IDENTIFICATION OF KEY PROCESS AREAS IN THE PRODUCTION OF AN E-CAPABILITY MATURITY MODEL FOR UK CONSTRUCTION ORGANISATIONS

Robert Eadie,
School of the Built Environment, University of Ulster
email:r.eadie-r@ulster.ac.uk

Srinath Perera,
School of the Built Environment, University of Ulster
email: s.perera@ulster.ac.uk

George Heaney,
School of the Built Environment, University of Ulster
email: sg.heaney@ulster.ac.uk

ABSTRACT

Uptake of e-procurement by construction organisations has been slow (Martin, 2008). Positive e-business achievements in other industries, point towards the potential for the construction industry to accomplish similar results. Since the Modernising Government White paper set targets through best value indicator BV157 for implementation in the public sector, Government has supported many initiatives encouraging e-procurement. These are based on documented efficiency and cost savings (Knudsen, 2003; Minahan and Degan, 2001; McIntosh and Sloan, 2001; Martin, 2008). However, Martin (2003, 2008) demonstrates only a modest increase in the uptake of e-procurement in the UK construction industry.

Alshawi et al (2004) identified the significance of possessing a model to sustain the embedment of any business process within an organisation. Saleh and Alshawi (2005) describe a number of model types used to gauge maturity in an organisation. One of these models is the capability maturity model. Paulk et al (1993) released the Software Capability Maturity Model (CMM) in 1991. Since then many CMM's have evolved. This paper reports on how a CMM based on Drivers and Barriers to e-procurement identified in Eadie et al (2009) can be developed to gauge the maturity of an organisation in relation to e-procurement.

This paper presents details of a research project which used factor analysis to produce a set of Key Process Areas (KPA) from the drivers and barriers identified in Eadie et al (2009). These KPAs were then subjected to a mapping process linking them to maturity levels to develop a CMM to analyse the e-procurement capability of construction organisations. The mapping will be reported in a later paper. This termed as e-readiness of organisations will indicate the current state of a construction organisation in terms of its readiness to carry out e-procurement. The paper describes in detail the identification of the KPA's.

KEYWORDS

Capability maturity model, Construction, e-procurement, e-readiness

1.0 INTRODUCTION

The increased use of the internet offers greater opportunity for E-Procurement and E-Tendering can offer viable electronic alternatives to traditional paper-based processes. National Procurement Strategy for Local Government (2003) defined procurement as "*the process of acquiring goods, works and services, covering both acquisition from third parties and from in-house providers. The process spans the whole life cycle from* *identification of needs, through to the end of a services contract or the end of the useful life of an asset. It involves options appraisal and the critical 'make or buy' decision.*' Rowlinson and McDermott (1999) define procurement for construction as "*the acquisition of project resources for the realisation of a constructed facility*". It has been identified as a strategic actor within the construction process (Egbu et al, 2003). E-Procurement improves numerous facets of the procurement process. (National Institute of Governmental Purchasing 2001, Minahan and Degan 2001, McIntosh and Sloan 2001, Ribeiro 2001).

The theory behind electronic procurement is provision of a system of transmitting electronic input from the contractor's tender to contract management and final account. This removes the inefficiencies, delays and cost associated with manually completing the tender process and the retyping for assessment and contract management activity. E-Procurement can then be defined as "*the use of electronic technologies to streamline and enable procurement activities*" (Hawking et al 2004).

Despite Kheng et al (2002) stating that "*Electronic commerce is one of the fastest growing sectors globally*", Martin (2008) and Martin (2003) have shown a slow uptake within the construction industry. This shows that there are obstacles to be overcome before e-procurement benefits can be maximised.

1.1 Business Maturity Modelling

In number of industry sectors it has been shown that the development of business process models has supported the embedment of the business process within the organisation (Alshawi et al, 2004). Saleh and Alshawi (2005) show that there are a number of different models which can be used to establish the maturity of a system and therefore embed it within the industry. This paper reports on a stage in the production of a standard model for e-procurement with implications for the complete construction industry. This current study into e-procurement produced a model in the normative category. Shere (2004) shows that capability maturity models look inward at a process ensuring that measurements are taken, policy exists, training is given and a review process is in place.

Humphrey (1989) constructed the concept of Capability Maturity Models(CMM) and produced a marking framework. This followed an initial paper published in 1987. Paulk et al (1993) from Carnegie Mellon University released the Software CMM in 1991. The Software CMM (SW-CMM) was superseded by the Capability Maturity Model Integration (CMMI) (Chrissis et al, 2007). CMMI is currently published in its second edition. A large number of models for various business processes have been developed since its publication.

Chrissis et al (2007) show that in the staged representation there are five levels of maturity. To move between these levels success in Key Process Areas (KPA) must be achieved. Under each KPA there are goals to be met. How well an organisation meets these requirements will result in an allocation of a maturity level to that organisation. This paper reports on the definition of these KPAs for the e-procurement process within construction using the drivers and barriers to e-procurement as the goals.

1.2 E-Procurement Drivers and Barriers

The e-procurement CMM was developed from the identification of the drivers and barriers to e-procurement in construction. The recognition of the process dynamics of e-procurement, both positively (drivers) and negatively (barriers) is vital to attaining a comprehension of how the benefits of e-procurement can be employed to maximise uptake and provide a model to embed e-procurement in construction. These identified drivers and barriers became the goals for the model. The ranking of the drivers and barriers was acted on by a data reduction technique to produce the KPAs for the e-procurement CMM.

A limited study had been carried out in order to identify the importance of drivers and barriers to construction e-procurement, where Eadie et al (2007) carried out a preliminary study into drivers and barriers from a Northern Irish Public Sector Construction Contractor's perspective. As little work on ranking Drivers and Barriers from a construction perspective existed, the study applied drivers and barriers identified from other industries to e-procurement in construction and produced a ranking of driver and barrier importance. Eadie et al (2009a) further reported a rigorous verification process which produced a collated set of Drivers and barriers to construction e-procurement by defining the applicability of each driver and barrier identified from literature to construction e-procurement. This was completed through the application of a Delphi methodology to a group of domain experts and analysed the applicability of each driver and barrier to construction e-procurement throughout the UK construction industry. Eadie et al (2009b) followed this with a UK wide study which ranked these from the different construction industry perspectives. Eadie et al (2009b) produced a ranking which combined results from the different experts within the industry. This was then utilised to produce the e-procurement capability maturity model.

2. METHODOLOGY FOR DEVELOPING AN E-PROCUREMENT CAPABILITY MATURITY MODEL

This current study relied on the findings of Eadie et al (2009a, 2009b), the rankings of the drivers and barrier found in this study were categorised by principle components analysis. The Eadie et al (2009a) sample contained a total of 775 organisations who ranked the drivers and barriers (483 surveyors, 42 Public Sector clients, 172 Architects, 35 Private sector clients and 43 Consulting Engineers) from January to March 2008. A 77% valid response rate was achieved.

Table 1 Sample Valid Response Breakdown by Discipline

	Organisations (Total No.)	Organisations using E-Procurement	Organisations not using E-Procurement	Organisations not contactable, no longer trading or with no one available for comment	% valid response
Quantity Surveyors	483	83	247	153	68%
Public Sector Clients	42	29	10	3	93%
Architects	172	12	156	4	98%
Private Sector Clients	35 in sample	0	35	Unknown	
Engineers	43	4	25	14	67%
	775	128	473	174	77%

Table 1 shows the number of organisations contacted during the telephone survey and the percentage valid response from the total sample. These figures show the extent of the survey and show that the results can be generalised across the industry.

Once the organisations confirmed that they carried out e-procurement from the phone survey they were asked to complete a ranking of the drivers and barriers to e-procurement. For the purposes of data collection during this phase of the study Limesurvey was mounted on webspace and used to conduct the survey in 2008. This software package collected the responses through a web-based interface and stored these in an on-line MySQL database. Data collected was exported directly into SPSS for analysis.

2.1 Suitability of data for factor analysis

Tests confirming the suitability of the data collected via the web-based survey for factor analysis were carried out using internal SPSS tests. The correlation matrix produced for the drivers and barriers showed that the majority of the coefficients with values greater than 0.3 showing that the data is suitable for examination by this method. High correlations mean that these items are likely to be viewed as the same factor after analysis (Leech et al, 2005).

Further inspection of the Kaiser-Meyer-Oklin (KMO) value shows the sampling adequacy to be 0.731 for the drivers and 0.606 for the barriers which exceeds the 0.6 value that Kaiser (1970, 1974) suggested as adequate for accurate completion of analysis. The KMO value shows that there are enough items predicted by each factor.

Examination of the Bartlett's test of Sphericity shows whether or not the variables are correlated enough to enable factor analysis to be carried out. Bartlett (1954) suggested that the significance should be less than a value of 0.05. As the value for both drivers and barriers was below this value the correlation is deemed strong enough to be accurate.

3. PRINCIPLE COMPONENTS ANALYSIS OF THE DRIVERS AND BARRIERS FOR E-PROCUREMENT

Principle Components analysis was carried out on the drivers for e-procurement. This showed that for both the raw and rescaled analysis options that the first five components had initial eigenvalues greater than 1. These five factors explained 73.309% of the variance being 38.667, 12.615, 9.474, 6.949 and 5.604 respectively. It was decided to retain all five components meeting the Kaiser criterion. Leech et.al (2005) point out that once an eigenvalue is less than one the factor would explain less information than a single item would have explained and therefore can be excluded from further consideration.

A similar Principle Components analysis was carried out on the barriers to e-procurement. This showed that for the first nine components had initial eigenvalues greater than 1. These nine factors explained 80.682% of the variance being 32.992, 13.662, 7.275, 5.839, 5.024, 4.817, 4.016, 3.701 and 3.356 respectively. However the scree plot suggested that only eight be analysed.

4. CLASSIFICATION OF THE PRINCIPAL COMPONENTS IDENTIFIED IN THE PRINCIPAL COMPONENTS ANALYSIS OF THE DRIVERS FOR E-PROCUREMENT

The component matrix is used to decide the loadings of the items on the factors. To allow easy interpretation of the factors, the factors are "rotated". This does not change the result. There are a number of different types of rotation possible within SPSS. These are variants of orthogonal (uncorrelated) or oblique (correlated) factor solutions. As each of the drivers and barriers have been identified as independent items by the Delphi process, an orthogonal solution is appropriate. SPSS contains three orthogonal solutions. These are Varimax, Quartimax, and Equamax. Varimax is the most commonly used of the three as it minimises the number of variables that have high loadings on each factor resulting in a cleaner, easier interpreted result. Grover and Vriens (2006) recommend its use for orthogonal solutions. For this reason, it was chosen for this study. The results are shown in Table 4.

The loadings which result from carrying out the Varimax rotation are the correlation coefficients. These range in value for +1.0 to -1.0. Factor loadings of less than 0.3 are considered low (Leech et al, 2005) and during the analysis SPSS was asked to ignore loadings under 0.3.

Table 2 Rotated Component Matrix for Drivers to e-procurement

	Component				
Driver	1	2	3	4	5
Process, Transaction and Administration Cost Savings		.817			
Service / Material / Product Cost Savings		.881			
Increasing Profit Margins		.768			.357
Strategic Cost Savings	.413	.713			-.348
Enhanced Inventory Management	.613	.306			-.319
Shortened Overall Procurement Cycle Times	.357			.823	
Shortened Internal and External Communication Cycle times			.431	.682	
Reduction in time through greater transparency (Less objections)	.655			.494	
Reduction in Evaluation Time	.634				
Reduction in purchasing order fulfilment time - Contract Completion	.650				
Reduction in time through increased visibility	.656			.379	
Increased Quality through increased competition	.789				
Increased Quality through Benchmarking (Market Intelligence)	.826				
Increased Quality through increased visibility in the supply chain	.782				.361
Increased Quality through increased efficiency		.400	.536	.437	.341
Increased Quality through Improved Communication			.857		
Gaining Competitive Advantage	.371				.701
Increased Quality through increased accuracy (Elimination of errors through Computer use)			.507		.528
Convenience of archiving completed work			.826		
Develops the Technical Skills, knowledge and expertise of procurement staff	.771				

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalisation.
a Rotation converged in 10 iterations.

Table 2 identified five factors. The contents of these factors will be discussed later. Columns one to five in Table 2 show the impact of drivers on each of these factors.

5. CLASSIFICATION OF THE PRINCIPAL COMPONENTS IDENTIFIED IN THE PRINCIPAL COMPONENTS ANALYSIS OF THE BARRIERS FOR E-PROCUREMENT

A similar method was used in regard to the barriers. The results are shown in Table 3. Table 5 identified the eight factors. The contents of these factors will be discussed later. Columns 1 - 8 in Table 3 show the impact of drivers on each of these factors.

Table 3 Rotated Component Matrix for Barriers to e-procurement

	Component							
Barrier	1	2	3	4	5	6	7	8
No Upper Management Support / Lack of Leadership		.458	.373				.495	
Other Competing Initiatives			.731					
Resistance to change		.517	.344				.549	
Lack of a widely accepted e-procurement software solution						.558		
Magnitude of Change		.493					.640	
Lack of a national IT policy relating to e-procurement Issues		.362				.541		
Lack of Flexibility		.768						
Bureaucratic dysfunctionalities		.871						
Complicated procedures and extended relationships		.861						
Lack of technical expertise		.544				.532		

Staff Turnover			.514			.420		.371
Lack of a forum to exchange ideas	.413					.701		
Company Access to the Internet			.664		.336			
Reluctance to "Buy-into" one off systems					.904			
Insufficient assessment of systems prior to installation		.316	.472		.593		-.321	
Security in the process - Data transmission to the wrong person	.718							
Confidentiality of Information - unauthorised viewing	.819					.362		
Prevention of Tampering with Documents - changes to documents	.754							
Data Transmission reassembly - incorrect reassembly of data transmitted in packets	.870							
Partial Data Display - incomplete documents provided	.877							
Lack of Pertinent case law	.636							-.402
Different national approaches to e-procurement	.564			.320			.364	-.338
Proof of intent - electronic signatures	.568		-.365	.310				
Clarity of Sender and Tenderer Information	.434			.713				
Enforceability of Electronic Contracts				.851				
Information Technology Investment Costs			.526	.499	.426			
Perception of no Business Benefit Realised		.553		.481	.313			
Internal and External interoperability of e-procurement software	.389	.319	-.354		.356			.542
Lack of publicity / awareness of best practice solutions								.734
Investment in compatible systems					.670		.455	

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalisation.
a Rotation converged in 13 iterations.

Table 3 identified five factors. The contents of these factors will be discussed later. Columns one to eight in Table 3 show the impact of drivers on each of these factors.

6. PRINCIPAL COMPONENTS MAPPING TO KEY PROCESS AREAS (KPAS) FOR THE DRIVERS FOR E-PROCUREMENT

A KPA is defined as a cluster of related activities (common features) that, when performed together, achieve a set of important goals (Paulk et al, 1995). The PCA clustered related drivers and barriers for e-procurement into factors. The five factors in the driver analysis were combined with the eight barrier factors to give thirteen KPAs in total. After mapping one driver factor was combined with a barrier factor into a single factor making twelve KPAs in the model. The grouping of the drivers and barriers (common features) through the factor analysis provide the KPA's. Table 4 shows the correlations between KPA's from other models (mapping later) and the findings of the Factor Analysis. The findings of the factor analysis, group the common features for each driver and barrier identified from Table 2 and Table 3 as having impact of over 0.3. The weighting (W) for each Driver / Barrier was then determined by the formula below:-

$$W = \frac{PCA}{\sum PCA_T} \times 100$$

Where PCA is the PCA impact for the individual Driver/Barrier (Table 4 and 5) and, $\sum PCA_T$ is the sum of the PCA impact for the KPA.

In other capability models, such as the e-sourcing model, these KPAs have been of a similar high level nature. The link to the maturity level was completed via a Delphi process on an expert group and is the subject of a further paper. The calculation of overall maturity level will also be described in this future paper. The linking to the maturity levels is provided for completeness in Table 4.

Table 4 Detailed Summary of EP-CMM

KPA	Common Feature Label	Common features	Weighting (W)	Link to Maturity Level
KPA1 : Quality Management System Mapped using features described in CMMI Kulpa and Johnston, 2003	QM01	Strategic Cost Savings	5.49%	2
	QM02	Enhanced Inventory Management	8.15%	2
	QM03	Shortened Overall Procurement Cycle Times	4.75%	2
	QM04	Reduction in time through greater transparency (Less objections)	8.71%	2
	QM05	Reduction in Evaluation Time	8.43%	2
	QM06	Reduction in purchasing order fulfilment time - Contract Completion	8.65%	2
	QM07	Reduction in time through increased visibility	8.73%	2
	QM08	Increased Quality through increased competition	10.50%	2
	QM09	Increased Quality through Benchmarking (Market Intelligence)	10.99%	2
	QM10	Increased Quality through increased visibility in the supply chain	10.40%	2
	QM11	Gaining Competitive Advantage	4.94%	2
	QM12	Develops the Technical Skills, knowledge and expertise of procurement staff	10.26%	2
KPA2 : Cost Management System Mapped using Features described in Sukhoo et al, 2007	CM01	Process, Transaction and Administration Cost Savings	21.03%	2
	CM02	Service / Material / Product Cost Savings	22.68%	2
	CM03	Increasing Profit Margins	19.77%	2
	CM04	Strategic Cost Savings	18.35%	2
	CM05	Enhanced Inventory Management	7.88%	2
	CM06	Increased Quality through increased efficiency	10.30%	2
KPA3 : Intergroup Coordination Mapped using features from Paulk et.al., 1995; Nelson et.al., 2000; Nidomula, 1996	IC01	Shortened Internal and External Communication Cycle times	4.23%	3
	IC02	Increased Quality through increased efficiency	5.26%	3
	IC03	Increased Quality through Improved Communication	8.40%	3
	IC04	Increased Quality through increased accuracy (Elimination of errors through Computer use)	4.97%	3
	IC05	Convenience of archiving completed work	8.10%	3
	IC06	Lack of a forum to exchange ideas	4.05%	3
	IC07	Security in the process - Data transmission to the wrong person	7.04%	3
	IC08	Confidentiality of Information - unauthorised viewing	8.03%	3
	IC09	Prevention of Tampering with Documents - changes to documents	7.39%	3
	IC10	Data Transmission reassembly - incorrect reassembly of data transmitted in packets	8.53%	3
	IC11	Partial Data Display - incomplete documents provided	8.60%	3
	IC12	Lack of Pertinent case law	6.24%	3
	IC13	Different national approaches to e-procurement	5.53%	3
	IC14	Proof of intent - electronic signatures	5.57%	3
	IC15	Clarity of Sender and Tenderer Information	4.26%	3
	IC16	Internal and External interoperability of e-procurement software	3.81%	3

KPA	Common Feature Label	Common features	Weighting (W)	Link to Maturity Level
KPA 4 : Time Management System mapped using Features from Sukhoo et al, 2007	TM01	Shortened Overall Procurement Cycle Times	29.24%	2
	TM02	Shortened Internal and External Communication Cycle times	24.23%	2
	TM03	Reduction in time through greater transparency (Less objections)	17.55%	2
	TM04	Reduction in time through increased visibility	13.46%	2
	TM05	Increased Quality through increased efficiency	15.52%	2
KPA 5 : Operational Analysis Mapped using Features described in Sukhoo et al, 2007	OA01	Increasing Profit Margins	12.08%	2
	OA02	Strategic Cost Savings	11.78%	2
	OA03	Enhanced Inventory Management	10.80%	2
	OA04	Increased Quality through increased visibility in the supply chain	12.22%	2
	OA05	Increased Quality through increased efficiency	11.54%	2
	OA06	Gaining Competitive Advantage	23.72%	2
	OA07	Increased Quality through increased accuracy (Elimination of errors through Computer use)	17.87%	2
KPA 6 : Organisational Change Management System Mapped using Features described in Hefley and Loesche, 2005	OC01	Upper Management Support / Lack of Leadership	7.56%	4
	OC02	Resistance to change	8.53%	4
	OC03	Magnitude of Change	8.13%	4
	OC04	Lack of a national IT policy relating to e-procurement Issues	5.97%	4
	OC05	Lack of Flexibility	12.67%	4
	OC06	Bureaucratic dysfunctionalities	14.37%	4
	OC07	Complicated procedures and extended relationships	14.20%	4
	OC08	Lack of technical expertise	8.97%	4
	OC09	Insufficient assessment of systems prior to installation	5.21%	4
KPA 7 : Integrated Teaming Mapped using Features described in Chrissis et al, 2007 and Kulpa and Johnston, 2003	IT01	Upper Management Support / Lack of Leadership	8.59%	3
	IT02	Other Competing Initiatives	16.83%	3
	IT03	Resistance to change	7.92%	3
	IT04	Staff Turnover	11.84%	3
	IT05	Company Access to the Internet	15.29%	3
	IT06	Insufficient assessment of systems prior to installation	10.87%	3
	IT07	Proof of intent - electronic signatures	8.40%	3
	IT08	Information Technology Investment Costs	12.11%	3
	IT09	Internal and External interoperability of e-procurement software	8.15%	3
KPA 8 : Governance Management System Mapped using Features described in Hefley&Loesche,2005	GM01	Different national approaches to e-procurement	10.08%	5
	GM02	Proof of intent - electronic signatures	9.77%	5
	GM03	Clarity of Sender and Tenderer Information	22.46%	5
	GM04	Enforceability of Electronic Contracts	26.81%	5
	GM05	Information Technology Investment Costs	15.72%	5
	GM06	Perception of no Business Benefit Realised	15.15%	5

KPA	Common Feature Label	Common features	Weighting (W)	Link to Maturity Level
KPA 9 : Requirements Development, Mapped using features described in Chrissis et al, 2007; Hefley & Loesche (2005)	RD01	Company Access to the Internet	9.34%	3
	RD02	Reluctance to "Buy-into" one off systems	25.13%	3
	RD03	Insufficient assessment of systems prior to installation	16.48%	3
	RD04	Information Technology Investment Costs	11.84%	3
	RD05	Perception of no Business Benefit Realised	8.70%	3
	RD06	Internal and External interoperability of e-procurement software	9.89%	3
	RD07	Investment in compatible systems	18.62%	3
KPA 10 : Knowledge management system Mapped using Features described in Hefley and Loesche, 2005	KM01	Lack of a widely accepted e-procurement software solution	17.92%	4
	KM02	Lack of a national IT policy relating to e-procurement Issues	17.37%	4
	KM03	Lack of technical expertise	17.08%	4
	KM04	Staff Turnover	13.49%	4
	KM05	Lack of a forum to exchange ideas	22.51%	4
	KM06	Confidentiality of Information - unauthorised viewing	11.62%	4
KPA 11 : Integration Management System Mapped using Features described in Chrissis et al, 2007; Hefley & Loesche (2005) and Sukhoo et al, 2007	IM01	Upper Management Support / Lack of Leadership	17.53%	3
	IM02	Resistance to change	19.44%	3
	IM03	Magnitude of Change	22.66%	3
	IM04	Insufficient assessment of systems prior to installation	11.37%	3
	IM05	Different national approaches to e-procurement	12.89%	3
	IM06	Investment in compatible systems	16.11%	3
KPA 12 Organisational Environment Mapped using Features described in in Chrissis et al, 2007; Kulpa and Johnston (2003)	OE01	Staff Turnover	15.54%	3
	OE02	Lack of Pertinent case law	16.84%	3
	OE03	Different national approaches to e-procurement	14.16%	3
	OE04	Internal and External interoperability of e-procurement software	22.71%	3
	OE05	Lack of publicity / awareness of best practice solutions	30.75%	3

7. CONCLUSIONS

This paper set out to report the production of an e-capability maturity model for construction organisations based on Drivers and Barriers to e-procurement already reported in Eadie et.al.(2009). It achieved this by using factor analysis as a data reduction technique to reduce the 20 drivers and 32 barriers identified as being applicable to e-procurement in construction to 12 Key Process Areas. The twelve Key Process Areas used by the research were KPA1 : Quality Management System, KPA2 : Cost Management System, KPA3 : Intergroup Coordination, KPA 4 : Time Management System, KPA 5 : Operational Analysis, KPA 6 : Organisational Change Management System, KPA 7 : Integrated Teaming, KPA 8 : Governance Management System, KPA 9 : Requirements Development, KPA 10 : Knowledge management system, KPA 11 : Integration Management System and KPA 12 Organisational Environment. The Key Process Area titles had been identified from other CMM's and mapped to the contents of each of the common features. The mapping is shown in Table 4.

These 12 Key Process Areas were then linked via a maturity mapping process by a group of domain experts to a maturity level of one to five. This produced a model that linked each of the Drivers and Barriers to construction e-procurement to a maturity level for a given organisation. The mapping process and calculation of the final organisational maturity level is the subject of a future publication.

Further work will have to be completed to refine and prove the model in practice.

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