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DEVELOPMENT OF A DESIGN AUDIT TOOL FOR SMEs

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DEVELOPMENT OF A DESIGN AUDIT TOOL FOR SMEs

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EXTENDED ABSTRACT

There is strong evidence of the importance of good design to company success. However, it is apparent that despite this evidence, design skills are often marginalised in Small and Medium Sized Enterprises (SMEs). This article presents a design audit tool that captures 'good design' principles in a form accessible to industry. Previous audit approaches have focused extensively on the management of new product development (NPD). In this research, the audit tool is based on process maturity principles and explicitly targets the design related activities in NPD; specifically in small firms.

The design audit has been developed iteratively by application in action research mode and is supported by evidence from literature and exploratory cases. This inductive development enabled the generation of a robust audit tool through intervention in small firms to improve design practices.

The resulting audit tool is designed for use in a multi-functional workshop setting. Typical outputs from application include the generation of action plans for improvement in future performance. This audit tool is based around a model of good design that explicitly distinguishes between management and design related activities in NPD. The audit tool has succeeded in encouraging managers to pay greater attention to the design related elements of NPD. This complements the satisfaction of managerial goals typically emphasised in many NPD processes.

DEVELOPMENT OF A DESIGN AUDIT TOOL FOR SMEs

This article reports on research which aimed to understand product development challenges in Small and Medium sized Enterprises (SMEs) and to develop an approach to helping firms overcome these challenges. The primary output is a novel design audit tool, developed iteratively through application in action research mode. This article reports specifically on the development of this audit tool which targets the design process. However, this research also resulted in a tool aimed at assessing the design of products.

Effective product design is essential both to ongoing business success and the national economy as a whole [83, 62]. High quality product design can provide distinctiveness, can reinvigorate products in mature markets and can communicate value to the consumer. Kotler & Rath [47] suggests that "well designed products can provide high levels of satisfaction for target customers through an appropriate blend of the major elements of the design mix". The value of 'good design' in improving competitiveness has been established in many studies. In a review of 60 small engineering firms, Black & Baker [6] determined that firms with a strong 'design orientation' also exhibited high growth. Walsh et al [95] identified a generally positive relationship between 'design consciousness' and commercial success (profit margin) in small firms. In a follow up study of SMEs [78], it was concluded that growing firms used more external design expertise, had a more positive attitude towards product design and were more innovative. In 2001, Hertenstein et al [43] reported a five year study of 51 companies across 4 sectors, concluding that the firms regarded as exhibiting 'good design' were stronger along all measure of business performance. Gemser [35] studied the specific role of industrial design in 20 SMEs and identified a positive relationship between industrial design involvement and company performance, which may be moderated by the industry environment and the pervading competitive strategies. Collectively, these studies provide compelling evidence on the importance of a strong design orientation for company success – especially in small firms.

Further evidence can be found in a wide range of articles from well respected commentators and academics. Zentner [99] for example claims that clear product differentiation through effective design can provide significant commercial advantage. Lorenz [53] supports this view, adding that conventional means of differentiation (cost and quality) are now 'entry tickets' – design is now the key to producing meaningful distinction; not just shape and appearance, but character. Harkins [42] goes further, to suggest that design is emerging as the leading key to product development success.

Marginalisation of good design practices (in SMEs)

There is both theoretical and anecdotal evidence that good design is a critical contributor to business success. However, there is also evidence that many small companies fail to take advantage of these benefits [e.g. 11, 28]. In 1985, Walsh noted that "product design is a crucial, but often neglected and misunderstood activity (in SMEs)" [94]. Similarly, others have pointed towards 'design illiteracy' as a characteristic of inward looking organisations, with internally sourced market information and an over-emphasis on engineering at the expense of ease of use and visual appeal [10, 47]. More recently, Mynott [62] noted that managers in UK firms have "surprisingly low awareness" of the importance of what is possible through good design.

A symptom of design marginalisation is the completion of design activities by people who have no design training or aptitude; defined by Gorb & Dumas [38] as "silent design". They claimed that silent design pervades British industry to the detriment of the quality, usability and desirability of products. Norman [65] also noted that "most design is not done by designers, it is done by engineers, programmers and managers". It is specifically those activities traditionally associated with industrial design specialists which are marginalised as they are "seen by many firms as tasks that can be done by anybody with a modicum of common sense" [60].

A possible explanation for this design marginalisation is resistance from senior managers towards design, based on unfounded prejudices and tradition bound behaviour [11, 47]. Alternatively, these prejudices may be the result of previous experiences, where designers have produced inappropriate solutions [80].

Product development research has generally focused on the larger firm and ther is a "paucity of studies on how SMEs can incorporate the principles and practices of innovation" [56]. Small firms must adopt different approaches to managing product development to larger organisations [15, 44]. For example, small firms face significant financial and human resource limitations [11, 53]. Furthermore, staff may lack the skills of their large company counterparts [79] and multi-functional teamwork may be inhibited by 'deeply embedded tribal hostilities' and resentment between designers, engineers and marketers [24, 60]. Finally, the perceived costs of employing specialist design skills are often perceived as prohibitive [47] and despite the lack of internal skills, they are reluctant to look outside for help [79].

Aims of this research

There is clear evidence of the importance of design in small firms. However, there is also a strong indication that effective design practices are marginalised in such organisations. This research aimed to address this important need, through the development of an audit tool to enable the assessment and improvement of design practices in small firms. This goal is consistent with the findings of a DTI and EPSRC sponsored study in 1999, entitled "Future Issues in Design Research" which concluded that the priority for the short, medium and long term (for design research) is improvement in the quality of design [27].

This article describes the development of this audit tool. First, there is a comprehensive review of existing approaches to assessing the performance of New Product Development (NPD), to identify a clear gap for an audit approach targeted at ***design*** as part of the wider NPD process. Having clarified a gap in extant work, the research approach is then described. Literature supporting the development of an audit tool is next reviewed, followed by an overview of an exploratory study exploring the specific challenges of managing and executing design in small firms. Insights from exploratory cases and literature were combined to inform the creation of the audit tool, which is next described in detail, before providing examples of application in four cases. Finally, the implications for theory and practice are discussed.

APPROACHES TO ASSESSING DESIGN & DEVELOPMENT PRACTICES

Process audits are allied to general process improvement methods, which rely upon measurement as a basis for establishing current status. Quantitative measurement is appropriate when the relationship between inputs and outputs is known or can be modelled and parameters can be modified accordingly [46]. Benchmarking (typically) has the advantage of relying upon objective and quantitative data, such as sales figures etc.

However, measurement alone is not appropriate for developing a deep understanding about the way in which processes are performed and does not lead directly to improvement in performance [46]. Chiesa et al [16] suggested that "auditing goes beyond measuring: it builds on this to identify gaps between current and desired performance, and to provide information that can be used in developing action plans to improve performance". The European Foundation for Quality Management (EFQM) defines a self-assessment audit as:

> *"a comprehensive and systematic review of an organisations activities and results referenced against a model of business excellence. It allows the organisation to discern clearly its strengths and areas in which improvements can be made and culminates in planned improvement actions which can be monitored for progress." [92]*

Thus, measurement is appropriate for benchmarking current performance and comparing performance across projects and organisations. Auditing however aims to generate insights which lead towards improvement [92].

The simplest means of assessing an attribute or characteristic of a process is with a binary 'yes/no' response (figure 1 scale #1). However, this binary response provides little genuine information about 'good practice' and offers little granularity when scoring. It is also highly subjective and responses are open to an extremely wide degree of interpretation.

An alternative is to provide a Likert type scale, where the issue is posed as a positive (or negative) statement and participants score the extent to which they agree or disagree (figure 1 scale #2). Whilst providing greater granularity, the Likert scale still provides little insight into what might constitute 'good-practices'.

A third alternative is to adapt the Likert style questionnaire, to provide anchored phrases, describing performance at each end of the scale (figure 1 scale #3) [e.g. 41]. This has the advantage of providing greater insight into the potential extremes of performance. However, the transition from low to high performance is not necessarily linear and thus, the scale provides little additional insight into what the intervening points might mean or how a firm might migrate to the higher levels.

The process maturity principle extends the anchored scale with descriptions at a number of points along the scale (figure 1 scale #4). These intermediary descriptions provide insight into how a firm might progress between each level; and improves objectivity when scoring. This principle has been extended further to provide richer descriptions at each point along the scale, to create the process maturity grid (figure 1 scale #5) [e.g. 25].

FIGURE 1 ABOUT HERE (Approaches to auditing processes)

Maturity based audit tools

Process maturity approaches are rooted in the Quality Management domain, but have become a popular way of capturing 'good practice' knowledge in a form which supports improvement initiatives. Process maturity can be formally defined as:

> *The degree to which a process/activity is institutionalised and effective [29, 69]. Maturity assessment helps to predict an organisation's ability to meet its goals [69] and provides guidance on targeting improvement [16] by describing the progression of performance through incremental stages of development.*

There are two general approaches to developing maturity based assessment tools; Maturity grids and Capability Maturity Models. Maturity Grids aim to communicate a few basic principles in a simple but effective way [25]. The grid aims to codify what might be regarded as good (and bad) practice along with a number of intermediate or transitional stages. There is generally no attempt to prioritise one activity over another, or to aggregate scores into an overall maturity rating. This maturity grid approach has been applied to a variety of business issues [34], with several audit tools targeted at various aspects of product development:

In the 1990s, the underlying principles of process maturity were adapted and applied to the management of software projects, under the banner Software Capability Maturity Model (S-CMM). However, the S-CMM discarded the simplicity of the maturity grid to provide a comprehensive and complex tool capturing all aspects of software development. The S-CMM combined both a process assessment and a capability evaluation, to provide guidance on the control and improvement of software design and enable the selection of improvement strategies based on current performance [69]. It has since become one of the best-known tools for process improvement.

Maturity audits in product development

Both styles of maturity model (Maturity Grids and CMM-style) have been applied to various aspects of product development. The Software-CMM inspired the development of a range of further models, including the Integrated Product Development CMM, which aimed to assess product development capability across an organisation [29]. However, this model was never released and there is anecdotal evidence which suggests that it was too complex and unwieldy to be of practical use. This is typical of many CMM style models, which seek to be comprehensive and complete, at the expense of ease of use or accessibility [84]. CMM based tools have been applied to other aspects of product development, including: Product usability – human factors for product design [30]; Continuous improvement in NPD [13]; Project management [29]; Collaboration capability [98]; Application development quality [93]; Testing – for evaluating software [12]; and Product reliability [82].

The simpler maturity grid approach has also been applied to product development, including: Product development management [57]; Technical innovation [16]; R&D Management [88]; and Project Management [45].

In 1986, Pittliglio Rabin Todd & McGrath (PRTM) developed the 'Product and Cycle-time Excellence' (PACE) model for auditing product development management capability [57]. The PACE model describes the performance of seven management practices over four evolutionary stages of capability (informal, functionally focused, cross functional, enterprise wide). The model uses language that is "familiar to the practitioner" to enables a company to identify its strengths/weaknesses. Outputs are semi-quantitative, and responses are intentionally subjective, although objectivity may be increased by gaining consensus from multiple respondents.

Szakonyi [88] developed a maturity grid for the measurement of 'R&D effectiveness', based on literature and insights generated from consultancy and research work with over 300 firms. The audit tool consists of 10 activities viewed as critical to R&D performance. For each activity, a maturity grid was developed, describing performance over six levels, representing a progression from 'not recognised' through to 'continuous improvement'. Descriptions of performance were derived where possible from industrial experience. Szakonyi aimed to create a tool which was "logical, free from qualitative judgement and enabled benchmarking standards between companies" [88].

The Szakonyi and PACE audit tools avoided any detailed explanation of the theoretical constructs underpinning their approach. However, before developing their 'technical innovation audit', Chiesa et al [16] reviewed relevant literature and conducted exploratory cases to produce a 'process model of innovation' as a foundation for their audit methodology. This process model provided the underpinning theoretical framework, which addressed the "managerial processes and organisational mechanisms through which innovation is performed". They believed that success in innovation is related to good practice in the relevant management processes [16]. Their process audit contains eight process areas (product innovation, product development process, process innovation, technology acquisition, leadership, resourcing, systems and tools and increased competitiveness), containing a total of 22 sub-processes.

Chiesa et al also developed a more detailed, 'in depth audit' which consisted of a detailed list of focused but open discussion questions, which aimed to encourage debate. However, industrial response indicated that the simpler "scorecards were sufficient". Even though the self-evaluation was less onerous than CMM-based procedures, companies still preferred the simplicity of the scorecard [16].

Finally, Ibbs & Kwak [45] adapted both the 'grid' and the CMM approach to develop an audit tool for the assessment of project management maturity. This detailed model has 148 multiple choice questions, covering eight knowledge areas and six project phases and adopts a five stage approach to improvement; ad-hoc, planned, managed, integrated and sustained [45]. This questionnaire approach enables a high degree of granularity, with each question probing a specific element of project management. However, the drive for detail results in an audit tool that is complex to both visualise and use.

Implications for a 'design audit' tool

There is a gap between 'best practice' understanding and the implementation of this in firms [5], as these best practises are rarely provided in a prescriptive form to enable other companies to achieve similar benefits [52]. One response to this apparent gap has been the emergence of a variety of 'maturity models' aimed at different aspects of innovation and product development. These maturity models codify best practice understanding in an accessible way to enable opportunities for improvement to be determined. They also provide information that can be used in developing action plans for improvement [16]. Capability Maturity Models provide a rigorous solution but at the expense of accessibility to the average industrialist. In SMEs, where managers notoriously have little time to consider process improvement, the maturity grid offers a simple and user-friendly solution and is thus a more appropriate approach.

There are a number of existing maturity grid based models addressing the *management* of product development and providing insight into specific issues such as human factors. However, there are none that explicitly tackle the design process itself; addressing issues relating to the execution of good design practices.

Thus, not only is there a clear need to raise awareness of good design issues in SMEs, there is no current solution that fills this gap.

METHODS

Much research in innovation and design management seeks to uncover patterns and behaviours through following a positivistic approach; controlling variables and testing research hypotheses. However, design in its manufacturing context is a complex, interdisciplinary phenomena, which is dependent upon the interaction of many specialists. Product design takes place in a social context, where variables and motivations are difficult to isolate and the impact of design decisions may not be known for months or years. In such complex social systems, it is difficult to isolate 'immutable laws' which can be viewed as independent from human influence, as would be expected for example in the natural sciences. Swann notes that "design deals in human interactions with artefacts and situations that contain a great deal of uncertainty. Design research is tied to a domain that derives its creative energy from the ambiguities of an intuitive understanding of phenomena" [87].

Susman and Evered [86] argue that the positivist model of science is less appropriate for generating knowledge for solving problems "that members of organisations face." Similarly, Platts [71] noted the scientific paradigm is less effective in generating results of direct relevance to real world practitioners. In contrast, the phenomenological paradigm of research focuses on generating the meaning and understanding of events and the pursuit of "achieving a more desirable future for the participants" [86]. This satisfies the dual goals of contributing to knowledge whilst also providing direct benefits to participants. This philosophical perspective and methodological approach is consistent with the ambitions of this research to develop a practical and industrially relevant design audit tool, which can be evaluated actively in real organisations.

Research approach

Action Research (AR) emerged as an important approach to research in business and management [36], with the dual goal of "contributing to both the practical concerns of people … and to the goals of social science" [75]. Traditionally, AR approaches demanded a highly immersive role for the researcher [96], to collaboratively diagnose, define and address a 'problem'. However, in many firms, it is impractical for the researcher to be fully immersed over a significant time period. Recognising this limitation, Platts [71] pioneered the Procedural Action Research (PAR) approach. Here, a procedure is created, tested and developed, where the testing and development phases are collaborative with industrial partners. Thus PAR is analogous to traditional action research, with the dual goals of developing theory, whilst providing practical support to the collaborating organisation [55]. However, there is less emphasis on the shared diagnosis and definition of a problem, as the procedure is already targeted at a previously identified issue. PAR specifically aims to result in generaliseable procedures which can be followed, are easy to use and which result in the desired outcomes.

Research in the field of design also aims to generate understanding which leads towards improvement in practice, to increase "the chances of producing a successful product" [7, 31]. To satisfy this goal, Blessing et al [7] proposed a generic design research methodology for the creation of tools to support design. This methodology starts with the identification of explicit success criteria, against which the tool can ultimately be measured. Eckert et al [31] propose that a pragmatic approach to evaluate the success of such a tool is to establish success in terms of "perceptions of value" of the new method to industry. This is consistent with the goals of PAR, which also places low emphasis on establishing the tool's utility, recognising the inherent difficulty of assessing this dimension, due to the time lags between intervention and likely long-term impact. Platts [71] explicitly states that the PAR sets out to test the process (under development) and not the outcome.

This study combined elements of design research and procedural action research methodologies, to develop a design audit tool, which aimed to raise awareness of the importance of 'good design' issues and encourage improvement in practices. This then satisfies the goals of action research through contributing to both understanding and practice. Practice is improved through the application of the tool, whilst knowledge and understanding is developed inductively through the process of application and refinement. This is embodied both in the tool itself as well as observations on design practice during intervention in firms.

This tool included the following elements:

› An intended or desired ***outcome*** – criteria for success [7] or value to practitioners [31].

› An empirically developed ***model*** of the phenomenon under consideration, combining concepts, categories, overall architecture and where appropriate relationships between elements; this model is often represented graphically [7, 71].

› A ***tool*** based on the underlying model which aims to satisfy the desired outcome [7, 71].

› A delivery ***process***, including the sequence of events, guidance on facilitation and supporting materials [71].

In practice of course, there is an intimate relationship between the model, the tool and its delivery process and variation in one will potentially impact the other. This co-development is hinted at by Platts [71] who recognises that in application the procedure will be refined and developed. In the context of this research, the design audit tool can be viewed in itself as the vehicle to capture 'good design' issues. Thus, the model of 'good design' is captured in the audit tool's architecture, organisation, concepts and delivery process.

Research design

The research was conducted over four phases, as illustrated in figure 2. Each phase is described in greater detail below and all cases are summarised in figure 3.

FIGURE 2 ABOUT HERE (Research process and cases at each phase)

FIGURE 3 ABOUT HERE (Summary of cases)

- ***Phase1 – exploratory study***: four SMEs about to start a new development project agreed to take part in a longitudinal study of design practices. This phase generated insights into design issues from initial concept through to production. This lengthy engagement limited the number of possible cases, due to both time and access to organisations, but provided rich data to compare with findings from literature. Data was captured through regular progress meetings, anecdotal observations, project documentation and a semi-structured interviews at the end of each project.
- ***Phase 2 – tool creation and feasibility***: informed by findings from literature and the exploratory cases, a prototype audit tool was developed. Initial feedback was sought on the viability of the approach, the content and the structure of the audit; including errors of omission and commission. Data was collected through semi-structured interview based around a presentation of the audit tool concepts. Modifications were made in response to this feedback. The audit tool was then applied in three companies in action research mode. Multiple data sources were used in each case. Firstly, each workshop produced physical outputs, in the form of completed worksheets. Secondly, time was allocated for verbal feedback from all participants at the end of the workshop. Thirdly, feedback forms exploring elements of usability, feasibility and utility were completed (anonymously if required) by each participant. An additional researcher-observer was also present at each workshop, to provide an independent perspective. Finally, a post-workshop meeting with management was conducted to review outcomes and perceptions.
- ***Phase 3 – tool development***: following modifications resulting from the feasibility stage, the re-designed tool was applied in a further three companies, again following an action research approach. Responses to the audit were captured in the same way as for phase 2.
- ***Phase 4 – validation***: to evaluate the wider applicability of the audit approach, ten companies were identified from the local industry network around Cambridge University to provide

feedback on the feasibility and usability of the audit tool. In all cases, the respondents were given a copy of the design audit (in workbook form) before being asked to make comments. Multiple data collection methods were used, including recorded semi-structured interview, questionnaire, and written feedback

Evaluating the design audit tool

In application, the audit tool was evaluated for usability and utility as well as the generation of outputs. These criteria were based on those used in similar managerially focused action research [e.g. 14, 55, 63, 70, 71], as described below:

› ***Outputs***: explicit (and implicit) outputs from using the tool, including completed worksheet and action plans, improved awareness etc [31, 55].

› ***Usability***: the audit tool is clear, unambiguous and can be followed as described without clarification. This included establishing errors of omission or commission, as well as ensuring that the tool was appropriately structured and presented. In addition, the influence of the facilitator was evaluated through feedback from both participants and independent observation [14, 55, 71].

› ***Utility***: to establish whether the audit approach achieved the intended objectives (from both the company's and the researcher's perspectives), and that the outputs were as a result of using the audit tool [63, 70, 71].

Summary of research approach

This study aimed to both develop a robust audit tool integrating principles of 'good design' in a form accessible to industrialists, whilst simultaneously developing a better understanding of design practices in SMEs. Recognising that product design is a complex, interdisciplinary activity, the audit tool was developed following a four-phase research programme which integrated accepted models of procedural action research and design research. Data was collected using a variety of ideographic methods (e.g. observation and semi-structured interview) as appropriate at each phase of the research programme. During trial applications in firms, the audit tool was evaluated for utility (functionality and usefulness), usability and evidence of direct outputs. Finally, the wider applicability and validity of the tool was considered, with further industrial feedback again using multiple sources of data.

CREATING THE AUDIT TOOL: EVIDENCE FROM LITERATURE

As a multi-functional activity, with inherently unpredictable outcomes, New Product Development (NPD) is acknowledged as being risky, difficult and highly complex [21]. Whilst it may be possible to achieve a successful outcome once, through a mixture of luck, perseverance, perspiration and inspiration, it is much more difficult to repeat success again and again. Wheelwright & Clarke [97] claim that in order to respond effectively to increasing market, technical and business uncertainties, NPD needs to be clearly structured, rapid and highly productive. It is generally accepted that the likelihood of success is significantly increased if some form of structured process is followed. But, what are the characteristics of a 'good' design process and what might an effective process look like?

The process of product creation can be described from two perspectives; the design process and the NPD process. Design processes can be applied to all types of creative activity. In manufacturing businesses, the design process describes a sequence of 'technical activities' and does not (generally) provide any managerial framework; to control risks, to support 'go/no-go' decisions or enable investment analysis [66]. The focus of the design process is thus on the generation, evaluation and implementation of solutions. In contrast, the NPD process aims to ensure the appropriateness of these solutions to the business. Thus, whilst clearly related, there is a subtle difference between the two:

> *The **NPD process** is … "the entire set of activities required to bring a new concept to a state of market readiness … including everything from the initial inspiring new product vision, to business case analysis activities, marketing efforts, technical engineering design activities, development of manufacturing plans, and the validation of the product design to conform to these plans, through to the development of the distribution channels for marketing and introducing the product." [66]*

> *The **design process** is "… the set of technical activities within a product development process that work to meet the marketing and business case vision" [66]*

Thus, the 'design process' can be viewed as an essentially technical process. In contrast, the NPD process, emphasises strategic and managerial issues, to ensure that the *right* product is developed and managerial targets are achieved [11]. The boundaries between the two are clearly fuzzy and it can be difficult in practice to distinguish design activity from the many other activities that it supports in the NPD process [64]. The distinction however is important in the development of an audit tool which seeks to focus on *design* issues in an NPD context. Recognising these differences, this section aims to capture established perspectives on the elements of good design from extant literature from both design and the NPD perspectives.

New Product Development (NPD) processes

Since the 1960s, there have been in excess of 50 studies investigating the factors which contribute to success (or failure) in product development. These studies provide valuable insights into the prevailing academic perspectives on 'good practice' as a key input to the development of a design audit tool.

Following some early exploratory studies [48, 8], Myers and Marquis [61] studied 567 projects in 120 firms, measuring project success financially. In 1974, Rothwell et al [77] carried out the first dyadic comparison between successful and unsuccessful projects. There have since been a number of further success factor studies [e.g. 18, 19, 49, 54, 91]. In addition, there have been several attempts to collate findings from previous studies, to establish common success factors [e.g. 4, 5, 9, 33, 39, 50, 59, 74, 91].

Outputs from 47 such success factor studies were reviewed, coded and clustered to establish the recurring themes. It is possible to devise a number of schemes for the grouping success or failure factors from previous research. Any scheme is to a degree arbitrary, and tends to reflect the research interests of the author. For example, Brown's review [9] aimed to link the design management and R&D management domains, using a 'systems' approach. For this study, the success factors were clustered under the two broad headings of 'design management' and 'design execution' acknowledging the differences between the design and the NPD process. Only factors receiving multiple citations were included and where terminology varied, the most dominant or frequently occurring terms were used.

Design management

Perhaps unsurprisingly, the large majority of success factors relate to the way in which projects are organised and managed. 23 studies identified some form of cross-functional or multi-functional teamwork as a pre-requisite for success [e.g. 5, 9, 39, 61]. Effective management of multi-organisation teams and networks was also viewed as important [e.g. 9, 40, 77], whilst others focused on the provision of appropriate human resources [22, 32]. Several studies also identified the importance of adequate financial resources [e.g. 9, 37]. Functional skill or competence was cited in eight studies, encompassing specific functional activities such as marketing [e.g. 18] through to technical competence [e.g. 4, 59]. Others studies took a more generalist view, with overall competence in 'product development' as a good indicator of potential success [e.g. 9, 8, 49].

The second most frequently occurring management issue was 'top management support' with 17 citations [e.g. 33, 49, 74, 81]. Strong project management to meet time, cost, spend and performance objectives appeared in 11 studies [e.g. 17, 48]. Interestingly however, several studies noted that efficient and successful project execution can be more important than speed [e.g. 39, 77]. This finding is potentially contradicted by studies claiming that shortening time to market and early product launch are critical factors [e.g. 51, 54].

Nine studies identified the formulation of an effective product strategy, leading to the selection of the right projects as critical [e.g. 8, 22, 67, 74]. Project selection in terms of either commercial screening [e.g. 33] or structured idea screening [e.g. 8, 91] was also noted.

Having a formal, effective and stable product development process was cited in many studies [e.g. 8, 22, 33]. Such a process should be multi-step [8] and should include action oriented decision points [e.g. 22, 72]. Griffin [39] however acknowledged that a product development process is a necessary, but not alone sufficient contributor to success.

Some studies noted that the provision of non-financial team rewards and a tolerance of failure were key success factors [39, 40, 67]. Finally, an organisational culture which supports creativity and innovation was noted in two studies [4, 22]

Design execution

Several factors appeared which relate specifically to the execution of the design work. Typically, these included early stage design activities, such as understanding users and customers [e.g. 4, 9, 17, 40]. Similarly, ten studies concluded that firms with a strong market focus or orientation are more likely to be successful [e.g. 9, 18, 48, 58, 85].

Six studies commented on structured and high quality pre-development planning or 'up front homework' [e.g. 20, 22, 33, 54]. This predevelopment planning typically results in the definition of the proposed project and product, which was also frequently cited [2, 22, 81, 91].

Technical design activities received less attention, with effective prototype development cited as a success factor in four studies [3, 4, 40, 67] and concept evaluation in just two studies [3, 33].

The product itself received little attention. However, several studies comment on the importance of product superiority [e.g. 8, 18, 59, 85], benefits [33], and uniqueness [e.g. 19, 58, 67]. Product factors such as technical quality, aesthetics, ease of manufacture and ergonomics are rarely mentioned, even though it is through these characteristics that superiority and novelty are achieved.

FIGURE 4 ABOUT HERE (summary of NPD success factors)

Design processes

Representations of the design process can be classified as either descriptive or prescriptive [26]. 'Solution focused' descriptive models suggest the early proposal of a 'straw man' solution for subsequent evaluation, refinement, development or abandonment. In contrast, prescriptive representations tend to be 'problem focused' and are often based on views of 'good practice', providing a highly detailed and systematic sequence of activities, for the practitioner to follow if desired [26, 73, 68]. Prescriptive models are most often represented as a linear progression, sometimes with feedback loops or overlapping stages to indicate iteration [26, 73].

While there is no overall agreement on a specific instantiation of the design process, it is possible to establish some common elements. However, unlike the NPD domain, there have been no success factor studies explicitly investigating the design process. Thus, to enable comparison, with the findings from NPD success factor research, eight well established 'design' processes including BS7000 [1, 26, 66, 73, 68, 89 90] were compared, to identify recurring activities and is summarised in figure 5.

FIGURE 5 ABOUT HERE (Summary of design activities from design processes)

Implications for the design audit tool

From an NPD perspective, the success factors emphasise the importance of managing (rather than executing) the design process as the key to success. Some early stage design issues are prominent, but the remainder of the design process is only rarely mentioned. Factors relating to 'good design' are only evident in the apparent importance of strong product differentiation and unique product features. However, whilst it may be obvious that clear differentiation is a vital ingredient of competitive success, there is little attempt to identify which aspects of the design mix are appropriate in generating uniqueness or differentiation in different contexts. There is little focus in this domain on issues such as prototyping or creativity.

Within the 'design' domain however, there is very little consideration of project management issues, such as the generation of a 'business case' or the need for project authorisation. Both the NPD and Design communities place most importance on pre-development activities, including the need for strong market and customer intelligence.

This combined design process and NPD process perspective provided a key input to the generation of the design audit tool, placing the technical design activities within their wider managerial framework. These complementary, but normally separate perspectives enabled a rich picture of 'good practice' to be derived and provided a strong theoretical underpinning to the creation of a design audit tool. It is not claimed that the resulting list of activities/issues is exhaustive. However, it is indicative of the issues considered important in design and NPD literature.

Finally, it should be remembered that both the NPD success factor work and many of the established design processes are derived from or targeted at large firms. Thus, it was important to moderate evidence from literature based on findings from the exploratory case work.

CREATING THE AUDIT TOOL: EVIDENCE FROM EXPLORATORY CASES

At the outset of the research programme, four longitudinal cases were completed, to explore design issues throughout the duration of four separate projects. There were two specific aims:

- To identify the extent to which good design practices were marginalised in SMEs to confirm findings from literature.
- To explore good design practices in SMEs to inform the generation of a design audit tool.

Each company was in the initial stages of a new product development project and was selected from a shortlist of 20, based on the nature of the product, the degree of technical complexity, location and keenness to collaborate. All four companies produced technically complex goods, sold mainly to commercial buyers. Data was taken from project documents, visit reports, notes from telephone conversations and observation.

Company A was established in 1917, and was a leading manufacturer of precision optics and diagnostic instrumentation. The project aimed to replace a 15 year old product with a low risk, low cost update to increase sales and respond to competitive action. The project was viewed as a 'maintenance' activity in a saturated market, aimed at regaining market share. Engagement with the project lasted around 20 months and included several visits, attendance of meetings, telephone conversations and a wrap-up interview.

As a family owned firm, company B had grown through innovativeness, practicality and technical excellence in the paper collation industry. The family culture pervaded the organisation, with many design decisions deferred to the owner. Over 10 years, the highly modular product range had developed incrementally, and the product's user interface needed a radical update. The new interface project addressed usability issues, whilst also tackling component obsolescence. Engagement with the project lasted 22 months and included several visits, attendance of meetings, telephone conversations and a wrap-up interview.

Established in the 1970s, company C was a world leader in the design and manufacture of pneumatic ventilation systems. The company had recently seen significant changes in the organisation following a corporate takeover. The project aimed to update a mature product which was facing threats from cheaper competitors. However, delays to a previous project, combined with changing organisational priorities and difficulties clarifying the market resulted severe delays. Engagement with the firm lasted around 14 months and included several visits, attendance of meetings, telephone conversations and a wrap-up interview.

Company D became independent following a management buy out in 1996 and had a turnover of around £120 million, split between three main product groups. The new product was envisaged as an upgrade to an earlier product. The project suffered major delays to technical difficulties on related products which required skilled and scarce engineering resources. However, this resulting hiatus presented the team with the opportunity to review the project objectives and undertake new market research. Engagement with the company lasted around 18 months, including visits, interviews and telephone conversations.

Summary of cross case observations

This phase of the research aimed to identify recurring or common themes which might influence the development of a design audit tool. Key points are summarised below under the headings of 'design management' and 'design execution'.

Design management

In all four cases, it was clear that the product strategy was a (relatively) weak link and reactive to competitive, technological and market developments. All four firms exhibited little ongoing generation of new product ideas and as a result, there was little evidence of structured project selection: the next project tended to select itself. In companies A, B and C, scarce resources meant that only one project could be conducted at a time. In company D, poor aggregate project management resulted in horse-trading for valuable resources. In all cases, there was clear evidence of 'the last project still biting', impacting on the progress of the current project.

Two of the companies were struggling to implement a viable new product development process. Company A had recently introduced a 'phase-milestone' process, in response to "the chaos" of previous development projects. Company C was implementing the process mandated by their parent company. With the exception of Company B, all four firms struggled to balance the need for managerial control against the problems of increased bureaucracy. There were different approaches towards teamwork in the four companies. Company A described their teams as autonomous, empowered to make their own decisions, but with an 'over the wall' approach to communication. Companies C and D both exhibited 'lightweight' project management, with functional boundaries still dominant. Company B, as the smallest company, was the most informal, and as a result displayed the best communication between team members.

There was little evidence of proactive risk management in any of the companies and as a result, all of the projects overran, due to technical or market difficulties. Finally, project management skills were generally weak, with little ongoing management of time, spend or unit cost targets.

Design execution

Companies A, C and D all struggled to clearly segment, define and characterise the market place for their new products. Poor segmentation in company A resulted in product cannibalisation and ultimately several late feature changes to the new product. The project at company C stalled due to the inability of the design team to clarify the needs of the new market. Company D initially viewed the market as a homogenous whole, but later recognised the value of clear segmentation to support the collection and interpretation of user needs.

There was also little evidence of effective competitive analysis, with an over reliance on comparison of brochure specifications in companies A and B. Company C viewed the competitors products as technically inferior, and thus ignored anecdotal feedback about consumer preferences. When users were involved, the companies all gained valuable information. In company A, user observation led to the development of snap on covers, an original feature which helped differentiate the product. In all firms, there was little user or customer involvement at later stages of the design process. Finally, weak market analysis impacted the generation of effective specifications. In companies A and C, where separate market and technical specifications were produced, there was later conflict and negotiation. Company D however benefited from clearly defining the product sub-systems and interfaces. Without exception, all companies were weak at market and user research activities, relying instead on experience and 'gut-feel'. In part, this might be explained by inexperienced marketing staff whose roles were more aligned to sales support.

To a limited extent, all companies divergently explored a range of alternative concepts, although in most cases, the teams had clear preconceptions over product functionality and technology. Perhaps the greatest divergence was evident in proposals for product aesthetics. There was some early testing of concepts with users, but generally, concepts were evaluated internally, based on the 'calibrated gut feel' of managers. In company D, several design changes resulted from concept evaluation with real users. Only company B had a clearly defined product platform strategy, to ensure maximum product variety to customers, whilst minimising complexity in the company.

Company A had the opportunity to establish a common product architecture, but instead developed a unique product to satisfy unit cost and timescale targets.

There was little use of design for manufacture approaches in any of the cases. Only in company D were unit cost targets established and managed throughout the design process. There was little 'early prototyping' of new technology, resulting in late design changes in companies A, C and D. Perhaps most concerning was the lack of evaluation to assess market acceptability, which in company C resulted in "adverse feedback following launch".

Timing of industrial design involvement was critical in all cases. In case C, the designer was involved too late to make a real difference. In cases A and B, the designer was involved sufficiently early to influence technical decisions and the product's architecture. However, there were criticisms from staff in companies A, C and D over the technical feasibility of proposals from the industrial designers. In companies B and D, the designers remained involved throughout the design process. However, in company A, the designer finished at the concept stage and the engineers subsequently made inappropriate changes to the product's appearance. Thus, despite attractive concept designs, the preproduction prototypes were large and unattractive. As a result, the designer was recalled to remedy this situation.

Companies A, B and D all benefited from investing in professional design expertise. At Company A, the designer challenged traditional preconceptions over the product configuration and produced visualisations which "helped to generate excitement around the new product and contributed to a sense of buy-in across functional boundaries". The designer also influenced "product strategy and positioning decisions through visualising concepts and facilitating the interaction between customers, marketing and engineering". Finally, company C perceived little benefit, due to the narrow scope of their original design brief. This confirmed their view that design is expensive and unnecessary in a market where technology is believed to provide the commercial advantage.

Implications for the audit tool

The exploratory cases supported many of the factors identified in literature. In addition however, they also pointed to specific issues of concern in managing and executing design in small firms. Company B were perhaps the most accomplished, with the others displaying a range of capabilities. Collectively, the cases confirmed the marginalisation of good design issues and identified many opportunities for improvement to the design process. This supported the need for a tool which captures good design issues in a form which is accessible to managers in SMEs.

The projects were typically reactive, with little proactive exploration of new ideas for new markets. Firms A, C and D were trapped in a vicious circle of delays to previous projects producing delays in the current project. Each of the companies had some form of structured product development process, although they were all struggling to balance excess bureaucracy against sufficient managerial control. Weak project management was also evident through poor teamwork and cross functional disagreements.

They all displayed weaknesses in their marketing and user focused activities. These deficiencies were evident in poor product specifications and uncertain requirements. There was some divergence in concept design, although concept selection was largely internally focused with little user involvement. There was scant evidence of effective early prototyping or design for manufacture, resulting in frequent late design changes.

Aesthetic and ergonomic concerns were important for all projects, and industrial design specialists were involved accordingly. Early and ongoing engagement was seen to be crucial to ensure that the designer's vision was maintained. Product appearance or usability generally provided differentiation, whilst reliability, durability and technical performance were generally viewed as order qualifiers.

Observations of good (and not so good) practice enabled the identification of several practices which should be addressed in such the audit tool. Even the strongest company exhibited several areas where design practice could be improved. The four firms displayed weaknesses not just in design execution but also in design management. This confirmed the need for the design audit to emphasise design execution issues, whilst also addressing basic design management concerns.

THE DESIGN AUDIT TOOL

Informed by findings from literature and exploratory cases, a prototype audit tool was created. This prototype tool was then developed and refined through a process of application, review and modification. During this stage, the audit tool underwent four major changes of its architecture and presentation and around 50 smaller changes (to phrasing etc). The result is a robust model of 'good design', capturing key design management and design execution activities (Figure 6). This model forms the structure of the audit tool, which develops these activities in the form of simple maturity grid The model aims to visually distinguish between the design process and the product development process. The activities chosen reflect a synthesis of issues from multiple strands of literature and case evidence.

FIGURE 6 ABOUT HERE (Model of good design – structure of design audit)

Activities: Design execution

Design activities were chosen to address aspects of design execution that were consistently poorly performed and were also judged as important to success. These are clustered under three headings, which are visually represented as overlapping phases of a design process: requirements capture; concept design; and implementation.

› ***Requirements capture***: literature emphasised user understanding, market analysis and product definition. Evidence from cases supported these findings, but also highlighted the need for ongoing involvement of users in the design process, strong competitive analysis and effective market segmentation.

› ***Concept design***: Literature in the design domain supported the importance of divergent concept generation and structured concept selection. Cases specifically emphasised the importance of user focused concept selection. Cases also indicated the importance of simultaneous architecture, aesthetic and ergonomic design drawing together technical and industrial design specialists.

› ***Implementation***: Early and frequent prototyping is viewed as important in design literature and was found to be essential in practice, to reduce both technical and market risks. In the exploratory cases, all firms were weak at design for manufacture and assembly.

Activities: Design management

Whilst not the primary focus of the audit tool, it was evident that the managerial activities had to be included to address weaknesses observed in case examples and reflect the dominance of these issues in previous studies. Managerial activities were clustered under two headings: project generation and project management. The project generation activities reflect all 'off-line' activities that do not necessarily correspond to one specific project. Project management issues relate to a specific project and were given slightly more emphasis, due to clear weaknesses observed here in the exploratory cases.

› ***Project management***: Cases and literature confirmed the need for a product development process, although the cases perhaps suggest that this should be as 'light' as possible. The cases highlighted the need for both risk management and effective design reviews. Cases also indicated the importance of monitoring key design targets such as unit cost. Teamwork was of utmost importance in literature. Involvement of specialist designers was not considered a success factor in the NPD literature, but received significant emphasis in the design domain. Evidence from the exploratory cases confirmed its importance in addressing resource limitations.

- ***Project generation***: All of the case companies had an essentially incremental product strategy, with little ongoing generation and capture of new ideas. Product strategy and selection however were viewed as essential in many previous studies.

The design audit tool

The final audit tool is constructed in the form of a maturity grid [25] of 24 Key Design Activities.

The process audit classifies performance against 4 maturity levels (none, partial, formal and culturally embedded). Descriptions of performance encompassed 5 key ingredients: benefits perceived, people involved, timing, degree of formalisation and the level of expertise. This schema helped to ensure consistency in description of performance across activities.

The process audit is presented in two forms; summary grids and detailed grids. The summary grid captures the performance of each activity in a simple statement, designed to be succinct and to the point. The detailed grids expand on this heading to provide a richer description. An example summary grid is illustrated in figure 7. An example detailed grid is illustrated in figure 8. Summary grids for the whole audit tool are included in Appendix 1.

FIGURE 7 ABOUT HERE (Example summary grid for requirements capture)

FIGURE 8 ABOUT HERE (Example detailed grid of for market segmentation)

The process audit has been designed for use in a workshop setting, taking about half a day, with representatives from a variety of functional groups. Workshop participants are first introduced to the range of activities and asked to identify any which in their view might be missing. Participants are then asked to score current performance and identify opportunities for improvement. Various strategies for scoring current performance have been tried. In early applications, individual participants scored each activity alone, and later collated responses to identify activities for further discussion. This approach was effective in highlighting differences in opinion, but was also divisive. In later applications, participants were split into sub-groups to discuss each activity, using the summary and detailed grids to agree scores for both current and desired future performance. These sub-groups then shared views and discussed alternative priorities. This approach proved more useful in generating practical outputs. The workshop culminates with the capturing and prioritisation of actions for improving the design process.

AUDIT TOOL APPLICATION

The audit tool was applied in six cases in action research mode. Responses to the audit tool were collected in three ways; verbal feedback from participants, independent researcher observation and structured feedback in the form of a simple questionnaire. The researcher-observer was present in each case to provide independent feedback on the audit tool, its content and the delivery process. The questionnaire captured responses to overall value as well as insight into the utility and usability of each aspect of the process. An example of questionnaire feedback is provided in figure 11, for Case P. The combined feedback also aimed to determine the degree to which the audit tool could be followed without facilitation, potential errors of omission or commission and recommended modifications. In early applications, the questionnaire was completed directly following the workshop. In later cases, the questionnaire was circulated a few days after the workshop to enable a short period of reflection on behalf of the participants. Finally, there was a follow up meeting with the company sponsor at least 6 months after the audit tool application, to determine longer term impact and perceptions towards the audit tool.

Due to space constraints, application of the design audit tool will be described in four of the case studies, reflecting different stages of the audit tool evolution.

Case K: Consumer hi-fi

Company K was a leading UK manufacturer of hi-fi equipment. Their products were differentiated through technical performance and UK manufacture. The products were renewed every 2-3 years, with mostly incremental developments. The firm did little technology research, adapting proven technologies. Before the design-audit workshop, a meeting was held with the New Products Manager, to agree objectives. The audit was subsequently delivered in an afternoon workshop with 6 members of the product development team.

Case K: The audit tool

This early version of the audit tool comprised 22 design activities, split roughly equally between those with a 'managerial' focus and those addressing design execution. The audit was presented as a single grid comprising activity title (and definition) and maturity definitions over 4 levels. This included both a concise headline, as well as more detailed descriptions (figure 9).

FIGURE 9 ABOUT HERE (Audit tool grid from application case K)

Case K: Audit tool delivery process

The workshop began with brief introductions, followed by a ten minute 'warm-up' exercise, discussing the company's approach to innovation and the characteristics which differentiate their products in the market place. Participants were then asked to score each activity for 'importance vs performance' numerically (on a 1-5 likert style scale); before seeing the audit tool. Here, a wide range of scores were generated for each activity. The design audit tool was then used to score activities in a more structured way. In several cases, there were still differing opinions over current performance. However, the detailed descriptions enabled these differences to be discussed to arrive at a consensus opinion. This demonstrated the benefits of the maturity grid in comparison to a simple numerical scale, in generating consistent and useful results. However, participants commented that it was excessive to score each activity twice. Six activities were chosen for further discussion, based on consistently low scores or clear opportunities for improvement: market learning; setting design targets; product specification; prototyping to reduce technical risks; maintaining the design vision; and structured development process. The maturity grids were then used as a focal point for discussion, with a view to identifying potential actions for improvement.

Tangible outputs included a written summary of the discussion, focusing specifically on actions for improvement. Key actions were identified to address the following areas:

› ***Structured development process***: which was described as "unusable" due to its complexity, with frequent conflicts between functions.

› ***Market learning***: was functionally led, with little wider team input. Team members were generally poorly informed about market activities and agreed that market analysis was often supported by "calibrated gut-feel". One engineer even asked "who are the marketing people – is it those two ladies in that office?"

Case K: Audit tool usability

During the first exercise, the scoring of 'importance' was seen by some participants as redundant; "if they weren't important, they wouldn't be down here". As an alternative, it may have been better to rank the activities in order of importance or progress directly to the summary grids. In addition, insufficient time was allocated to the detailed discussion phase, with too much time given to scoring without debate. As a result, potentially useful discussion was curtailed due to time constraints; ideally, more time would have been useful.

The activities were generally felt to be complete, with nothing either missing or inappropriately present. There were some misgivings over the specific choice of words describing maturity levels for some activities. There were also several suggestions for improving the layout and design of the forms; including avoiding acronyms and changing the grid layout to provide a linear progression. However, the design audit was also considered to be highly detailed, and as a result, was daunting at first sight. Participants suggested that it might have been beneficial to have seen the design audit before the meeting. In addition, it was felt that a more reliable approach to capturing actions was required.

Case K: Audit tool utility

Participants viewed the design audit as useful and usable, but with reservations over the practical value of the workshop as a whole. One commented that it was a *potentially* excellent self-audit tool. Three specific points were noted as being "most useful". Firstly, participants believed that discussions around low performance activities were useful. Secondly, debating differing opinions was beneficial. Thirdly, the novel and simple presentation of the design process was viewed as helpful. The scoring of the 'importance vs performance' (before progressing to the maturity audit) was viewed as least useful. One participant commented that the design audit suffered due to its "apparent theoretical base."

Participants were largely drawn from the engineering team, with insufficient cross functional representation. As a result, it was not possible to determine the true value of the design audit in generating cross-functional discussion. However, even in this environment, there were still differences in perception amongst the design team, indicating the inherent difficulty of creating a genuinely objective way to assess current performance. The audit approach (by design) avoids prescribing specific actions. However, one participant commented that although it "stimulated useful discussion … what I'd have liked is for you to say 'this is what is wrong and what you have to do is this, this and this'." It was evident therefore that the practical outcomes needed to be more explicit to minimise this type of response.

Finally, the audit was viewed as helpful in raising general awareness of design issues and identifying gaps between where the company is and where they could be. Participants clearly felt more aware of design issues, but there was little to suggest that the team would subsequently design a better product as a result. It was evident that weaknesses in the delivery process had a strong influence on perceptions of the audit tool itself. Improvements were also required to ensure actions were adequately captured.

Case L: Building supplies

Established in 1972, company L was a market leader in the provision of ventilators and window fittings employing about 250 people. Their core customers were the construction and window fabrication industries, demanding simple installation, low cost and ease of transportation. Their ultimate users were homeowners and office workers who desired attractive, non-intrusive and simple to use equipment. The company had two UK sites, 50 miles apart, housing the manufacturing and product development functions. The audit tool was applied over two workshops comprising a cross functional team of 6 people. The management team aimed to generate shared understanding of their current design capabilities, raise awareness of design issues, and identify opportunities for improvement.

Case L: The audit tool

The audit tool comprised 22 design activities. The layout of the audit had been revised to include both 'summary' and 'detailed' grids to reduce potential for adverse initial reactions due to perceived audit tool complexity. Each grid was also presented as a linear progression from low to high performance.

Case L: Audit tool delivery process

The workshop began with an introduction to general 'good design' principles and clarification of the aims of the workshop. The workshop started with participants brainstorming design activities of importance to their firm, mapped against the outline structure of the design audit. This provided an introduction to the audit tool and confirmed their relatively narrow understanding of the design process and the lack of consideration given to user focused or project management concerns. Participants were then asked to individually score their perceptions of current performance using the 'summary grids'. Individual responses were collated to identify issues for further discussion. Interestingly, participants did not just choose activities with the lowest scores, preferring instead to focus on those where improvement was believed to be most necessary or where opinions were most widely spread. The discussion stage used the detailed grids to provide indications of improvement opportunities. This revised delivery process was an improvement, with clearer aims and structure.

Direct outputs included the completed worksheets and evaluation forms. Discussion using the detailed grids led to actions around the following activities:

› ***Product specification***: Specifications were viewed as internally driven and not focused on a deep understanding of customer needs. One participant commented that "we don't know what sales think the customers want." However, there was reluctance for greater customer involvement due to concerns that confidential information might leak to the competition. It was agreed that loyal customers should be invited onto a 'review panel' for future developments.

› ***Teamwork and communication***: there were no formal project teams, with production only involved on an ad-hoc basis. All team members saw themselves as "function first, team second". One person even suggested that "the left hand doesn't know what the right hand is doing" in relation to communication between design and production. The production manager claimed that his relationship with design could not be described as "them and us" but more "us and them!"

- ***Market learning***: The team felt that they didn't have sufficient confidence in market information or the communication of market activity. They believed that sales estimates were over-optimistic, to justify tooling budgets.

Teamwork and product development process issues were the focus of a subsequent workshop, the result of which was a new product design process.

Case L: Audit tool usability

The aims of the session were believed to be clear, and the approach was judged to be both feasible and sensible. Handouts (audit worksheets) were considered to be clear and well laid out. Commenting without prompt, one participant said "these sheets of paper are brilliant … it is all there basically". Participants felt that they could have delivered the design audit themselves, with some preparation, but that external facilitation was beneficial; only one person felt that external facilitation was essential. One participant found the content of the design audit to be "a revelation". The rest claimed to be familiar with most of the concepts, but not in this form. Few issues were noted as missing, suggested that (in this case), the audit tool was relatively complete. Potential additions included "evaluation", "communication techniques", "testing" and "patents". Several activities however were viewed as less relevant, including "branding", "technology management" and "product and process design sign off". The content and structure of the audit tool was generally considered to be appropriate and its application identified many potential opportunities for improvement. The inclusion of the summary grids was a success and had the benefit of enabling all participants to evaluate the full design process. The detailed grids encouraged useful debate, although there were still some areas where descriptions of performance were unclear and it was possible to score at multiple levels

Case L: Audit tool utility

The design audit resulted in visible change. They indicated that the design audit had helped confirm the need to improve, but they remained unsure about their ability and willingness to complete the change. However, the team had made conscious efforts to improve communication. The audit highlighted the need for many small improvements, and not just a major change in one area. As a specific result, the firm developed a new product design process, which encouraged multi-functional involvement. However, it is impossible to claim that this result would not also have been gained if other tools had been used instead or that it would ultimately result in an improved product. Whilst some design issues such as "product specification" and "product architecture" were considered, the main discussions were essentially organisational, including teamwork and process concerns. This was by no means a poor result and justified the inclusion of these issues in the design audit. However, it was evident that further modifications to both the tool and the delivery process needed consideration if the design audit was to genuinely raise awareness of good practice issues and ultimately result in the design of better products.

Case N: Medical Lasers

Founded in 1991, company N had pioneered the use of diode lasers for medical applications, with a US head office. The UK R&D facility employed around 70 staff. As technology leaders, the company's products were differentiated through performance and service provision. However, whilst entry barriers were high, new entrants were challenging the company's market leading position. Thus, the company was beginning to consider other ways of differentiating its products. The Engineering Director believed that the audit approach would help him gain cross functional support for improvements to the company's product design process. He wished to increase the formality of the process, but with grass-roots consensus for these changes.

Case N: The audit tool

Following earlier applications, the audit tool had been revised to respond to the lessons learnt and to better reflect insights from literature. Nine activities were added, resulting in a total of 31 design activities; 14 with a managerial focus and 17 addressing design execution. The layout still represented a linear progression from low to high performance, with separate 'summary' and 'detailed' grids.

Case N: Delivery process

Following two meetings with the senior management team, a design audit workshop was held with ten participants, eight of whom had completed the summary grids before the session. This workshop was followed by an action planning session primarily addressing design for manufacture issues.

The delivery process was modified to accommodate changes in the audit tool itself. With an additional nine activities, it was believed that scoring them during a workshop would potentially be tedious. Thus, participants were requested to assess their design process (using the summary grids) before the workshop. By enabling participants to view the audit before the workshop, it was hoped that they would have had time to reflect and come prepared for discussion.

Following a brief introduction summarising the aims of the project and the audit tool, results from the process audit were presented by displaying all participant scores on a single chart, to demonstrate the diversity of respondent opinions. By presenting the scores this way, the range of views was evident, but the individual scorers remained anonymous. This had the negative effect of curtailing potential discussion and debate around the underlying reasons for differing opinions. Having reviewed all 31 activities, issues for potential improvement were noted. Improvement opportunities were then explored further. To support this activity, a simple worksheet was used to record the group's consensus score, capture strengths and weaknesses and describe the desired future state. During this stage, the 'detailed grids' were used to prompt discussion, indicate performance at higher levels of maturity and thus support action planning. However, due to time constraints, this activity was not completed, and the detailed grids were only briefly used.

As the workshop progressed, it became apparent that despite two up-front meetings with management, participants had not been briefed effectively (by the management team) on the aims of the session. Thus, halfway through the workshop, the team began to discuss their improvement aims at length, and a direct effect was to change the planned timings and activities for the remainder of the workshop. This encouraged debate, but also served to highlight many areas of conflict and mistrust in the organisation.

The process audit indicated the weakness in several areas, including design for manufacture, user understanding and teamwork. The design process itself was also nominated as a candidate for improvement.

Tangible outputs included a co-developed an action plan addressing a wide range of design issues. In addition, a summary of perceptions towards the execution of design activities and the design of current products was provided.

Case N: Audit tool usability

Responses towards individual elements of the design audit were generally very positive. However, this was heavily moderated by participant's feelings towards the ambiguity of the overall aims and objectives. In part, the delivery process was poorly structured, but this was compounded by the company sponsor failing to adequately brief his team members. Almost all participants commented on the need for increased clarity of objectives.

By scoring their perceptions towards design performance off-line, opportunities for discussion had actually been somewhat curtailed. One person specifically commented that "filling out the grids beforehand caused a little too much confusion."

Several participants noted that they were unsure whether they were scoring current performance or ideal performance. It was felt that this uncertainty would be reduced with clearer worksheet design. Once this issue was clarified, the audit tool was perceived as effective in identifying key issues.

A few activity descriptions were judged as ambiguous, suggesting that a further iteration was required to ensure clarity and consistency of descriptions. As a measure of usability, the participants were asked to score their confidence in using the audit tool themselves. Responses were generally positive, especially from the more experienced and senior staff. The audit tool was judged as complete, although it was criticised for "taking too long to fill in – without losing interest". The addition of nine activities had clearly reduced its usability. This supported the earlier findings that a simpler model, whilst less comprehensive is more usable and therefore more appropriate for use in a company setting.

Case N: Audit tool utility

There was a clear split between the negative and the positive responses towards the design audit tool. The positive respondents felt confident that the company had identified several areas for improvement as a result of the audit process. However, one person commented that time would have been "better spent working out improvements to our practices on our own, without the presence of outsiders". Another was unsure about the value of the process, noting that at best "it gave a list of prompts as the company goes through the design process and at worst it wasted many man hours." Others however were more complementary, suggesting that the audit process gave "good insights into the design process".

The team recognised the value of the maturity grids in capturing examples of practice, but would still have preferred a more dictatorial approach to "… just tell us what to do!" The management team perhaps viewed the audit process as more useful than their subordinates, as it satisfied their implicit goal of encouraging communication and discussion amongst functional groups.

Whilst there were reservations about the audit tool's usefulness, it had still satisfied the research goals. Most participants for example commented that the audit process provided insights into good design issues. One person suggested that the audit tool raised awareness of general perceptions about the company and its products, going on to suggest that the workshop provided a "good platform to build a new project team."

Case P: Agricultural Machinery

This family run business produced and install systems for sorting, cleaning and packing root crops; including potatoes, carrots, onions and parsnips. The firm has around 130 staff, with 15 people involved in the generation of new products and customising standard products to meet specific customer needs. In this specialised market, the company competed by offering leading technical features and delivering reliable machinery at a competitive price. The engineering director aimed to improve the new product design process and ultimately increase the competitiveness of their products. Following an initial meeting with senior management to clarify objectives, the design audit was applied in a workshop setting over a whole day, involving ten members of staff from across the business.

Case P: The audit tool

Further refinement to the audit tool had reduced the number of activities to 24. It was felt that this number provided an appropriate balance between usability (in a workshop setting) and comprehensiveness. In the main, managerially focused activities had been removed, resulting in 10 activities targeted at managerial issues and 14 focusing on design execution. The audit tool layout had also been further refined, to explicitly include spaces for scoring current and desired future performance (figures 7 & 8).

Case P: Audit tool delivery process

Following an introductory presentation, participants were split in to two teams to score current and desired performance using the design audit tool. The summary grids were used to capture their scores. The detailed grids were available for consultation where further information was required. In practice, they used both summary and detailed grids in unison throughout this analysis stage. The two teams were asked to nominate five activities that warranted improvement and five which they believed were performed well.

Having scored current and desired performance, the teams fed back discussions to each other. Team 1 identified 'investigating user needs', 'ongoing user involvement', 'product specification', 'product development process' and 'teamwork' as candidates for improvement. Team 2 added 'concept generation', 'design for manufacture and assembly' and 'managing design targets'. The whole group then discussed these findings to agree a consensus view of both current and desired future performance. The two groups again worked individually to identify potential actions for short term, medium term and long term improvement.

Tangible outputs resulting from the audit process included improvement action plans, the introduction of a new design process and further training in design for production.

Case P: Audit tool usability

The separation of the whole group into two teams worked well; resulting in a high level of discussion, debate and ultimately producing a strong consensus on performance. The use of the summary and detailed grids in unison enabled the teams to score performance with ease. Whilst not being mandated, the teams voluntarily chose to refer to all of the detailed grids during the assessment phase. The design change to the worksheets to capture current and future performance enabled clear and unambiguous scoring. The participants viewed the worksheet content as complete, with nothing missing. A summary of the questionnaire feedback is provided in figure 10 (note: similar feedback was collected in all cases).

FIGURE 11 ABOUT HERE (Example feedback from Case P)

Case P: Audit tool utility

Participants commented that many of the concepts (contained within the audit tool) were new to the team, challenging their established view of the design process.

The audit tool was viewed as a way to "improve the design process and encourage the creation of successful products every time". The participants were satisfied that this objective had been achieved, commenting that the process audit had "proved that there could be a process that is controllable for new projects/products". This anecdotal evidence was supported by questionnaire feedback, indicating that the workshop was a worthwhile investment of time. The process audit had succeeded in raising awareness of good design issues, with the company interested in improving design for manufacture and increasing user involvement.

As a direct result from the audit tool process, the firm redesigned their product development process, addressing many of the issues which had been raised. In addition, the company requested further training in design for production principles. However, perhaps greatest evidence of the potential impact was a new product released 6 months after the design audit workshop, encompassing improved aesthetics, ergonomics and design for production. Whilst it would be inappropriate to claim that these changes are solely the result of the audit process, company feedback indicated that they were strongly influenced by the design audit. Thus, it would be safe to conclude that there was an increased awareness of good design issues.

Application case analysis

The audit tool developed iteratively during the application phase. Where necessary, changes were made to the audit tool, its delivery process and the design of the worksheets in response to findings from each application. A summary of each case, responses to the audit tool and resulting changes is provided in figure 11.

FIGURE 11 ABOUT HERE (Cross case comparison)

The audit tool evolved during application, to address issues of completeness, usability, utility and also usefulness. In Case K for example, there were 22 activities, presented as a single maturity grid. Responses indicated the potential benefits of the approach but indicated a lack of completeness in the model. Detailed grids were developed for application in cases L and M to address this concern. Throughout the research process however, there was a fine balance between comprehensiveness and usability. This is reflected most strongly in case N, where additional activities resulted in a perception of over-complexity. In addition, the design of the worksheets themselves has a moderate impact on participants' ability to follow, use and engage with the audit tool. In cases O and P, incremental changes to the phrasing, presentation and delivery of the audit tool resulted in very positive responses from participants.

Although each application company was very different, the audit tool and its contents remained applicable in each case. In part, the audit tool has its own in-built contingency model; it is neither necessary nor desirable for all companies to perform at the higher levels for each activity. In addition, in each case, participants were asked to consider additional activities that might be specific to their unique circumstances.

The delivery process itself also evolved during the research process. During the early cases (K, L and M), the participants scored the activities individually before collating their responses as an input to further discussion. During the later cases, it was found to be more effective to have smaller groups discussing scores to arrive at a consensus view at an early stage. This also enabled each group to explain their perceptions of performance and further debate on differences between the groups. A key part of the implementation process was the systematic capture of potential actions for improvement, using the detailed grids for guidance on the types of behaviour that might be expected at higher levels of performance. Finally, the facilitator has a strong role in establishing the objectives, approach and atmosphere of the discussion.

DISCUSSION

This research has contributed to both academic understanding and industrial practice, by synthesising insights from multiple sources, to create a design audit tool which is useful to industry. The main contributions of this work are:

› A model of 'good design' based on evidence from cases and literature (figure 6).

› A design audit tool and its associated delivery process enabling the assessment of current design capability to raise awareness of good design practices and target improvement initiatives.

› Together, the model and audit tool represent a synthesis of good practice issues from a wide variety of sources, integrating literature from multiple domains.

› Insights into how design is both executed and managed in SMEs

A model of good design

The model of good design provides the underlying structure of the design audit tool (figure 6) and represents a holistic view of product design issues. It takes a step towards integrating literature from a wide range of perspectives; including design and NPD processes, marketing, aesthetics, ergonomics, and design for manufacture. In addition to insights from literature, this model has been iteratively developed through the application of the audit tool in six companies and is informed by four longitudinal exploratory cases. It does not aim to present a comprehensive set of all activities that may be executed in the design process. Instead, it provides a representative sample of the key issues of concern in the design of new products in SMEs. Application and evaluation supported the choice of activities/issues and did not reveal additional, more pertinent concerns.

This model provides an alternative visualisation of the product development process, by integrating and making explicit both design and managerial perspectives. Improvements to managerial concerns typically impact on the achievement of project goals such as time to market or project spend. Improvements to the design process may have a greater impact on product quality. However, evidence from exploratory (and application) cases indicates a preoccupation with managerial concerns, resulting in the design of weak products, which fail to satisfy the demands of consumers and produce insufficient rewards for the company. Thus, by visually distinguishes between these two interrelated processes, the model aims to raise the profile of the design process, to counter an over-emphasis on the NPD process issues in many companies.

The design audit tool

Built around this model of good design, the design audit tool enables the assessment of design capability in SMEs and has been demonstrated to be feasible, usable and useful through application in action research mode. It was successful in raising awareness of good design issues amongst managers and staff engaged in product development; encouraging a more holistic approach to design.

In creating this tool, there was a careful balance to be found between comprehensiveness and usability. The success of the final audit tool was intimately related to its delivery process, as also noted by Chiesa et al [16]. In application, the way in which the process was introduced, the sequence of activities, the skills of the facilitator and the way in which actions were captured all played a significant role in perceptions towards the tool itself. Whilst efforts were made to gain feedback on the delivery process and the tool separately, in practice of course, they are closely intertwined. Guidance on the delivery of the tool was included as a key part of the workbook that emerged as a result of the research.

In developing the audit tool, there was a careful trade-off between the ideal control of variables and the pragmatic need to adapt to the demands of the case companies. These limitations are characteristic of action research approaches and efforts were made to mitigate any potential sources of error, including the triangulation of verbal and written feedback from participants with observations from the facilitator and an independent researcher-observer.

A further and perhaps greater challenge was to encourage companies to make the transition from increased awareness to actually planning and implementing actions. To some extent this hurdle was overcome, by using specific worksheets to encourage the capture of actions. Ultimately however, a process of this type can only lead a company a way along the path – it is up to them to take the final steps.

The maturity grid enables the codification and presentation of a range of practices, described in language which is familiar to the practitioner. It was assumed that the detailed descriptions contained within the maturity grid would result in a high degree of consensus between respondents. However, individuals in a single firm may still have greatly differing perceptions over current performance. This highlights the inherent unreliability of any single respondent assessment and demonstrates the value of the tool in generating discussion and raising awareness. It also indicates that this tool (and similar tools) would be inappropriate for benchmarking performance between companies.

Contribution to theory

Two perspectives have largely dominated research in new product development; 'success factors' studies [e.g. 59, 77] and 'stage-gate' style processes [e.g. 21]. Both of these perspectives reinforce the prevailing wisdom that 'success' is a function of an effective new product development process. Moreover, there is an implication that it is the management of this process which is critical. Whilst these ideas have made a substantial contribution to the understanding and practice of product development, there is also evidence that they may be insufficient.

The outputs of many NPD success factor studies seem to suggest that a well managed process is the key route to success. The need for that process to deliver exceptional products is often overlooked. Several studies identify 'product superiority' [33, 59] as a key factor, which is in many ways somewhat tautological. To be truly useful to practitioners, some sense of how this superiority is to be achieved is essential. There is thus an opportunity for new product development success factors to be derived using other measures of success (e.g. excellent ergonomics or high gross margin). There is also some evidence that the factors quoted are incomplete. Many empirical studies for example have confirmed the positive relationship between a design orientation and commercial success [e.g. 43]. Others have more specifically identified industrial design as a key contributor [35]. However, these (and other) design related elements are mostly overlooked in almost all NPD success factor studies.

Many of the lessons of new product development are only gradually being adopted in practice [23], especially in SMEs [9]. In 1992, Barclay [5] surveyed around 149 companies and concluded that only 7% of managers were familiar with the results from the major academic studies. In part, this may be due to much of this literature being functionally biased and (relatively) inaccessible to practicing industrialists. Therefore, a key goal of this research was to capture established wisdom on good design practices in a form which was accessible to industrialists. It was not the specific intention to uncover new practices or new behaviours. This research was therefore essentially integrative, drawing together inputs from a variety of sources, demanding an extensive review of literature. The final audit tool provides busy industrialists with a readily digestible synthesis of good practice principles.

Maturity approaches to assessing process capability provide a way of capturing such good practice principles in an accessible form which leads to action for improvement. A number of maturity based tools have been devised for product development issues. However, existing approaches have focused largely on managerial concerns. Thus, this research sought to adapt process maturity principles to design issues.

A clear observation from this study is that this overtly managerial approach to product development is insufficient. To develop excellent products, there also needs to be sufficient emphasis on the design process. Arguably, in SMEs, there needs to be less emphasis on management controls, checks and measures and a greater emphasis on high quality 'design thinking'. Product development research needs to be more explicit in distinguishing between these intertwined, but essentially different elements. By making this distinction explicit, NPD research could offer greater benefit to practitioners by providing a more holistic and balanced approach.

Design and design management in SMEs

Throughout this research, a number of small-companies were involved, primarily from the industrial goods sector. These engagements resulted in a number of general impressions about the way in which product design is executed and managed. Whilst these cannot be described as concrete findings, they do however provide some insights which might inform possible future research and are described briefly below:

- ***Scarce resources & risk aversion***: almost all of the firms had clear constraints on their financial and human resources. As a result, several practices associated with larger firms were not evident. For example, the firms did not have the luxury of developing technology 'off-line', to be later implemented in new products. These limited resources meant that the firms were unable to simultaneously develop a portfolio of high risk, medium risk and safe projects. As a result, they erred towards safer projects, which were typically incremental developments of existing offerings. Furthermore, it was apparent that the product development process generally prevented the riskier projects by presenting (business) hurdles which could not easily be overcome. Most of the companies were also wary of the expense of employing external designers. However, these external skills offered the opportunity to develop more radical solutions than their internal resources were capable of.
- ***Quality to market***: most of the firms were influenced by the higher profile product development findings; notably, the time-to-market perspective. However, it was apparent in several companies that time (and to a lesser extent spend) were not the critical factors. Almost without exception, the more important requirement was the need to deliver high quality products to market; especially when the business' future rested on a single new product. In several cases, the knock-on effect of poor quality was expensive re-work, which correspondingly delayed further projects.
- ***Weak functional skills & 'silent marketing'***: There was an evident weakness in some basic design skills. For example, although the principles of design for manufacture are well established, there was little evidence their usage. This was manifest by the general reluctance of the development teams to estimate the likely unit cost of a new product. Almost without exception, 'inbound' marketing activities (e.g. market research, competitive analysis etc.) were poorly performed. The marketing staff were typically acting as 'sales support' engaging in 'outbound' marketing activities (advertising, PR, technical sales etc). As a result, there was an over-reliance on managerial gut-feel, occasionally calibrated by experience in the industry. Where market analysis was carried out, it was generally performed by people with little previous training, experience or skill in that area - 'silent marketing'.
- ***Insufficient user/customer involvement***: there was a general reluctance to actively involve users (or customers) in product creation. Efforts to really understand the motivations of users were often half-hearted, and served to provide justification to decisions already made. Several companies expressed reservations in involving customers to assess original concepts due to concerns over intellectual property and commercial confidence. However, this fear was often misguided as rapid competitive response was in most cases unlikely and the benefits of user feedback far outweighed any potential risks.

› ***Unconventional teams***: In most cases, dedicated project teams were unrealistic, as the work load demanded a highly flexible work force. Perhaps surprisingly however, most of the firms adhered to the traditional organisational structure of sales (and marketing) and operations (engineering and production). There was a good case for this model to be reconsidered to emphasise the central business processes of order fulfilment (sales and production) and product introduction (marketing and engineering).

› ***Process bureaucracy vs managerial control***: Almost without exception, the firms struggled to find the right balance between sufficient managerial control and excessive bureaucracy. Where 'phase review' processes had been implemented, it typically replicated processes exhibited in larger firms and were in several cases inappropriately complex.

› ***Organisational turbulence***: Constant changes in company ownership, senior management structure, location and financing arguably had a far greater influence on product development than external factors (such as competitive activity). With each change, priorities were reassessed, the strategy changed and the flow of new products was disturbed. As a result, the need for each new project to succeed increased and thus the desire to take on risks reduced.

The structure and content of the audit tool reflects these observations and goes some way towards helping small firms understand the specific challenges that they face.

Research limitations

This research has contributed to both academic understanding and to the improvement of industrial practice. A key strength of the audit tool is that it holistically addresses a wide breadth of topics. As a result, however, it does not cover the individual topics in great depth. Thus, it is likely that an expert in any one area might find the contents to be superficial. In addition, whilst striving to produce a usable tool, many potentially valid activities were removed. Again, it would also be possible to criticise the tool for errors of omission. Whilst potentially fair criticisms, the depth and content of the final audit tool are consistent with the aims of the research; to capture good practice issues in a form accessible to industrialists.

During the early phases of the research, time was spent identifying good design issues in four longitudinal exploratory cases. Whilst providing valuable insights, these cases delayed the application of the design audit in action research mode. Ultimately, the audit tool was applied in six cases, which was sufficient to demonstrate the viability of the approach and its potential usefulness. Further application cases may have been beneficial although it is likely that these would have only introduced minor changes and not raised more fundamental concerns.

Given the limited number of applications, practical considerations needed to be considered above rigorous control of variables in each case. For example, in different applications, there were changes to the audit tool, the delivery process, the nature of the company and team and the design of the tool's visual appearance. When drawing conclusions about the success of these changes, judgements needed to be made which were appropriate to the circumstances in each case. It would have been impractical to assess the impact of individual changes whilst keeping all other variables constant. Whilst noted as a potential limitation, every attempt was made to ensure that these judgements were objective and valid, drawing insights from participants (verbal and formal feedback) as well as an independent researcher observer.

It is difficult to attribute and improvements in design practice specifically to the design audit tool. For example, in the final case, there was a noticeable change in the design of their products following the design audit process. However, merely by attending the workshop, participants had already accepted the need for change. Indeed, one of the contributing factors to the tool's success could well be the participating company's basic willingness to adopt new practices. Thus, it was difficult to establish direct causality between the audit tool and the ultimate outcome. Acknowledging this potential limitation, feedback on the usefulness and usability of the design audit was generated using a variety of inputs, including a structured feedback form, researcher observation and post-workshop interviews. Where possible, feedback was also gained from independent observation.

The audit tool was designed for application in SMEs, typically producing industrial products. During application and evaluation, there were concerns about whether the tool was applicable in different contexts. Accepting that a goal of most research is to develop generaliseable knowledge, then a key limitation of action research approaches is the necessity to focus on implementation in a small number of companies [96]. It is unlikely that a specific procedure will prove useful in all organisations, and thus it is difficult to generalise the possible effects of a procedure. However, the design audit contains an inbuilt contingency framework. It is not expected or desirable that all companies exhibit leading performance in all areas. Different responses to audit questions would be expected in different context (e.g. volume of manufacture, company size, company sector or culture). Nonetheless, a potential limitation of this research is the lack of time to both develop a robust tool in specific contexts and also to demonstrate wider generalisability. The final validation phase goes some way towards addressing this concern.

CONCLUSIONS

A design audit had been described which encourages attention to be focused on effective execution of the design process. The audit tool emphasises the design process as a component of the wider NPD process. In application, it enables a balanced consideration of 'good design' issues to complement more traditional project objectives (cost, time and spend).

By drawing together information from a diverse range of sources, this study hopes to raise practitioner awareness of good design issues and provides a useful and usable tool to support managers in improving both products and the design process that delivers them.

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FIGURES & TABLES

Do you involve your customers and users in design	
Yes	No

Scale #1 – binary yes/no scale

We always involve our customers and users						
1	2	3	4	5	6	7
Strongly disagree		Disagree		Agree		Strongly agree

Scale #2 – Likert type scale

How do you involve your customers and users?						
1	2	3	4	5	6	7
Users rarely involved						Relevant stakeholders involved throughout

Scale #3 – modified Likert style scale

Ongoing user involvement			
Level 1	Level 2	Level 3	Level 4
Users rarely involved	Users sometimes involved at the start	Users involved at start and end	Relevant stakeholders involved throughout

Scale #4 – 'maturity' scale with multiple anchor phrases

Ongoing user involvement			
Level 1	Level 2	Level 3	Level 4
Users rarely involved	Users sometimes involved at the start	Users involved at start and end	Relevant stakeholders involved throughout
• Users rarely involved at all • The only contact with users is through the sales force	• Users occasionally asked for early input • Some feedback may be sought after product launch • A marketing task - results not widely disseminated	• Users are always involved early - typically during product definition • A marketing activity, but responses are collated and fed back to the core team	• Users involved throughout, including idea generation, concept selection and evaluation of prototypes • Internal and external stakeholder involvement

Scale #5 – maturity grid, with extended descriptions

Figure 1: Approaches to auditing processes

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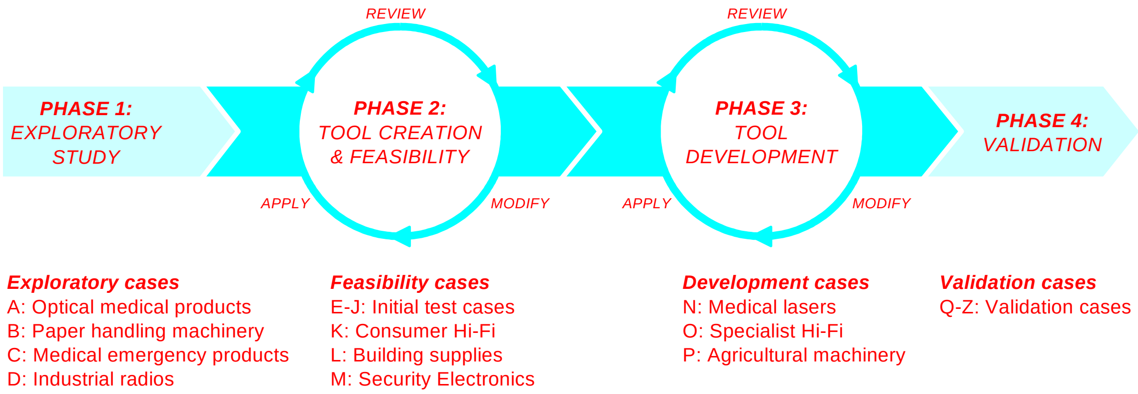

Figure 2: Research process and cases at each phase

	Case company	Sector / Products	T/O £m	Staff
Exploratory study	A	Optical medical products	£12.0m	133
	B	Paper handling and collation	£4.0m	80
	C	Medical emergency products	£5.5m	100
	D	Industrial radios	NA	NA
Tool creation and feasibility	E	Scientific instruments	£1.2m	25
	F	Industrial ink-jet printing	£150m	1500
	G	Software	£3.0m	45
	H	Design consultancy	£1.0m	12
	I	Food machinery	£20.0m	200
	J	Consumer tools	NA	NA
	K	Consumer Hi-Fi	£10.0m	110
	L	Building supplies	£15.0m	250
	M	Security electronics	£3.0M	50
Tool Devpt.	N	Medical lasers	£6.0m	70
	O	Specialist Hi-Fi	£3.5m	30
	P	Agricultural machinery	£9.0m	130
Tool validation	Q	Instrumentation: Spectrometers	£10m	75
	R	Instrumentation: Sensors	£543m (Group)	664 (Group)
	S	Instrumentation: Scientific equipment	£6m	100
	T	Instrumentation: Hygrometers	£5m	60
	U	Instrumentation: Sensing & control	Group £23bn	Group 15,000
	V	Consumer electronics: Audio	£3.5m	30
	W	Consumer goods: White goods	>£20m	>200
	X	Industrial goods: Building supplies	£15m	275
	Y	Consumer electronics: Audio	£4m	45
	Z	Design consultancy	£0.75m	12

Figure 3: Summary of cases

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	Success factors	Indicative sources
DESIGN MANAGEMENT	Cross functional teamwork & communication	3, 4, 5, 9, 18, 20, 22, 33, 39, 50, 51, 61, 67, 72, 74, 76, 81, 85, 97
	Top management support & involvement	2, 3, 5, 8, 9, 22, 33, 40, 49, 50, 54, 59, 76, 77, 81, 91
	Strong project management & control	4, 17, 18, 33, 39, 48, 51, 54, 74 , 77
	Product strategy & project selection	8, 22, 33, 67, 72, 74, 91
	Effective NPD process	8, 22, 33, 39, 58, 72
	Functional competence & skill	4, 8, 9, 18, 49, 59, 74, 85
	Outside support / alliances	9, 40, 77, 91
	Appropriate team rewards	39, 40, 67
	Adequate / appropriate resources	9, 22, 32, 37
	Creative / innovative culture	4, 22
DESIGN EXECUTION	User / customer analysis & involvement	17, 40, 49, 50, 54, 59, 76, 77, 81, 91
	Market analysis & understanding of market needs	3, 9, 18, 33, 37, 48, 58, 74, 81, 85
	Pre-development planning	20, 22, 33, 54, 91
	Product and project definition	4, 8, 18, 19, 22, 50, 59, 67, 91
	Prototyping / concept testing / experimentation	3, 4, 33, 40

Figure 4: Summary of NPD success factor studies

	Activities	processes
DESIG N MANA GEME	Trigger, find product ideas	BS7000, Pahl & Beitz
	Opportunity and problem identification & analysis	Otto & Wood, Cross, Pugh, Urban & Hauser
	Product & portfolio planning	Ulrich & Eppinger, BS7000, Otto & Wood
DESIGN EXECUTION	Problem statement / vision / product proposal	Pahl & Beitz, Cross, Otto & Wood, Ulrich & Eppinger
	Competitive analysis [Otto & Wood, Ulrich & Eppinger]	
	Customer & lead user needs analysis	Otto & Wood, Ulrich & Eppinger
	Market segmentation and product positioning	Urban & Hauser, Ulrich & Eppinger
	Product specification, and requirements list	Pugh, Pahl & Beitz
	Identify goals, essential problems & constraints	Ulrich & Eppinger, Pahl & Beitz
	Technical and economic feasibility	BS7000, Ulrich & Eppinger, Pahl & Beitz,
	Idea generation and conceptual design	Urban & Hauser, BS7000, Pugh, Cross, Pahl & Beitz
	Industrial design, product form & material concepts	Ulrich & Eppinger, Pahl & Beitz
	Product architecture / system design	Otto & Wood, Pahl & Beitz, Ulrich & Eppinger, Cross
	Concept selection, select best primary layouts	Pahl & Beitz, Pugh, Ulrich & Eppinger
	Design for X (manufacture, assembly, service etc)	Otto & Wood, Ulrich & Eppinger
	Prototypes, physical / analytical modelling, evaluation	Ulrich & Eppinger, Otto & Wood
	Full production documentation: detailed engineering drawings, tooling, parts lists, assembly documents	Urban & Hauser, Cross, Pugh, BS7000, Pahl & Beitz, Ulrich & Eppinger, Otto & Wood
	Field and market testing	Urban & Hauser, Ulrich & Eppinger
	Performance testing (reliability, life, quality)	Pahl & Beitz, Ulrich & Eppinger, Urban & Hauser
	Manufacture, Production, production ramp up	Pugh, BS7000, Ulrich & Eppinger

Figure 5: Summary of 'design activities' from the design domain

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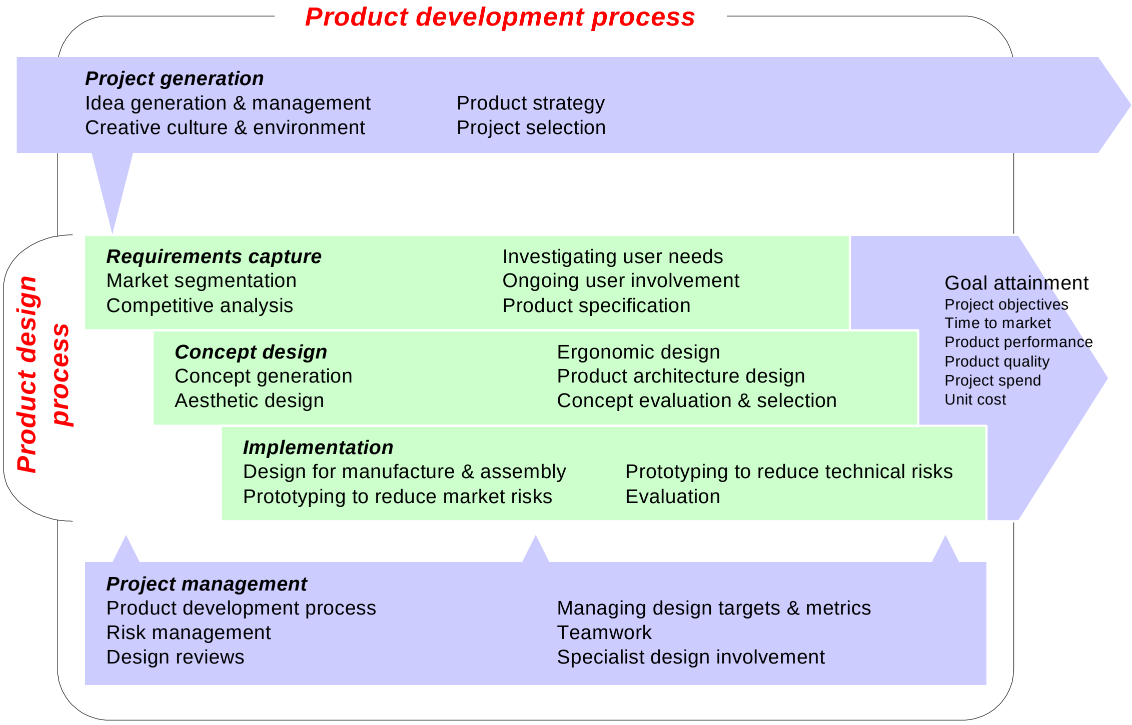

Figure 6: Model of good design - structure of design audit

Design execution: Requirements capture

Activity	Level 1: None / ad-hoc	Level 2: Partial	Level 3: Formal	Level 4: Culturally embedded	Current score (1-4)	Desired score (1-4)
Market segmentation	No obvious segmentation	Price based segmentation	Performance based segmentation	Benefits based segmentation		
Competitive analysis	Little up to date competitive information	Compare numbers on brochures	Good understanding of competitors	Deep understanding of competitors		
Investigating user needs	Rely on anecdote and opinion	Opinions sometimes sought	Ōvoice of CustomerÕa standard process	Range of methods including empathic research		
Ongoing user involvement	Users rarely involved	Users sometimes involved at start	Users involved at start and end	Relevant stakeholders involved throughout		
Product specification	A poorly defined wish list	Different market and technical specs	A single, testable specification	Unambiguous USPs		

Figure 7: Example summary grid for 'requirements capture'

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Market segmentation

ÒMarket definition, segmentation and product positioning based on a clear understanding of customers and their needsÓ

Level 1: **No obvious segmentation**	*Level 2:* **Price based segmentation**	*Level 3:* **Performance based segmentation**	*Level 4:* **Benefits based segmentation**	*Current score (1-4)*	*Desired score (1-4)*
☐ What is market segmentation? ☐ No clearly defined market segments ☐ Not sure who buys our products or why	☐ Segmentation based on price - Ôtop endÕ, ÔmiddleÕ and Ôentry levelÕ ☐ Some overlap in products ☐ No accurate data on market size and share	☐ Segmentation based on product functionality or performance ☐ Clear understanding of the profiles of customers in different segments ☐ Understand the competitors in each segment	☐ Segmentation based on the benefits offered to different types of user ☐ Deep understanding of the needs of users in each segment ☐ Reliable data for each segment		

Figure 8: Example detailed grid for 'market segmentation'

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STRUCTURED DEVELOPMENT PROCESS

"A clear and well documented process to deliver new products to market"

Level 1 No formal NPI process	Level 2 A process exists but …
• Resource conflicts • No documented procedure • Heroics and individual skill • Ad-hoc • Inconsistent • Guesswork as to what to do • Frequent time and cost overruns	• It is used inconsistently • It is not respected • It is often ignored by project teams • It is seen as a burden and not an aid to product innovation • It is over-bureaucratic
Level 3 Process used and understood	**Level 4 Continuous NPI improvement**
• Clear roles and responsibilities • Process understood by all • Supports consistent new product innovation • It is not bureaucratic and supports effective decision making	• Metrics exist for performance of new products and projects • Process reviews • Process culturally ingrained and understood

Figure 9: Audit tool grid from application case K

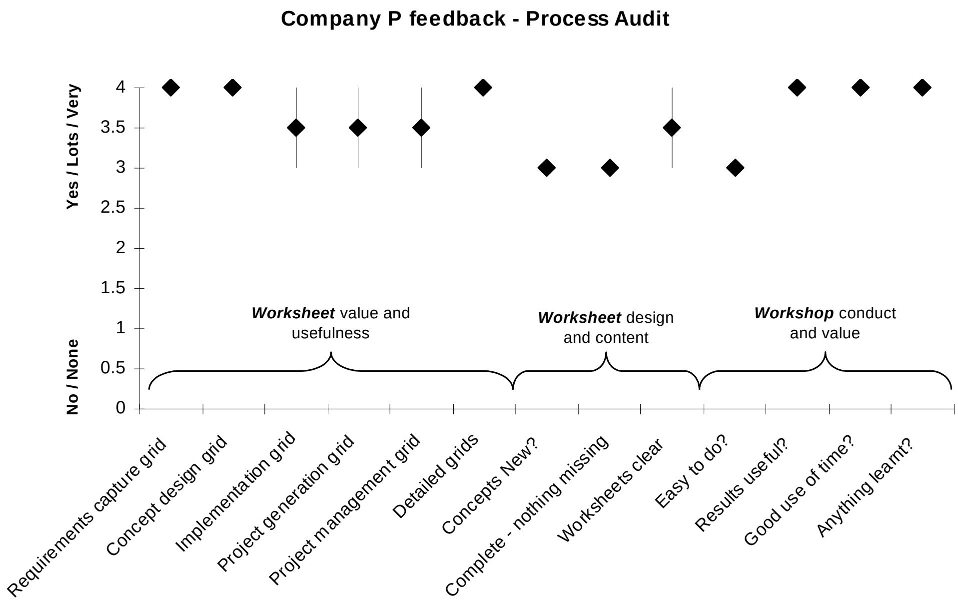

Figure 10: Example feedback from Case P

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	Case K	Case L	Case M	Case N	Case O	Case P
Sector	Consumer Hi Fi	Building supplies	Security Electronics	Medical Lasers	Specialist Hi Fi	Agricultural Machinery
Company size	110 staff, £10.0M	250 staff, £15.0M	50 Staff, £3.0M	70 Staff, £6.0M	30 Staff £3.5M	130 Staff, £9.0M
Participants	6 (mainly technical)	6 (multifunctional)	10 (multifunctional)	10 (multifunctional)	4 (multifunctional)	10 (multifunctional)
Audit tool	22 activities in a single maturity grid	22 activities presented in separate summary and detailed grids	22 activities presented in separate summary and detailed grids	31 activities presented in separate summary and detailed grids. Revised visual design	24 activities presented in separate summary and detailed grids. Revised design to include space for current and future performance	24 activities presented in separate summary and detailed grids. Revised design to include space for current and future performance
Delivery process	› Warm-up › Individual scoring › Collation › Analysis › Focused discussion	› Intro presentation & aims › Design activities at Company L › Individual scoring (summary grids) › Collation & analysis › Focus (detailed grids)	› Intro presentation & aims › Design activities at Company L › Individual scoring (summary grids) › Collation & analysis › Focus (detailed grids)	› Pre-completion and analysis of summary grids › Intro presentation & aims › In Depth Analysis (detailed grids) › Action planning	› Intro presentation & aims › Scoring of current & desired performance (using summary & detailed grids) › Action planning	› Group split into 2 teams › Group scoring of current & desired performance (using summary and detailed grids) › Group feedback & discussion › Consensus view › Action planning
Outputs	› Completed worksheets › Summary of importance vs. perceived capability › List of potential actions › Improved understanding of design process › Improved teamwork › Issues chosen for improvement included 'teamwork' and the 'design process'	› Completed worksheets › Initial action plan › Further training in user understanding › Improved communication between functional groups › Improved teamwork › Plans to involve industrial design skills in future projects › Implementation of a simple product development process › Appointment of a marketing specialist	› Completed worksheets › Summary report of discussion › Improvements in team communication › Creation and implementation of a new product design and development process	› Completed worksheets › A co-developed action plan › Summary report of discussions › Implementation of specific actions to improve design for manufacture	› Completed worksheets › Summary report of discussion › Consideration of product modifications › Improved awareness of good design issues › Recruitment of specialist designer on next project	› Completed worksheets › Summary report of discussion › Action plans for product and process improvement › Implementation of a new design process › Specific attention to product aesthetics & ergonomics on new product › Further training in design for manufacture › Improved teamwork
Usefulness	Medium	High	High	Medium	Medium	Very high
Utility	Low	Medium	High	Low	High	Very high

Figure 11: Cross case comparison

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APPENDIX 1: PROCESS AUDIT SUMMARY GRIDS

Design execution: *Requirements capture*

Activity	*Level 1: None / ad-hoc*	*Level 2: Partial*	*Level 3: Formal*	*Level 4: Culturally embedded*	*Current score (1-4)*	*Desired score (1-4)*
Market segmentation	No obvious segmentation	Price based segmentation	Performance based segmentation	Benefits based segmentation		
Competitive analysis	Little up to date competitive information	Compare numbers on brochures	Good understanding of competitors	Deep understanding of competitors		
Investigating user needs	Rely on anecdote and opinion	Opinions sometimes sought	ÕVoice of CustomerÕ a standard process	Range of methods including empathic research		
Ongoing user involvement	Users rarely involved	Users sometimes involved at start	Users involved at start and end	Relevant stakeholders involved throughout		
Product specification	A poorly defined wish list	Different market and technical specs	A single, testable specification	Unambiguous USPs		

Design execution: *Concept design*

Activity	*Level 1: None / ad-hoc*	*Level 2: Partial*	*Level 3: Formal*	*Level 4: Culturally embedded*	*Current score (1-4)*	*Desired score (1-4)*
Concept generation	Go with the first idea	Engineering led concept generation	X-functional involvement	Radical ideas encouraged		
Aesthetic design	Looks donÕt matter, performance does	Technology sometimes ÕstyledÕ	Aesthetics critical for differentiation	Design leaders in our industry		
Ergonomic design	Little consideration of usability	Engineers design user interface	Early specialist involvement	Total Õuser experienceÕ design		
Product architecture design	Configuration evolves ad-hoc	Intuitively consider modularity	Formal architecture planning	Platform based product strategy		
Concept evaluation & selection	There is only one concept	ÑChosen by the ChairmanÕs wifeÓ	Internal stakeholders involved	Internal and external stakeholders involved		

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Design execution: *Implementation*

Activity	*Level 1: None / ad-hoc*	*Level 2: Partial*	*Level 3: Formal*	*Level 4: Culturally embedded*	*Current score (1-4)*	*Desired score (1-4)*
Design for manufacture & assembly	Over the wall	Ad-hoc manufacturing involvement	Regular design reviews with manufacturing	Formal use of DfM and DfA techniques		
Prototyping to reduce market risks	Trust me itÕll sell	Occasional user testing	Always test with users	Hi-Fi & Lo-Fi modelling a way of life		
Prototyping to reduce technical risks	Trust me itÕll work	Pre-production prototypes	Prototype all risky elements	Hi-Fi & Lo-Fi modelling a way of life		
Evaluation	Customers do the QA	Minimal evaluation - no time or plan	Engineering evaluation - to a plan	Independent pre & post launch evaluation		

Design management: *project generation*

Activity	*Level 1: None / ad-hoc*	*Level 2: Partial*	*Level 3: Formal*	*Level 4: Culturally embedded*	*Current score (1-4)*	*Desired score (1-4)*
Idea generation & management	No idea management - flavour of the month	Ideas generated & then forgotten	Formal idea management	IT tools used to manage and encourage ideas		
Creative culture & environment	No playing at all	Creativity kept Ôunder the deskÕ	Some managed Ôplay timeÕ	Creativity expected & rewarded		
Product strategy	One project at a time	A strategy exists - but É	Medium term view	Shared long term vision		
Project selection	Next project chooses itself	Whoever shouts the loudest	Thorough business case	Balanced project portfolio		

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Design management: *project management*

Activity	*Level 1: None / ad-hoc*	*Level 2: Partial*	*Level 3: Formal*	*Level 4: Culturally embedded*	*Current score (1-4)*	*Desired score (1-4)*
Product development process	No process	A process exists - but É	Process used and understood	Continuous process improvement		
Risk management	Press on regardless	Aware of most technical risks	Formal management of risks	Proactively manage risks		
Design reviews	No design reviews	Design reviews at crisis	Periodic formal reviews	Regular formal and informal reviews		
Management of design targets & metrics	No targets - point & shoot	Targets - but goalposts keep moving	Targets set and partially managed	Balanced scorecard of project measures		
Teamwork	Functional rivalry	Lightweight project management	Heavyweight project management	Autonomous project teams		
Specialist design involvement	Not used - Ōsilent designÕ	Specialists come in late to Ōtart upÕ the product	Early specialist input	Strategic specialist input		