1 INTRODUCTION

Engineering design and development projects are replete with difficulty and complication, a trend that is ever-increasing with the complexity of engineered systems and capability of ICT. Where engineering once occurred through concerted efforts of tens to hundreds of workers performing manual design, analysis, and manufacture; technological advancement and inter-connectedness has enabled global collaboration between thousands, working on tens of thousands of parts, and with communications and documents numbering in the millions (Watson 2012). In addition, engineering design and development is by nature multi-faceted, with challenges to progression and performance ranging from those innate to the design and development process (Pahl & Beitz 1984; Pugh 1990), to those surrounding engineering project and process management and implementation (Pinto & Mantel Jr. 1990; Snider et al. 2015). Particularly within the latter category these challenges are broad and variable, with project performance varying dependent on such factors as scale (Floricel & Miller 2001), risk (Chapman & Ward 1996), and team characteristics and cohesion (Barrick et al. 1998), amongst many others (Snider et al. 2015). This breadth creates a significant challenge for the effective operation of engineering design and development projects as, in addition to the number and diversity of factors that may be of importance, the influence of each will vary between scenarios (Engwall 2002). Put simply, what is vital for high performance in one case may be less so in another.

In support of engineering design and development these issues lead to two requirements. First, the development of systems and tools that aid understanding of project performance and support those managing or working within; and second, understanding of the form of variation between individual and unique scenarios. The former of these has been approached through increased capability of project monitoring systems, such as those developed for automatic project monitoring through analysis of engineering digital assets (Snider et al. 2016; Gopsill et al. 2016). The latter, however, is less well studied - while project-specific variation is recognised, the extent and form of variation between scenarios, as well as impact on performance of both project and output, remains unclear.

This work aims to clarify key influencers on performance within engineering, and scenario-specific variation, through the study of two engineering design and development cases. First, a preliminary survey with industry is used to identify general "project features of high performance". Next, through interview and workshop, issues in engineering design and development project implementation are identified in two specific scenarios. These are then associated with the survey results, allowing weighted study of the specific context that each scenario presents. Through cluster analysis, inter-related groups of issues and features are then established for each scenario, in essence identifying the inter-dependent webs of features that influence performance and/or contribute to issues experienced. This detailed analysis allows deeper understanding of the state and individual performance of each project, and of the unique or shared characteristics of each. Finally, by weighting groupings according to survey results, those with the largest influence on performance in each context are identified, hence providing scenario-specific priorities for support of design, development and project implementation.

For academia, this work provides scope for better understanding of engineering project performance within industry, including the importance of contextual difference, hence clarifying strengths, weakness, issues, and needs of individual scenarios, and directions for the development of engineering and managerial support systems and tools. For industry, the work allows identification of key groups of features that influence performance within a given scenario, and hence priority areas in which support or improvement may be most beneficial.

2 FEATURES OF PERFORMANCE

Typically, project performance is determined through KPIs such as the "iron triangle" (Toor & Ogunlana 2010) - time, cost, and quality - providing consistent criteria against which managers may judge. While providing useful information, these metrics often neglect the inherently dynamic and multi-faceted nature of engineering projects, in that the causes for a particular project state can arise from many different factors that will vary across projects and time. As a result, it often falls to the skill of the manager to determine their case-specific root cause of poor performance, and to act accordingly.

Recognising this deficiency, a large body of work has sought to identify the causal influencers on performance in project management, termed "success factors" (Westerveld 2003; Baccarini & Collins 2003). This work aims to identify and allow control of those aspects of a project that may lead to high or low performance through project operation. Difficulty remains however in identification of the level of importance, particularly in each specific industrial context, a factor exacerbated by their broad nature. Consequently, it is again often left to the skill of the manager to consider success factors and structure their project appropriately for high performance.

In this study, a set of 88 success factors, here termed "features" and identified in the context of engineering (see Snider et al. 2015), are used as basis for representation of factors that influence performance. The relative level of influence upon performance of these factors is explored through a survey. This clarifies the important features for performance within the engineering context, and thus the areas in which priority may be given for support system development and management effort. For the purposes of the survey, features are separated into four categories and eight sub-categories, as shown in Table 1. The complete feature list cannot here be displayed for brevity.

2.1 Survey Structure

A survey was performed with 35 participants from 3 industries; engineering systems and design consultancy, composite development; and high-value infrastructure implementation. All participants were asked to rate each project feature on a 5-point Likert scale according to its relative influence on overall performance, see Figure 1. A definition for each feature was given, and participants were given verbal clarification when requested. Participants typically took 30mins to rate all 88 features, which were separated into six categories. Participants had a mean of 10 years technical experience (range 0-35), 7.5 years managerial (range 0-35), with 26 participants in leadership roles, and typically rated their seniority as medium to high level. It should be noted that the results presented here are considered preliminary, and are subject to ongoing extension and further analysis.

Section 1 - Features relating to individuals Please think of your answers in terms of a typical person working in one of your projects, or who works with you in your projects.	What is the relative level of influence of this feature on project performance?					
	Very Low	Quite Low	Neither High nor Low	Quite High	Very High	No Opinion / Don't Know
Awareness Level The knowledge of the person about the project work of others						
Culture The perspective, customs and social behaviour of an individual						

Figure 1: Format of the Survey

2.2 Survey Results

Influence of features on performance was analysed through median and inter-quartile range (IQR) of participant responses. This highlighted consistency in all categories of feature, with agreement of importance for all and low deviation between participants, see Table 1. Taking the proportion of participants who rated the influence of a feature as Quite High (QH) or Very High (VH), higher levels of deviation can be seen. Where the majority in each case rated features at QH, particular attention can be drawn towards Sponsor (41.1% rated at VH), Information (36.6% rated at VH), and Resource features (36.5% rated at VH), which were consistently considered to be of higher influence. These each form part of the high-rating Context category, demonstrating the important role context plays in the eventual performance of engineering projects. In the general case and at a higher level, while some variation is evident, there is consensus that all features have a high influence on eventual performance.

Stronger variation is evident at the level of individual features (see Table 2). Higher scoring features typically showed consensus, with participants drawing particular attention to the skills of an individual, the definition and specification of the output, and the buy-in and support of both manager and sponsor. Of note is that all features within the "information" category received consistent higher scores, and that many features received near-zero variation between participants, particularly those relating to awareness, roles, and responsibility of team members. Lower rated features, conversely, held higher variation in participant views. Drawing particular attention to the work habits of individuals, team culture, and process novelty level, although generally thought of lesser influence, a higher IQR suggests that this does hold true in the minds of all participants. As such, the results suggest a case-by-case or person-by-person difference in importance, where certain features are consistently rated as vital, and others are known to be or considered as vital only in certain scenarios.

While the preliminary survey results are presented in brief, these results highlight important characteristics of the features within engineering projects that influence performance. Of the 88 queried all are rated as influential to at least a medium degree, highlighting the breadth and associated challenge in implementing engineering design projects. This in the general case suggests consistency in that which is important for performance across engineering - the state of all features has potential to have a manifest impact, and all should be considered and managed appropriately. While some features may be prioritised as more influential in the general case (those highest rated in Table 2), and thus may be of particular importance in management and support of design and development, further work is needed to validate the generality of the findings.

Table 1: General Survey Results

	Median	IQR	Proportion of Participant ratings (%)				
			V. High	Q. High	Neither	Q. Low	V. Low
All Features	4	1	27.8	46.8	18.7	5.42	1.33
Person	4	2	26.8	46.9	16.9	7.58	1.74
- Individual	4	2	24.0	50.2	17.2	6.63	1.97
- Team	4	1	26.3	47.7	17.2	6.87	1.91
Design	4	2	29.3	45.2	19.5	4.78	1.19
Process	4	1	22.2	49.9	20.9	4.64	2.32
Context	4	1	30.7	45.9	18.8	4.10	0.50
- Management	4	1	33.7	50.0	12.5	3.85	0.00
- Sponsor	4	1	41.1	40.6	16.0	2.29	0.00
- Information	4	1	36.6	47.4	13.7	1.71	0.57
- Personnel	4	1	18.8	44.6	27.5	7.92	1.25
- Resource	4	1	36.5	48.2	11.8	2.94	0.59
- Properties	4	1	21.3	47.1	27.2	4.41	0.00

Table 2: Feature-Specific Survey Results

Category	High Influence			Low Influence		
	Feature	Med.	IQR	Feature	Med.	IQR
Person						
- Individual	Skills	5	1	Work Habit	3	2
- Team	Awareness level, roles, responsibility	4	0	Work Habit, culture	3	2
Design	Definition level, confidence level, specification level	5	1	Dependency, re-use level, scope stability	4	1
Process	Confidence Level	4	0	Novelty Level	3	1.5
Context						
- Management	Buy-in	5	1	Engagement	4	2
- Sponsor	Buy-in	5	1	Engagement, influence, relationship, role	4	1
- Information	Availability, design knowledge level, diffusion, process knowledge level, structure				4	1
- Personnel	Conflict level	4	0	Outlook	3	1
- Resource	Churn	4	0	Efficiency	4	1.75
- Properties	Profile, environment	4	1	Structure	4	1.75

Variation in the case of lower-scoring features supports potential scenario-specificity of influence on performance, where criticality may vary depending on case. This thinking is extended by the higher ratings given to contextual project features. The contextual characteristics of every project or company, which are potentially unique, may take different forms and demand differing approaches to management dependent on the specific engineering scenario. It is as a result vital that the specific conditions of each individual project are understood in order to ensure that high overall performance is encouraged, and those features that may be critical to a project are monitored and understood. To explore this potential variation in more depth, this work continues by investigation of two engineering scenarios.

3 DESIGN SCENARIOS

To clarify areas important for performance in different engineering contexts, issues into operation and performance were gathered from a large engineering consultancy (EC), and a student-led Formula Student (FS) design and development team. These provide significant interest due to their inherent difference - the characteristics of the industrial context of the consultancy are expected to differ greatly from the semi-academic context of FS, thus providing scope for different roles of project areas on performance. Comparability is also maintained, however; in both cases participants are working on real engineering problems, operating collaboratively within a team structure, and face the goals and pressures associated with project delivery.

Issues - statements of the participants with regard to issues or wants within their engineering scenario - were gathered through either workshop, for the EC, or interview, for the FS team. In the former case, data collection took place as part of an extended participatory design session, in which participants were required to interview each other, reflect on issues and difficulties, and then design interfaces or systems that would support their work. Issues were gathered from written statements recorded during the interview and reflection stages; all were recorded by the researcher and duplicates removed, with 57 unique issues identified. For the FS team, issues were gathered through semi-structured interviews with team principle engineers from three University teams based in the UK. Interviewees were asked to describe the difficulties that they as a team faced, and what they would want to see as a potential solution. Issues were then extracted directly from transcripts, with duplicates removed, resulting in 38 issues across the FS team. For brevity, issues cannot be listed in full, but examples for each of the scenarios are given in Table 3.

Table 3: Example issues from the Engineering Consultancy and Formula Student teams

Engineering Consultancy (EC)
- Managing too many projects - unable to check every week
- More extensive market knowledge
- Cohesion and team work; Effective working relationships; working in a collaborative environment
- Define competencies; Capture skills at the right level
- Clear goals and expectations; Support awareness of progress
- Support problem understanding; give ownership to problems and objectives
- Lack of historical project data
Formula Student (FS)
- Difficulty in finding files
- Lack of experience / skills in judging CAD quality and maturity, or in process understanding
- Poor exploitation of sponsors capabilities, resources, and input
- Team awareness of and motivation to meet key deadlines
- Poor inter-personnel vocabulary; Lack of cross-team communication
- Lack of awareness of skill sets and training needs
- Lack of flexibility / scope for downstream changes during testing processes

As basic analysis, certain themes can be extracted from the two contexts. As expected given the differing levels of experience, there is higher emphasis on difficulties relating to skill and experience amongst FS members; while EC, a global firm, associates difficulties with communication and information sharing.

Further processing is required however to understand the situation presented by and underlying cause of these issues within each scenario. The likely impact of each on performance is difficult to predict, posing a challenge for identifying those that form a priority for support system development or management. It is also difficult to perform direct comparison or identify inter-linking between issues, and hence to extract potential inter-related groups with commonality in their cause or solution principle. To overcome these issues, the following sections study each scenario through alignment with the project features, which form a common frame for analysis, allowing deeper analysis and direct comparison.

4 ISSUE AND FEATURE RELATIONSHIPS

Issues within a project are a result of the state of its features (Snider et al. 2015), which govern the way in which workers may operate, the form of their process, and the design context. For example, an engineer's skills and experience define their capability, and hence the process that they follow (Feist 1999); the cohesion, conflict, and culture of a team influence their communication and collaborative activity; and the maturity and definition of a product define the processes and exploration required for its design. As a result, the issues extracted can be aligned against the project features, creating relation against their potential source. This allows deeper understanding of the aspects of each scenario from which issues arise, and provides a common frame for comparison between engineering contexts.

Each issue was, based on experience and interpretation, classified by the researchers by the features from which they may stem, see examples in Table 4. In future work, this process of relation may be performed by workers within each context, ensuring validity and completeness. Following classification, the influence of each feature can be assessed in each context, and compared using the common frame of reference that the performance features provide.

Table 4: Relations between issues and performance features

Insight	Related Feature(s)
Define Competencies	Individual / Team: awareness level / skills / experience
Improve knowledge transfer - facilitate moving between teams	Individual / Team: awareness level; Information: availability / diffusion / structure
Support goals and awareness of progress	Process / Design: definition; Process / Design: progress level / progress rate
Awareness and understanding of rationale behind design changes	Individual / Team: awareness level / design knowledge level; Information: design knowledge level
Ensuring material and design choices are within rule bounds	Design: definition level / specification level / technical difficulty
No access to previous work as a reference for design implications	Individual / Team: design knowledge level; Design / Process: re-use level; Information: availability level / design knowledge level

4.1 Key Scenario-Specific Performance Features

Those features that are most frequently aligned with issues in each scenario may be those that have a broader influence on performance. Analysis of feature / issue alignment therefore allows clarification of common sources, and hence formation of priorities for support or managerial input.

Further, these priorities can be extended by weighting based on the results of the survey. By noting the proportion of survey respondents who stated that a feature was of QH (Quite High) or VH influence on performance, a weighting for likelihood of that feature having a high influence in the general case can be determined. Applying this weighting to the feature / issue relations gives the extent to which each feature is causing issues, highlighting those that may be of priority for managerial attention. As survey respondents displayed reasonable consistency in their rating of influence on performance of each feature this weighting can be expected to be realistic, although it should be formalised with workers in each scenario to assess validity on a case-by-case basis. With weighting, the key features within each engineering scenario can be identified, see Table 5. Weighting is defined as frequency of appearance of each feature in all issues, multiplied by feature weight from survey. Normalised weighting divides by number of features, representing comparable level of potential impact across the scenario.

In both the EC and FS team, there is consistency in the types of performance features that arise. In both, a high proportion of issues bare relation to the "person" category of features (65.5% EC; 55.3% FS), followed by the "process" category at a lower-but-notable level (32.8% EC; 26.3% FS). In-line with survey results, there is therefore suggestion of consistency in the higher-level feature categories that influence performance. Key attention and support should then focus on those features that stem from the people performing the work and the process that they follow rather than the product under design, in order to aid performance in the general case.

Difference can however be derived from the specific features that are prominent in each scenario. Dominated by those from the "Person" category, key features in FS relate to knowledge, experience, and motivation of individuals and teams, perhaps resulting from the level of their training. Those important features in the EC are similarly person-centric, but lean towards broader project characteristics and issues rather than solely the workers involved. Here, the availability of information in the project context, the working culture of staff, suitability of skills to tasks, and the definition of processes to follow play a stronger role. Issues may therefore stem more from the interaction of workers with each other and the project system, rather than the workers experience and knowledge. Given the professional level of the EC it is logical that experience and knowledge are less key, although further study is required to determine whether highlighted features are scenario-dependent or endemic across engineering industry.

Further, the normalised weighting of high-scoring features for EC is higher than for FS, even when for the same feature, indicating that these features have a role in a higher proportion of the issues presented by the workers. This would suggest that these features are of higher impact across the EC than in the FS team, and therefore that a narrower portfolio of features impacts performance within the EC. Given that EC is a more established enterprise than the student-led FS this is a logical finding, but does demonstrate difference in performance drivers and level of impact across differing engineering scenarios.

Table 5: High impact performance features

Engineering Consultancy			**Formula Student**		
Sub-category	**Proportion of Insights (%)**		**Sub-category**	**Proportion of Insights (%)**	
Person	65.5		Person	55.3	
Product	8.62		Product	7.89	
Process	32.8		Process	26.3	
Context	12.1		Context	5.26	
Feature	**Weighted appearance**	**Normalised**	**Feature**	**Weighted appearance**	**Normalised**
Individual / team awareness level	11.9 / 11.5	.205 / .199	Ind./team process knowledge level	4.76	.125
Personnel culture	9.71	.167	Individual / team awareness level	4.57 / 4.43	.120 / .117
Individual / team outlook	8.49 / 8.17	.146 / .141	Individual / team outlook	3.86 / 3.71	.101 / .0988
Process definition level	8.36	.144	Individual design knowledge level	3.65	.0960
Individual / team skills	8.00 / 7.54	.138 / .130	Individual / team experience	3.55	.0932

While here features are aligned with issues individually, they often do not occur in isolation. A project presents a complex and inter-related web between causes, which may be navigated to identify root cause and clarify specific project circumstances. Detection of these inter-dependent webs is of primary importance from a monitoring and support perspective, allowing prioritisation of feature groups, deep insight into the nature of issues faced in industry, and comparison between contexts.

4.2 Performance Feature and Issue Grouping

Given the one to many relationships between issues and features, a bipartite dependency matrix can be formed, allowing network analytics to be applied. Specifically, each matrix of feature-issue relations was modularised through Louvain community detection (Blondel et al. 2008), in which groups of features and issues are formed that are internally closely linked while weakly linked to one another. Features that were not identified as related to any issue were excluded from analysis, as they conflate the apparent modularity produced by the clustering algorithm.

The analysis detects a series of feature groups with high inter-relation through the issues with which they are aligned, presenting discrete groups with interwoven contribution to project performance. Figure 2 shows the modularised matrices for each scenario, while Tables 6 and 7 present the features and issues assigned to each group. For example, in the EC, Group 2 suggests that one or more issues are raised by the combinatory state of the skills and experience of individuals and teams, the awareness about the work and skills of others, and the technical difficulty of the work, and therefore that these features have a combinatory effect on performance in this case.

Each matrix is highly modular, demonstrating structure (EC: 0.667; FS: 0.726, where structure exists when > 0.3). This confirms each scenario can be decomposed into largely distinct groups of features / issue alignments. Each group can also be analysed for its weight, determined by mean weighting of contained features from survey results; its density, defined as proportion of the potential connections within the group that are exist; and separation (Sep. in Tables 6 and 7), defined as the proportion of connections for each feature and issue that are associated to the group. These inform of group importance, the level of inter-linking within, and the level to which each group is distinct from other features and issues for each case.

Perhaps as expected given the person-based preponderance of issues, several feature groups in each context are associated with workers people working within each scenario (Groups 1, 2, 5, 6, 8, 9 EC; 2, 6, 7, 8, 9, 11 FS). Other groups comprise a broader range of features but with common themes, including associated with the Design output and its definition and specification, understanding of Design and Process progress rates, and Information availability and structure. In all cases the level of modularity suggests that these groups are perhaps best managed and supported as a whole, where all features within a group lead to a common set of issues, and intervention in any of those internal to a group will likely affect the others.

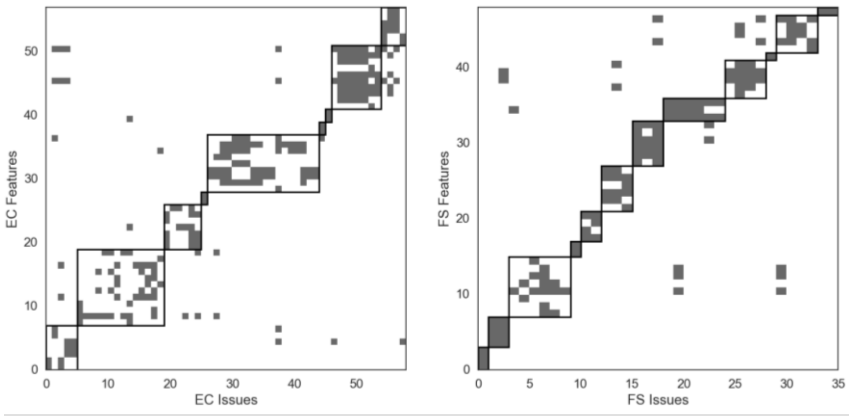

Figure 2: Modularised alignments; where boxes indicate groups of aligned features / issues

Table 6: The 9 Performance Feature Groups (Engineering Consultancy)

	Features	Weight	Density	Sep.
1	Individual / Team: workload / profile; Information: availability / diffusion / structure	0.596	0.343	0.480
2	Individual / Team: roles / responsibility; Design: definition level; Management: buy-in / effectiveness / engagement; Process: compliance/ definition/ robustness/ stability	0.803	0.262	0.815
3	Design / Process: effectiveness / progress level / progress rate; Process: cost	0.698	0.452	0.826
4	Resource: availability / consumption level	0.800	1.00	1.00
5	Individual / Team/Personnel: culture / outlook; Team / Personnel: cohesion; Team: structure	0.721	0.383	0.873
6	Individual / Team: work habits	0.386	1.00	0.667
7	Design: scope stability / specification level	0.886	1.00	0.667
8	Individual / Team: Awareness / experience / skills; Personnel: experience / skills; Design / Process: technical difficulty	0.848	0.675	0.761
9	Individual / Team / Information: process / design knowledge level	0.826	0.583	0.609

Table 7: The 12 Performance Feature Groups (Formula Student)

	Features	Weight	Density	Sep.
1	Design: definition level / specification level / technical difficulty	0.876	1.00	1.00
2	Individual / Team: design knowledge level; Design: output complexity / re-use level; Information: availability level / knowledge level / structure; Process: re-use level	0.650	1.00	0.800
3	Design: progress level / progress rate; Process: progress level / progress rate	0.644	0.333	0.696
4	Design: robustness; Process: robustness	0.814	1.00	1.00
5	Sponsor: buy-in / engagement / relationship / roles	0.705	0.750	1.00
6	Individual: responsibility / roles; Team: responsibility / roles / structure; Management: effectiveness	0.790	0.667	0.857
7	Individual / Team / Personnel: experience / skills	0.871	0.889	0.800
8	Individual / Team / Personnel: process knowledge level	0.825	0.889	0.727
9	Individual / Team: culture / outlook; Personnel: culture	0.663	0.650	0.619
10	Properties: environment	0.743	1.00	1.00
11	Individual / Team: awareness level; Team / Personnel: cohesion	0.833	0.550	0.500
12	Resource: capability	0.743	1.00	1.00

The density and separation of the groups present a similar picture between the scenarios; those groups not associated with people tend to be both highly inter-linked and separate, while those groups associated with people tend to have higher external relations across other features and issues, and sparser internal relations. This suggests that features external to the characteristics of people within a project tend to be quite discrete, with a shorter reach in influence on other aspects of the project. As a result, feature groups not associated with people perhaps form a simpler target for support and management; high inter-relation may create clearer paths to altering the state of all features within the group, while low separation decreases risk of causing knock-on effects throughout the project. Those groups associated with people are then the converse, with a more complex internal web potentially obscuring the manner in which the group may be supported, and higher external relation to other features increasing risk of knock-on effects for any intervention.

Influence on performance of feature groups is high for many in both scenarios, with the dense and separate groups associated with Design definition, specification, and scope showing the highest weight (mean influence on performance). These are followed by groups associated with experience and skills of workers, design and process knowledge, and the roles, responsibilities, and management of teams. Such groups of features present key areas that management and support should target and, as there is consistency between the scenarios, the key areas that research should target to generate significant benefit in engineering design and development. High influence on performance of feature groups associated with people is perhaps most significant in both cases - higher complexity in inter- and extra-relationship between groups suggests extra care should be taken when addressing to ensure appropriate methods are used and negative knock-on effects are minimised.

Some differences between the two scenarios can also be identified. With fewer groups, lower density, and higher separation of features, the EC presents a generally more complex picture. Here, high-interlinking between different project features may be linked to the established nature of the business, which is larger-scale, global, and more complex in nature than FS. This would underline the difficulty in operating at larger scales and capability - such systems and procedures may bring with them a broad and complex web of inter-relation between project characteristics. The higher modularity and density shown in FS may reflect the relative simplicity of the project context; it is more feasible for persons to understand the broader performance of the project when extends only to the walls around them.

5 DISCUSSION AND CONCLUSIONS

The aim of the analysis presented here is two-fold: first, a deeper understanding of the features which influence performance in engineering design and development, and the variation that exists between the influencers of performance across different project contexts.

From the results of the survey alone it is challenging to state which features of a project are the most critical for performance; with most rated as being of influence, and even those of lesser rating to have an IQR that suggests importance in certain cases. Although the survey does perhaps highlight the importance of certain higher-level factors, such as management and sponsor support, more detailed analysis is needed to form a generalisable picture of the key elements of performance.

To clarify, issues into difficulties faced within engineering projects were gathered, and related to the features of performance. Key groups of features identified in both contexts were found to relate to characteristics of the design and process such as definition, specification, and scope, as well as the structure and availability of information. These may be a priority in support and management, where their state form primary conditions for higher project performance and the broader influence of features across the project and issues are clear. Second, many issues stemmed from features related to the individuals or teams working within the project context. There is suggestion therefore that while many elements of a project are important in performance, it is those associated with people that most frequently cause issues, particularly in the knowledge, communication, cohesion, roles and responsibility and, in the case of the less experienced FS team, in skills and experience. The findings also reveal the challenge in management of these features, which typically show complex inter-relationships and broader influence across the project context. This factor may indeed form part of the reason for the emergence of person-centric issues - such complex and influential webs may be expected to bring inherent difficulty in their management.

The findings presented here portray some subtlety in how that which influences performance varies between contexts. In much of the analysis significant agreement was found, despite the considerable differences in scenario context. Of those differences identified, each appears to stem from a logical source; issues associated with skills and experience arise in the less-experienced FS scenario, while higher inter-relation and influence between features appears in the more sophisticated scenarios of the EC. There is suggestion then that differences in what is important are less prevalent across scenarios. Care must be taken, however, in ensuring that the form of individual features in any given project is appropriate for the specific situation that each project presents. While what is important for each project may be similar, the state of each feature that is appropriate in each case may not be.

Some limitations in the results of this work must be raised. The survey results presented are considered preliminary and for extension. While they are sufficient to provide direction and basic evidence, they are not suitable for generalisable output. Such extension is ongoing, and has potential both to increase confidence in results and the variations in influence on performance found. All analysis drawn from issues is entirely dependent on the persons involved. While care was taken in extraction, some thought should be given to the extent of their understanding of performance - it is certainly feasible that key issues were not elicited. This raises an interesting question for those features and groups identified as important - those not raised by participants may be of equal importance, but below the awareness of those asked. It may even be pertinent to study those features not raised in each context, as their impact, although unnoticed, may be high. In addition to the findings presented here around the nature of performance within engineering projects, the approach utilised has potential value for individual project scenarios. Through the relationship and clustering approach taken, the individual groups of features found for each scenario present those areas in which management attention may be most pertinent for their specific case - these groups most strongly influence the issues experienced. The work would benefit significantly from extension to further cases. Inherent difference between the EC and FS cases give scope for understanding variation, but with these two examples alone the findings are not to be thought conclusive. Further analysis of industry-based scenarios may be of particular benefit.

Through the study of two engineering design and development scenarios, of significant difference in context, this paper has attempted to clarify the influencers on performance in engineering projects. Through a combination of survey, interview, and workshop, the views of engineers in practice were considered; with subsequent network and cluster analysis used to clarify the nature of those project elements that influence performance, their inter-relationship, and key areas in which management, support, and system development may be of highest benefit.

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REFERENCES

Baccarini, D. & Collins, A., 2003. Critical success factors for projects. In Surfing the Waves: Management Challenges; Management Solutions,.
Barrick, M.R. et al., 1998. Relating Member Ability and Personality to Work-Team Processes and Team Effectiveness. Journal of applied psychology, 83(3), pp.377–391.
Blondel, V.D. et al., 2008. Fast unfolding of communities in large networks. , pp.1–12.
Chapman, C. & Ward, S., 1996. Project risk management: processes, techniques and insights, Chichester, UK: John Wiley & Sons, Ltd.
Engwall, M., 2002. No project is an island : linking projects to history and context. Research Policy, 32(2003), pp.789–808.
Feist, G.J., 1999. The influence of personality on artistic and scientific creativity. In R. J. Sternberg, ed. Handbook of creativity. New York: Cambridge University Press.
Floricel, S. & Miller, R., 2001. Strategizing for anticipated risks and turbulence in large-scale engineering projects. International Journal of Project Management, 19(8), pp.445–455.
Gopsill, J.A. et al., 2016. Automatic Generation of Design Structure Matrices through the Evolution of Product Models. Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 30, pp.424–445.
Pahl, G. & Beitz, W., 1984. Engineering Design: A Systematic Approach, London: Springer.
Pinto, J.K. & Mantel Jr., S.J., 1990. The causes of project failure. Engineering Management, IEEE Transactions on, 37(4), pp.269–276.
Pugh, S., 1990. Total Design: integrated methods for successful product engineering, Harlow: Prentice Hall.
Snider, C. et al., 2016. Determining Work Focus, Common Language, and Issues in Engineering Projects Through Topic Persistence. In DESIGN 2016: International Conference on Engineering Design. Dubrovnik, Croatia.
Snider, C. et al., 2015. Understanding Engineering Projects: An Integrated Vehicle Health Management Approach to Engineering Project Monitoring. In ICED15: International Conference on Engineering Design. Milan, Italy.
Toor, S.-R. & Ogunlana, S.O., 2010. Beyond the “iron triangle”: Stakeholder perception of key performance indicators (KPIs) for large-scale public sector development projects. International Journal of Project Management, 28(3), pp.228–236.
Watson, J., 2012. Keynote address at the University of Bath.
Westerveld, E., 2003. The Project Excellence Model®: linking success criteria and critical success factors. International Journal of Project Management, 21(6), pp.411–418.