Design engineering competencies: future requirements and predicted changes in the forthcoming decade

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This paper seeks to address omissions in previous research by identifying a future competency profile for design engineers. A three-phase methodology using both quantitative and qualitative methods was employed. A competency profile for the future design engineer, 10 years hence, was generated. The profile consisted of 42 competencies divided into the following six competency groups (in descending order of criticality): personal attributes, project management, cognitive strategies, cognitive abilities, technical ability, and communication. Furthermore, non-technical competencies were forecast to become increasingly important in the future. Results were discussed with reference to their implications for the design engineering industry.

Keywords: creativity, design behaviour, design cognition, innovation, psychology of design

The present study seeks primarily to identify the future competency requirements of design engineers, a role that little recent competency research has examined. This is an important omission for such a crucial engineering role, as competency-based approaches serve to enhance an organisation's performance and therefore yield a competitive advantage (Lawler, 1994).

A relatively typical definition of the term competency encompasses those underlying motives, traits, values, knowledge, and skills that are causally linked to effective job performance (Spencer and Spencer, 1993). It is important to note, however, that some authors additionally

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include both tasks and roles performed as competencies (Duncan, 1991). Furthermore, others, while distinguishing competencies from roles and tasks, nevertheless include tasks within the overall term competencies (Plonka et al., 1994). Indeed, even experts in organisational psychology themselves acknowledge the wide range of definitions (Schippmann et al., 2000). In the current paper, the operational definition of a competency also includes tasks, where this serves to more clearly illustrate the nature of the underlying behaviours and cognitions of job incumbents. By employing this broader definition, we hope to address two of the most frequent criticisms of competency-based approaches (Illes, 2001). First, we remove the conceptual ambiguity from the term 'competency', and second we enable both task-oriented *and* people-oriented competencies to be incorporated in the same profile.

Although recent research on design engineers is sparse, several technical roles in related fields have been explored, for instance: civil engineers (Leiper and Khan, 1999); software engineers (Turley and Bieman, 1995); construction project managers (Edum-Fotwe and McCaffer, 2000); and technical project managers (Duncan, 1991). Unfortunately, due to the different terminology and categorisation methods used, it is difficult to compare specific competencies across these studies. However, the main competency *themes* to emerge were: role-specific technical competencies; competencies indicating a high level of motivation; the use of intelligence to solve problems and make decisions; teamwork; the management and leadership of others; communication; planning and management of projects and resources; innovation; and strategic awareness of the wider business and customer context. Although not all studies rated the relative importance of the various competencies, in those that did, the above themes were all of at least moderate importance.

Role-specific technical competencies therefore, although clearly essential, are just one of several important competency themes, even for such specialised technical roles. This differs somewhat from traditional views of design engineers' work that have hypothesised that 100% of their time is spent within the 'steps' of the technical design process (Pahl and Beitz, 1984). More recently, however, empirical studies have verified the prevalence of non-technical work. Hales (1993), for example, empirically tested Pahl and Beitz's hypothesised time allocations using participant-observation of design engineers, and found that only 47% of their time was spent engaged in such design process steps. The remaining 53% was spent planning work, reviewing/reporting, estimating cost, retrieving information, interacting socially, and helping others.

Ethnographic studies of design engineers have also suggested the great importance of 'non-technical' skills. Those studied by Baird et al. (2000) displayed highly developed skills of planning and the inherent task prioritisation it entails, essential skills in a work environment of changes and tighter timeframes. They also demonstrated full awareness of the many parties that depend on their work and this was reflected in the manner in which they closely monitored work as it unfolded, and then communicated any changes to those involved in downstream processes. Furthermore, they were shown to engage in complex thought processes when evaluating long-term implications alongside more immediate outcomes, before then prioritising work accordingly.

The need to closely monitor work in order that unforeseen complications can be quickly addressed is critical. Diary studies of design engineers by Jagodzinski et al. (2000) revealed that unforeseen problems – such as technical difficulties, disruptions, management complications, and changes in requirements – occur often and can significantly affect progress. Furthermore, using weekly interviews, the researchers tracked design engineers as their projects unfolded. Such obstacles to progress were demonstrated to have substantial negative effects on morale, suggesting that resilience is also essential for design engineers.

Design engineering has also been demonstrated to be a highly social process. Indeed, some researchers have even distinguished between engineering work occurring in the object-world and the social-world (Bucciarelli, 1994; Bucciarelli and Kuhn, 1997). The former is concerned with the technical scientific problem solving traditionally associated with engineering, while the latter relates to the interactions with others that occur while working.

Research by Busby (2001), into errors occurring during the design process, has demonstrated the importance of work occurring in the so-called social world. Interviews with design engineers of varying seniority and disciplinary backgrounds revealed that 87% of such errors could be attributed to failures in what Busby referred to as *distributed cognition*. Distributed cognition refers to those circumstances where the knowledge required to solve a particular problem is distributed between several collaborators, thereby necessitating interaction. Between them, three different types of distributed cognition were found to be responsible for 87% of these errors, namely: interactions between several participants, interactions between participants and designs, and interactions between the participants and the organisation. Analysis of such incidents revealed that errors had not occurred as a result of communication failures per se, but rather because of the interpretations of, and assumptions that people bring to bear on, such information. Communication skills of a high order are therefore also clearly necessary for design engineers.

There is evidence to suggest that not only are engineers aware of this distinction between technical and non-technical work, but that the competing demands of each cause tension. For example, the mechanical design engineers interviewed by Perlow and Bailyn (1997) classified such technical work as 'real engineering' (p. 232) and contrasted this with the managerial and administrative tasks, required by their organisation, that prevented them from doing such work.

In common with most competency identification research, the studies reviewed so far have focused on those competencies required in the present. However, it is also prudent to ensure that the future is considered to some extent, especially in periods of high change. Focusing solely on the present will ensure that the competency profile identified and, consequently, the organisation, remain in the past (Shackleton, 1992), a frequent criticism of competency-based approaches (Illes, 2001). Indeed, this is especially true in the current business climate of rapid change, where increasing globalisation, greater numbers of small businesses, increasing levels of teamwork, and flatter organisational structures are set to have an impact (Gow and McDonald, 2000).

When viewed over time, as a future-oriented approach encourages, competencies can be considered to have a *life cycle* (Sparrow and Boam, 1992). Those that are set to remain as important in the future as they are now are referred to as *core* competencies, those set to increase in importance are *emerging*, those set to decrease in importance are said to be *maturing*, and finally, those whose importance will shortly increase before then declining are referred to as *transitional*. The current study, by exploring the perceived importance of various competencies at two time-points, namely the present and 10 years into the future, will enable an assessment of the life cycle of these competencies to be made (for all but transitional competencies).

Although numerous studies have investigated future competency requirements in a variety of roles (Association of Graduate Recruiters, 1995; Henderson et al., 1995; Gow and McDonald, 2000), such future-focused research examining engineering roles is relatively scarce. Two examples are noted here. Rifkin et al. (1999) encouraged the technical managers they interviewed to consider how their organisation's future plans would impact upon the competencies they identified. The resultant findings generated a five-tier hierarchical competency pyramid model, with each successive competency tier supported by a tier of prerequisite competencies. Personal attributes were the foundation of this pyramid, followed, respectively, by skills and knowledge, work activities, critical accomplishments, and finally, at the apex, the overall role that the technical manager was required to perform.

A competency model for the manufacturing engineer of the 21st century was proposed by Plonka et al. (1994). Four main competencies were identified, of which three, namely *know self and work with others*, *solve unstructured problems*, and *lead change*, were found to support the final competency *design, build and run high value-added systems*. Each of these four competencies were divided into more detailed sub-competencies: (1) *know self and work with others* consisted of examine and evolve self; act ethically; communicate; team; and mentor; (2) *solve unstructured problems* consisted of access information and knowledge; perform experiments; develop predictive models; and use the engineering design process; (3) *lead change* consisted of value others; articulate a vision; optimise globally; seize opportunities; innovate; and continuously improve; and (4) *design, build, and run high value-added systems* consisted of develop a manufacturing strategic plan; design and implement manufacturing systems; support the continuous improvement of manufacturing operations; and run manufacturing equipment.

Neither of these two studies provided any indication of the relative importance of the competencies they identified, however. Furthermore, no such future-oriented research has specifically examined *design* engineering. This is an important omission, for as case study research has demonstrated, the very nature of design engineering, as well as the organisational learning challenges that it entails, is considered to be changing radically (Blackler et al., 1999). The current study aims to address these omissions in the literature by identifying the future competency profile of design engineers, and furthermore by providing an indication of the relative importance of these competencies. This is the primary aim of the current paper. In accordance with previous research into other such technical roles, it is expected that a combination of technical and non-technical competencies will be identified.

The current study will also improve upon the methodology of Rifkin et al. (1999) and Plonka et al. (1994). First, a structured multi-phase approach to identifying future competency requirements will be adopted. Second, a precise future horizon — 10 years hence — will be specified, unlike the vague horizons used in these previous studies. Such methodological improvements should serve to increase the accuracy of predictions.

In addition to identifying general competency requirements for future design engineering work, the current study seeks to explore the two closely related competencies of innovation and creativity. For over a decade, questions have been asked about the impact that increasing automation is having on creativity and innovation in engineering work (Azani and Khorramshahgol, 1991). Tucker (2002) argues that innovation is the core competency around which future business success will be built, and furthermore '…the only sustainable source of growth, competitive advantage, and new wealth' for companies (p. 112). It is also clear that the importance of innovation is recognised by the engineering industry (Steiner, 1998; Stoffel, 2000; Donofrio, 2001). Case studies of highly innovative individuals such as Formula One designer Gordon Murray (Cross and Clayburn-Cross, 1996) and racing bicycle designer Mike Burrows (Candy and Edmonds, 1996) have also demonstrated the importance of this competency for gaining a competitive business advantage. Creativity, meanwhile, has been historically recognised as a key competency for engineering roles (Sprecher, 1959; Datta, 1964; Jones, 1964; McDermid, 1965).

Innovation is a complex competency, however, and it is widely acknowledged that two distinct types exist. The first, whereby existing products or processes are improved, is referred to as *incremental* or *evolutionary* innovation, and the second, whereby entirely new products or processes are generated, is referred to as *radical* or *revolutionary* innovation (Rabson and DeMarco, 1999; McDermott and O'Connor, 2002).

Within the aerospace industry, the focus of the current study, it seems more likely that incremental innovation will be of greater importance in the forthcoming decade. The last major paradigm-shift within the relevant sector of this industry appears to have occurred with the invention of the turbojet engine in the 1930s, and its subsequent dominance over its piston engine counterparts (Hughes, 2003), a view supported by Utterback and Kim (as cited in McDermott and O'Connor, 2002). Since this radical change, innovation has been of a more incremental nature, and it seems likely that this trend will continue in the forthcoming decade. Furthermore, there is evidence to suggest that radical technological innovation initially emerges from a strong basic research background, rather than from industrial sources (Friedman, 2002). It therefore seems likely that although innovation will be important to the future design engineer, it will be of the incremental type, rather than the radical type.

Given the perceived importance of innovation, we now define it and consider its relationship with creativity. Innovation has been defined as the ability to introduce and apply beneficial processes, products, or procedures that are new to that area (West and Farr, 1990), whereas creativity is typically defined as the ability to generate ideas that are novel, useful, and appropriate (Amabile, 1983). From these definitions, it appears that innovation is comprised of two distinct stages – the generation of an idea and its subsequent application – whereas creativity only involves the first of these stages. This is the first crucial difference between the two competencies, and indeed there is empirical evidence for this two-stage composition of innovation (Unsworth, 1999). However, even when this common idea-generation stage is considered in isolation, there is still another crucial distinction to be made (West and Farr, 1990). Creativity involves the generation of ideas that are entirely novel, whereas innovation only requires that such ideas are new to a particular area. As such, innovation is clearly the broader competency, and although creativity *can* be a central component of innovation, it is also possible for the two competencies to be entirely independent. From such definitions, it therefore seems likely that creativity is more closely aligned with radical rather than incremental innovation. As such radical innovation is expected to be less prevalent in the future, it seems likely that creativity too will decline, or *mature* (Sparrow and Boam, 1992), in importance. This is not to say that creativity will be less important to the nature of the industry, but that the nature of the next paradigm-shifting changes is at this stage necessarily unknowable and attention will naturally be focused on managing and exploiting incremental developments within the overall paradigm. Innovation, however, due to the increasing need for incremental changes, should increase, or *emerge* (Sparrow and Boam, 1992), in importance. These expectations will also be explored in the current study.

1 Methodology

1.1 Selection of future time horizon

The company under study primarily manufactures aerospace products with an average timescale of four years from initial design to initial production. Furthermore, the company had a relatively full order book and was therefore relatively financially stable for the short-term future. It was therefore felt that a five-year horizon would be too short. Looking 20 years ahead was considered too speculative. Consequently, a 10-year future time horizon was selected as most appropriate.

1.2 Overview of three-phase methodology

The current research is divided into three distinct phases, namely: Phase 1 – Preliminary interviews; Phase 2 – Questionnaire; and Phase 3 – Critical Incident Technique interviews. Outputs from Phases 1 and 2 were used to inform Phase 3, from which the final future competency profile was generated. Each of these Phases is described in detail in the following sections. For clarity, a diagrammatic overview of the three-phase methodology is provided in Figure 1.

1.3 Phase 1 – Preliminary interviews

Within Phase 1, two separate stages of interviews were conducted. The first focused on identifying (a) future scenarios predicted to impact upon the design role during the forthcoming decade, and (b) which of the company's six design stages to focus on during subsequent research. The second stage served to further explore those scenarios and design stages judged to be the most important.

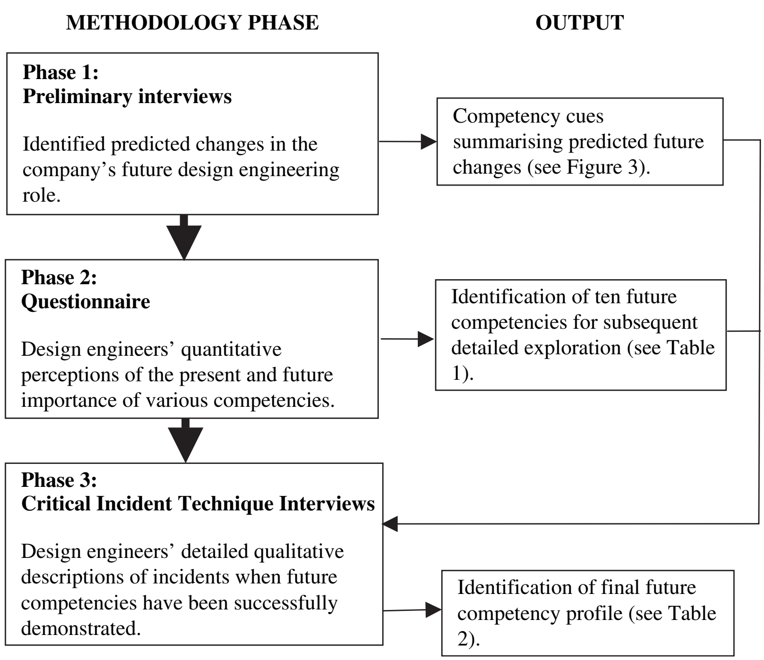

Figure 1 Overview of three-phase methodology

In the first stage, nine semi-structured interviews were conducted with 11 senior managers and directors from engineering and HR functions within the company. Interviewees were selected such that they would offer diverse and complementary perspectives on the future design engineering role. In addition to these interviews, members of the research team attended two 'away days', that were being used to interpret the implications of future commercial strategy and commercial investments, alongside engineering staff from the company. Here, attendees' views on the company's future design engineering role were elicited.

The second stage involved a further five semi-structured interviews with five different managers and directors. These interviewees had been identified as *subject matter experts* (SMEs) by the original interviewees. More specifically, between them, these five interviewees were deemed to have an expert knowledge of the three future scenarios and three design stages that had been identified as most important during the preceding interviews.

Following this second stage of interviews, a series of competency *cues* were created. These cues, one set for each design stage, and one set for each future scenario, summarised what interviewees had felt were the most important likely changes in each of these areas.

1.4 Phase 2 – Questionnaire

1.4.1 Sample and procedure

A questionnaire was e-mailed to 181 design engineers working in 18 departments of the company. These design engineers were a sample of the larger population of design engineers working within the company, and were selected by the company's Design Capability Manager according to ease of accessibility. Fifty-eight completed questionnaires were returned, representing a response rate of 32%. The respondents occupied a wide range of seniority levels within the organisation.

1.4.2 Measures

The questionnaire contained a list of 49 competencies with accompanying definitions. These competencies were synthesised from an original list of 100 competencies consisting of (a) 67 generic competencies from a competency analysis tool called LEADERSHIP ARCHITECT® (Lominger Limited, 2002), which is widely used in the company, and (b) 33 competencies from earlier research conducted within the same company that had specifically examined the attributes of design engineers (Pathfinder and Lim, 1998). Examination of this original list had revealed substantial overlap between the various competencies, and it had therefore been possible to condense the list whilst still retaining all the original competency themes.

The competency definitions were compiled by synthesising definitions from the two original competency sets (Pathfinder and Lim, 1998; Lominger Limited, 2002), with the exception of the competencies *innovation* and *creativity*, which were operationalised by West and Farr (1990), and Amabile (1983), respectively. The role of creativity and innovation in the context of automation of engineering work has been given prominence (Azani and Khorramshahgol, 1991) since the early 1990s.

Respondents were required to rate the importance, to their current job, of each of the 49 competencies, in two ways: (a) in their job as it is currently, and (b) in the same job as they think it will be in 10 years' time (these ratings are subsequently referred to as 'present importance ratings' and 'future importance ratings', respectively). This 10-year period corresponded to the 10-year future horizon of the research. The nine-point response scale had end-points labelled 'not at all important' (1), and 'extremely important' (9).

1.5 *Phase 3 – Critical Incident Technique interviews*

Analysis of the questionnaire responses had served to identify the most important perceived future competencies for these design engineers. However, if used in isolation, such analysis would not have provided much detail as to the exact nature of these competencies in the company's future design engineering role. Phase 3 research therefore focused in greater depth on the most important of these competencies. This approach was preferred to a broader focus. The company, in which the research was conducted, currently adopts a competency-based approach to selection and development and, consequently, already has a thorough understanding of the broader competency requirements of design engineering. It was therefore felt that a focused approach would be more beneficial.

Subsequent interviews were therefore conducted to further explore the 10 competencies with the highest future importance ratings (FIR), as listed in Table 1, namely: motivation for results; sound judgement; concise communication; time management; problem solving; technical ability; planning and measuring work; perseverance; intelligence; and ability to learn.

In so doing, it is recognised that the FIR of any of these 10 competencies does not differ significantly from that of the competency with the 11th highest FIR. Indeed, it is necessary to go down to the competency with the equal 20th highest FIR, namely *composure*, before one finds an FIR significantly lower than that of the competency with the 10th highest FIR, namely *ability to learn*, $t(56) = 2.01$, $p < .05$. Nevertheless, there were no preferable alternative methods for selecting the 10 competencies rated most important in the future, so this method was used.

1.5.1 Framework for exploring future competencies

The three design stages, and the three future scenarios identified during research Phase 1, were used as a framework through which to explore the 10 competencies further. Figure 2 illustrates this framework, using the competency *intelligence* as an example. Furthermore, the methodical use of such a framework addresses the criticism that most competency-based approaches focus on generic models at the expense of organisation-specific factors (Illes, 2001).

1.5.2 Sample and procedure

Interviewees were all design engineers. Stratified sampling was used such that both the design stage the interviewee worked in, and the level of exposure they had to particular future scenarios corresponded to a particular cell of the framework in Figure 2. Furthermore, only those design engineers who were judged, by their managers, to be performing their jobs well were selected as interviewees. A total of 27 interviewees were selected, three for each of the nine cells of the framework.

The Critical Incident Technique (CIT) (Flanagan, 1954; Kandola and Pearn, 1992; Pearn and Kandola, 1993) was used to explore the competencies during the interviews (see Appendix I). For each of the 10

Figure 2 Research framework through which the 10 most important future competencies from the questionnaire were explored further during Phase 3 Critical Incident Technique interviews

Future scenario	**Design Process**		
	Stage 1: Preliminary Concept Definition	**Stage 3: Product Realisation**	**Stage 5: Service Support**
Increased customer focus	e.g. Intelligence	e.g. Intelligence	e.g. Intelligence
Increased internationalism	e.g. Intelligence	e.g. Intelligence	e.g. Intelligence
Increased computer capability for communication	e.g. Intelligence	e.g. Intelligence	e.g. Intelligence

competencies, interviewees were first read the definition that had appeared on the original questionnaire. Next, they were asked to describe a situation where either themselves, or a colleague, had successfully demonstrated the competency. They were also asked to ensure, where possible, that the incident they described had occurred whilst working in the relevant cell of the framework in Figure 2.

Each interview lasted 75 minutes, of which 50 minutes was spent exploring the 10 competencies (5 minutes per competency). In order to ensure that each critical incident generated was future-oriented, interviewees were provided with a series of competency cues as described in Phase 1. Interviewees were instructed to ensure that any critical incidents that they described would be neither hindered, nor prevented, by the occurrence of the changes suggested by such cues. It was felt that the utilisation of cues in this way, in conjunction with the description of critical incidents that had *actually occurred* in the workplace, would enable the construction of an accurate picture of future design engineering competencies. This approach was preferred to asking interviewees to generate imaginary or hypothetical future critical incidents, which it was felt would be too subjective (Shackleton, 1992) and hence inaccurate. Support for the benefits of this approach can be found in the selection literature (Taylor and Small, 2003).

1.5.3 Interview analysis methodology

All interviews were tape recorded and then fully transcribed afterwards. The transcripts were then *content analysed* (Kandola and Pearn, 1992) to elicit *indicators* (Honey, 1992; Kandola and Pearn, 1992) linked to effective performance for each of the 10 competencies. Two types of indicators were identified through this process: *behavioural* indicators and *cognitive* indicators. As a rule, the former comprise visible behaviours, actions, and abilities, while the latter comprise hidden thought processes that usually have to be inferred (Spencer and Spencer, 1993). Initially, this analysis process was conducted separately for each of the nine cells of the framework in Figure 2. This yielded 90 sets of indicators: nine sets for each of the 10 competencies.

These 90 sets of behavioural and cognitive indicators were then closely examined and compared for differences and similarities. The nature of these indicator sets was not found to differ meaningfully as a function of the future scenarios. In other words, for a given competency and a given design stage, there was no meaningful difference between the detailed indicators for each of the three future scenarios. Put simply, intelligence looked the same whether in the context of increased customer focus, internationalism, or increased computer capability for communication. Consequently, the data from the three future scenarios were merged, whilst still retaining the categorisation along the other two dimensions: design stage and competency. This resulted in 30 newly created sets of indicators. Where particular indicators, within each of these new sets, were judged by trained psychologists to be sufficiently similar, they were synthesised using common terminology.

During subsequent analysis stages, the nature of the indicators was not found to differ as a function of either the 10 original competency labels or the three design stages. Consequently, similar dimension-merger and terminology-synthesis processes were used to generate new data structures of three, and finally one, sets of indicators, respectively.

In order to structure this one final set of indicators in an organised manner, two additional grouping levels were created. First, where sufficiently similar, the indicators were grouped into small clusters that were subsequently labelled *competencies*. Next, where such competencies were sufficiently similar, they were grouped together into *competency groups*. This classification process was guided by psychological competency sub-groupings such as motives, traits, values, knowledge, and skills (Spencer and Spencer, 1993).

1.5.4 Methodology for calculating competency criticality

The competencies identified during this research served as the foundation for selection and development processes. As such, it was necessary to generate a measure of the importance of each competency. The CIT, as used here, seeks to identify those competencies that distinguish excellent performers from those who are adequate, in other words, those skills that are *critical* (Smith and Davidson, 1991). Therefore, if an importance rating is directly derived from CIT research, as it was here, such a rating indicates to what extent that particular competency distinguishes between excellent and adequate performers. For this reason, the term *criticality* shall be used here in preference to *importance* when discussing those competencies derived from the CIT interviews.

It was decided that the most effective criterion, from which to infer such criticality, would be the proportion of interviewees who had mentioned each behavioural or cognitive indicator during their interview. The resultant criticality rating could then be expressed as a percentage. This criterion was selected in preference to the alternative of the total number of times a given indicator was mentioned, in total, in all interviews. It was felt that this latter measure would be both more difficult to measure accurately, and also possibly disproportionately affected by individual interviewees who might have provided a more homogeneous range of incidents. For individual competencies the method differed somewhat, although it was still based on the same principle. Here, the proportion of interviewees who had mentioned one, or more, of the indicators comprising a particular competency, was used as the criticality percentage. Due to the similar nature of indicators within a given competency category, it was felt that this was a more appropriate method.

The criticality rating of each competency group was obtained by aggregating the criticality ratings of all its constituent competencies. Then, by aggregating the criticality ratings of all six competency groups, it was possible to express the relative criticality of an individual competency group as a percentage of the aggregate criticality rating of all six competency groups.

1.5.5 Validation workshop

Once the final future competency profile had been generated, a workshop was held to establish its *content* validity (Cook, 1998). In addition to the research team, attendees included the following company representatives: the Head of Design Engineering, the Company Specialist for Design Technology, the Design Capability Manager, and a senior HR Manager.

It is important to note that, because this research sought to identify *future* competency requirements, it was not possible to establish the *criterion* validity of the competency profile using conventional methods. Traditionally, tests that assess the competencies identified in the competency profile would be administered to potential recruits (for *predictive* validation) or the current workforce (for *concurrent* validation). Their results on these tests would then be correlated with their work performance (or subsequent work performance, in the case of predictive validation), with significantly high correlations indicative of the *criterion* validity of the competency profile (Smith and Davidson, 1991; Cook, 1998). However, such an approach is contingent on the competency profile being valid to the job as it is *currently*. Our competency profile was relevant to the job as it was expected to be *10 years hence*, however. Current job performance would not therefore have been an adequate criterion against which to gauge the profile.

This problem is an inevitable feature of such future-focused research, and does conflict somewhat with the typical definition of competencies as being causally related to job performance (Spencer and Spencer, 1993). Despite this problem, however, our research took stringent steps to ensure, as much as it is possible to do, that our future competency profile would be predictive of future job performance. First, all CIT interviewees were selected such that they represented the appropriate cells of the framework in Figure 2. This framework, in turn, was developed such that it was concerned with 'cutting edge' areas of the company that represented what the rest of the company would be like in the future. Such a method is accepted as one of the most effective available for examining likely future work environments (Shackleton, 1992). Second, in addition to satisfying the sampling criteria, only those design engineers who were judged, by their managers, to be performing their jobs well were selected as interviewees. This is important because interviewees were asked to draw upon successful incidents from their own, or others', work experience during the CIT interviews. In the former case, we can therefore be confident that the incidents provided were from design engineers who were performing their jobs well, according to their managers. In the latter case, interviewees would have selected incidents involving other design engineers who were successfully achieving objectives – in other words, good performers. Research has demonstrated that ratings by peers and managers are similar (Conway and Huffcutt, 1997) and we can therefore infer that the design engineers they selected to describe would have also been rated as good performers by their managers.

Taken together then, these two features of our methodology should instil confidence that our competency profile is predictive of future job performance.

2 Results

2.1 Phase 1 – Preliminary interviews

The company in which this research was conducted has a six-stage design process. Phase 1 interviewees had recommended focusing on three particular stages when exploring the future competencies, namely: *Stage 1: Preliminary Concept Definition*; *Stage 3: Product Realisation*;

and *Stage 5: Service Support*. It was felt that these three stages offered sufficient contrast to be of research interest. The interview data also identified likely changes in each of these stages over the next 10 years.

Several future scenarios were considered likely to impact upon the future design engineering role. Of these, three were predicted to have greatest influence, namely: *increased customer focus*, *increased internationalism*, and *increased computer capability for communication*.

Consequently, these three design engineering stages and three future scenarios were selected as a framework through which to explore future competency requirements, as illustrated in Figure 2.

As explained in the Phase 1 methodology, the most important issues to emerge from these interviews were distilled into a series of competency cues. Examples of these cues are provided in Figure 3.

2.2 Phase 2 – Questionnaire

Data were initially screened in order to check for errors in data entry and missing values. Next, an analysis of the ratings given to each of the 49 competencies was conducted. The mean importance ratings, both present and future, together with associated standard deviations and rankings were calculated. Pair-wise comparisons between the present and future importance ratings for each competency were also conducted

Design Stage 1

- Timescales will be much tighter (e.g. reduced from 6 months to 3 months for Design Stage 1 in Civil Aerospace).

Design Stage 3

- Increased computer technology will enable iterative work and information access to be performed more quickly.

Design Stage 5

- 'Power-by-the-hour agreements' will become more prevalent.

Future scenario 1: Increased customer focus

- The company will work even more closely with its customers, not just air-framers, but increasingly airlines also.

Future scenario 2: Internationalism

- Customers will also become more international. As well as developing links with new countries, the company will also secure further custom in countries it is already working with.

Future scenario 3: Increased computer capability for communication

- As working becomes even more geographically diverse, the need for, and use of, such computer technology for communication will increase.

Figure 3 Examples of competency cues provided during the Phase 3 Critical Incident Technique interviews (Phase 1 output) using paired-sample *t*-tests. Based on the results of this latter analysis, competencies were then categorised as either: *emerging* – judged to become more important in the future; *core* – judged to remain equally important in the future; or *maturing* – judged to become less important in the future (Sparrow and Boam, 1992). Due to the substantial number of pair-wise comparisons conducted here, the conventional probability level of $p < .05$ was adjusted to $p < .0017$ using a modified Bonferonni procedure (Jaccard and Wan, 1996) in order to reduce the risk of type 1 statistical errors. A conventional $p < .05$ probability level was used for the analysis of the two competencies *innovation* and *creativity*, however, as *a priori* predictions had been made here. The results of all these analyses are displayed in Table 1.

Table 1 shows, in accordance with the hypotheses, that *creativity* was rated as a maturing competency – less important in the future than in the present – while *innovation* was rated as an emerging competency – more important in the future than in the present. Furthermore, a 2-way ANOVA demonstrated that the interaction between *creativity* and *innovation* was also significant, $F(1,56) = 26.09$, $p < .001$ (see Figure 4).

2.2.1 Analysis of inter-rater agreement

In order to establish the inter-rater agreement of the questionnaire data, intra-class correlation coefficients (ρ) were calculated to assess the ratings of the 58 respondents in accordance with the procedures outlined by Shrout and Fleiss (1979). Both the present ratings ($\rho = .91$) and future ratings ($\rho = .87$) were found to have high inter-rater agreement.

2.3 Phase 3 – Critical Incident Technique interviews

To briefly reiterate the methodology, for clarity, outputs from Phases 1 and 2 were used to inform Phase 3, from which the final future competency profile was generated.

2.3.1 Competencies identified

The final future competency profile comprised 91 *behavioural and cognitive indicators* divided among 42 *competencies* that, in turn, were divided among six *competency groups*, namely: *personal attributes*, *project management*, *cognitive strategies*, *cognitive abilities*, *technical ability*, and *communication*.

Table 2 lists the 42 competencies that were identified; they are listed within their competency groups in order of criticality.

Table 1 Analysis of the rated importance over time of the 49 competencies on the questionnaire (Phase 2 output)

	Importance ratings						t (df = 56)	Competency type
	Future			Present				
	M	SD	R	M	SD	R		
Motivation for results	7.87	1.12	1	7.49	1.45	5	−3.25	Core
Sound judgement	7.74	1.42	2	7.58	1.45	= 3	−1.07	Core
Concise communication	7.68	1.15	= 3	7.19	1.29	11	−4.49**	Emerging
Time management	7.68	1.34	= 3	7.00	1.43	15	−5.34**	Emerging
Problem solving	7.68	1.32	= 3	7.77	1.22	2	0.71	Core
Technical ability	7.65	1.46	6	7.81	1.04	1	1.01	Core
Planning and measuring work	7.60	1.49	7	6.40	1.52	27	−6.23**	Emerging
Perseverance	7.60	1.27	8	7.44	1.24	6	−1.46	Core
Intelligence	7.58	0.98	9	7.58	0.91	= 3	0.00	Core
Ability to learn	7.49	1.38	10	7.12	1.35	13	−2.25	Core
Textual communication	7.46	1.20	11	7.28	1.13	9	−1.65	Core
Commercial awareness	7.35	1.28	12	6.27	1.52	34	−8.13**	Emerging
Accuracy	7.33	1.50	13	7.42	1.28	7	0.61	Core
Pictorial communication	7.26	1.59	14	7.18	1.43	12	−0.46	Core
Presentation skills	7.23	1.44	15	6.42	1.34	= 25	−5.94**	Emerging
Work/life balance	7.20	1.54	16	6.76	1.82	17	−2.49	Core
Innovation	7.16	1.56	17	6.65	1.59	= 19	−3.29*	Emerging
Organisation	7.12	1.68	18	6.28	1.75	= 32	−5.70**	Emerging
Ethics and integrity	7.11	1.91	19	7.25	1.62	10	1.00	Core
Direction of others	7.07	1.61	= 20	6.11	1.63	37	−5.40**	Emerging
Composure	7.07	1.50	= 20	6.65	1.40	= 19	−3.77**	Emerging
Interpersonal skill	7.07	1.47	= 20	6.53	1.49	21	−3.67**	Emerging
Dealing with ambiguity	6.91	1.57	= 23	6.33	1.59	30	−3.53**	Emerging
Teaming	6.91	1.68	= 23	6.75	1.57	18	−1.24	Core
Curiosity	6.89	1.71	25	7.04	1.70	14	1.18	Core
Self-development	6.84	1.36	= 26	6.51	1.43	22	−3.40**	Emerging
Creativity	6.84	2.09	= 26	7.30	1.63	8	2.12*	Maturing
Process management	6.82	1.67	28	6.39	1.42	28	−2.57	Core
Career ambition	6.75	1.84	29	5.84	1.70	42	−5.89**	Emerging
Total quality management	6.72	1.87	30	6.28	1.73	= 32	−3.58**	Emerging
Negotiation	6.70	1.64	31	5.98	1.61	38	−5.78**	Emerging
Visualisation	6.67	2.01	32	6.91	1.77	16	1.25	Core
Ability to synthesise	6.63	1.90	= 33	6.47	1.96	= 23	−1.59	Core
Organisational savvy	6.63	1.58	= 33	5.91	1.43	39	−3.35**	Emerging
Abstract thinking	6.58	2.09	35	6.47	2.04	= 23	−0.60	Core
Motivation of others	6.51	1.97	36	5.88	1.82	41	−4.42**	Emerging
Action orientation	6.49	1.59	37	6.37	1.52	29	−0.88	Core
Patience	6.47	1.62	38	6.42	1.49	= 25	−0.39	Core
Personability	6.46	1.57	39	6.32	1.26	31	−0.92	Core
Strategic perspective	6.35	1.98	= 40	5.39	2.09	46	−5.06**	Emerging
Comfort around higher management	6.35	1.94	= 40	6.14	1.81	36	−1.39	Core
Managerial courage	6.33	2.04	42	5.65	1.99	45	−4.75**	Emerging
Dealing with paradox	6.28	1.93	43	5.89	1.82	40	−2.23	Core
Standing alone	6.23	1.96	44	6.21	1.79	35	−0.11	Core

Table 1 (*continued*)

	Importance ratings						t (df = 56)	Competency type
	Future			Present				
	M	SD	R	M	SD	R		
Caring about direct reports	6.21	2.04	45	5.80	1.95	43	−1.96	Core
Sizing up people	5.88	2.00	46	5.32	1.93	48	−2.87**	Emerging
Humour	5.67	2.02	47	5.67	1.98	44	0.00	Core
Hiring and developing direct reports	5.37	2.58	48	4.79	2.52	49	−3.12	Core
Personal disclosure	5.21	1.91	49	5.35	1.89	47	1.13	Core

Note: M = mean, SD = standard deviation, R = rank, df = degrees of freedom. *$p < .05$ (for a priori predictions only), **$p < .0017$ (probability level adjusted in accordance with the modified Bonferonni procedure [Jaccard and Wan, 1996]).

An example of the indicators comprising the competency *judges importance*, from the competency group *cognitive strategies*, is provided in Figure 5.

2.3.2 *Validation workshop*

The consensus among the subject matter experts (SMEs) who attended the validation workshop was that the competency profile did accurately represent the company's likely future design engineering role. The competency profile can therefore be said to have acceptable *content* validity (Cook, 1998).

3 *Discussion*

The six competency groups to emerge from the final analysis contain a mixture of both technical and non-technical competencies, as suggested by previous research examining the future requirements of technical roles (Plonka et al., 1994; Rifkin et al., 1999). Unfortunately,

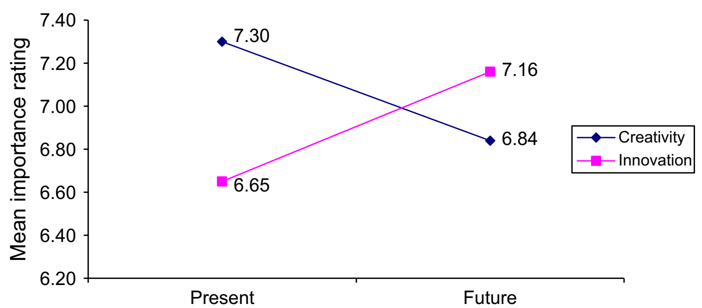

Figure 4 Interaction between the present and future importance ratings of the competencies creativity and innovation (questionnaire data from Phase 2)

Table 2 Final future competency profile: competencies and competency groups identified by the Critical Incident Technique interviews (Phase 3 output)

Competency group	CGCR	*R*	Competency	CCR	*R*
Personal attributes	371	1	Is motivated	78	=2
			Works hard	56	=10
			Has job satisfaction	52	=12
			Enjoys challenges	44	=18
			Is assertive	44	=18
			Is open minded	37	21
			Has good interpersonal skills	22	29
			Is self-confident	19	30
			Proactively seeks training	11	=31
			Copes with ambiguity	4	=35
			Adopts a calm approach	4	=35
Project management	359	2	Plans work	85	1
			Monitors progress	63	=7
			Seeks support from others	52	=12
			Manages problems	48	=16
			Stays focused	44	=18
			Manages time	30	=25
			Understands the task	26	28
			Conducts risk assessments	11	=31
Cognitive strategies	237	3	Judges importance	78	=2
			Analyses tasks	70	=5
			Identifies factors	52	=12
			Learns from mistakes	33	=22
			Seeks simplest solutions	4	=35
Cognitive abilities	218	4	Makes effective decisions	70	=5
			Thinks intuitively	59	9
			Thinks ‘outside the box’	52	=12
			Is able to learn	33	=22
			Thinks quickly	4	=35
Technical ability	215	5	Uses effective learning methods	78	=2
			Is knowledgeable about engineering	63	=7
			Applies engineering knowledge	33	=22
			Is technically versatile	30	=25
			Has IT skills	7	=33
			Visualises geometry in 3D	4	=35
Communication	153	6	Uses appropriate communication formats	56	=10
			Prepares and rehearses presentations	48	=16
			Summarises information	30	=25
			Communicates clearly	7	=33
			Communicates directly	4	=35
			Attends to detail when communicating	4	=35
			Empathises with audience	4	=35

Note: CGCR = competency group criticality rating, *R* = rank, CCR = competency criticality rating.

Figure 5 Example of competency structure arising from the analysis of the Phase 3 Critical Incident Technique interviews

Competency group: Cognitive strategies
Competency: Judges importance
Indicators:

- Evaluates the relative importance of activities, using official procedures and with reference to business objectives where applicable, and prioritises them accordingly
- Accurately gauges, and compares, the importance and relevance of different factors, thereby realising which are critical
- Evaluates the advantages and disadvantages of alternative actions

neither Plonka et al. (1994) nor Rifkin et al. (1999) assessed the importance, or criticality, of the competencies they identified. In our research this was done, and interestingly the technical ability competency group was only the fifth most critical. Furthermore, it was judged to be substantially less critical than both the personal attributes and project management competency groups.

The findings of the current research do *not* suggest that technical ability is unimportant; it clearly is and will remain so. Instead, the implication is that, in future design engineering work, *differences between excellent and adequate performance* are more likely to be as a result of differences in the levels of personal attributes, project management skills, and, to a lesser extent, cognitive strategies and cognitive abilities. In other words, these competency groups will be more *critical*. Such findings should not come as a great surprise, however. After all, a prerequisite for recruitment into an engineering role in this particular company is an engineering degree, or equivalent. Clearly then, one would expect the basic engineering technical ability of every design engineer to be at least equal to this minimum level, and therefore relatively similar on the overall spectrum of ability. Differences in such technical ability are only likely to emerge when increasingly specialist technical fields are considered. By contrast, however, when personal attributes and project management competencies are considered, there is likely to be far greater differentiation in ability levels across the company's design engineers. Consequently, it is these non-technical competencies that are more critical to excellent performance.

There are similarities to be found between this explanation and the future competency model for technical managers proposed by Rifkin et al. (1999). They proposed a five-tier hierarchical pyramid model, with personal attributes at the base, followed, respectively, by skills and knowledge, work activities, critical accomplishments, and, at the apex, the overall job role. Each competency tier was said to enable or support the tier above it. Interestingly, it is personal attributes, the most critical competency group in the current study, at the very base of their pyramid model as a prerequisite foundation for the other four tiers. Unfortunately, it is difficult to compare the upper four tiers of Rifkin et al.'s model with the results of the current study as they adopted a more macro approach to competency analysis, and also used a different taxonomy.

The criticality of such non-technical competencies also challenges traditional views of design engineering as a predominantly technical role (Pahl and Beitz, 1984). Furthermore, it is interesting to consider these results in light of the work of Bucciarelli (1994) and Bucciarelli and Kuhn (1997), suggesting that engineering work occurs either in the object-world or in the social-world. While two of the six competency groups – technical ability and communication, respectively – fit neatly into these categories, the other four competency groups could be equally applicable to either 'world'. Perhaps then, this dichotomy is an oversimplification. It would appear that additional dimensions are required in order to classify design engineering competencies, or tasks, adequately.

One such possible dimension arose from research examining design engineers conducted by Perlow and Bailyn (1997). The engineers they interviewed distinguished between 'real engineering' and 'the rest of the job' (p. 232), and furthermore expressed frustration that their organisation required them to do the latter at the expense of the former. If one considers the results of the current study, however, it is apparent that 'the rest of the job' constitutes a very important element of the design engineer's role. Indeed, four competency groups – personal attributes, project management, cognitive strategies, and cognitive abilities – were all rated as more critical than technical ability. Regardless then of how design engineers view such competencies, it appears that they are predicted to be an integral part of their future role. Rather than being the case that design engineers are being distracted from doing 'real engineering', it appears instead that the very *nature* of 'real engineering' is changing.

Indeed, in the company under study, although design engineers used to work primarily alongside their peers in dedicated departments, the company structure has now changed substantially. Increasingly, design engineers are working in integrated project teams (IPTs) alongside technical and non-technical specialists from a variety of disciplines. The role of design engineers in such IPTs is an integrative one, responsible for leading and coordinating the efforts of these diverse specialists.

Indeed, design engineers themselves during the CIT interviews described their role as akin to being the 'hub of a wheel'. Clearly, such a role would demand competencies such as planning work, monitoring progress, seeking support from others, and managing problems, thereby explaining why the competency group project management was rated so critical here.

Thus far, we have considered the competencies identified at a group rather than individual level. Such a macro analysis enables an overview of the major trends and areas of importance. However, in order to gain a more detailed picture, it is necessary also to consider the individual competencies identified. Two methods were used in the current study to identify future competencies: a questionnaire and CIT interviews. If one examines the most important future competencies to emerge from each of these methodologies (see Tables 1 and 2, respectively), it is clear that there are several differences. This is to be expected somewhat, due to the different nature of the methodologies; however, it should be emphasised that the questionnaire was merely an *intermediate* stage in the identification of the final competency set, as derived from the CIT interviews. Furthermore, the analysis of the CIT interview data employed a more intensive *bottom-up* analysis approach – where it was seen what themes emerged from the data – rather than the *top-down* approach of the questionnaire – where respondents were restricted by a pre-existing set of competency labels (Sparrow and Boam, 1992). For these reasons, the set of competencies derived from the CIT interviews is more likely to provide an accurate picture of future requirements. Consequently, it was these competencies that constituted the final set.

If the 10 most critical of this final set of competencies are examined, they are distributed evenly among the five most critical competency groups. *Plans work* is the most critical competency, and this certainly supports the notion that the future design engineering role will involve a substantial degree of project management. The criticality of *plans work* together with *judges importance*, *makes effective decisions* and *monitors progress*, the second, fifth and seventh most critical competencies, respectively, resonates strongly with the results of ethnographic research. Baird et al. (2000) noted that design engineers exhibited highly developed *planning* skills and, furthermore, were sufficiently skilled to *judge the relative importance* of both short-term and long-term consequences before *deciding* on the best course of action. They would also closely *monitor* events as they unfolded and react accordingly, where necessary, rescheduling and informing those engaged in downstream processes who would be affected by such changes.

Such unforeseen obstacles to progress that regularly arise have been shown to have substantial negative effects on design engineers' morale (Jagodzinski et al., 2000). It is not surprising therefore that the competencies *is motivated* and *works hard* were both also among the 10 most critical. Such resilience would clearly be essential in such trying circumstances.

It is still clear, however, that the technical aspects of a design engineer's work will remain critical: the competencies *uses effective learning methods* and *is knowledgeable about engineering* are both also within the 10 most critical identified.

Two of the remaining three competencies among the 10 most critical, namely *analyses tasks* and *thinks intuitively*, are somewhat intriguing. Previous research had suggested that *intuition* and *analysis* represent either end of the *cognitive style* dimension (Allinson and Hayes, 1996). More recently, however, psychologists have argued that, on both theoretical and empirical grounds, there is increasing evidence that intuition and analysis are in fact separate dimensions [see the recent point–counterpoint debate between Hodgkinson and Sadler-Smith (2003) and Hayes et al. (2003)]. Indeed, the current research suggests that future design engineers will indeed be called upon to use *both* competencies, depending on which is more appropriate at the time. This point is well illustrated by the case study of innovative Formula One designer Gordon Murray (Cross and Clayburn-Cross, 1996). When seeking to circumvent newly introduced restrictions from the sport's governing body, Murray noted that his initial idea came as 'sudden illumination' (p. 94) and was then subsequently developed systematically – an example of intuitive and methodical approaches working in harmony.

The one remaining competency in the 10 most critical, and the least critical of these 10, is *uses appropriate communication formats*. Furthermore, competencies such as *communicates clearly*, *attends to detail when communicating*, and *empathises with audience* were rated as considerably less critical than many others in the final profile. This is somewhat in conflict with Busby's (2001) work on distributed cognition that suggested the interpretations and assumptions that people bring to bear on the information they communicate are important determinants of errors in the design process. An explanation for these discrepant findings may lie in the different methodologies adopted by these two studies. Although both examined critical incidents, Busby's study focused on *errors*, whereas the current study focused on *successful* *achievement of objectives*. Perhaps then, although such communication skills are necessary for avoiding errors, the avoidance of such errors does not in itself necessarily enable high performance. Similarly, the increasing routinisation of design engineering work, through the use of quality control procedures to manage key 'gateway' decisions as projects move from one phase of the design process to another, may reduce both the likelihood and centrality of error to effective performance.

Comparing the results of different competency analysis studies at a detailed level is a difficult task. Different taxonomies and methods of clustering indicators serve to make a precise competency-by-competency analysis impossible. Furthermore, one study's definition of the magnitude of a competency may be of a more micro or macro level than another's. Despite such difficulties, it is still possible to compare these competencies with the *themes* to emerge from the Plonka et al. (1994) and Rifkin et al. (1999) studies of the future competency requirements of related technical roles. Common themes to emerge included planning, technical skills and knowledge, communication, and working with others. In terms of those competencies identified by previous research as important for *current* technical roles (Duncan, 1991; Turley and Bieman, 1995; Leiper and Khan, 1999; Edum-Fotwe and McCaffer, 2000), all nine competency themes are well represented within the 42 competencies identified here. Furthermore, of the 10 most important competencies identified here, all except one, *thinks intuitively*, are represented in these nine themes.

The competency life cycle analysis of the questionnaire data also supports the notion of a change in the nature of design engineering towards greater levels of project management. Technical ability was found to be a core competency and highly important to design engineering in both the present and the future. Although ranked as the most important present competency, it was only the sixth most important future competency. This change in ranking was largely as a result of the emerging nature of several other highly important non-technical competencies such as time management and concise communication. Indeed, if one considers the other most important emerging competencies, such as planning and measuring work, commercial awareness, presentation skills, innovation, organisation, direction of others, and composure, it is clear that most are of a non-technical nature. Furthermore, if one considers the other competencies that are highly related to technical engineering work, such as problem solving, intelligence, ability to learn, accuracy, pictorial communication, visualisation, and ability to synthesise, all are classified as core competencies.

The forecasted increasing importance of innovation was in line with predictions and is also in agreement with previous research (Steiner, 1998; Stoffel, 2000; Donofrio, 2001; Tucker, 2002). Conversely, creativity was found to be a maturing competency, also in line with predictions. As discussed in the introduction, it seems likely that this is due to the increasing need for incremental innovation, and the decreasing need for radical innovation in the industry studied. The former type is likely to draw inspiration from technologies in different fields, whereas radical innovation, involving paradigm shifts, is more likely to be based upon completely novel thought, and hence creativity.

Despite its emerging nature, however, innovation was only rated as the 17th most important future competency. When news of this result was relayed to design engineers during the CIT interview process, many expressed surprise at this relatively low rating. Unfortunately, and as a direct result of this relatively low rating, the competency was not selected for subsequent interview exploration. Consequently, it is only possible to speculate about the underlying reasons for this finding.

Discussions during the validation workshop with those working within the company's design engineering function suggested a possible explanation. Although innovation is seen as essential to the company, it is felt that only a small proportion of highly innovative design engineers are required in order to invent new technologies. Indeed, the case studies of highly innovative individuals such as Formula One designer Gordon Murray (Cross and Clayburn-Cross, 1996) and racing bicycle designer Mike Burrows (Candy and Edmonds, 1996) support this notion, suggesting that such people are very much the exception, rather than the norm. In both of these cases, the initial innovative ideas themselves – hydropneumatic suspension and monocoque frames, respectively – were generated *solely* by these exceptional individuals. Furthermore, both of these design engineers were the *primary* champions of their ideas, successfully defending them against the controversy and initial prohibition they encountered. Such innovation then, although important, may only be required by a select few individuals.

Indeed, it may even be *detrimental* to have too many highly innovative individuals. Those attending the validation workshop suggested that the vast majority of design engineers needed to be methodical and process-driven – competencies that are often in conflict with those found in highly innovative, or creative, individuals. Baird et al's (2000) ethnographic study of design engineers supports this latter point: they found there to be '…a tension between doing detailed formal planning and doing creative work' (p. 342).

Indeed, there is also empirical support for such a theory. Highly innovative people have been found to dislike both a structured working environment and a highly methodical or planned approach to work (Patterson, 2000). Clearly then, such innovative individuals may not demonstrate some of the other competencies that this research revealed to be important to the design engineering process, such as *plans work* – the most critical future competency to emerge from the CIT interviews. The case study research discussed above partially supports this theory, but also suggests that the situation may be more complex than this. Although they may adopt an unstructured approach when designing, such innovative individuals are often highly organised when performing other aspects of their job (Cross and Clayburn-Cross, 1996). Clearly then, further research examining this issue is required.

Finally, we believe that the current research has also demonstrated how methodological modifications can serve to address many of the frequent criticisms of competency-based approaches (Illes, 2001). First, we adopted a broader definition of the term competency than most previous research, thereby eliminating much of the conceptual ambiguity often present in this field. This also enabled the incorporation of both task-oriented *and* people-oriented competencies within our profile, thereby increasing its efficacy and applicability. Second, we adopted a future-focused methodology, thereby ensuring that our competency profile would have longevity, unlike most others. Finally, by using a business framework through which to identify competencies, we ensured that the resultant profile was sufficiently detailed and organisation-specific: a considerable advantage over traditional generic competency profiles.

4 Conclusion

The present study sought to identify a competency profile for future design engineers. Forty-two competencies were identified, divided into the following six competency groups (in descending order of criticality): personal attributes, project management, cognitive strategies, cognitive abilities, technical ability, and communication. Furthermore, there is evidence to suggest that the future design engineering role may be changing. Although technical competencies are forecast to remain equally important in the future, their *relative* importance is set to decline as a consequence of the emerging importance of non-technical competencies. Two competencies of particular interest, namely innovation and creativity, were forecast to increase and decrease in importance, respectively. Such forecasted changes were felt to reflect the increasing need for incremental innovation at the expense of radical innovation, in the industry studied.

Appendix I. The Critical Incident Technique line of questioning used in Phase 3

1. Can you think of an occasion when you, or a colleague, demonstrated [insert competency name here] leading to an objective being met?
2. What were the circumstances leading up to this example?
3. Describe exactly what was said and/or done that makes this a noteworthy example of good performance.
4. What were the consequences of these words and/or actions?

Note: The above is adapted from Kandola and Pearn (1992), and Pearn and Kandola (1993).

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