Developing maturity grids for assessing organisational capabilities: Practitioner guidance

Authors:
Anja M. Maier*, Engineering Design Centre, University of Cambridge
James Moultrie, Institute for Manufacturing, University of Cambridge
P. John Clarkson, Engineering Design Centre, University of Cambridge

*Correspondence author:
Dr. Anja M. Maier
Engineering Design Centre
Engineering Department
University of Cambridge
Trumpington Street
CB2 1PZ Cambridge, UK
anja.maier@cantab.net
+44 1223 748574

March 2009

Research-based paper (and experience-based paper)

Abstract

The principal idea of the maturity grid is that it describes in a few phrases, the typical behaviour or position exhibited by a firm at a number of levels of 'maturity', for each of several aspects of the area under study. It is a flexible technique that is used by practitioners in industry, consultants and researchers in academia for diagnostic, reflective and improvement purposes.

A large number of maturity grids have been proposed to assess a range of capabilities including quality management, software development, supplier relationships, R&D effectiveness, product development, innovation, product design, collaboration and communication. Each of these assessments focuses on a specific knowledge domain, and, as a result, is normally published in specialised journals relating to the domain addressed. Consequently, this body of work is characterised by a diversity of approaches, prescriptions and practices that can be confusing and sometimes contradictory.

The purpose of this paper is to present a common reference point in the form of practitioner guidance for developing and applying maturity grids to assess organisational capabilities. Acknowledging that some compromise is necessary and appropriate in the interests of producing a useful and usable tool, this paper provides a set of four phases whilst the development process unfolds, namely: planning, development, evaluation and maintenance. A set of specific considerations to pay attention to is added to each phase, most notably the rationale underlying maturity levels to progress form an initial to a more advanced state.

The overall research approach of this paper combines a conceptual analysis of extant maturity grids in the literature complemented with semi-structured interviews of experts who have developed and used maturity grids.

As maturity grid assessments are not just performance measures but also mechanisms for change, in developing and applying maturity grid assessments, the consultants' role shifts from being 'mere' analysts to becoming facilitators and doers.

All truth passes through three stages.
First it is ridiculed, second it is violently opposed, and third it is accepted as being self-evident.'
Arthur Schopenhauer, German philosopher, 1788–1860.

1. Introduction

Strategic and operative capabilities in an organisation, such as: design and innovation; knowledge management; and interfacing with customers, suppliers and vendors all have an impact on the bottom-line. These capabilities can be improved in many different ways, including process reengineering, total quality management, continuous-improvement and process excellence initiatives; and within that through the use of a number of performance assessments. One way of assessing a organisational capabilities is by means of maturity grids. Maturity grids are tools to assess the capabilities of an organisation required to deliver a product or a service. Thus, a maturity grid assessment can be used in one of two ways: as a stand-alone assessment or as a sub-set of a broader improvement initiative.

An assessment via a Capability Maturity Grid (CMG) is typically structured around a matrix or a grid, which creates a series of cells by allocating levels of maturity against key aspects of performance or key activities (Austin, Baldwin et al. 2001). An important feature of a maturity grid approach is that it provides descriptive text for the characteristic traits of performance at each level, referred to as a 'behaviourally anchored scale' by Grant et al. (2006). A maturity grid thus provides both an assessment tool as well as a tool for improvement.

This body of work is founded on an implicit assumption of a relationship between higher levels of maturity and improved performance in organisational capabilities (Herbslerb, Zubrow et al. 1997). This paper uses the terms organisational capabilities as the collective skills, abilities and expertise of an organisation (Ulrich and Smallwood 2004). In this vein, organisational capabilities refer to, for example, innovation, collaboration and leadership (Teece, Pisano et al. 1997; Ulrich and Smallwood 2003).

Maturity grids are deceptively simple in terms of format and use, but their development poses significant challenges. As deBruin et al. (2005) note, whilst maturity grids are high in number and broad in application, there is little documentation on how to develop a maturity grid that is theoretically sound, useful, rigorously tested and widely accepted. The main aim of this paper is to begin to fill this gap by providing a structured approach, through which a sound and useful maturity grid can be created for assessment of organisational capabilities.

This guide is intended primarily for practitioners in industry and consultants as change agents expecting to establish or review organisational capabilities. It is also intended for academic researchers concerned with intervention and change management in organisations.

This paper is structured as follows: in Section 2, origins, examples, benefits and limitations of maturity grids are listed; Section 3 presents the generic phases required for development and discusses a number of considerations at each phase, where appropriate, using a number of selected maturity grids as examples. Finally, the paper concludes with a brief discussion on the role and responsibility of a consultant – the target audience of this conference – as potential developer and facilitator of a maturity grid assessment.

2. Capability Maturity Grids (CMGs): origins, examples, benefits, limitations

Be it owing to cataclysmic failures that shake an organisation out of complacency, extrinsic motivators, such as regulatory pressures and supplier selection criteria, or intrinsic motivators, such as the desire to become better, there is a general trend to shift attention away from assessment of a product to the assessment of the process or capabilities that deliver the product – the assumption underpinning all maturity grid assessments.

2.1 Origins of maturity grids

The idea of capability or process maturity has its roots in the field of quality management, pioneered by Crosby (1979; 1996) with the Quality Management Maturity Grid (QMMG). The best known derivative is the Capability Maturity Model (CMM) for software development; developed by the Software Engineering Institute (SEI) in the US (Paulk, Curtis et al. 1993), it was originally developed to assess the capability of a supplier to design and develop software, but it has since been extended and used in many different disciplines and has now reached the level of a compliance standard (Mutafelija and Stromberg 2003). Maturity principles have also been incorporated into ISO 9004:2000 as a measure of the maturity in quality assurance.

Over the last ten years, however, there has been a rapid growth in the number of CMG assessments developed by academics, professionals in industry and by consultants (for an overview see Maier et al., 2008). These tools address areas as diverse as knowledge management (Kulkarni and Louis 2003), project management (Cooke-Davies, Schlichter et al. 2001; Crawford 2002; Hackos 2004; Grant and Pennypacker 2006), and patient safety (Parker, Lawrie et al. 2006; 2008) – a number of these CMGs are described in Section 2.2. Each of these assessments focuses on a specific knowledge domain and, as a result, is normally published in specialised journals relating to the domain addressed. Consequently, this body of work is characterised by a diversity of approaches, prescriptions and practices that can be confusing and sometimes contradictory.

Maturity grids, with few exceptions, are presented without reference to that which precedes it and new descriptions are developed for concepts that have already been described. Extant grids are therefore difficult to locate and useful conceptual developments are often overlooked. The consequences of this are that unnecessary effort is expended in developing assessments that duplicate those that already exist or new grids are developed from inappropriate foundations, with each new grid following a different rationale. Although these initiatives have often been influenced by the Capability Maturity Model (CMM), there is currently no guidance that helps developers of capability maturity grid (CMG) tools.

2.2 Examples of extant maturity grid assessments

Motives for developing and using a maturity grid have been described by a number of people, though these and their corresponding application areas are diverse and include the following:

- ***Product development management:*** good design is important to company success. Yet, especially in Small and Medium Sized Enterprises, design skills are often marginalised. Emphasising the design process as a component of the wider New

Product Development (NPD) process, Moultrie et al. (2006) developed a design audit in form of a maturity grid. The tool aims to raise awareness of good design issues and to support managers in improving both products and the design process that deliver them.

- ***Patient safety culture:*** Parker (Parker, Lawrie et al. 2006; 2008) developed a maturity grid to help organisations reflect on their progress in developing a mature patient safety culture. This initiative was part of a broader drive towards cultural change so that those working within the National Health System (NHS) move away from a culture of blame to one that is open, fair and continually encouraging improvement.

- ***Communication management:*** there is general consensus that effective communication within and between teams avoids problems. Equally, many problems of project management, engineering accidents, and healthcare-associated harm have been attributed to poor communication (e.g. Allen, 1977; Clark and Fujimoto, 1991; Nemeth, 2008). However, it is often difficult to ascertain whether communication as such is the problem or whether it is a manifestation of influences, such as lack of common understanding of goals and objectives or use of differing terminology. Maier et al., (2006; 2008) developed a maturity grid to increase reflection on factors influencing communication in engineering design.

- ***Team management:*** reacting to a report on the UK construction sector, Eclipse Consultants developed a maturity grid to assess effective teamwork (Constructing 2004). The report concluded that the construction sector does not use successful collaborative working strategies and that this can lead to animosity between consultants over territory or between contractors during the tender process. The Eclipse maturity grid aims to improve teamwork and collaborative working between professions, in this case, engineers, architects, surveyors and planners and any others involved in contributing to the design of a project.

- ***Data management and data security:*** companies frequently collect information about their customers, products, suppliers, inventory and finances. However, it can become increasingly difficult to accurately maintain that information in a usable, logical framework over time. Further, outsourcing, offshoring, mergers and acquisitions, demands for increased productivity and reductions in work force – all events that have increased in the past decade – often are accompanied by data management problems. In addition, as enterprise data is frequently held in disparate applications across multiple departments and regions questions of data security come into play. Therefore, Hackos (2004) and Stacey (1996) developed maturity grids to help companies improve information development practices and security respectively.

- ***Risk management:*** Good risk management practice, including assessment of health and safety, environmental and financial risks, is essential for businesses. In the UK, for example, the management of safety and environment are subject to regulator controls which ask for appropriate practices which, in turn, can have implications for an organisation's capability to manage safety and risk. To address this, a number of maturity grids to assess risk and reliability have been developed, e.g. by Hillson (1997) and Strutt et al. (2006).

2.3 Benefits of using maturity grids

Evidence from literature review and expert interviews suggest that maturity grids are attractive for a number of reasons which include:

- ***Supporting creation of a high-performance environment:*** akin to an overarching goal in quality management (Deming, 1986), the idea behind many maturity grid assessments is to elicit requirements for systems that help people do their best work. Conducting a maturity assessment is about creating an environment that allows and, at the same time, encourages people to do their best work.

- ***Eliciting different perspectives:*** despite differences in set-up and in execution, most maturity grids assume that perspectives of employees in the organisation will differ and present a structure for exploring these different viewpoints. A maturity grid may be used to capture both the 'as-is' and the 'to-be' situations intersubjectively, whilst at the same time taking note of the individual perspectives of the participants. Intersubjectivity between people is defined as agreement on a given set of meanings or definitions of the situation.

- ***Providing and stimulating reflection:*** conducting and participating in the process of assessment provides the possibility to mirror back individual and aggregated assessment scores and thus triggers active and collaborative thinking.

- ***Providing a guide for decisions and identifying areas for improvement:*** A maturity grid provides an organising principle which helps direct attention to important issues, raises problems that need further investigation, and provides some structure to work out how to improve an organisation.

- ***Flexibility:*** a maturity grid is an inherently flexible technique, generic and adaptable at the same time that is widely used within industry as an evaluative and comparative basis for improvement. A maturity grid can be applied to a range of organisations and teams associated with the process under assessment. In addition, capability assessment can be conducted at any stage in the design of a product or a service offering.

- ***Speed:*** the technique is appealing as it is quick, graphical and allows for instant feedback for the participants. Although it is a questionnaire of some sort, a maturity grid is an engaging exercise that captures the 'as-is' situation in a quick and engaging way.

2.4 Limitations associated with using maturity grids

Maturity grids have been criticised for a number of reasons, for example, for oversimplifying complex issues. A maturity grid needs to strike an appropriate balance between an often complex reality and the simplicity of the underlying model. A maturity grid that is oversimplified may not adequately reflect the complexities of the domain and may not provide sufficiently meaningful information for the audience whilst a grid that appears too complicated may limit interest or create confusion. Conversely, a grid that is too complicated raises the potential for incorrect application, resulting in misleading outcomes.

An inherent limitation of a maturity grid-approach, if this function is desired, is the lack of direct connection between the process areas. In reality, process areas may mutually influence each other, which should be accounted for. Results are not usually interpreted from pre-established hypothesised patterns of interrelations (other than improvement higher maturity levels of process areas have a positive effect on performance, whatever performance is defined to mean).

Finally, the implied notion of how a process ought to change might not be adequate or conversely too suggestive in a particular case. Therefore, it is all the more important to carefully select the rationale (Section 3.2.2) and follow considerations listed for each development phase presented in the subsequent sections.

3. Guidance to develop maturity grids

Problem situation: The ISO 9000 standard outlines a detailed procedure for developing capability maturity models (CMM). This proves the exception, since what is missing in the literature is guidance to develop rigorous Capability Maturity Grids (CMGs) that are not attempting to reach the status of a standard.

Research approach: An approach relying on heuristic guidance and examples is identified as a means to bridge this gap. Research to date has seen deBruin et al. (2005) and Strutt et al. (2006) suggesting a sequence of steps to go through when developing a maturity grid. Their analyses are, however, based on a comparison of one or a few examples only. This paper builds on this and other research conducted by Fraser et al. (2002) who started to compare a number of maturity grids to elicit best practices. The overall research approach of this paper combines a conceptual analysis of existing maturity grids in the literature and semi-structured expert interviews. Guidance was developed in two steps: Firstly, more than twenty extant capability maturity grids for assessing capabilities were reviewed (see Figure 2). The sample contains contributions resulting from academic studies, industry and consultancies in the fields of management science, new product development, engineering design and healthcare. Secondly, experts who have all independently developed and applied a maturity grid for assessing organisational capabilities were interviewed. All experts have undertaken consulting work. They are now pursuing academic careers in architecture, engineering and construction. Insights from reviewed literature, the experts' feedback and the authors' own experience were used to write this guide.

This guide suggests four phases: planning; development; evaluation; and maintenance. A number of considerations are associated with each phase, as depicted in Figure 1. Whilst these phases are generic, their order is important. For example, decisions made when planning the maturity grid will impact on the research methods selected to populate the grid, or the manner in which the grid can be tested. In addition, progression through some phases may be iterative and earlier phases might have to be re-visited to adjust decisions made. Although decisions within the phases of this framework may vary, the phases are consistent. Consequently, they lend themselves to being applied across multiple disciplines. The following sections describe each of these phases in more detail.

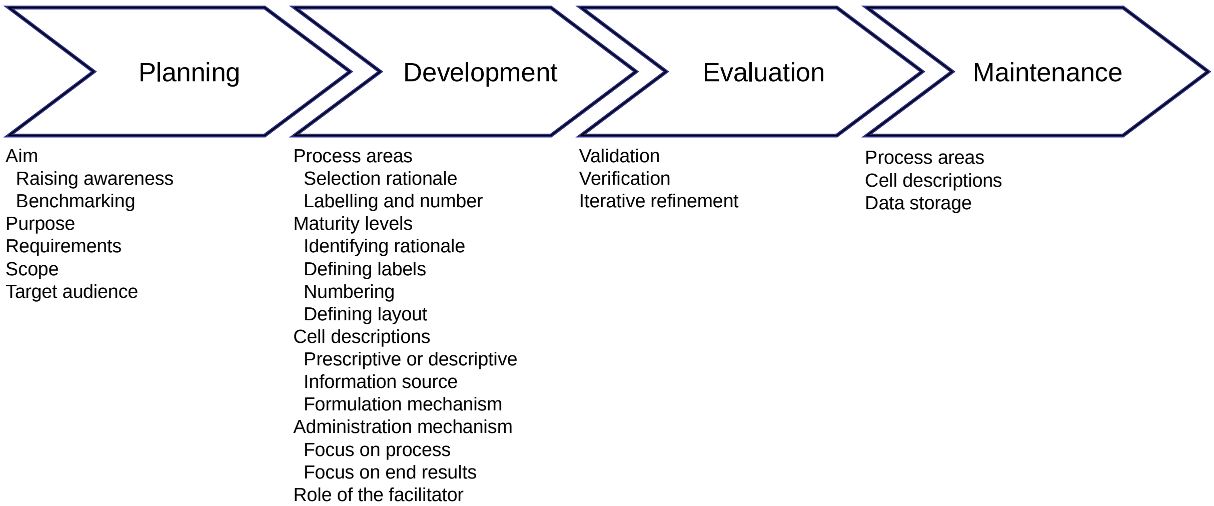

Figure 1 Phases and considerations for developing a capability maturity grid

3.1 Planning

3.1.1 Aim

It is evident from looking at existing maturity grids that two overarching aims can be identified; firstly, improvement through 'raising awareness' and secondly improvement through ‘benchmarking’ across companies or industry sectors. The latter seems to incorporate the former but not vice versa. Maturity grids that aim to raise awareness can be further distinguished into ‘descriptive’ and ‘prescriptive’ (deBruin and Rosemann 2005).

To distinguish a descriptive from a prescriptive grid, it is sufficient to look at the text descriptions in the cells (Section 3.2.3). A descriptive maturity grid provides a snapshot of the ‘as-is’ situation and, if designed in, the ‘to-be’ situation. It does not give pre-set recommendations of how to climb the maturity ladder, but rather trusts the participants’ expertise in formulating appropriate improvement steps given the specific situation of a process or capability, team or company. Conversely, a prescriptive grid gives specific recommendations how to approach maturity improvement in order to positively affect business value.

The different types of grids can be seen as distinct, yet, as deBruin et al. (2005) argue, they can also be seen to represent evolutionary phases of a grid’s lifecycle. A grid might start out as being descriptive and upon deeper understanding of the subject area it can then be evolved into being prescriptive; provided that this aligns with the underlying theoretical stance embraced by the developer and the rationale chosen for cell descriptions (see Section 3.2.3). In order for a grid to be used to benchmark processes and capabilities across an industry sector it must be applied to a high number of companies with similar parameters to attain sufficient data to enable valid comparison.

3.1.2 Purpose

Although originally assembled from an environmental regulation point of view, Pollard et al., (2004) point to four principles in the area of risk assessment that can be used as analogies of what functions a maturity grid assessments could fulfill, namely: the precautionary principle; the enforcement principle; the communication and participatory principle; and the monitoring and education principle. Emphasis on one or several principles might vary, however, these regulatory principles are generally applicable, whether the maturity grid is prescriptive or descriptive (Section 3.1.1 and 3.2.3).

3.1.3 Requirements

The developer needs to define general requirements, e.g. usability and usefulness (Moultrie 2007) and subdivide it into specific requirements, e.g. usability in terms of clarity of description and usefulness, e.g. in terms of stimulating learn effects and triggering reflection.

Usability: A product will not be usable if it does not contain the functions necessary to perform the tasks for which it is intended. Having appropriate functionality is a prerequisite, but not a guarantor of usability. Usability includes a number of areas and predominantly addresses the degree to which users understand the language used (Wilson 2002).

Usefulness: Usefulness could be seen in terms of companies' perceptions of whether they found it helpful in stimulating learn effects, in triggering reflection, or in leading to effective plans for improving a certain situation.

The two high-level requirements listed above are some of the generic ones mentioned for managerially focused action research (Moultrie 2007). The requirement list needs to incorporate the developer's and the client's objectives.

3.1.4 Scope

A developer needs to determine the scope of the grid. Is it desired to be generic or discipline specific? For example, is a grid developed to assess and improve energy management in general or in a particular discipline, e.g. construction? If it is supposed to be discipline-specific, it is especially important to gather information about the context, the idiosyncrasies and terminology of the specific discipline in order to be understood by and of relevance to the target audience.

3.1.5 Target audience

Developers of a grid have to make decisions on how their diagnostic tool is going to be used. For reasons of clarity and accuracy of interpretation, it is necessary to differentiate between different 'target audiences' and the 'unit of analysis'.

The term target audience refers to all audiences that will participate in various aspects of the assessment, be it for the data acquisition process or as the subject of the assessment. In other words, a quality manager or product development engineer, for example, will be the target audience for providing information on the product design process to be assessed. The unit of analysis, however, could be the whole research and development department. Further, the whole assessment exercise might be aimed to provide recommendations for the Chief Executive Officer's corporate planning.

To reiterate, whilst planning an assessment exercise, it is necessary to think of the target audience in three ways: 1. Who is the user, i.e. who will provide the scores? 2. Who is the subject of the analysis? and 3. Who are the results aimed at? Answers to these three questions might not be one and the same.

Decisions will have both logistical and conceptual implications. Logistical implications concern predominantly time and resource constraints relating to the participants and facilitator of the assessment. Conceptual implications relate mainly to validity, reliability and generalisability of the assessment and address questions and concerns. For example: Can one person in the company judge or decide alone for the company in question? Can results acquired from one group of employees be transferred to hold true for a different group?

3.2 Development

3.2.1 Process areas

This section of the development requires four basic decisions to be made in descending order of importance: what to select, how to select it, how many to choose and what to call it.

Selection rationale: Chiesa et al. (1996) note that an effective assessment should be based on an underpinning conceptual framework, generated from (traceable) principles of good practice, with a clear boundary delineating the scope and generalisability of the tool. The conceptual framework underlying the assessment method determines the scope of the assessment, while the choice of the process areas impacts on verification. Inevitably the selection of process areas yields insights into the authors' conceptualisations of the field.

In selecting what is to be assessed the goal is to attain key process areas that are mutually exclusive and collectively exhaustive. Typically, a number of options are available. Selection of the most appropriate technique/s will to a certain extent depend on the stakeholders involved in the grid development and the resources available to the developer or development team. Justification could be given by using an established collection of process areas to be assessed. In the area of project management, the Project Management Institute (PMI's) knowledge areas could be referred to, for example, as in Grant et al. (2006).

In a relatively new field it may not be possible to gather sufficient evidence through existing literature to derive a comprehensive list of process areas. In this instance, a literature review is considered only sufficient in providing a theoretical starting point and other means of identification are necessary. In addition, it is recommended that exploratory research methods are used. For example, through brainstorming discussions involving specialists in the field of interest or through the identification and selection of a panel of experts from whom information about a specific topic is solicited through the use of the iterative completion of a number of surveys (using, for example, the Delphi technique), e.g. deBruin et al. (2005). Alternatively, process areas may be selected through interviewing a number of industry experts, synthesising he most critical and most frequently mentioned concepts in literature, and/or a combination of the two in either order (Moultrie 2007; Maier, Moultrie et al. 2008).

Strutt et al., (2006) argue that understanding and recognising organisational process goals is an important part of defining the key processes. They recommend defining associated goals which are considered necessary to achieve the organisation's overall objective first. Then, from the goals, key processes areas can be derived. For example, one could break safety management down indo safety demonstration, safety implementation, strategies relating to sustaining companies' capabilities in the long-term etc. and find processes associated with these categories that show strategic and operational significance.

Labelling and number: Comparing extant maturity grids, labelling and selection of key process areas varies greatly, including: ‘management categories’ (Crosby 1979), ‘attributes’ (Radice, Harding et al. 1985), ‘characteristics’ (Hackos 2004), ‘processes’ (Szakonyi 1994a; 1994b), ‘activities’ (Moultrie 2004; 2007), ‘levers of change’ (Fisher 2004), or ‘factors’ (Maier, Eckert et al. 2006; 2008). Notwithstanding the label, as long as it is used consistently and its use is justified, the challenge for developing a maturity grid is to address the right level of detail. Within the 22 approaches compared, the number of selected process areas ranges from five to 132. Five of the CMGs chose six process areas. For reasons of feasibility and logistics, an appropriate number of items for such an assessment method is estimated to average around 20 (Moultrie 2004). The selection of the process areas provides the conceptual framework for the issue being addressed.

3.2.2 Maturity levels

The next step in the development is to define a set of maturity levels. A review of existing maturity grids identifies a common principle is to represent maturity as a number of cumulative stages where higher stages build on the requirements of lower stages. The practice, with the highest number representing high maturity and the lowest number low maturity, was made popular by the CMM and appears to have wide practical acceptance.

At this phase in the development, the following decisions need to be taken, in chronological order of importance, starting with the most important: identifying rationale, defining labels, numbering, and defining layout:

Identifying rationale: What makes capabilities more mature? There are many possibilities to answer this question, where each answer is based on a certain rationale. Such rationale is usually - whether known or unknown, explicitly or implicitly embraced – a theory about how organisations or processes are ‘supposed’ to work and/or about how organisational change is envisaged. It is important to be clear about this underlying rationale as it impacts on the interpretation of results and affects suggestions of how a chosen unit of analysis should change to improve its performance. An explicit statement of the underlying rationale and consistent implementation is required to provide theoretical rigour of a maturity grid.

In order to highlight the challenge involved in deciding on the rationale or a set of maturity levels, a number of examples are referred to. Cell descriptions of four capability maturity grids are selected, directly to compare structural differences and theoretical assumptions about (organisational) maturity and (explicit or implicit) notions of organisational change. Excerpts of all four grids concern 'coordination' and 'collaboration'. In some examples, e.g. Szakonyi et al. (1994b), we find a mixture of organisational structure and emphasis on people.

Reviewing existing capability maturity grids, we discern a number of different underlying notions of how improvement through change in an organisation may be initiated, namely:

- **Existence and adherence to a structured process (infrastructure, transparency):** a number of extant grids base the selection of maturity levels on the rationale underlying the 5-level ranking system introduced by the Software Engineering Institute (SEI) e.g. (Kulkarni and Louis 2003; Grant and Pennypacker 2006). Maturity is defined as "*… the extent to which a specific process is explicitly defined, managed, measured, controlled, and effective"* (Paulk, Curtis et al. 1993). Thus, maturity is defined as the degree to which a process is institutionalised and effective (Paulk, Curtis et al. 1993; Dooley, Subra et al. 2001). Maturity criteria that follow this underlying assumption encourage organisations to use existing and well-known methods and practices to progress along the maturity scale. The assumption is that the more structured a process and the more transparent in terms of measurability of performance the better. The levels range from Level 1 'initial', to level 2 'repeatable', level 3 'defined', to level 4 'managed' and level 5 'optimised', where the lowest maturity, level 1, corresponds to initial or learner and the highest maturity, level 5, corresponds to a desired performance of a process of best practice. In software, for example, this translates into continuous improvement through focused and sustained effort towards building a process infrastructure.

- **Alteration of organisational structure (e.g. job roles):** for Szakonyi, (1994b) (Figure 2), maturity seems to be an increase in knowledge about skills, methods and responsibilities. The most mature form of collaboration between, in this case, Research and Development (R&D) and Marketing seems to be materialised in a technical person being in charge of marketing. This imposes a specific form of organisational model as an instantiation of best practice. The description is 'static' and does not indicate what aspects lead to improvement. In fact, the job-role is more related to responsibilities. It could be inferred that organisational change with regard to coordination of teams is best initiated via structural changes in job roles and training in skills and methods.

- **Emphasis on people (skills, training, building relationships):** text descriptions in Constructing (2004)(Figure 3) seem to embrace the underlying notion of "the more interchange and participation is practiced among teams the better", regardless of the specific task. Further, "lack of trust" and "power struggles" are placed at the lowest level of maturity. It could be inferred that the underlying assumption is that organisational change could be successful by focusing on interventions in the social relations among employees, in contrast to structural changes as we have seen above.

- **Emphasis on learning (awareness, mind-set):** Strutt et al. (2006) and Maier et al. (2006) operating in very different application areas have chosen to adapt ideas from the concept of single and double loop learning (Argyris and Schön 1978; 1978b) in order to discriminate between the capability levels. Despite aligned rationale, individual operationalisation of the theory manifested in the text descriptions characterising the process areas for each maturity levels varies greatly. Strutt et al. (2006) chose to define the text descriptions in a prescriptive way, Maier et al. (2006) in a descriptive (see Section 3.2.3). Maier et al. (Maier 2007) (Figure 4) chooses an underlying maturity concept progressing towards raising awareness for adequacy of actions and attitudes. The underlying notion of change seems to be that proactive collaboration (Level C) is favoured over reactive (Level B). Ultimately, mapping of the current and desired situations is preferred, irrespective of the specific levels. The underlying notion of organisational change and intervention sees choice of direction, initiation and reception of change to come from the employees themselves. This is in line with the sociological systems theory chosen for this approach.

		Points
Level A (Not recognized)	R&D department does not think that it needs to work with marketing in developing new products (*aerospace*)	0
Level B (Initial efforts)	Technical people want better coordination with marketing, but lack the skills to analyze the business applications of a technical idea (*petroleum equipment*)	1
Level C (Skills)	Technical people know how to develop applications of a technology, but lack of methods for working backward from a customer need to selecting technical projects (*chemical)*	2
Level D (Methods)	Work closely with marketing, but has difficulties in sorting out where responsibilities lie between technical concept and product concept (*food processing*)	3
Level E (Responsibilities)	Close coordination between R&D and marketing departments, but has not figured out how to develop new products effectively (*chemical*)	4
Level F (Continuous improvement)	Close coordination, with a former technical person in charge of marketing and taking the lead in technical marketing and new market development (*industrial equipment*)	5

Figure 2 Redrawn 'Coordinating R&D and Marketing' by Szakonyi et al. (1994b)

	Level 0	Level 1	Level 2	Level 3	Level 4
Collaboration and participation	Insularity, lack of trust or power struggles reduce participation and collaboration	Team members prefer to work alone and give more priority to their own concerns than to those of the team	The team seeks ideas, proposals and solutions from all its members	All members are given opportunities to contribute and build on suggestions from others	Familiarity, honesty, mutual trust and full participation harness the collective expertise of the team

Figure 3 Redrawn 'Collaboration' by Constructing Excellence (2004)

Factors	A: No action	B: Change of action	C: Change of action and attitude	D: Continuous adaptation	Current	Desired
Collaboration	Everyone looks solely after his or her tasks	Collaboration happens only if asked for in order to fulfill tasks	Collaboration happens proactively in order to learn from others and improve own approaches	Collaboration is constructive, happens regularly whenever necessary and there is continuous effort to improve it		

Figure 4 Redrawn 'Collaboration' by Maier (2007)

In addition to underlying notions of how change might be achieved, the choice of maturity levels and consistency of scale across text descriptions has implications for validity of resultant data (see Section 3.3.1).

- ***Defining labels:*** levels need to be distinct and well-defined. Definitions need to be intuitive and show a logical progression, since clear definition eases interpretation of results.

- ***Numbering:*** in extant grids, the number of levels varies from example to example, ranging usually between four to six (see Figure 5 for an overview).

- ***Defining layout:*** reviewing extant maturity grids, common practice seems to be to place maturity levels in the columns and process areas in the rows. This said, a further consideration when designing a grid is to decide how the results will be presented to the audience. For example, if one were to draw a profile by using lines to connect individual scores for a number of process areas on the grid, spikes and troughs are more intuitive when running vertically and hence it is advised to place maturity levels in the rows.

Name	Number	Labelling						Reference
Quality Management Maturity Grid (QMMG)	5 stages	Stage I: Uncertainty	Stage II: Awakening	Stage III: Enlightenment	Stage IV: Wisdom	Stage V: Certainty		(Crosby 1979)
Process Grid	5 levels of maturity (5=low; 1=high)	Level 5 = traditional	Level 4 = awareness	Level 3 = knowledge	Level 2 = skill and wisdom	Level 1 = integrated management system		(Radice, Harding et al. 1985)
Energy Management Matrix	5 levels	Level 0	Level 1	Level 2	Level 3	Level 4		(Research Establishment 1993)
Measuring R&D effectiveness	6 levels	Level A = issue is not recognized	Level B = initial efforts are made toward addressing issue	Level C = right skills are in place	Level D = appropriate methods are used	Level E = responsibilities are clarified	Level F = continuous improvement is underway	(Szakonyi 1994a; Szakonyi 1994b)
The Information Process Maturity Model (IPMM)	5 (+1?) levels	Level 0 = Oblivious?	Level 1 = Ad-hoc	Level 2 = Rudimentary	Level 3 = Organized and Repeatable	Level 4 = Managed and Sustainable	Level 5 = Optimizing	(Hackos 2004)
Product and Cycle-time Excellence (PACE)	4 stages	Stage 0 = Informal	Stage 1 = Functionally Focused Project Management	Stage 2 = Cross-Functional Project Management	Stage 3 = Enterprise-Wide Integration of Product Development			(McGrath 1996)
Innovation Audit	4	1	2	3	4			(Chiesa, Coughlan et al. 1996)
Information Security program maturity grid	5 stages	Stage I: Uncertainty	Stage II: Awakening	Stage III: Enlightenment	Stage IV: Wisdom	Stage V: Benevolence		(Stacey 1996)
PM Solutions Project Management Maturity Model (PMMM)	5 levels	Level 1=Initial Process	Level 2=Structured Process and Standards	Level 3=Organizational Standards and Institutionalized Process	Level 4=Managed Process	Level 5=Optimizing Process		(Fincher and Levin 1997; Crawford 2002; Grant and Pennypacker 2006)
Towards a Risk Maturity Model	4 levels	Level 1: Naïve	Level 2: Novice	Level 3: Normalised	Level 4: Natural			(Hillson 1997)
Berkeley PM process maturity model	5 levels	Level 1: Ad-Hoc Stage	Level 2: Planned Stage	Level 3: Managed Stage	Level 4: Integrated Stage	Level 5: Sustained Stage		(Kwak and Ibbs 2000)
Integrated Collaborative Design (ICD)	6 maturity levels	Level 1 = Don't know	Level 2 = Haven't thought about it	Level 3 = Thinking of doing something about it	Level 4 = Doing it as normal business	Level 5 = Full deployment and improvements	Level 6 = Inherent practice throughout operations	(Austin, Baldwin et al. 2001)
Collaboration Audit	4 levels	Level 1	Level 2	Level 3	Level 4			(Fraser, Moultrie et al. 2002; Fraser, Farrukh et al. 2003)
Design Atlas: A tool for auditing design capability	4 levels	Level 1	Level 2	Level 3	Level 4			(Bruce and Bessant 2002)
Knowledge Management Maturity (KMM)	5 levels	Level 1: Possible	Level 2: Encouraged	Level 3: Enabled/Practiced	Level 4: Managed	Level 5: Continuously Improved		(Kulkarni and Louis 2003)
The Business Process Maturity Model (BPMM)	5 states of process maturity	1. Siloed	2. Tactically Integrated	3. Process Driven	4. Optimized Enterprise	5. Intelligent Operating Network		(Fisher 2004)
Design Process Audit	4 levels	Level 1: None/ad-hoc	Level 2: Partial	Level 3: Formal	Level 4: Culturally embedded			(Moultrie 2004; Moultrie 2007)
Effective Teamwork Matrix	5 levels	Level 0	Level 1	Level 2	Level 3	Level 4		(Constructing 2004)
Communication Grid Method (CGM)	4 levels	Level A: Status Quo/No action	Level B: Change of action	Level C: Change of action and attitude	Level D: Continuous adaptation			(Maier, Eckert et al. 2006; Maier 2007; Maier, Kreimeyer et al. 2008)
NPD Process audit (Establishing an NPD Best Practices Framework)	4 levels of sophistication	Level 1	Level 2	Level 3	Level 4			(Kahn, Barczak et al. 2006)
Manchester Patient Safety Assessment Framework (MaPSaF)	5 levels	Level 1: Pathological	Level 2: Reactive	Level 3: Calculative or bureaucratic	Level 4: Proactive	Level 5: Generative		(Ashcroft, Morecroft et al. 2005; Parker, Lawrie et al. 2006; 2008)
The Process and Enterprise Maturity Model (PEMM)	4 levels/stages	P1/E1	P2/E2	P3/E3	P4/E4			(Hammer 2007)

Figure 5 Label and number of maturity levels of existing grids

3.2.3 Cell descriptions

Identification and formulation of behavioural characteristics for capabilities or processes is one of the most important steps in developing a maturity grid assessment. Process characteristics need to be described at each level of maturity. Descriptions should be precise, concise and clear to discriminate between levels. This requires: (1) decision on whether the cell-text is ‘prescriptive’ or ‘descriptive’; (2) justification of the information source; and (3) decision on the mechanism of formulating the text descriptions.

Prescriptive or descriptive: for a prescriptive approach, specific and detailed courses of action are suggested for each maturity level of a process area. For a descriptive approach, the focus is on a detailed account of the individual case and concerns for direct comparability of results between application cases are less paramount. The choice also has an impact on maintenance since detailed activities, if not sufficiently generic, need to be maintained for relevance and accuracy. In summary, there are a number of aspects to consider, e.g. underlying rationale (see Section 3.2.2), characteristics and knowledge of the subject area.

- ***Characteristics of the subject area (technical or social):*** prescribing detailed activities of what should be done at what stage is easier for technical issues. For example, if deciding on energy management, specific regulations can be used. Whereas for a social issue, such as teamwork, a generally acceptable and widely applicable detailed prescription might be more difficult.

- ***Knowledge of the subject area (established or new):*** in addition to the consideration of whether a subject area is more technical or more social in nature, deBruin et al. (2005) point to another consideration which asks whether a field is well established or new. Given the answer, different strategies can be adopted to define individual cell descriptions and even maturity levels, for example, a top-down or bottom-up approach (deBruin and Rosemann 2005). In a top-down approach, definitions are written first and then measures or a set of practices are developed to fit the definitions. In a bottom-up approach, the requirements and measures are determined first and then definitions are written to reflect these. A top-down approach works well if the field is relatively new and there is little evidence of what is thought to represent maturity. The emphasis in this instance is first on what represents maturity and then how this can be measured.

Information source: building upon interviewees' comments and the authors' experience, a number of options are available to formulate the text descriptions in each cell: (1) by synthesising viewpoints from a sample representing the future recipients of the assessment; or (2) by reviewing and comparing practices of a number of organisations, for example, by conducting empirical studies, reviewing written case-studies in literature and best practice guides from excellence initiatives.

Formulation mechanism: there are two mechanisms to formulate the actual text. One is to identify extreme ends of the scale, i.e. best practice and worst practice, and then to determine characteristics of all the stages in between. In this case, key tasks and procedures considered to represent best practice should be based on discussion with relevant stakeholders and experts in the field. This strategy assumes that the rationale for individual cell descriptions is inductively generated from the descriptions of practices. Alternatively, individual text descriptions for the cells in each selected process area to be assessed are deduced from the underlying rationale and formulated accordingly. However, this depends on the decision as to whether a definition is prescriptive or descriptive in nature.

3.2.4 Administration mechanism

The administration/delivery mechanism of a maturity grid is integral to the success of the assessment. In choosing this mechanism, consideration needs to be given to the aim of the assessment and the resources available for conducting the assessment.

The main value of an audit based on a maturity grid is to capture a companies' own assessment. This is possible by looking at the scores of the participants and by using the scores as an explicit and motivational driver for management to change the maturity level of their team, project or organisation. Existing grid assessments follow different administration procedures. In reviewing extant approaches, the choice of delivery method appears to be connected to the general goals and objectives of the assessment.

Approaches aiming at raising awareness and improving performance appear to be selecting paper-based distribution mechanisms, be it through interview and/or group-workshops (Fraser, Moultrie et al. 2002; Maier 2007; Moultrie 2007). Approaches aiming at benchmarking seem to prefer electronic systems in form of a questionnaire to reach a wide variety and large number of participants (Grant and Pennypacker 2006).

Focus on process (raising awareness): individual scores are taken as prompts for a discussion and identification of steps for improvement. Ideally, a workshop should be held to discuss what informed a participants' score of a process area and why might it deviate from his or her colleagues' perception. Overall, emphasis lies on the (discursive) process of arriving at the result.

Completion of the grid in a group-administered workshop (Fraser, Moultrie et al. 2002; Maier 2007; Moultrie 2007) has a number of advantages. The response rate is high. In addition, single-respondent bias can be avoided. Further, if respondents are unclear about the meaning of a term they can ask for clarification. This ensures participants have a common reference point which facilitates interpretation of the resulting scores. The workshop can be conducted in a number of ways, for example:

- At the start a proportion of the workshop time can be allocated to completing the set of individual grids. In the remaining time, discussion can then be directed to a selected number of pertinent aspects chosen by collecting preference statements from each participant. This option facilitates discussion based on each participant's preference.

- Data acquisition interviews based on the grids can precede the workshop so that the ensuing workshop can be structured around pre-selected pertinent items resulting from data analysis of the scores. This option emphasises and enables a thorough discussion on individual items.

- Each process area on the grid is addressed in a group, negotiating between the different individual scores. This option also functions as a team-building exercise (Chiesa, Coughlan et al. 1996).

Focus on end results (benchmarking): scores are collated to give an overall assessment of the capability and an overall maturity level for the project, business unit, company, or any other chosen unit of analysis. An overall assessment assumes that all processes are of equal importance. However, as individual scores for each process are averaged out, aggregation of results can mask potentially outstanding performance in one area or potentially weak performance in another. It also obscures differences in individual scores, which are often interesting intervention points. Overall, emphasis lies on the end result.

3.2.5 Role of the facilitator

A maturity grid assessment is a self-assessment tool, most often facilitated by a team, project or programme leader, external independent organisations, consultants or researchers. Once the tool is tested, the developer needs to decide how the assessment is going to be disseminated. If the developer is not the facilitator, it is important to have appropriate documentation and briefing material so that adequate implementation is ensured. A common way of disseminating an assessment method is by cooperating with trade institutions and/or governmental authorities.

Added value from the maturity grid assessment is in identifying the gap between the outcomes of the assessment and the necessary or desired end state for the management team or any other client. In this the facilitator plays a vital role in leading and focusing the discussion. This is not to say that the facilitator has the answers, but that they steer the discussion towards finding viable avenues for future progression. As maturity grid assessments are not just performance measures but also mechanisms for change, the facilitator's role assumes great responsibility, and thus, at this stage, the facilitator's role can become that of a 'doer' rather than a 'mere' analyst.

3.3 Evaluation

Evaluation is an important stage in the development of a maturity grid and serves a number of functions. For example, tests are used to validate the grid, to obtain feedback on whether the grid fulfilled the requirements when applied in practice, and to identify items for refinement. Ideally, evaluations are conducted within companies or institutions that are independent of the development. During this phase it is important to test input into the grid (Section 3.2.1 – 3.2.3) for validity and the results acquired by applying the grid in practice for correctness - in case of benchmarking also for generalisability (see Section 3.1.1).

3.3.1 Validation

Once a grid is populated, it must be tested for rigour and relevance. It is important to test the content composing the grid for validity. Construct validity is represented by both face and content validity.

Face validity is assessed by whether good translations of the constructs have been achieved. This is done during the population of the grid using techniques such as ‘member validation’, i.e. demonstrating a correspondence between the developer’s findings and the understandings of members of the group analysed; and triangulation, i.e. the selection of complementary methods for populating the grid, such as feedback interviews, focus groups and questionnaires (Bloor 1997).

Content validity is determined by how completely the domain has been represented. Whilst the extent of the literature review and breadth of the domain covered provides a measure of content validity, an element of subjectivity exists. This requires a degree of agreement on what particular elements need to be included or excluded, justifying the use of the theoretical framework underlying the selection of process areas (see Section 3.2.1).

In addition to testing the content of the grid for validity it is necessary to ensure that the results obtained through applying the grid ‘in the field’ are correct, accurate and repeatable. A case study approach to method evaluation may be employed. Although case studies cannot provide the scientific rigour of formal experiments, they can provide sufficient information to help judge if specific methods will benefit a project or an organisation (Kitchenham, Pickard et al. 1995). If benchmarking is desired (see Section 3.1.1), results acquired through the assessment need to be tested for generalisability.

3.3.2 Verification

Through application, the method developed needs to be evaluated against the requirements defined at the outset (Section 3.1.3).

3.3.3 Iterative refinement

Grids are likely to evolve over time where, through continued use, difficulties or limitations may be revealed (Strutt, Sharp et al. 2006; Moultrie 2007). As the assessment is used and feedback gained from the experience of companies, the grid should be iteratively refined. As consequence, evaluations should be continued until a saturation point is reached, i.e. until no more significant changes are being suggested by participants and/or until evaluation results are satisfactory (see Section 3.3.2). The first applications of the assessment should ideally be treated as a final stage of practical testing and validation.

3.4 Maintenance

The continued relevance of a maturity grid will be ensured by maintaining it over time. Access and provision of necessary resources to maintain the model will affect its evolution and use. Maintenance becomes necessary as domain knowledge and understanding broadens and deepens. Similarly, current best practice becomes outdated as a result of, for example, new technological developments. Maintenance is especially necessary if detailed and prescriptive activities have been specified in the cell-text (Section 3.2.3).

In addition, if the tool was developed for benchmarking purposes, it is particularly important to ensure accurate data storage and retrieval. In general, whilst regular maintenance is recommended, updating a tool to reflect current best practice can compromise validity. Hence, if substantial changes are made after a tool has been formally evaluated, the evaluation phase needs to be repeated.

4. Conclusions

This guide has presented a structured approach to develop capability maturity grid assessments. It suggested four phases: planning; development; evaluation; and maintenance. It also pointed to a number of considerations that are associated with each phase. Most prominently, the rationale underlying maturity levels to progress form an initial to a more advanced state. Concluding this paper by synthesising comments from expert interviews and building on our own experience in developing and applying maturity grid assessments in new product development, we would like to sketch some lessons learned.

Firstly, when developing maturity grids, we encounter the issue of academic rigour vs logistical feasibility/practical utility. We encounter it particularly with respect to the s*election of process areas and* the n*umber and comprehensiveness of process areas.* For academic purposes, the list of process areas chosen needs to be comprehensive, complete, correct, consistent and, above all, theoretically justified. For industrial applicability, however, certain flexibility for adaptation and tailoring needs to be designed into the method. It is necessary to strike a balance between developing an exhaustive method and a usable one.

Secondly, when applying maturity grids, participants need to be informed about the purpose of the assessment and results need to be 'taken back to the field'. Engagement will be higher if participants know how they will benefit from the assessment. For successful preparation and implementation of an externally administered assessment, it is important that management personnel within the company inform participants.

Finally, consultants have been found to be both developers and facilitators of maturity grid assessments. As maturity grid assessments are not just performance measures but also mechanism for change, both roles assume great responsibility.

As developers, for example, the choice of underlying rationale for what makes a more mature organisational capability has consequences for organisational change initiatives. Conversely, as facilitators of assessments it is necessary to give direction, steering the discussion, whilst at the same time adapting to a certain extent to the specific situation. Developing and applying a maturity grid assessment method may make the consultant more *of a 'doer' rather than a 'mere' analyst.* Consequently, we need to be aware of the remit of our choices – a contribution to which is hopefully made with this guide.

5. References

Argyris, C. and D. Schön (1978). Organizational learning: A theory of action perspective. Reading, Mass, Addison Wesley.

Argyris, C. and D. A. Schön (1978b). Organization Learning II: Theory, Method and practice. Reading, Massachusetts, Addison-Wesley.

Ashcroft, D. M., C. Morecroft, et al. (2005). "Safety culture assessment in community pharmacy: development, face validity, and feasibility of the Manchester Patient Safety Assessment Framework." Quality and Safety in Health Care 14(December): 417 - 421.

Austin, S., A. Baldwin, et al. (2001). Design chains - a handbook for integrated collaborative design. London, Thomas Telford.

Bloor, M. (1997). Techniques of Validation in Qualitative Research: a Critical Commentary. Context and Method in Qualitative Research. G. Miller and R. Dingwall. London, Sage: 37-50.

Bruce, M. and J. Bessant (2002). Strategic Innovation Through Design, Financial Times Press.

Chiesa, V., P. Coughlan, et al. (1996). "Development of a technical innovation audit." Journal of Product Innovation Management 13(2): 105-136.

Constructing, E. (2004). Effective Teamwork. A Best Practice Guide for the Construction Industry. Construction Excellence. www.constructingexcellence.org.uk. Watford: 20.

Cooke-Davies, T., J. Schlichter, et al. (2001). Beyond the PMBOK guide. Proceedings of 32nd Annual Project Management Institute Seminar Symposium, Nashville, TN.

Crawford, J. K. (2002). Project management maturity model providing a proven path to project management excellence. New York, Marcel Dekker.

Crosby, P. B. (1979). Quality is Free. New York, McGraw Hill.

Crosby, P. B. (1996). Quality is still free. Making quality certain in uncertain times. New York, McGraw-Hill.

deBruin, T. and M. Rosemann (2005). Understanding the Main Phases of Developing a Maturity Model. 16th Australasian Conference on Information Systems, Sydney.

Dooley, K., A. Subra, et al. (2001). "Maturity and its Immpact on New Product Development Project Performance." Research in Engineering Design 13(1): 23-39.

Fincher and Levin (1997). Project Management Maturity Model. PMI 28th Annual Seminars and Symposium, Chicago, IL.

Fisher, D. M. (2004). The Business Process Maturity Model. A Practical Approach to Identifying Opportunities for Optimization. BP Trends. September.

Fraser, P., C. Farrukh, et al. (2003). "Managing product development collaborations - a process maturity approach." Journal of Engineering Manufacture, Proc. Instn Mech. Engrs, Part B 217(B11): 1499-1519.

Fraser, P., J. Moultrie, et al. (2002). The use of maturity models/grids as a tool in assessing product development capability. Proceedings of IEEE International Engineering Management Conference, IEMC, Cambridge, UK.

Grant, K. P. and J. S. Pennypacker (2006). "Project Management Maturity: An Assessment of Project Management Capabilities Among and Between Selected Industries." IEEE Transactions on Engineering Management 33(1): 59-68.

Hackos, J. (2004). "The Information Process Maturity Model: A 2004 Update." Best Practices 6(4).

Hammer, M. (2007). "The Process Audit." Harvard Business Review(April): 111-121.

Herbslerb, J., D. Zubrow, et al. (1997). "Software Quality and the Capability Maturity Model." Communications ACM 40(6): 30-40.

Hillson, D. A. (1997). "Towards a Risk Maturity Model." The International Journal of Project and Bbusiness Risk Management 1(1): 35-45.

Kahn, K. B., G. Barczak, et al. (2006). "Perspective: Establishing an NPD Best Practices Framework." Journal of Product Innovation Management 23: 106-116.

Kitchenham, B., L. Pickard, et al. (1995). "Case Studies for Method and Tool Evaluation." IEEE Software 12(4): 52-62.

Kulkarni, U. and R. S. Louis (2003). Organizational Self Assessment of Knowledge Management Maturity. Ninth Americas Conference on Information Systems.

Kwak, Y. H. and C. W. Ibbs (2000). "Calculating Project Management's Return on Investment." Project Management Journal 31(2): 38-47.

Maier, A. M., C. M. Eckert, et al. (2006). "Identifying requirements for communication support: A maturity grid-inspired approach." Expert Systems with Applications 31(4): 663-672.

Maier, A. M. (2007). A grid-based assessment method of communication in engineering design. Engineering Department. Cambridge, UK, University of Cambridge.
Maier, A. M., M. Kreimeyer, et al. (2008). "Reflecting Communication: a key factor for successful collaboration between embodiment design and simulation." Journal of Engineering Design Online First.
Maier, A. M., J. Moultrie, et al. (2008). A review of maturity grid based approaches to assessing organizational capabilities. Academy of Management Meeting, Anaheim, California, Academy of Management.
McGrath, M. E., Ed. (1996). Setting the PACE in Product Development: A Guide to Product And Cycle-time Excellence. Boston, Butterworth-Heinemann.
Moultrie, J. (2004). Development of a design audit tool to assess product design capability. Institute for Manufacturing. Cambridge, University of Cambridge.
Moultrie, J. (2007). "Development of a Design Audit Tool for SMEs." Journal of Product Innovation Management 24(4): 335-368.
Mutafelija, B. and H. Stromberg (2003). Systematic process improvement using ISO 9901:2000 and CMMI. Boston, Artech House.
Parker, D., M. Lawrie, et al. (2008). "The Manchester Patient Safety Framework: sharing and learning." Clinical Risk 14: 140-142.
Parker, D., M. Lawrie, et al. (2006). "A framework for understanding the development of organisational safety culture." Safety Science 44: 551-562.
Paulk, M. C., B. Curtis, et al. (1993). Capability Maturity Model SM for Software, Version 1.1, Carnegie Mellon University.
Pollard, S. J. T., M. Crawford, et al. (2004). "Characterising environmental harm: developments in an approach to strategic risk assessment and risk management." Risk Analysis 6: 1551–1560.
Radice, R. A., J. T. Harding, et al. (1985). "A programming process study." IBM Systems Journal 24(2): 91-101.
Research Establishment, B. (1993). Reviewing Energy Management. General Information Report 13. Watford, Building Research Establishment.
Stacey, T. R. (1996). "The information security program maturity grid." Information Systems Security 5(2).
Strutt, J. E., J. V. Sharp, et al. (2006). "Capability maturity models for offshore organisational management." Environment International 32(8): 1094-1105.
Szakonyi, R. (1994a). "Measuring R&D Effectiveness - I." Research - Technology Management March-April: 27-32.
Szakonyi, R. (1994b). "Measuring R&D Effectiveness - II." Research - Technology Management May-June: 44-55?
Teece, D., G. Pisano, et al. (1997). "Dynamic Capabilities and Strategic Management." Management Journal 18(7): 509-533.
Ulrich, D. and N. Smallwood (2003). Why the Bottom Line isn't!: How to Build Value Through People and Organizational Change, John Wiley & Sons.
Ulrich, D. and N. Smallwood (2004). "Capitalizing on Capabilities." Harvard Business Review 82(6): 118-127.
Wilson, J. (2002). Communication artifacts. The design of objects and the object of design. Design and the Social Sciences. Making connections. J. Frascara. London, Taylor and Francis: 24-32.

Acknowledgements:

The authors wish to acknowledge the support of the Engineering and Physical Science Research Council who funded the research on which this article is based. Further, we wish to thank our interviewees for their time and commitment. Our thank you also goes to all our colleagues who have supported us along the way and commented on earlier drafts.