Modelling skill competencies in engineering companies

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Overview

Engineering companies across many industrial sectors have recognised that their engineers' skills and competencies provide the greatest force for economic competitiveness. More specifically, the effective utilisation of a company's engineers, through the most appropriate application of their skills and competencies, can improve organisational performance, thus aiding competitiveness. Prior to enabling the effective utilisation of their engineers, companies need to model their skills competencies.

This article presents an overview of research in modelling skill competencies in engineering companies. Case studies are summarised in which engineering design and manufacture companies have modelled the skill competencies of their engineers. Consequently, the companies have been able to identify skill gaps and competency deficiencies, which are able to inform training, development and recruitment needs.

Skills and Competencies

Employee skills and competencies are widely acknowledged as an organisation's most valuable asset[1], a key driving force in economic development[2], and a source of competitive advantage[3]. In the current knowledge-based economy, human capital is high on the policy agenda of national governments and international organisations[4]. For example, the UK Government has signalled its desire to see better guidance for companies of all sizes on assessing the strengths and weaknesses of the skills of their people[5]. Indeed, it is expected that regular measuring of skills will become commonplace.

On this theme, it has been suggested that quantitative studies should be conducted to explore the relationship between skill compositions and company performance[6] and that companies need to develop mechanisms to determine the value of their employee base[7]. However, finding a means of quantifying a person's skills is a significant challenge.

While not offering a means of eliciting measures of skills, various numerical scales have been proposed such as levels of experience ranging from 0 to 9, where 0 represents no experience and 9 represents expert/specialist[8]. Despite these proposals, research suggests there is no universal formula to score the value of skills and competencies[9].

Industrial Case Studies

This research to-date has involved case studies with three companies. The most recent 'manufacturing oriented' case study is presented after an overview of two 'design oriented' case studies, which were carried out during the early stages of this research. The 'design oriented' case studies focus on how quantifying the skill competencies of a team of engineers and scheduling design work can inform potential improvements to team composition, such as development and recruitment. The 'manufacturing-oriented' case study reports on how a company has developed a process to enable its engineers' skill competencies to be assessed and modelled to inform training and development needs.

Design programme of a marine vessel conversion

The design programme consisted of 132 tasks associated with three disciplines: naval architecture, marine and electrical engineering. These tasks were related to the vessel's general arrangement, structural design and electric plant. Through consultation with the Senior Project Manager, 16 single-skilled engineers working within a multi-disciplinary team were assigned a skill competence according to their designation, ie, consultant engineer, senior design engineer or design engineer. Table 1 shows each engineer designations' skill competence, which ranges from 0.6 to 1.0. A skill competence of 1.0 indicates a consultant engineer who is most proficient in undertaking tasks associated with a specific discipline. While not assigned to any engineer, a skill competence of 0 would signify no capability of undertaking tasks associated with a specific discipline.

With knowledge of engineers' skill competencies and the benchmark duration of each task, an optimisation technique was used to generate the design programme's datum schedule, which was minimised in terms of expected duration and labour cost. Information relating to engineers' labour cost is not presented in this article. The datum schedule had an expected duration and labour cost of

Discipline	Designation	Number of Engineers	Skill competence
Electrical Engineering	Senior Design Engineer	2	0.8
	Design Engineer	1	0.6
Marine Engineering	Consultant Engineer	2	1.0
	Senior Design Engineer	1	0.8
	Design Engineer	2	0.6
Naval Architecture	Consultant Engineer	2	1.0
	Senior Design Engineer	4	0.8
	Design Engineer	2	0.6

Table 1: Skill competencies of team of engineers

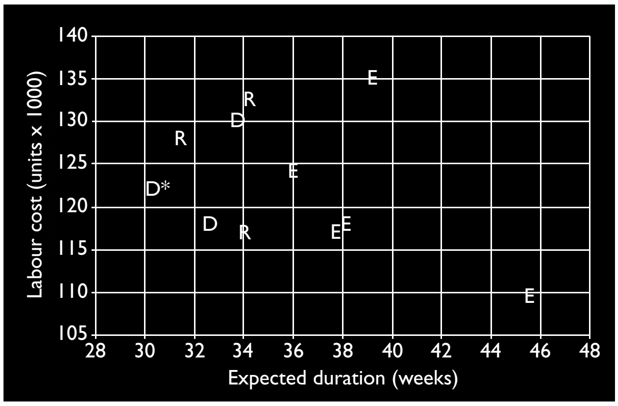

Figure 1: Labour cost versus expected duration

Design Engineer	Areas of Technical Work														
	Cost analysis	Drawing	Machining of castings	Machining of components	Design drum	Design air cooler	Design drum motor	Design other components	Build prototype	Review build	Amend drawings	Technical analysis	Revise build	Generate BOM	Testing
01	0.3	0	0	0	0	0	0	0.2	0.4	0	0.1	0	0.5	0.1	0.6
02	0.9	0.1	0.1	0.1	0.5	0.5	0.5	0.2	0.1	0	0	0.9	0	0.1	0.1
03	0.7	0.1	0	0	0.8	0.5	0.5	0.2	0.7	0.8	0	0	0.7	0.1	0.7
04	0.5	0.9	0.9	0.9	0.1	0.5	0.3	0.7	0.5	0.6	0.8	0	0.5	0.8	0.2
05	0.7	1.0	0.9	0.9	0.8	0.7	0.7	0.7	0.7	0.8	0.8	0	0.5	0.8	0.2
06	0	0	0	0	0	0	0	0	0	0	0	1.0	0	0	0
07	0.5	0.1	0	0	0	0.3	0.2	0.5	0.8	0.9	0	0	0.9	0.1	0.9
08	0	0	0	0.3	0.3	0	0.2	0.3	0	0	0	0	0	0	0
09	0.5	0.1	0	0	0	0	0.3	0	0	0	0	0	0	0	0

Table 2: Design engineers' skill competencies

59.5 weeks and 175,222 units respectively. Using an iterative approach, as detailed in a previous study[10], task duration-to-skill competence ratios were determined leading to quantitative-based decisions being made regarding modifications to the team's composition.

Subsequently, corresponding schedules were generated resulting in the identification of the near-optimal utilisation of the team of engineers. After several iterations, relative to the datum schedule, it was established that the recruitment of two consultant electrical engineers would yield reductions of 28% and 1% in the design programme's expected duration and labour cost respectively.

Design-development phase of compressed air treatment equipment

The design-development phase involved 190 tasks associated with 15 areas of technical work. The R&D Manager assigned measures of skill competencies to the nine design engineers in the team to undertake these tasks. Rather than using job designation, as in the previous case study, the R&D Manager based each measure of skill competence (for each engineer in each area of technical work) on past experience of similar design-development tasks undertaken by the members of the team. Measures of these skill competencies, which range from 0 to 1, as explained previously, are shown in Table 2.

The design-development phase's datum schedule generated had an expected duration and labour cost of 64 weeks and 223,554 units respectively. As indicated in the previous case study, using the iterative approach detailed in the previous study[10], quantitative-based decisions were made regarding modifications to the team's composition. These decisions included the:

- Exemption (E) of design engineers with low skill competencies being considered to undertake tasks associated with certain areas of technical work;
- Recruitment (R) of design engineers in appropriate areas of technical work, and;
- Development (D) of design engineers' skill competencies in appropriate areas of technical work.

The letters 'E', 'R' and 'D' shown in Figure 1 each represent a schedule generated using the optimisation technique with a specific exemption, recruitment or development in terms of design engineers and their skill competencies.

Note that schedules represented by 'R' and 'D' include the exemption of design engineers with skill competencies of 0.2 or less being considered to undertake associated tasks as this was found to reduce the design-development phase's expected duration and labour cost. That is, application of the optimisation technique could lead to assigning certain tasks to engineers with low competence in the associated areas of technical work with the effect of lengthening expected duration and increasing labour cost.

In Figure 1, 'D*' signifies a schedule generated involving the exemption of

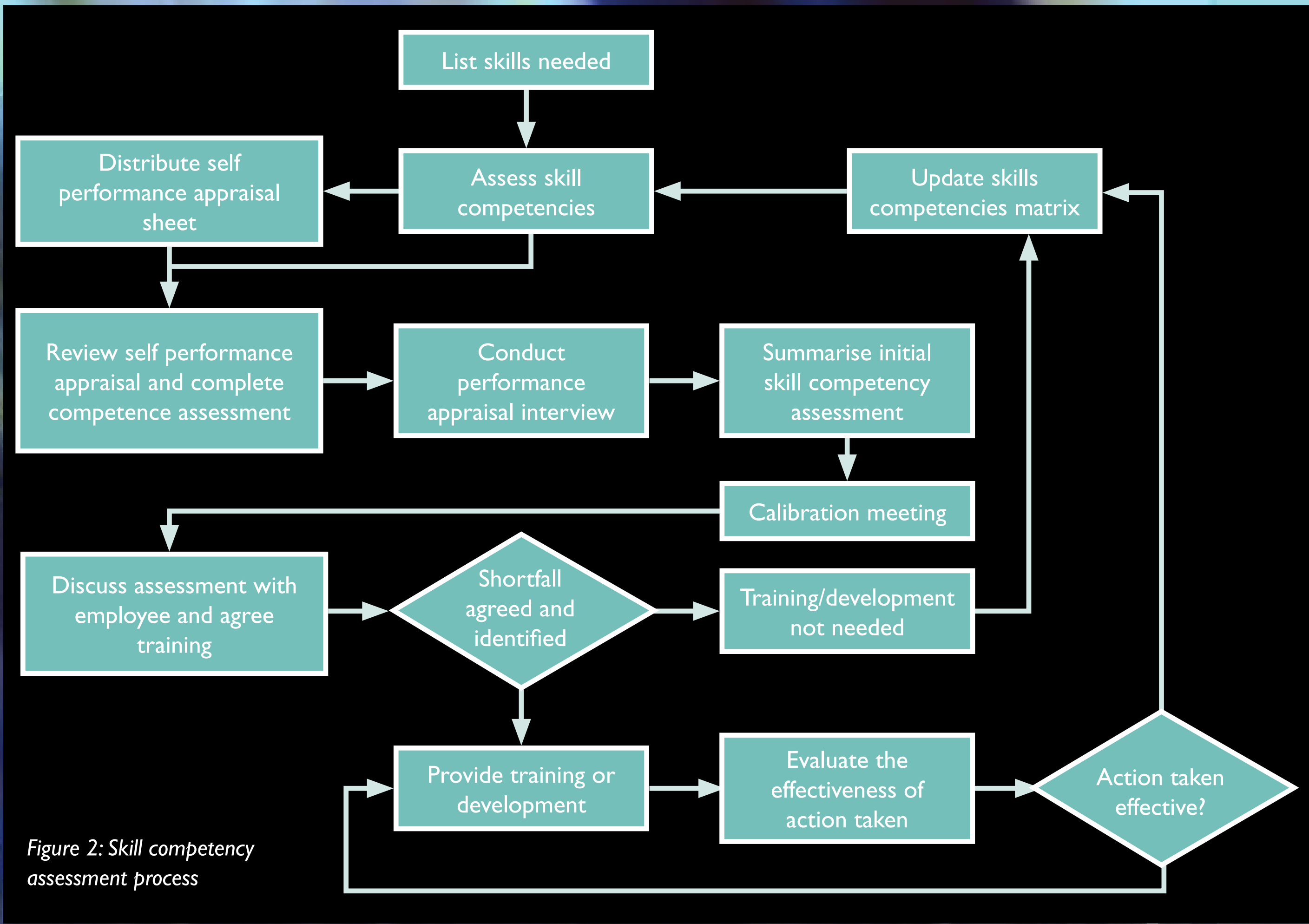

Figure 2: Skill competency assessment process

Manufacturing Engineer	Manufacturing Operation													
	Laser Operation	Guillotine	Manual Band Saw	CNC Bandsaw	Lathe Machine	Vertical Machining Centre	Manual Drilling and Tapping	Threading	Press Break	Punch Press	Mig Welding	Tig Welding	Dressing and Finishing	Shot Blaster
01			◑											
02	◕	◑	◑	◕										◑
03	◑	◕	◕	◑	◑	◑	◕	◕	◕	◕	◕	◕	◕	◕
04		◑	◕	◕	◑	◑	◕	◑	◕	◕	◕	◑	◕	◕
05													◕	
06							◔	◑	◔	◔	◕	◕		
07		◔	◔				◔		◔	◔	◑	◑		
08		◔	◔	◔	◑	◑	◔		◔	◔				
09		◔	◔				◔		◔	◔	◑	◑		
10		◔	◔				◔		◔	◔			◑	
11		◔	◔				◔		◔	◔			◑	

Key

◔ Beginner, can operate equipment or is able to perform operation with limited supervision

◑ Mature, can operate equipment or is able to perform operation without supervision

◕ Expert, can set and operate equipment and perform operation without supervision

● Master, as 'expert' but can also train others, diagnose problems and take corrective action

Table 3: Manufacturing engineering skills competencies matrix

design engineers with skill competencies of 0.2 or less, and the development of the skill competencies of design engineers '01' and '09' in component design and technical analysis. Using the optimisation technique, these changes to the team would result in an estimated 52% reduction in the design-development phase's expected duration and a 45% reduction in labour cost.

Manufacture of fabricated engineering components and machine parts for heavy equipment within the excavator industry

In contrast to the two 'design oriented' case studies, this one focused on a company establishing a means of eliciting and modelling the skill competencies of its manufacturing engineers. The skill competency assessment process outlined in Figure 2 was used to elicit engineers' skill competencies in the company's core manufacturing operations related to its wide product range.

The outcome of the skill competency assessment process conducted by the company is presented in the form of a matrix in Table 3.

Skill competency in each core manufacturing operation is represented over a range of four levels, each of which defines a unique degree of competence. This visual representation displays the current levels of skill competencies of each individual, which could be used to identify their specific training and development needs, enabling them to operate more effectively, thus improving organisational performance.

From Table 3, it can be seen that two manufacturing engineers (01 and 05) are single-skilled in operating the manual band saw and dressing/finishing respectively. Manufacturing engineers 02, 03 and 04 have been assessed as being highly competent in a number of operations, while others (06-11) possess low competency in many of the operations.

Based on the assessment process and resulting matrix, the company was alerted to considering the further development of manufacturing engineers 03 and 04 in order to raise their skill competency to master level for a number of operations, thus enabling them to train others. Importantly, these engineers would be developed at different times so as to not delay normal production schedules.

Due to the visual, rather than numerical, representation of the manufacturing engineers' skill competencies, an optimisation technique was not used as in the earlier case studies to determine modifications to the team's composition. In order to do this, the four levels of skill competence would need to be translated to a numerical scale, which presents a challenge, as a linear relationship does not exist between the visual representation and numerical scale. This is an area of further investigation.

Conclusion

Engineering companies are increasingly recognising that their engineers' skills and competencies are key to continuously improving organisational performance and maintaining competitiveness. The research overviewed in this article is only intended to provide an initial framework for further development in modelling the skill competencies in engineering companies.

Indeed, considerable scope exists to develop sophisticated methods of how to model and/or quantify the skill competencies of 'design' and 'manufacturing' engineers. For example, it is anticipated that a rigorous means of modelling and/or quantifying skill competencies may involve using questionnaires, assessment, and interviews with engineers in consideration of factors, such as their practical experience, theoretical knowledge, previous performance, training and qualifications. Also of importance is the establishment of a scale that is uniformly understood and widely accepted.

The industrial case studies summarise initial applications of the research. As a result of these case studies, companies have been able to identify areas for improvement in their engineers' skills and competencies. For these companies, improving the skill set of engineers would also result in reducing the vulnerability represented by people leaving the organisation and taking key competencies with them.

In light of the work done, there is a need to seek further case studies involving different companies. In addition, case studies must be sought involving companies working concurrently on multiple projects spanning design and manufacture.

References

1 Matsumoto, I T, Stapleton, J, Glass, J, and Thorpe, T, (2005), *Developing a framework to measure organisational and employee skills development in a professional engineering design consultancy*. Journal of Construction Engineering, 5(1), 53-66.

2 Delbridge, R, Edwards, P, Forth, J, Miskell, P, and Payne, J, (2006), *The organisation of productivity: re-thinking skills and work organisation*. Report to the Advanced Institute of Management Research by the National Institute of Economic and Social Research.

3 Coetzer, A J, (2006), *Developing human capital in small firms: a conceptual framework for analysing the effects of managers on employee learning*. Research And Practice in Human Resource Management, 14(1), 143-179.

4 Allen, J, and van der Velden, R, (2005), *The role of self-assessment in measuring skills*. In Transition in Youth Workshop, Valencia, Spain.

5 Butler, J, Cameron, H, and Miles, I, (2000) *Grasping the nettle: a feasibility study concerning a programme for research into the measurement and validation of intangible assets*. A study carried out for the Department of Trade and Industry.

6 Tether, B, Mina, A, Consoli, D, and Gagliardi, D, (2005), *A literature review on skills and innovation: how does successful innovation impact on the demand for skills and how do skills drive innovation?* A Centre for Research on Innovation and Competition Report for the Department of Trade and Industry.

7 Elias, J, and Scarbrough, H, (2004), *Evaluating human capital: an exploratory study of management practice*. Journal of Human Resource Management, 14(4), 21-40.

8 Ra, J, W, (1996), *Quantified skills matrix model for a project-oriented organization*. In Proceedings of the National Conference for the American Society for Engineering, pp. 279-282.

9 Elias, J, and Scarbrough, H, (2004), *Evaluating human capital: an exploratory study of management practice*. Journal of Human Resource Management, 14(4), 21-40.

10 Coates, G, Duffy, A H B, Hills, W, and Whitfield, R I, (2007), *A Preliminary Approach to Modelling and Planning the Composition of Engineering Project Teams*, Journal of Engineering Manufacture, Proceedings of the Institute of Mechanical Engineering Part B, 221(7), 1255-1265.