Construction
Leadership
Council

Proof of Concept Pilot Project

A quality metric for construction projects –
to reduce defects and help remove the need
for cash retentions in contracts

SUMMARY

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Construction Leadership Council

1.0 Introduction

1.1 Sustainable and productive supply chains are critical for the success of the construction industry. The Construction Leadership Council's (CLC) Business Models and Fair Practices workstream is focussed on improving collaboration within supply chains to improve project outcomes and profitability. This includes improving the fairness of commercial practices, with specific projects focusing on the elimination of onerous contractual clauses, driving better procurement approaches and identifying and promoting sustainable solutions for the practice of cash retentions.

1.2 The use of cash retentions is a long-established construction contractual practice, used through all the tiers of the supply chain. The practice originated as a means of providing security against defects in instances where quality of work in the industry remains inconsistent. The sums retained, typically 5% of the contract value, are typically insufficient to repair any outstanding defects and the withholding of payment often causes cashflow issues within the businesses awaiting payment. The system is ineffective and can be problematic for all parties in the supply chain due to late, partial or non-payment or permanently lost through upstream insolvency.

1.3 The industry needs to improve quality of work and develop mechanisms to support this. Both clients and contractors have indicated that quality of work is one of the main obstacles to achieving the industry ambition of zero retentions in construction contracts by 2025.

1.4 Over the last 18 months, the CLC[1] has worked with Actuate UK[2] and the Get It Right Initiative (GIRI)[3] to develop and test a proposal for a quality metric as a viable alternative to the withholding of cash retentions as a form of insurance against defects. GIRI funded the research project by the Centre for Design Engineering (C4DE)[4] at Cranfield University.

1.5 This report summarises the pilot project to test the proof of concept for this innovative work. **Annex A** provides the research findings by C4DE.

2.0 Project Aim

2.1 The long-term aim of this project was to drive improved quality of construction projects, reduce or eliminate defects and decrease the need for the use of retention clauses in construction contracts.

[1] Construction Leadership Council
[2] Actuate UK
[3] Get It Right Initiative
[4] Centre for Design Engineering

2.2 The proposal was to develop and test a methodology to record a contractor's quality performance across previous projects using outstanding defect information recorded on completion certificates. This data could then be collated and compared across businesses, projects and sectors. Use of publicly available performance tables could:

- support a client decision on the engagement of the contractor and use of retention clauses on future contracts.
- incentivise increased performance and quality of work by the contractor through a project.

2.3 This approach has been successful in changing behaviours for health and safety within construction and latterly for payment practices. Ultimately, the better the metric score the less risk there is that there will be a quality problem. In turn less requirement for the use of a cash retention.

3.0 Methodology

3.1 The first stage of the project was proof of concept - to develop and evaluate a data driven method for measuring the Error Frequency Rate (EFR) in the construction industry, based on a database of completed projects.

3.2 Data collection involved an online survey sent to construction companies, asking them to provide information on their projects' value, sector, contract type, and the number of outstanding items at completion.

3.3 The methodology used a mathematical programming model and algorithm to compute the EFR score for each project and company, based on the input and output data. The EFR score ranges from 0 to 100, with lower values indicating better performance. The model also allows for a breakdown of the EFR score by project value and sector.

4.0 Results and Next Steps

4.1 **Annex A** provides the research findings by C4DE.

4.2 Despite the small data set, key findings included:

- the data-driven method can measure and evaluate the EFR metric for construction projects and companies, and provide useful insights for improvement;
- the number of outstanding defects at project completion typically rises with an increase in project value (and complexity); and
- an increased number of outstanding defects at project completion are typically seen in the sectors of 'Public Housing – New' and 'Private Industrial – New'

4.3 However, the pilot project also faced some limitations, such as the low and incomplete response rate for the online survey, and the inability to identify the cost-efficient factors for mitigating the EFR.

4.4 Significant work was undertaken to encourage clients and contractors to participate in the pilot project and help test the proof of concept for this innovative work. All information was anonymised and managed by C4DE, at Cranfield University. The project sponsors, the CLC, had no knowledge of who had contributed, yet despite much enthusiasm and agreement that the industry would benefit from the sharing of data on defects, the number of participants was disappointing.

4.5 The low response rate has highlighted the challenges that exist in obtaining information about defects and performance within the construction sector from firms in the supply chain. Due to the adversarial nature of contracts, the question that is always asked when information is requested is “how could this be used against me?”. This is justified because many projects end in recrimination, claim and counter claim. However, this is not conducive to an industry wide approach to improving standards of performance and quality.

4.4 C4DE recommended:

- developing a new method to deal with partial and missing data;
- studying a new model and algorithm to determine the most cost-efficient factors;
- building a web-based app for data management and EFR evaluation; and
- developing a smart decision-making support tool for the CLC.

5.0 Conclusion

5.1 It is clear that the construction industry will not voluntarily provide project data on defects. The process of briefing and gaining commitment from participants has been challenging. Therefore, this project will conclude at this stage.

5.2 GIRI has decided to continue with the development of an app, providing the technical solution to a defect reporting metric. The CLC will support where appropriate.

ANNEX A

A Data-driven Method for Evaluation of Error Frequency Rate in Construction Industry

Project Aim:

The Centre for Design Engineering (C4DE), at Cranfield University, has developed a data-driven method to measure and evaluate the Error Frequency Rate (EFR) metric in construction industry, based on the database of completed construction projects. This will help support the aim of significantly reducing errors in construction industry. The aim of the pilot project is to test this method.

Data Collection:

An online survey was sent out to construction companies for data collection (from Feb 2023 to March 2024) to develop the data-driven method, run and evaluate the status (i.e., Error Frequency Rate) of construction companies and their projects. Participants were requested to provide the following data for their projects 'at completion' or 'substantially complete' for the preceding 3 years, where the project value at completion was greater than £250,000:

- Unique source project identifier;

- Number of items/issues outstanding at completion;

- Project value;

- Sector and sub sector based on ONS definitions; and

- Contract type (e.g. D&B, Traditional, ECI etc.).

Methodology:

The data-driven method for EFR evaluation was constructed on a mathematical programming model and algorithm, in which the dataset of completed construction projects were normalised and weighed to compute an EFR score (from 0 to 100, lower better). The EFR scores were also used to evaluate and rank the construction projects and companies, including a breakdown by project value and sector.

Figure 1 is a conceptual model for the method based on the collected data structure, and **Figure 2** is a mathematical programming model for measuring and evaluating the project's EFR. In the model, ρ_k is used to determine the EFR of project k, x_{ik} and y_{rk} are input data i (e.g., project value, etc.) and output data r (e.g., number of outstanding items, etc.) of project k, m and s are the number of inputs and outputs, s_i^- and s_r^+ are slack values for input i and output r , and λ_j is weight value of project j. The controllable variables s_i^-, s_r^+ and λ_j are automatically scaled/normalised (while running the model and algorithm) to compute corresponding weights for project data.

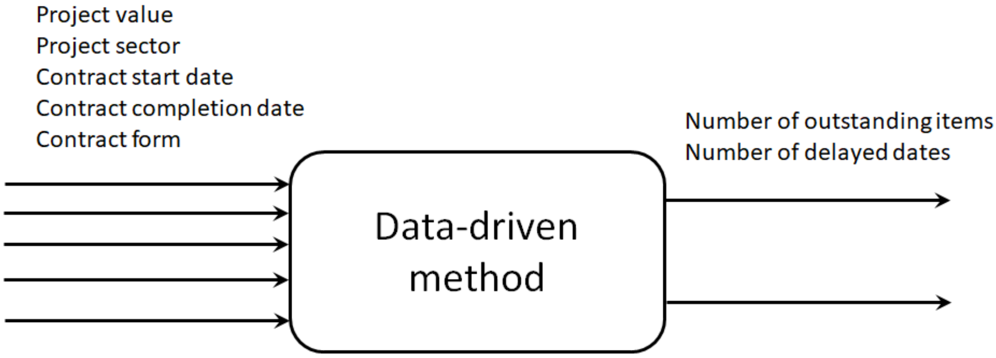

Figure 1: A conceptual model.

[SBM]:

$$\min\ \rho_k = \frac{1 - \frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{ik}}}{1 + \frac{1}{s}\sum_{r=1}^{s}\frac{s_r^+}{y_{rk}}}, \quad (1)$$

$$\text{s.t.: } x_{ik} = \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^-,\ i = 1, \ldots, m, \quad (2)$$

$$y_{rk} = \sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+,\ r = 1, \ldots, s, \quad (3)$$

$$\lambda_j \geq 0,\ j = 1, \ldots, n, \quad (4)$$

$$s_i^- \geq 0,\ i = 1, \ldots, m, \quad (5)$$

$$s_r^+ \geq 0,\ r = 1, \ldots, s, \quad (6)$$

Figure 2: A mathematical programming model.

Results:

After collecting data for one year, 12 responses in total were received, providing a total of 110 projects. 50 projects were used to measure and evaluate the EFR in this report. The EFR scores of the respondents and their projects are presented in **Table 1**. **Table 2** presents the average EFR score and the rank of respondents. **Tables 3 and 4** are the average EFR scores breakdown by the range of project values and sectors.

It can be seen that the average EFR score in Construction Industry is 12, which means that the construction companies have achieved completion with only a small number of defects outstanding. Among 5 construction companies who provided their data, companies C and A have EFR scores of 1 and 3, respectively, which demonstrates that they have done excellently their projects (only some projects are over the completion date planned and/or the number of outstanding items is very low). **Table 3** shows the fact that increasing project values can cause delay to the completion date as well as increasing the number of outstanding defects. It suggests that managers need to consider/monitor carefully the progress of projects with a value over 1 million due to the increased likelihood of outstanding defects and project delay. **Table 4** shows that “Public Housing New” and “Private Industrial New” are two sectors (with the highest EFR scores) that managers need to focus on to improve the EFR score.

Table 1: EFR score of the construction projects and companies.

Respondent	Project	Value	Sector	EFR score
A	A1	291,372	Construction	1
	A2	1,399,260	Construction	1
	A3	562,874	Construction	4
	A4	377,276	Construction	0
	A5	820,345	Construction	14
	A6	374,239	Construction	0
	A7	268,009	Construction	0
	A8	818,167	Construction	1
	A9	1,197,825	Construction	1
	A10	920,772	Construction	4
B	B1	2,050,000	Private Industrial New	19
	B2	11,900,000	Public Housing New	56
	B3	15,400,000	Public Housing New	17
	B4	2,600,000	Public Housing New	24
	B5	3,500,000	Private Industrial New	22
	B6	4,800,000	Private House Repair & Maintenance	25
	B7	3,500,000	Public Housing New	23
	B8	6,500,000	Private Commercial New	12
	B9	550,000	Private House Repair & Maintenance	0
	B10	12,200,000	Private House Repair & Maintenance	20
C	C1	377,276	Infrastructure Repair & Maintenance	0
	C2	1,399,754	Infrastructure New	1
	C3	820,345	Infrastructure Repair & Maintenance	4
	C4	374,239	Infrastructure New	0
	C5	309,239	Private Commercial New	1
	C6	268,009	Infrastructure Repair & Maintenance	0
	C7	850,503	Private Commercial New	1
	C8	1,371,734	Infrastructure New	1
	C9	1,300,051	Infrastructure Repair & Maintenance	0
	C10	306,838	Private Commercial New	1
D	D1	2,025,000	Private Industrial New	48
	D2	950,364	Private Industrial New	31
	D3	307,488	Public & Private Non-Housing Repair & Maintenance	11
	D4	1,142,485	Private Industrial New	0
	D5	372,843	Private Industrial New	0
	D6	2,227,000	Public & Private Non-Housing Repair & Maintenance	0
	D7	725,000	Public & Private Non-Housing Repair & Maintenance	28
	D8	900,000	Public & Private Non-Housing Repair & Maintenance	0
	D9	2,350,000	Public Non-housing New	11
	D10	2,219,959	Public Housing New	62

E	E1	3,722,930	Public Non-housing New	4
	E2	2,607,979	Public Non-housing New	25
	E3	1,257,859	Public Non-housing New	14
	E4	1,292,950	Public Non-housing New	11
	E5	2,122,000	Private Industrial New	34
	E6	794,169	Public & Private Non-Housing Repair & Maintenance	4
	E7	859,042	Public & Private Non-Housing Repair & Maintenance	21
	E8	16,334,760	Private Commercial New	32
	E9	24,750,000	Public Non-housing New	25
	E10	1,331,529	Public Non-housing New	0
Average		2,914,030		12
Min		268,009		0
Max		24,750,000		62

Table 2: Rank of construction companies based on the EFR score.

Respondent	Average EFR score	Rank
A	3	2
B	22	5
C	1	1
D	19	4
E	17	3

Table 3: The EFR score for the range of project values.

Project values	Average EFR score
[250k – 500k)	1.27
[500k – 1 million)	9.44
[1 million – 10 million)	15.36
Above 10 million	30.00

Table 4: The EFR score for the sectors.

Sectors	Average EFR score
Public Housing New	36.40
Public Non-housing New	12.86
Public & Private Non-Housing Repair and Maintenance	10.67
Private House Repair and Maintenance	15.00
Private Industrial New	22.00
Private Commercial New	9.40
Infrastructure Repair & Maintenance	1.00
Infrastructure New	0.67
Construction	2.60

Conclusion and Recommendations:

This pilot project shows that our method can measure and evaluate the EFR score, based on the dataset of completed construction projects, for each project and rank the projects as well as the construction companies. Specifically, we can provide:

- A series of company specific EFR's based on their project specific data including a breakdown by project value and sector.
- A single industry level EFR made up of all submitted data, also broken down by project value and sector.

However, more than a half of dataset collected was incomplete and only 5 respondents provided full data for projects. Hence, the results could not reflect fully and accurately the performance of contractors on these projects. In addition, this model cannot determine the cost-efficient factors for mitigating the EFR of project and company.

Recommendations:

1. Develop a new data-driven method to deal with the case of partial and/or missing data.
2. Study a new model and algorithm that can determine the most cost-efficient factors for mitigating the EFR of project and company. This idea could engage more respondents to provide their data.
3. Build a web-based app with the integration of above-developed model and algorithm, a graphical user interface (GUI) and cloud database for data management in which respondents (i.e. construction companies) can input their own data to get their EFR scores and determine the most cost-efficient factors for mitigating the EFR of project and company. Trial (free) and full (paid) versions of the web-based app could be deployed
4. Develop a smart decision-making support tool to help clients and contractors.

Construction
Leadership
Council

c/o Department for Business and Trade
Old Admiralty Building, Admiralty Place, London, SW1A 2DY

Email: construction.enquiries@businessandtrade.gov.uk

www.constructionleadershipcouncil.co.uk