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# THE DEVELOPMENT AND PILOTING OF A NOVEL METHODOLOGY FOR DETERMINING HOW DESIGNERS SPEND THEIR WORKING TIME

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## 1 Introduction

This paper introduces a highly effective methodology for exploring: (a) the variety of different activities that designers perform, (b) the proportion of their working time that each of these activities accounts for, and (c) designers' perceptions of these activities. The methodology is novel as it draws upon research in occupational psychology and also employs a technology-based technique for collecting data. The data analysis process is illustrated with reference to data from a pilot study conducted with designers working in Rolls-Royce – a large multi-national engineering organisation.

Little previous research has investigated how designers spend their working time; that which has done so has been somewhat methodologically limited. By addressing such omissions, the methodology described in this paper therefore makes an important contribution to the design engineering literature.

## 2 Review of previous research

### 2.1 The designer's role: previous research

The role of the designer is one of crucial importance to organisations working within the product development sphere [1]. It has been demonstrated, for instance, that 80 to 90% of production costs are 'locked in' at the conceptual design stage [2]. It is therefore crucial for such organisations to be aware of the full range of activities that designers undertake and also how their working time is allocated among these. Traditional models of the engineering design process [3] have tended to focus exclusively on the technical aspects of the job. However, empirical research has revealed that such technical aspects are merely one facet, albeit an important one, of the design role. Some key studies in this area are now critically reviewed.

An intensive observation-based research methodology was used by Hales in 1993 [4] to study 27 designers working on a gasifier test rig. The results revealed that only 47% of their working time was spent engaged in what other researchers have termed the 'steps' of the design process [3]. The remaining 53% of their time was divided between five further activities of a less-technical or non-technical nature, namely: planning work, reviewing/reporting, cost estimating, information retrieval, social contact, and helping others.

Hales also reclassified the same data using a more extensive set of activity categories. This second analysis revealed that only 22% of working time was spent performing what other researchers have termed design-related techniques [3]. The remaining 78% of time was spent performing other communicating, working, and motivating activities, of which reviewing and reporting accounted for most time (22%). However, the stringent criteria employed in this study – only hours directly attributable to the design process were included, and management roles were excluded – probably underestimated the true extent of the non-technical aspects of designers' roles.

A further observation-based study of 13 designers was conducted in 1997 by Marsh [5]. However, the focus of this research was deliberately narrow; it only investigated the percentage of work time spent acquiring and disseminating information. This specialist remit only accounted for 33% of total work time, of which 12% was spent obtaining or being given information, 8% providing information, 4% in overhead activities related to information transfer, and the remaining 9% attending meetings. This same data was also reclassified in terms of the type of information that was being conveyed. This further analysis revealed that 11% was concerned with process-related information, 6% with product-related, 3% with resource-related, and 4% with miscellaneous information (time spent in meetings was excluded from this latter analysis). Marsh suggested that the remaining 67% of time was therefore available for designers to focus on 'design work'. However, this assertion requires testing; it seems likely that other 'non-design' activities would also intrude on this remaining time.

It should be noted that, in addition to their initial analyses, both Marsh and Hayes reclassified their data using a further set of activity categories. This is a useful technique in that it enables the same activities to be viewed from different perspectives, thereby building a more complete picture of the work being performed. However, in each case, only two different sets of activity categories were used and both analyses were conducted in isolation. The current methodology improves upon this situation through the use of *multi-level* activity categories. This concept is described in detail in section 3.2 of this paper. Essentially though, multi-level activity categories enable any given activity to be simultaneously categorised from multiple perspectives, thereby greatly increasing the detail of any analyses conducted.

Furthermore, both Hales and Marsh used observation-based methods. Although very intensive, observation-based methods do have disadvantages. First, being observed by another person is known to influence a person's behaviour, especially when such observation is perceived as evaluative [6], and such results may not therefore be representative of normal working conditions. Second, the method is very time-consuming and labour-intensive for the observer, thereby limiting the number of designers that can be studied at any one time. Third, many activities, especially those involving internal thought processes, are not always observable [7]. Although the observer can ask questions to circumvent this problem, this increases the disruptiveness of the method and makes it even more labour-intensive. To address these issues, the methodology described in this paper makes use of self-report measures from the designers themselves, thereby eliminating the need for an observer and its inherent problems.

Although a small amount of other research investigating how designers spend their working time has been conducted, it is either substantially out-dated [8], or employed subjective retrospective methodologies [9,10] thereby generating inaccurate estimates of work-time allocation. The studies by Hales and Marsh, described above, are by far the most intensive conducted in this field. However, both studies were conducted in the early to mid-1990s and the findings are therefore likely to be outdated. This is especially true in light of recent research suggesting that designers' jobs are changing rapidly; although technical aspects remain crucial, non-technical aspects such as project management are increasing in importance substantially [11]. There is therefore a clear requirement for an effective methodology to address this research issue and this paper responds to this need.

## 2.2 Designers' perceptions of their role: previous research

In addition to investigating the work activities that designers perform, the current methodology also enables designers' perceptions of these activities to be explored. Furthermore, the methodology enables data on such perceptions to be collected while designers are actually engaged in the activities, thereby ensuring greater accuracy.

There is a growing body of research exploring how designers perceive their role. One of the key themes of such research has been the distinction between the 'technical' and 'non-technical' aspects of the job. Indeed, from the research reviewed in section 2.1, it appears that non-technical (or less-technical) activities account for a substantial volume of designers' work time – more than 50% in some cases [4]. Furthermore, it seems that this trend is likely to continue; recent research has demonstrated that although technical aspects remain crucial, non-technical aspects, such as project management, are increasing in importance substantially [11].

There is evidence to suggest that not only are designers aware of this distinction between technical and non-technical work, but that the increasing importance of the latter is a source of tension. This was clearly demonstrated in an extensive study of the true nature of design engineering work conducted in the product development division of a large and successful high-technology company [12]. The designers that were interviewed distinguished between "real engineering" and "the rest of the job"; the latter being other aspects of their work that prevented them from undertaking "real engineering". Interestingly though, the researchers noted that not all designers agreed on what activities constituted "real engineering" and, furthermore, how a task is classified may depend on a designer's perspective. A similar perceptual dichotomy has been noted by other researchers who suggested technical activities occurred in "the object world", which they contrasted with "the social world" involving interaction with others [13]. The methodology introduced in this paper also provides a tool for building upon this existing qualitative research by enabling designers' perceptions of their role to be examined from a quantitative research perspective.

In order to identify the psychological factors likely to be related to designers' perceptions of their jobs, a review was conducted of the occupational psychology literature concerning the issue of 'job design' [14,15,16,17,19]. The job design literature was felt to be particularly appropriate to this issue as several such variables have been shown to be strongly related to both job motivation and job satisfaction [15,17]. From a review of this research, and that in the engineering field [12], six psychological variables were selected to be included in the methodology presented in this paper. These variables provide a framework through which to explore designers' perceptions of the activities they perform within their role. The six variables are, in no particular order: (1) Effectiveness[1] – how effectively designers believe that their work activities are being performed, (2) Enjoyment – how enjoyable they believe these activities to be, (3) Complexity – how complex they believe these activities to be, (4)

[1] Rolls-Royce's Company Specialist for Design Technology expressed a desire that the variables effectiveness and creativity should be included.

Autonomy – how much control they perceive they have over how these activities are performed, (5) Engineering content – to what extent they perceive that these activities constitute "real engineering", and (6) Creativity – how creative they perceive they are being while performing each activity.

# 3 Overview of methodological framework

## 3.1 Work sampling methodology: theoretical overview

The current methodology utilises a work-sampling approach. Work-sampling, or activity-sampling, is an established method for accurately estimating the proportion of time that people spend engaged in each of several different pre-defined work activities [20]. The basic method is outlined by Pape [21] and essentially involves identifying and recording the activity that people are performing at a number of randomly-occurring sampling-points. Here, the activity was identified and recorded by the designers themselves; however, an alternative approach is to have an observer do this. Once data has been collected from a sufficiently large number of sampling-points, it is then possible to mathematically estimate the percentage of work time that people are spending performing each activity by using Formula 1, below:

$$\textit{\% of work time performing activity A} = \frac{\textit{number of sampling-points at which activity A is recorded}}{\textit{total number of sampling-points}} \times 100\% \quad (1)$$

The greater the number of sampling-points that data is collected from, the more accurate the estimates of the time percentages will be. It is possible to mathematically determine the number of sampling-points required for a given accuracy level. The calculations themselves are relatively simple, but will not be described here as they require a basic appreciation of statistical theory – which is beyond the remit of this paper to provide. Interested readers should consult Pape [21] for the full process. Nevertheless, a detailed example shall now be provided to illustrate the process.

The methodology described in this paper was tested in a pilot study that is described in sections 4 and 5 of this paper. The pilot study, in turn, was the preliminary study for a main study to also be conducted in Rolls-Royce. From this main study, Rolls-Royce wished to be able to accurately estimate the percentage of time that their designers spend engaged in activities that account for as little as 15 minutes of their working day. This is equivalent to 3.13% of the typical 8-hour working day in Rolls-Royce. The researcher decided that an acceptably high level of accuracy would statistically equate to "+/- 10%, with 95% confidence" [21]. What this means, for example, is that if the results of the main study indicated that designers spend 20 minutes per day photocopying, then it can be stated, with a 95% confidence-level, that designers spend between 18 and 22 minutes per day photocopying.

To obtain this level of accuracy, for activities lasting as little as 15 minutes per day, it was calculated – using Pape's formulas [21] – that a total of 11909 sampling-points would be required. The implications of this, in turn, for the length of study required was then determined in relation to the limitations imposed by Rolls-Royce. First, they suggested that 100 designers would be able to participate in the main study, so a mean[2] of 119.09 sampling-points per designer would be required. Second, they stipulated that designers should not be

[2] The 'mean' is the mathematical average.

‘sampled’ more than once per hour, as this could prove disruptive. With an average 8-hour day, this permitted 8 sampling-points per day, or 40 sampling-points per week. A three-week study would therefore yield 120 sampling-points per designer, which exceeded the required 119.09 sampling-points. Therefore, by considering Rolls-Royce’s requirements, it was determined that 100 designers would need to participate in a three-week study, with 8 sampling-points per day, to deliver sufficiently accurate estimates of the percentage of time that they spend engaged in each activity.

Work-sampling methodology offers a number of important benefits over approaches that rely on designers’ memories [9], or subjective estimates [10] to determine how their working time is allocated between activities. First, data is collected in ‘real time’ – activities are identified and recorded as they occur. This ensures that an activity will be recorded no matter how short in duration, forgettable, or seemingly insignificant it may be. Second, as designers are not themselves required to estimate the percentage of time they spend engaged in different activities – because this can be mathematically inferred – the time-allocation estimates yielded are less prone to bias – conscious or otherwise – and are thus much more accurate.

## 3.2 Activity category generation: theoretical overview

The first phase of any work-sampling methodology is the generation of the ‘activity categories’. Once generated, they are then used in the subsequent work-sampling process [20]. At each sampling-point, designers are required to indicate which of the activity categories best describes the activity or task that they are currently performing.

When generating activity categories, there are certain guidelines to follow. Kirwan and Ainsworth [20] suggest that activity categories must be: (a) Distinguishable – It must be possible to distinguish each activity category from all others. (b) Clear – It must be clear what type of activity each category refers to. In the event that such clarity is not immediately obvious, clear working definitions should be provided. (c) Exhaustive – Between them, the categories should cover every conceivable activity that designers may be called upon to perform during the course of their work. (d) Mutually exclusive – It should only be possible for a given activity to be classified using one of the activity categories. In the event that activity categories contain multiple levels, the activity categories presented at each level should be mutually exclusive.

As noted in section 2.1 of this paper, a noteworthy advantage of the current methodology – when compared to previous methodologies – is that it employs *multi-level* activity categories. Multi-level activity categories refer to the process of categorising activities from multiple perspectives. For instance, a designer may be “working on his computer”; this is one perspective of his activity. From other equally valid perspectives however, (s)he could alternatively be viewed as “e-mailing”, or “communicating with his manager”, or “providing technical information”, for instance. Any work activity that a designer may perform can be classified from multiple perspectives. Furthermore, the multi-level categorisation used here enables the information from different levels of activity categories to be *combined*, thereby creating a highly detailed multi-level perspective of the activities that designers perform.

The multi-level approach employed by the current methodology drew upon research in occupational psychology [17,18] that suggests activities can be described from perspectives such as “what”, “why”, “how”, and even “whom”. The level of detail required for particular activities was carefully considered; some required a more detailed description than others and in some cases not all these levels were used.

# 4 Methodology

## 4.1 Use of Personal Digital Assistants (PDAs) to collect data

In order to promote greater understanding of this methodology, it is first necessary to briefly describe the data collection equipment. Designers were required to enter data concerning their activities into a Personal Digital Assistant (PDA) – a small hand-held computer. The particular PDA model used by this methodology is displayed in Figure 1 (shown actual size). Participating designers are each issued with a PDA which they are required to carry with them at all times. At random sampling-points each hour, the PDA emits an alarm (a silent 'vibrate' mode is also offered), whereupon the designers are required to answer several questions concerning the activity that they are currently performing. Several questions are related to the different levels of activity categories; the other questions are concerned with designers' perceptions of the activity. This process is explained in greater detail in sections 4.3, 4.4, and 4.5 of this paper. Participating designers are also issued with a 'cradle' – a small plastic bracket attached to a cable – in which to charge the PDA's battery overnight.

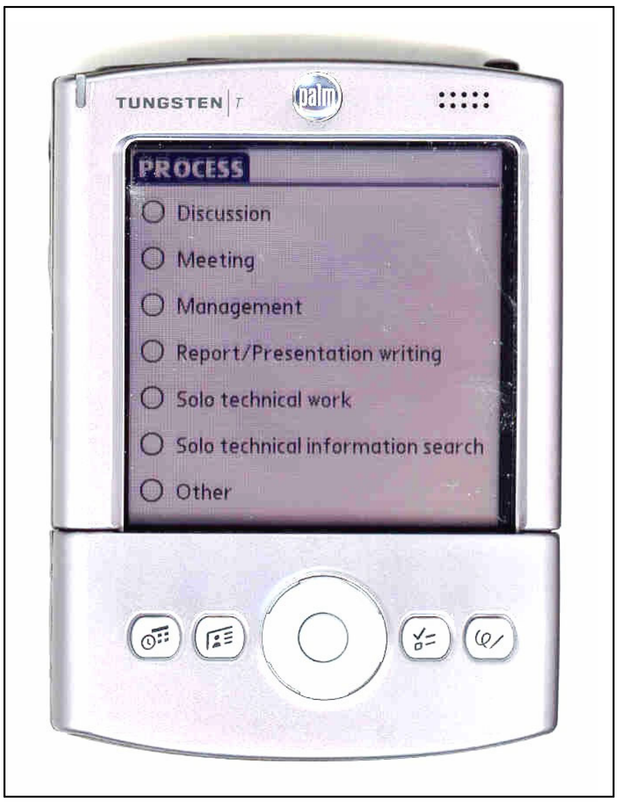


Figure 1. Personal Digital Assistant (PDA) used to collect data (shown actual size)

Several features of PDAs make them ideal for such data collection. First, an alarm is emitted at each sampling point, thereby ensuring that participants do not forget to enter data. Second, PDAs are extremely compact and lightweight and are therefore easily carried in a pocket. Finally, there is no need for designers to write anything; all data is entered into the PDA by 'tapping' the relevant responses on the screen with the integral plastic-tipped 'stylus'. This feature enables a large amount of data to be entered very quickly – essential for the regular sampling-points and long-duration studies that this methodology enables.

## 4.2 Activity category generation procedure

Initially, several sources of information concerning the working-time allocation and job content of designers were consulted. These sources included: (a) previous research on this topic [3,4,5,8,9,10,22,23], (b) transcripts of 27 critical incident technique (CIT) interviews examining designers' job content, also conducted in Rolls-Royce during previous research [11], and (c) Rolls-Royce documentation relating to designers' jobs, such as job descriptions and activity lists from work-booking systems. Each activity identified was written on a card and these cards were then sifted into a number of clusters by the researcher – an experienced job analyst. Each cluster was then labelled according to the underlying activity theme it represented.

Next, this initial list of activity themes was presented to a design expert – one of Rolls-Royce's senior design skill owners – for 'content validation'. The process of content validation, in this case, referred to establishing whether these activity themes accurately and comprehensively represented the true nature of the designer's role in Rolls-Royce [24]. As a result of this process, several categories were added, deleted, or amended until a refined list of content-valid 'activity categories' was established.

Following this, two of Rolls-Royce's designers were observed for a day each by the researcher, using a 'job-shadowing' approach. These designers were selected so as to provide different perspectives on the design-engineering role; one was a relatively junior designer, and the other had significant managerial responsibilities. A unit-sampling method was employed, such that a record was kept of every activity that the participant engaged in [7]. In the event that further information, or clarification, was required, the researcher was free to ask questions. Furthermore, both designers worked in open-plan offices alongside other designers, so it was also possible to periodically observe their colleagues – an additional note was also made of their activities. Throughout the entire observation process, each observed activity was classified using the refined list of activity categories. Following this observation exercise, several categories were either added or amended so that the list more accurately reflected the designer's role.

This latest version of the activity categories was then presented at Rolls-Royce's monthly Design Technology Working Group for further content validation. This meeting was attended by fifteen of Rolls-Royce's senior designers and design managers. Once again, their comments were used to amend the activity categories, where necessary, to more accurately reflect the content of the designer's role. Following this meeting, the updated version of the activity categories was presented and discussed extensively at one final meeting attended by Rolls-Royce's Head of Design Engineering, the Company Specialist for Design Technology, a senior Chief Design Engineer, and the researcher. Once again, some minor changes were made to the activity categories before the final set was agreed upon.

## 4.3 Activity category content

The final set of multi-level activity categories – that are used in the methodology under discussion – are shown in Table 1, relative to the PDA screens on which they are displayed. The four different mutually-exclusive routes through the various levels of activity categories are also displayed here. The streamlined presentation of the activity categories on the PDA

Table 1. Multi-level activity categories used by the methodology

| Route | PDA Screen | LEVEL 1 CATEGORIES | PDA Screen | LEVEL 2 CATEGORIES | PDA Screen | LEVEL 3 CATEGORIES | PDA Screen | LEVEL 4 CATEGORIES | PDA Screen | LEVEL 5 CATEGORIES | PDA Screen | LEVEL 6 CATEGORIES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ROUTE 1 | PDA Screen 1 | PROCESS<br>Discussion<br>Meeting<br>Management<br>Report / presentation writing | PDA Screen 2A | CONTENT<br>Technical<br>Programme<br>People<br>Facilities<br>Self<br>Other | PDA Screen 3A | PARTY<br>Manager<br>Reportee<br>Technical specialist<br>Within IPT<br>Across IPT<br>Customer – internal<br>Customer – external<br>Mixed group<br>No-one<br>Other | PDA Screen 4 | MANNER<br>Face-to-face<br>Telephone<br>Off-computer<br>On-computer:<br>Outlook (e-mail)<br>MS Word<br>MS Excel<br>MS PowerPoint<br>MS Project<br>CAD<br>PDM<br>SAP<br>Key System<br>SC03<br>Intranet<br>Internet<br>DRed<br>Other software | PDA Screen 5A | PURPOSE<br>Giving information<br>Receiving information<br>Seeking information<br>Answering question<br>Asking question<br>Conversing socially<br>Other | PDA Screen 6 | PROCESS<br>Capturing requirements<br>Managing requirements<br>Creating solutions<br>Capturing solutions<br>Analysing solutions<br>Understanding results<br>Planning<br>Monitoring<br>Cost estimating<br>Reviewing<br>Supervising<br>Other |
| ROUTE 2 | | Other | PDA Screen 2A | CONTENT<br>Technical<br>Programme<br>People<br>Facilities<br>Self<br>Other | PDA Screen 3B | ACTIVITY<br>Time booking<br>Arranging meetings<br>Arranging travel / accomm.<br>Travelling<br>Completing expenses claims<br>Photocopying<br>Filing<br>Checking e-mails<br>Other – administration<br>Breaks & personal interruptions<br>Training/development/education<br>Other | | | | | | |
| ROUTE 3 | | Solo technical work | Screen 2B | ACTIVITY<br>Data entry<br>Creating geometry<br>Conducting analysis<br>Other | | NOT APPLICABLE: SCREEN IS BYPASSED | | | | NOT APPLICABLE: SCREEN IS BYPASSED | | |
| ROUTE 4 | | Solo technical information search | PDA Screen 2C | CONTENT<br>Internal – current project<br>Internal – previous project<br>Internal – process<br>Internal – other<br>External – patent application<br>External – engineering literature<br>External – other | | NOT APPLICABLE: SCREEN IS BYPASSED | | | | NOT APPLICABLE: SCREEN IS BYPASSED | | |

Notes:

1.) PDA Screen 1 contains all the responses “discussion” to “solo technical information search” inclusive; the dashed lines are displayed merely to delineate subsequent routes.
2.) There are six different Levels of Activity Categories; these are displayed above each column. Levels 1, 4, and 6 are represented by one PDA Screen in each case: PDA Screen 1, PDA screen 4, and PDA Screen 6, respectively. Level 2 is represented by 3 PDA Screens (2A, 2B, 2C); Level 3 is represented by 3 PDA Screens (3A, 3B, “not applicable”); Level 5 is represented by 2 PDA Screens (5A, “not applicable”).
3.) There are four possible routes through the PDA Screens; these are indicated to the left of each row. Progression through each route of PDA Screens is horizontal, from left to right, as indicated by the arrows.
4.) On the PDA itself, the response “other” is displayed last on PDA Screen 1. It is only displayed fifth here to more easily illustrate the subsequent PDA Screens encountered via this route.

screens was influenced somewhat by an existing tool that Rolls-Royce was using to analyse engineering processes, called Process Engineering Language [25,26]. Several key features of the activity categories will now be discussed.

When the PDA alarm is emitted, the first screen that appears is PDA Screen 1, which displays the Level 1 Activity Categories. If the designer selects one of the Activity Categories "discussion", "meeting", "management", or "report / presentation writing", then (s)he is directed along Route 1. Route 1 involves the consecutive presentation of Activity Category Levels 1, 2, 3, 4, 5, and 6 – via PDA Screens 1, 2A, 3A, 4, 5A, and 6, respectively. If the designer selects the response "Other" from the Level 1 Activity Categories on PDA Screen 1, then (s)he is directed along Route 2. Route 2 is identical to Route 1 except that, when the Level 3 Activity Categories are reached, PDA Screen 3B is presented instead of PDA Screen 3A. This occurs because it was decided that due to the nature of the Activity Categories displayed on PDA Screen 3B – e.g. photocopying, filing, travelling – it was not necessary to explore these in as much detail as categories such as discussions, meetings, management, or report / presentation writing.

If the designer selects either "solo technical work" or "solo technical information search" from the Level 1 Activity Categories when PDA Screen 1 is displayed, then (s)he is directed along Route 3 or Route 4, respectively. For each of these two Routes, only Activity Category Levels 1, 2, 4, and 6 are presented – via PDA Screens 1, 2B/2C, 4, and 6, respectively. This occurs because it was decided that due to the "solo" nature of both of these Level 1 Activity Categories, it was not necessary to present Level 3 Activity Categories as these were primarily concerned with the question of "whom" the activity was been conducted with. Similarly, it was not necessary to present Level 5 Activity Categories on either of these two Routes, because the "purpose" of each activity – with regard to information transfer – could be logically inferred: "solo technical work" serves to "create information", while "solo technical information search" is concerned with "seeking information".

From the above discussions, the multi-level nature of the activity categories should be clear. Furthermore, it should be noted that the activity categories used by this methodology attempt to reduce redundancy by only presenting those activity categories that are relevant.

Every effort was made to ensure that the activity categories were as clear and understandable as possible. However, in the interests of efficiency and parsimony, the number of activity categories had to be restricted somewhat. For this reason, it was necessary to provide 'working definitions' for some activity categories, as shown in Table 2. Those activities for which definitions are not provided are assumed to be sufficiently self-explanatory. To ensure familiarity with the definitions, designers attend a briefing session prior to participating. Furthermore, they are also provided with a small reference booklet of key definitions to carry alongside the PDA.

## 4.4 Questions assessing designers' perceptions

At each sampling-point, once the designer has finished entering responses related to the various activity category levels, the PDA then displays – in turn, on different screens – six questions concerning the designer's perceptions of the activity (s)he is currently performing. The same six questions are displayed at every sampling-point, irrespective of previous responses, they are: (1) How effectively is this task being performed? (2) How enjoyable is this task? (3) How complex is this task? (4) How much control do you have over how you perform this task? (5) How much engineering is involved in this task? (6) How creative are

Table 2. Activity category definitions

| |
|---|
| **PDA SCREEN 1**<br>**Discussion** = A discussion that you had not pre-planned or scheduled. / **Meeting** = A discussion that both you and another party had pre-planned or scheduled. / **Management** = (In addition to the management of people or other resources, this also includes self-management, such as planning your daily tasks.) If you are a manager and are having a discussion with your reportee that is *within the remit* of your managerial relationship, and it was neither pre-planned nor scheduled, then you would categorise such a discussion as "management". If you are the reportee however, you would classify the same discussion as "discussion". / **Report / presentation writing** = Self-explanatory. / **Solo technical work** = Work performed alone that is of a technical engineering nature. / **Solo technical information search** = Work performed alone that involves seeking information related to work of a technical engineering nature. / **Other** = Any other tasks that do not fit into one of the above six categories. |
| **PDA SCREEN 2A**<br>**Technical** = Concerning work of a technical engineering nature. / **Programme** = Concerning work related to your programme, except work of a technical engineering nature which should be categorised as "technical". / **People** = Concerning people you work with, both Rolls-Royce employees and those outside the company. / **Facilities** = Concerning the physical environment in which you and others work (e.g. office furniture and computer hardware)./ **Self** = Concerning your own work, job, or career. / **Other** = Any other content that does not fit into one of the above five categories. |
| **PDA SCREEN 2B**<br>**Data entry** = The entry of data that is related to work of a technical engineering nature. / **Creating geometry** = The creation of geometry that is related to work of a technical engineering nature./ **Conducting analysis** = The conducting of mathematical analysis that is related to work of a technical engineering nature. / **Other** = Any other work that does not fit into one of the above three categories. |
| **PDA SCREEN 2C**<br>**Internal** = Information originating inside Rolls-Royce. / **External** = Information originating outside Rolls-Royce. / Other responses are self-explanatory. |
| **PDA SCREEN 3A**<br>**Technical specialist** = A person you approach for advice or assistance concerning work of a technical engineering nature. If this is the purpose of your interaction, you should select this response, regardless of the nature of the professional relationship between you and the other party. / **Within IPT** = Interaction with a person within the same IPT* you work in. / **Across IPT** = Interaction with a person in a different IPT from the one you work in. [If you are a member of more than one IPT, please respond in relation to the IPT that is most relevant at that particular data point.] / **Internal** = Within Rolls-Royce. / **External** = Outside Rolls-Royce. / Other responses are self-explanatory. / (* IPT = Integrated Product Team) |
| **PDA SCREEN 3B**<br>**Checking e-mails** = The brief reading, filing, and deleting of e-mails. However, if you stop to read a particular e-mail in detail, or reply to it, this would then be classified as a "discussion" (on-computer) – see Screen 1. / Other responses are self-explanatory. |
| **PDA SCREEN 5A**<br>**General note** = You should indicate what the purpose of your activity had been at the *precise moment* that the PDA alarm sounded. For example, if, during a conversation, you had been asking a question when the PDA alarm sounded, then you would respond "asking question". This would be true *even* if the *overall purpose* of the conversation had been for you to *answer* the question of another person. We are interested in what is happening at that *precise point*. / **Giving information** = Giving information to someone who has not requested it. If you are giving information to someone who has requested it, then you would respond "answering question" instead. / **Seeking information** = This is the equivalent of "asking question" in situations where you are not interacting with other people (for example, seeking information from a computer database, rather than a colleague). **Answering question =** As well as referring to the process of answering a question, you should also indicate you are answering a question if you are being asked a question when the alarm sounds. / **Conversing socially** = If your interaction is purely social, you should select this response, regardless of the purpose of the conversation. / Other responses are self-explanatory. |
| **PDA SCREEN 6**<br>**General note** = The first six responses ("capturing requirements" to "understanding results", inclusive) refer to work of a technical engineering nature only. / **Reviewing** = Reviewing work that has already been completed. / **Supervising** = Monitoring work as it is performed. / Other responses are self-explanatory. |

you being in this task? These six questions measure the variables effectiveness, enjoyment, complexity, autonomy, engineering content, and creativity, respectively. The designer is required to indicate his/her response, to each question, on a five-point scale. For the questions concerning effectiveness, enjoyment, complexity, and creativity, the five responses listed are: "not at all", "a little", "moderately", "a lot", "extremely". For the questions concerning autonomy and engineering, the five responses are: "none at all", "a little", "a moderate amount", "a lot", "a great deal".

## 4.5 Data collection process

Each designer is issued with a PDA, as described in section 4.1, which they are required to carry with them at all times. The PDAs are programmed to emit an alarm at intervals determined by a variation of 'stratified non-continuous random sampling' [21]. This sampling method requires the day to be divided into a number of layers, or 'strata'. In Rolls-Royce, most of the designers worked eight hours per day; it was therefore convenient to divide the day into eight strata of one hour each. The 'random' nature of this form of sampling stems from the fact that a random alarm is emitted within each of these strata. So, for instance, if a designer's working day occurs between the hours of 08:00 and 16:00, then a random alarm would be emitted within each of these hourly strata, for example: 08:47, 09:05, 10:14 etc.

Prior to participating, each designer is also required to complete a brief questionnaire concerning their job position and employment history within Rolls-Royce. More specifically, the questionnaire asks designers to provide their identification number, length of tenure, job title, job grade, business unit/project, the design stage they work in, and their geographical location. This information is entirely confidential – only the researcher has access to it, and designers are assured of this – and is only used to conduct anonymous analyses.

# 5 Pilot study results

## 5.1 Participants

The methodology introduced in this paper was first tested in a pilot study. The ten participants were all designers working in Rolls-Royce – a large multi-national manufacturing engineering organisation. The designers were selected such that their departments and projects represented the diversity of design roles within Rolls-Royce. All designers were working in relatively junior, non-managerial, grades. It had been decided not to include more senior designers in the pilot study, as it was felt that any technical 'teething problems' would be more disruptive to their work.

## 5.2 Data volume

Each designer participated for five working days. Their PDAs were scheduled to emit eight alarms per day during this period. Unfortunately, due to unforeseen technical difficulties that have since been resolved, the PDA alarm feature did not work as effectively as planned. Consequently, a reduced total of 229 alarms were emitted, across all 10 PDAs, during the course of the pilot study. Designers failed to respond to 15 of these 229 alarms, leaving a total of 214 complete sampling-points. This represents 26.75 complete working days of data.

Such a volume of data is insufficient to yield meaningful empirical findings; a far greater volume of sampling-points would have been required for this purpose, as explained in section 3.1. This was never the purpose of the pilot study however – it was conducted to test the effectiveness and robustness of the methodology. Nevertheless, the volume of data obtained is perfectly adequate for demonstrating the type of data analysis that it is possible to conduct when this methodology is used, as shown in section 5.3.

## 5.3 Data analysis

Several examples of the empirical results obtained from the pilot study will now be presented in order to illustrate the type and level of data analysis that this methodology enables. One considerable benefit of the multi-level nature of the activity categories used here is the detailed level of analysis that they enable. This detail results from combining different levels of the activity categories – analogous to the section in a Venn diagram where two or more circles overlap. This is illustrated in Figures 2, 3, and 4, below.

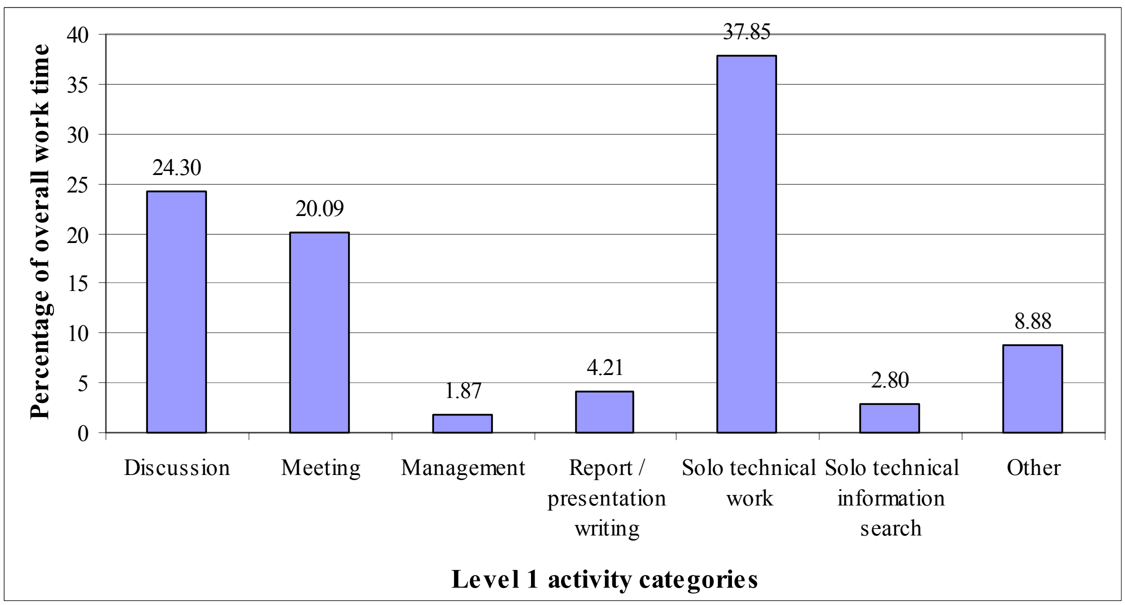


Figure 2. Percentage of overall work time that designers spent engaged in the Level 1 activities (pilot study data)

From Figure 2, it can be seen that – from the perspective of the Level 1 activity categories from PDA screen 1 – designers spent 37.85% of their overall working time engaged in 'solo technical work'. As explained, however, the multi-level nature of the activity categories enables this finding to be explored in much greater detail. Figure 3, for instance, shows the results of analysis that focused solely on this 37.85% of time spent engaged in 'solo technical work'.

From Figure 3, it can be seen that designers spent 51.85% of this 'solo technical work' time 'creating geometry'. Alternatively, if one wished to know the percentage of designers' *overall* work time that this accounted for, then this figure can be obtained through a simple calculation: 51.85% of 37.85% is 19.63%, so designers spent 19.63% of their overall work time engaged in 'solo technical work' that involved 'creating geometry'. This level of detailed analysis can be increased further by combining still more levels of the activity categories. Figure 4, for instance, illustrates how the 19.63% of overall work time – that designers spent engaged in ‘solo technical work’ that involved ‘creating geometry – was distributed among different software usage.

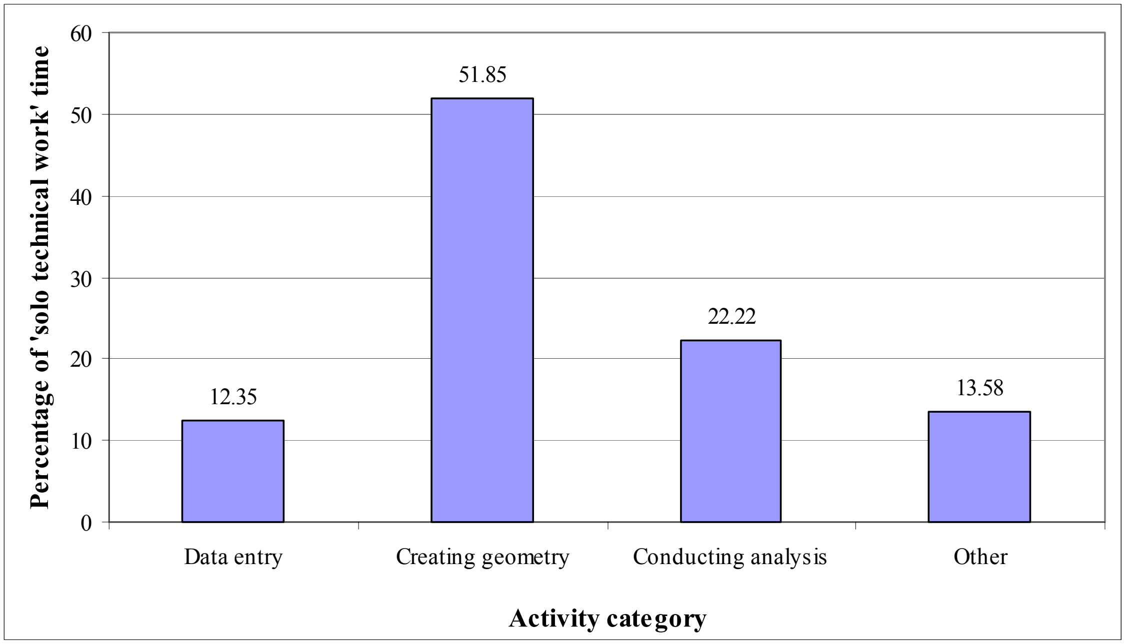


Figure 3. Percentage of ‘solo technical work’ time that designers spent engaged in various activities (pilot study data)

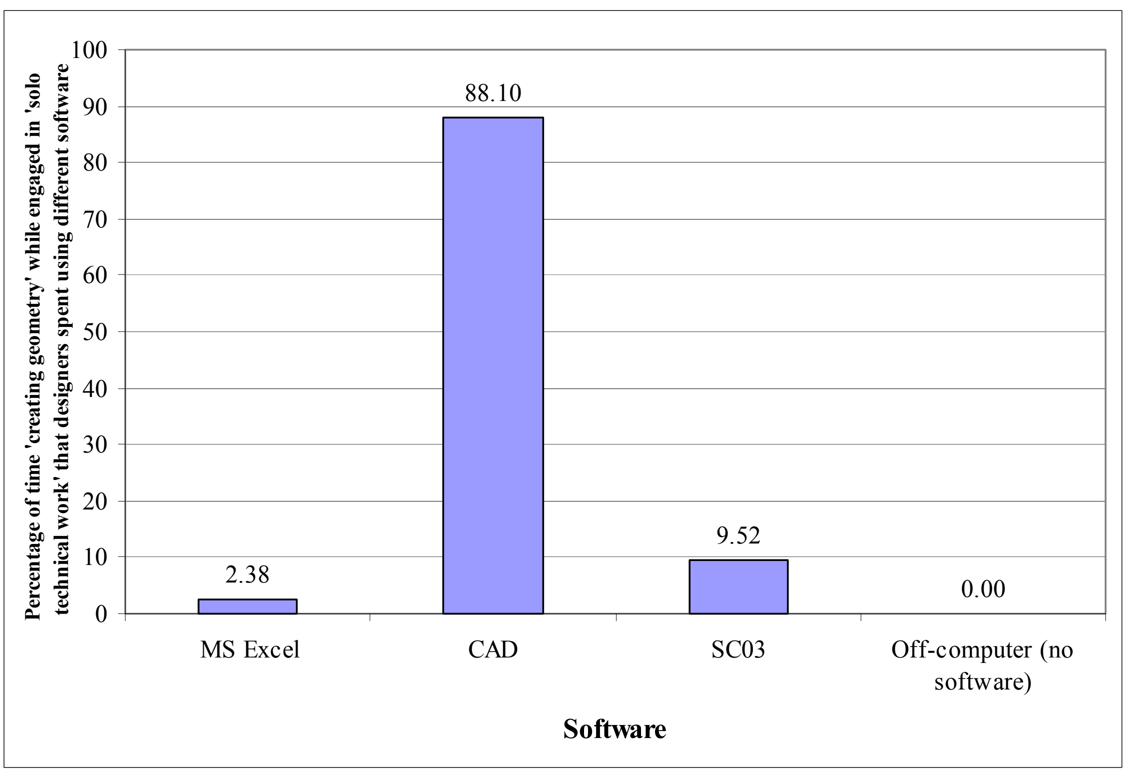


Figure 4. Percentage of time ‘creating geometry’ while engaged in ‘solo technical work’ that designers spent using different software (pilot study data)

From Figure 4, it can be seen that 88.10% of the time – that designers spent ‘creating geometry’ while engaged in ‘solo technical work’ – was spent using CAD software. Once again, if one wishes to know the percentage of *overall* work time that this accounts for, then this figure can be obtained through a simple calculation: 88.10% of 19.63% is 17.29%, so 17.29% of designers’ overall work time was spent ‘creating geometry’ while engaged in ‘solo technical work’ using ‘CAD software’. Still further levels of detail could be obtained by combining other levels of activity categories. Alternatively, the data that designers provided about their job roles could also be included to determine, for example, whether such time percentages differed between designers working at different stages of the product life cycle.

The other main feature of the methodology is that it also collects data concerning designers’ perceptions of such activities. Once again, this data can be combined with the activity data to yield very detailed results. To illustrate this simply, Figure 5 shows designers’ mean[3] enjoyment ratings of the Level 1 activity categories from PDA Screen 1.

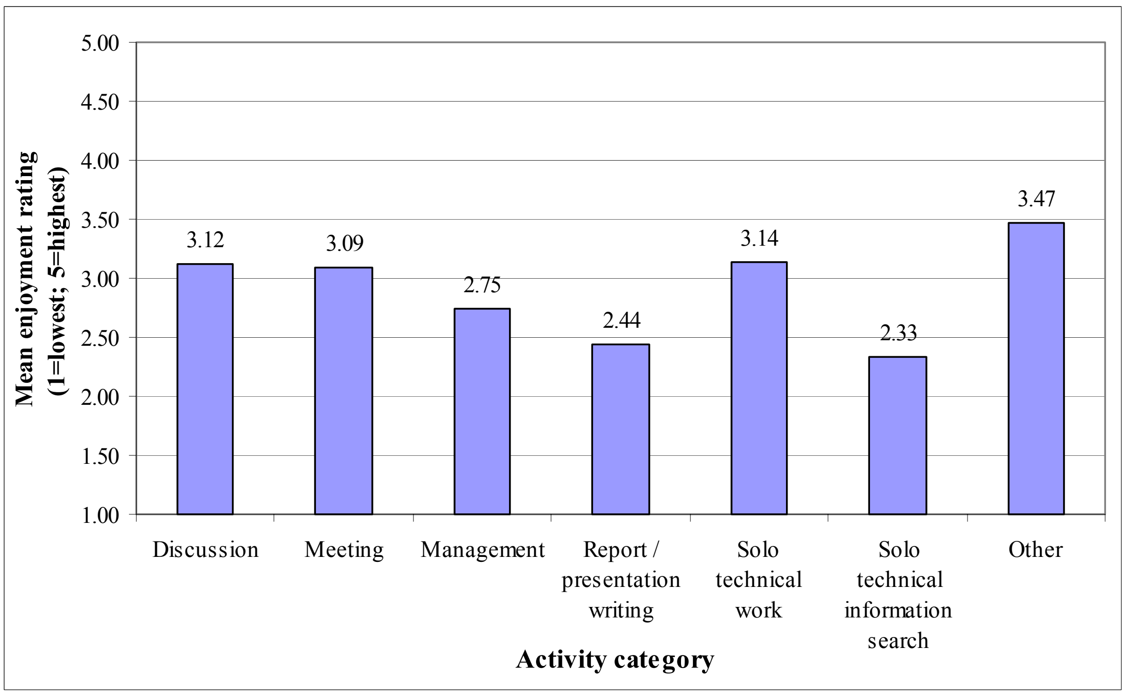


Figure 5. Designers’ mean enjoyment ratings of the Level 1 activities (pilot study data)

# 6 Conclusion

This paper has introduced a highly effective and novel methodology for exploring: (a) the variety of different activities that designers perform, (b) the proportion of their working time that each of these activities accounts for, and (c) designers’ perceptions of these activities. Three features of the methodology are of particular value and should be carefully noted. First, the multi-level activity categories enable work activities to be simultaneously viewed from multiple perspectives. This, in turn, enables extremely detailed analyses to be conducted – far more so than is possible with existing methodologies. Second, the novel use of PDAs enables data collection to occur in ‘real time’, i.e. while designers are actually engaged in the

[3] The ‘mean’ is the mathematical average.

activities that they are categorising. This ensures that the data obtained is incredibly accurate. Finally, the methodology also enables an exploration of designers' perceptions of these activities – from data that is also obtained in 'real time' – thereby illuminating this highly topical and important research area.

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