferred in-
151 person meetings and marking up printed documents in review meetings. With this option, it
152 took longer than remote engagements because of the challenge of getting stakeholders to
153 attend meetings while they were engaged on live projects. Lastly, although reconciling the
154 different views of stakeholders benefited from meetings, in-person and remote, getting the
155 required stakeholders to attend all at the same time was a challenge – and the option of
156 going back and forth between stakeholders never got the work done.

157

158 **4. Conclusion**

159 Despite good planning effort, several projects still overrun. This, in part, is because of the
160 difficulty with properly assessing the unanticipated side effects on planning decisions. Most
161 planning efforts are based on an open loop mental model in which a sequential path exists from
162 the beginning to the end of a task or project. Contrarily, there are interactions and feedback that
163 loop back - and almost all are unintended. The case discussed in this briefing paper
164 demonstrates this by reviewing an effort to develop process maps to be used for digital
165 twinning. The effort took a significantly longer time than planned. To move on from the task
166 without understanding the feedback may let some assume the experience is normal. So,
167 analysing the experience helps in representing the mental model of what ought to be done. It is
168 important to note that all models are wrong, and reality is what it is. However, a model close to
169 reality will provide insight that improves our mental models. This will ensure actors engaging in
170 similar tasks in the future are able to make better planning decisions.

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174

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