Project management for NPD

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Abstract

This paper examines the intersection of the project management (PM) body of knowledge with new product development (NPD). The area under examination is development of consumer products (e.g. dishwashers) that have a significant engineering production content. It is concluded that the PM method, with its structured task definition and software tools, is generally useful for managing NPD projects. However, in some areas PM incompletely meets the needs of NPD. Specifically, NPD is characterised by complex interrelated activities and large uncertainties about precisely which solution path will be taken, such that the full scope of the project can often not be anticipated beforehand. The paper identifies that more research is required to validate the stage-gate and lean project management methods, and to clarify which areas in particular they benefit and how to reliably achieve those benefits. Whereas cost is the primary focus in PM (because conventional projects tend to only spend money), with NPD there is a need to consider both cost and income (from product sales) in making strategic decisions. Communication and human resource management are important factors in NPD success, but existing project management perspectives have little to say about the social and behavioural aspects, such as organisational culture, team dynamics, and leaderships styles, especially not for NPD. Some findings from human resource (HR) management are discussed here. Current PM practices are very much based on 'output control' (targets, appraisal, rewards, management by objectives), which the HM literature identifies as inhibiting innovation. There is also likely to exist an intersection, as yet poorly understood, between PM and knowledge management, particularly for innovation processes such as NPD. For practitioners the main message is that the PM method provides a basic, but imperfect, tool for managing NPD. Thus it is recommended that practitioners use, but not rely on, the PM method and the PMBOK. Practising managers might benefit from adopting new PM ideas as they appear, but need to do so with an open mind. The relevance for researchers is that gaps have been identified in the PM method as it is currently applied to NPD. Several places are identified where further research is required to (a) better understand the causality between factors (e.g. human resource management) and

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project success, and (b) adapt PM methods to better serve the NPD process.

Keywords: new product development, design, project management,

1 Introduction

New product development (NPD) is an important organisational activity since it provides future business opportunity for the organisation. However NPD involves technical, marketing, and financial risks. It therefore requires that senior executives make decisions under uncertainty, and this is helped by having adequate information before (and during) the NPD project. Thus effective project planning and control are valuable for decision-making.

Furthermore, at times the organisation may have multiple NPD candidates to consider. Since organisational resources are limited, it will have to select some candidates for further development, and abandon others. This is the problem of capital rationing. It is assisted by having estimates of life-cycle costs and risks, which again requires effective project planning.

2 Definition of the problem scope

Thus there is a need for project management (PM) methods that can handle NPD. The problem of course is that some forms of NPD, especially those involving a high degree of innovation, are notoriously difficult to manage. Many NPD projects use project management tools, at least elements thereof. However these are not always fully satisfactory, and the formal PM method in its entirety is not a complete solution for the management of all NPD projects.

Why? Some ascribe this to lack of diligence: that the PM principles were not applied thoroughly, or the staff had a motivational reason not to do so (e.g. to avoid accountability). It may also be that the uncertain outcomes of NPD defeat even the most diligent project management. Conventional project management requires relatively complete initial definition of outcomes and scope, which can be problematic for NPD: the uncertain outcomes cause the scope of work to be dynamic. This is especially the case when research is involved. Other ways in which NPD differs from other forms of project management, e.g. the construction industry, are the ongoing effort (long life cycle, product families, ongoing team working relationships), and complex work (conditional on other tasks, parallel activities).

In the engineering literature there is a distinction between different types of design/innovation, particularly research vs radical design vs new product development (NPD) vs incremental design improvements (Hubka, 1987; Hubka & Eder, 1988, 1996) vs process innovation. Different cognitive processes are understood to be required for ‘early conceptual’ design vs ‘detailed’ design

(Andersson, 1994; Calantone, Di Benedetto, & Schmidt, 1999; Fairlie-Clarke & Muller, 2003; Finger & Dixon, 1989a, 1989b). Organisations generally desire to have multiple types of innovation occurring simultaneously. For example, continuous improvement of production processes is a central tenet to manufacturing efficiency, and radical product development to customer satisfaction (Bergman & Klefsjö, 1994; Gustafsson, 1996), and firms desire both. There are even standards on the topic (BS7000, 1989) and established ways to manage innovation within particular industries (Hales, 1994; Krishnan, Eppinger, & Whitney, 1995; McCallion & Britton, 1991; Olin & Wickenberg, 2001; Pahl & Beitz, 1988; Pugh, 1991; Raine, Pons, & Whybrew, 2001; Sivaloganathan & Hillis, 2001; Tatikonda & Rosenthal, 2000). By comparison the project management perspective is not as fine-grained, but tends to view NPD as a project to be handled as any other.

This paper explores the intersection of PM and NPD, for which there is surprisingly little research (though much conjecture). It examines the existing research to determine the efficacy (or otherwise) of using project management for NPD, and provides a case study for comparison. Several strengths, and a few weakness, are found in the standard project management body of knowledge and the paper concludes with recommendations for practitioners and researchers.

3 Description of process and results

The area under examination is development of consumer products (e.g. domestic appliances) that have a significant engineering production content. Representative case study data are used in the analysis, simulating the issues that are faced by a typical organisation that designs, manufactures and sells dishwashers.

Case study component
A project was developed for the life cycle of a dishwasher (taking the producer's perspective rather than the customer's). Producing a project of this magnitude is a challenging task, because of the extended durations and the large uncertainties. There are several phases to the project, including design, testing, production, market growth, and provision for eventual withdrawal of the product. This list formed the basis of the high-level work breakdown structure (WBS), which is shown in Table 1. This was compiled by the author from personal experience in several NDP projects, and is representative rather than comprehensive. Thus no attempt has been made to provide detail down to the level of allocating tasks to individuals, and indeed such detail would vary considerably depending on the type of NPD undertaken.

By comparison the Project Management Institute (PMI) approach to project development also offers a high-level work breakdown, in the form of five stages: initiating, planning, executing, monitoring & control, closing (PMI, 2004, p42). However, these stages are too general for the NPD case under examination, hence the development of a custom list of activities.

These activities are broadly based on the extant models of the engineering design

process, such as the linear (or systematic) model (Finger & Dixon, 1989a, 1989b), Hales' model of intra-organisational influence (Hales, 1994), Raine's cylindrical model that integrates marketing, manufacturing and design (Raine, 1998), Crisp's wrapped reticule model (Crisp, 1986), the concepts of distributed design (Medland, 1996), phase diagrams (Hales, 1994; Raine, Whybrew, Dunlop, Van Rij, & Ward, 1997), and the mechanisms and constraints model (Pons & Raine, 2005). All these models are broad representations of the design process, and seek to descriptively capture the complex interconnected activities that occur in design. The models are also mostly graphical, and therefore the challenge is to translate them into a form, i.e. a WBS, that can be recognised by the project management method. The model shown in Table 1 is therefore the author's proposed translation of those design theories into a project plan, informed by experience and observation of actual industry practice. Like any WBS, it is likely that there are many different but equally valid representations, i.e. alternative WBS, but this one is sufficient for the present purposes.

The high-level activities provided in Table 1 are necessarily a simplification, and many activities are tacitly included but only become explicitly evident in lower levels of detail which are not included here. Thus the conceptual design stages involve marketing (as do the later stages of the life cycle) but thus is not detailed here. Likewise several possible strategies for treating the risk of 'market decline' are provided (see C3, Table1) but not elaborated here.

These activities were modelled with MS Project® software (MSP, 2003). Other representative information, such as resources, was included, and finally several reports were produced. Sample progress and performance measures were also determined. MS Project was selected as the software tool since it is one of the most common and accessible to practitioners.

PMBOK component

The case study was then analysed with the Project Management Institute (PMI) 'Body of Knowledge (PMBOK)' (PMI, 2004). This document describes all the activities that a professional project manager might have to consider for a general project. The PMBOK identifies nine knowledge areas where management is necessary: Project Integration, Scope, Time, Cost, Quality, Human Resource, Communications, Risk, and Procurement. Thus the analysis was structured into these nine facets. The PMBOK is not the only way of structuring the PM knowledge and process, but it is one of the more common approaches, hence its inclusion.

New product development Life cycle

A1 Idea generation	
	Identify customer needs
	Evaluate quality of existing products
	Define objectives of new product (e.g. functional, aesthetic, quality, cost)
A2 Concept design	
	Creative idea generation
	Refine concepts
	Retrieve past design intent
A3 Feasibility study	
	Check strategic feasibility (e.g. SWOT)
	Check market
	Check technology capability
	Check financial feasibility
	Check schedule feasibility
	Check for resources available
	Make decision to proceed (or not)
A4 Detailed design	
	Set the specifications
	Design key characteristics
	Produce drawings
	Produce prototype
A5 Test product	
	Test product for user satisfaction
	Test key characteristics (e.g. engineering)
A6 Finalize design	
	Review the design
	Board approval
	Revise design
	Freeze the design
B1 Set up production	
	Procure manufacturing capability
	Design the tooling
	Build the tools
	Modify building
	Obtain equipment
	Obtain manufacturing staff capability
	Start up production
	Get first parts from production
	Test parts
	Verify quality tolerances
	Produce in volume
B2 Arrange marketing	
	Identify key benefits of product
	Identify potential users
	Plan marketing strategy
	Produce brochures, adverts
	Produce 'Rainforest' campaign
B3 Arrange distribution	
	Establish sales chain

	Find local representatives
	Establish business procedures for ordering, shipping, accounting, repair
	Set up technical support capability
	Write user manual
	Write service manual
	Decide on warranty conditions
	Obtain staff capability
C1 Market growth	
C2 Market maturation	
C3 Market decline	
	C3a Declining sales
	C3b Refresh product
	C3c Launch derivative product
	C3d Differentiate service
	C3e Launch new product
C4 Product withdrawal	
	Decision to withdraw
	Produce lifetime spares requirement
	Decommission production
	Archive documentation
Project closure	

Table 1: High-level work breakdown structure for a representative NPD project, e.g. dishwasher development.

4 Results

This section describes the intersection of the case study, the PMBOK, MS Project, and the research literature on NPD. For convenience the results are categorised by the PMBOK nine knowledge areas, starting with 'project integration management'.

4.1 Project Integration Management

Project Integration Management is simply the overall project management task that keeps the whole project together. This activity occurs throughout the project (see Figure 4-1 and 4-2, PMI, 2004) and includes planning, control and closure.

Research has shown that the intensity of project management efforts in NPD varies with the development stages, being low during the conceptual stages and higher during development (Lewis, Welsh, Dehler, & Green, 2002; Panico, 2004). In many organisations product development occurs on multiple different projects simultaneously, and since development resources are typically limited, it may be necessary for the project manager to coordinate resources between multiple projects. Recent developments in project management software have actively pursued this functionality, by permitting multiple projects to be integrated using one resource pool (MSP, 2003). Further, those resources, at least the people

component, may be extracted from organisational email address books, and the task allocation and monitoring also done via email. Even so, the management of multiple projects is problematic for the project management methodology (Elton & Roe, 1998).

4.2 Scope Management

Scope management is about defining the scope and creating the work breakdown structure (WBS) down to the level of work packages (see Figure 5-1 and 5-2 PMI, 2004).

Many product development projects aim for a particular window of opportunity in the market, especially if the product life cycle is fast. Consequently, robust estimates of duration are valuable. However, this is particularly difficult to achieve when the product is innovative and experience is lacking. Existing methods such as project evaluation and review technique (PERT) and critical path method (CPM) provide some support for this case, but have the significant limitation of being unable to accommodate the uncertainty in project formulation (Sonnemans, Geudens, & Brombacher, 2003).

A popular approach to managing the uncertainty inherent in product development is to have a check point or decision 'gate' (Hart, Jan Hultink, Tzokas, & Commandeur, 2003; Palmer, 2002) at the end of major stages, hence 'stage-gate'. This approach fits well with conventional project management methods, such as the Gantt chart, in which the gates may be represented as milestones. The stage-gate methodology applies concurrent engineering, and sets mandatory activities for various stages. These stages might include preliminary investigation, business case, develop, test, and launch. There will be one or more decision gates at the end of each stage. It is a prescriptive approach, that produces a 'road-map' for the project (Howe, Mathieu, & Parker, 2000).

However, not everyone believes that the stage-gate approach is necessarily the best for NPD, because it tends to be risk-averse (Buggie, 2002). Furthermore, there is surprisingly little research literature about the actual effectiveness of the stage-gate approach, and most of the claimed benefits are conjectural rather than substantiated. On the positive side, it borrows some concepts, e.g. concurrent engineering, and formal stages of design, that are intuitively consistent with other design theories (Hubka, 1987; Hubka & Eder, 1988, 1996; Pahl & Beitz, 1988). However, those theories along with stage-gate are built on the implicit premise that design is deterministic: that it proceeds in known stages towards predictable outcomes under rational decision-making. This can sometimes be problematic when it does not capture the full complexity of design, especially innovative design. The decisions surrounding design, both management and technical, are dynamic, complex and risky. The complexity arises because the causality between work and successful outcomes is uncertain. Circumstances change (Augustine, Payne, Sencindiver, & Woodcock, 2005), and this is difficult for project management. Thus there may be rework activities, multiple partial solutions, dead-ends, changed scope, and different stakeholder views of what constitutes 'success'. Decision-making is seldom a fully

rational process (Wagner, 1991). Thus the universality of the stage-gate method is doubtful.

Product development projects often have complex interrelated activities (Söderlund, 2002). Project management, and indeed several of the engineering design theories, require that the problem be decomposed into smaller subproblems (activities and functions respectively). The PM and design mechanisms then seek to find solutions to these sub-problems. For this to be successful it is necessary that the sub-problems are sufficiently independent of each other that solving one does not disturb another. In practice the subproblems are seldom completely independent (Finger & Dixon, 1989a, 1989b) and this is termed *distributed design* or *ill-structured design*. In these problems the solution decision for one part of the problem affects that for another part. Distributed design problems may be intractable with the above approaches, or compromised in terms of efficiency. To force independence on a problem when it does not really exist, for the purposes of fitting into a management tool, is to make sweeping simplifications that manifest as divergence from the tool. This may be one reason why PM methods have sometimes struggled with highly innovative projects, e.g. research, and why rule-breaking may be necessary (Olin & Wickenberg, 2001).

Furthermore, design projects may large uncertainties about precisely which solution path will be taken. The full scope of the project can often not be anticipated beforehand, especially with novel projects. This imposes challenges on project management, which tends to prescribe complete scope definition (Buggie, 2002; PMI, 2004) because it materially affects the work breakdown structure. With product development projects it is necessary that senior managers set overall goals that are clear and relatively stable (Barczak & Wilemon, 2003) or risk poor team motivation. Against this must be balanced the need for managers to avoid unrealistic expectations as to the certainty of the process, e.g. be accommodating of changes to the work breakdown structure as the project unfolds.

4.3 Time Management

Time management covers the definition of detailed activities, estimating their duration, and linking (sequencing) them together. It also includes allocation of resources and a number of other matters (see Figure 6-1 and 6-2, PMI, 2004).

The biggest problem with estimating time (and cost) is the intrusion of bias. Bias refers to a person's inability to see something impartially. Projects may be affected by bias in various ways. At the activity level this might be someone underestimating (or overestimating) the time required to complete the activity. Many people are usually involved in providing the information that goes into a project plan. Therefore the project manager has to be vigilant about bias, not only self bias, but also that of others. Different types of bias (adapted from Vose, 1996) are:

- representativeness (stereotyping)
- availability (vividness of experience)
- over/under confidence

- motivational (comply with group expectations, management requirements, personal ambitions)
- anchoring (can't conceive the possible range)

During the control phase of NPD it is necessary to monitor the degree to which the work is completed and according to schedule. Unfortunately, there is no reliable way of determining percent-complete (Meredith & Mantel, 1995). The conservative approach is to set it as either 0% or 100%, but this is unhelpful when the tasks have durations longer that the minimum financial period (causes large inaccuracies in cash flow analysis). It only works when the WBS can be extended down into such small tasks that no accuracy is lost by following the 0% or 100% approach. In other cases it will be necessary to estimate a value from the range 0% to 100%, which may rely on the worker's own perceptions of completeness of tasks (and any associated biases). There does not appear to be any research on the accuracy of self-reported percent-complete, and this might be a useful future area of investigation. By comparison there is a substantial body of literature on human error cognition, in which there may be some common concepts.

4.4 Cost Management

Cost management covers the estimate of costs, production of a baseline, and then the cost control activities that arise when the project is under way (see Figure 7-1 and 7-2, PMI, 2004). Deterministic project paths are typically assumed, although this may result in inaccurate cost estimates (Herroelen, van Dommelen, & Demeulemeester, 1997; Isidore, 2001; Isidore & Back, 1999; Isidore, Back, & Fry, 2001).

The strategy taken towards cost management on NPD may be important, since research suggests that a focus on target costing may be inappropriate when the product is differentiated not on cost but on technology, time-to-market, or customer satisfaction (Davila & Wouters, 2004). Thus a single-minded cost focus may distract designers away from creating other value in the product.

Primary cost categories are fixed, labour, and consumables. Fixed costs are relatively straight-forward since they represent the work that is subcontracted, or plant and equipment. However the labour costs in NPD can be ambiguous since some organisational facilities, perhaps specialist engineering designers, may be shared organisational overhead. In the case under examination such costs were nonetheless included, since the objective was to provide information about the total project cost and to potentially compare that to other candidate NPD projects. Even so the project plan only includes the time that staff are budgeted to work on the project: their slack time is not costed to the project although in reality it may be. There is a work-around, which is to assign the staff to a single task that runs the full duration of their expected involvement. However, while this would fix the cost ambiguity, it would make it more difficult to determine workload, and for this reason it is not a particularly viable option. We conclude that the costing of slack time could be

better handled by the software (MS Project in this case).

From the project management perspective the NPD case under examination has the unusual characteristic of involving both expenses and income. Conventional projects tend to only spend money, and thus cost is the primary focus in the PMBOK, and also in the MS Project software. In the present case there was also income because the project included the entire life cycle. It is unfortunate that the sign conventions for project management and accounting are in conflict because this increases the risk of confusion and error when integrating project management into life cycle considerations. The overall cashflow implications for the sample project were determined by data processing of the cash flow report using a spreadsheet. The budgeted costs and incomes are shown in Figure 1 at present value (PV). However, to achieve these required external manipulation on a spreadsheet, so we conclude that there might be opportunity to improve MS Project software in this regard.

The financial performance of a project is evident in several metrics. The most popular of these is earned value, which in MS Project is termed budgeted cost of work performed (BCWP). However the term 'earned value' has variable usage (Meredith & Mantel, 1995 p524). Thus the metrics are unfortunately not all the same, adding confusion that the discipline needs to resolve.

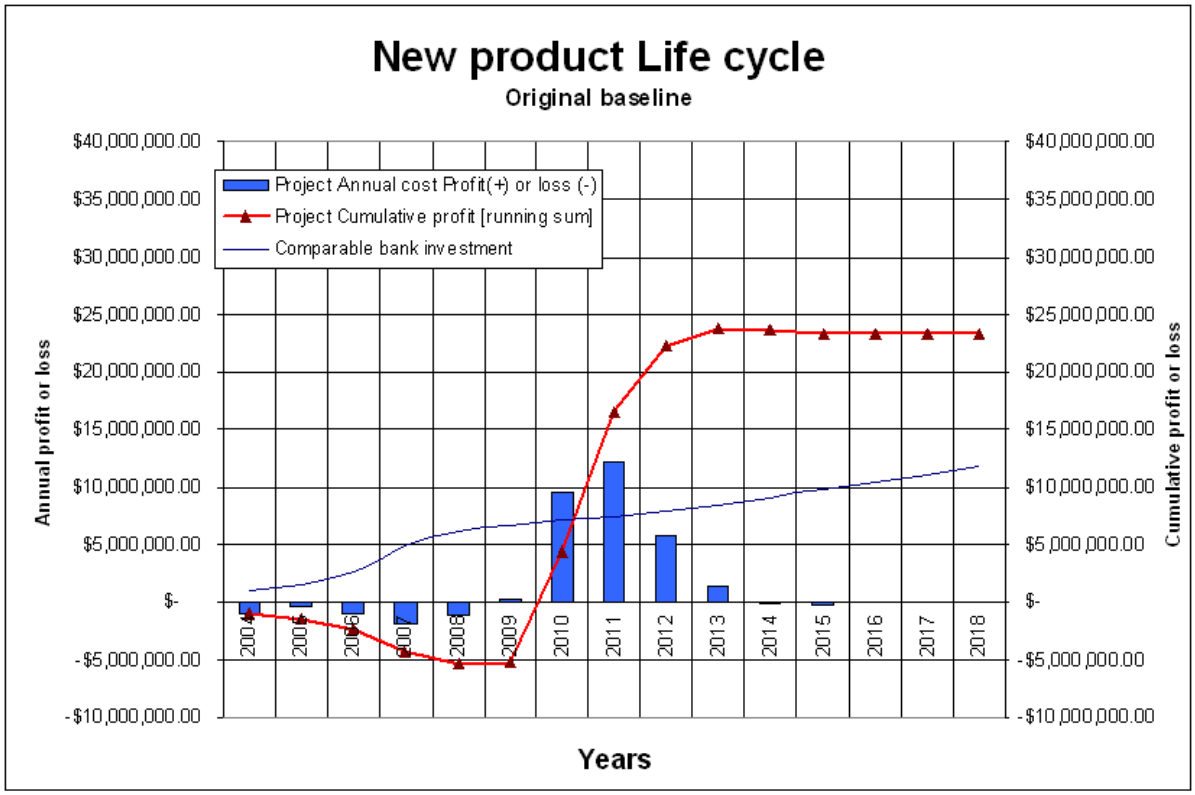

Figure 1: Life cycle cost for NPD project (baseline). The bars show the annual profit(loss), the thick line (with triangle markers) shows the cumulative profit(cost). The project sinks capital up to 2008, reaches breakeven in 2010, and eventually

returns $23M. The light line shows the alternative investment, of leaving the money in the bank at 6% and forgoing both the opportunity and the risk: the balance would be $9.9M at 2015. The NPD gives a better return (IRR is 16%, calculation not shown).

4.5 Quality Management

Quality is a broad discipline that originally developed in the manufacturing engineering areas. Topics such as total quality management (TQM) have since been developed to apply quality principles to the whole organisation. In the process the focus of quality has moved away statistical techniques, though those are still useful in production environments, to include customer satisfaction (e.g. 'voice of the customer') and continuous improvement (e.g. the plan-do-check act cycle, six sigma). Design of experiments is also included, but this is a mainly a statistical tool for research and development or problem solving, and is thus of limited relevance to many projects.

The PMBOK provides an abbreviated coverage of the comprehensive topic of TQM (see Figure 8-1 and 8-2, PMI, 2004). It includes topics like control charts, run charts, scatter diagrams (among others) that are relevant to continuous production processes. However these are not particularly relevant to project management, other than perhaps in commissioning of plant. The main quality activities from the general project management perspective are rather to determine the required quality of the deliverables, in such a way that comparison of actual vs intended quality can be done. In projects involving subcontractors, payment is often conditional on quality.

Turning to NPD, the objective here is to develop a design, and the quality thereof is complex as it is measured from multiple viewpoints, including functional, aesthetic, and production. For example, for a dishwasher the functional metrics include wash performance (ANSI/AHAM, 1992), electrical power consumption, water usage, noise, electrical and fire safety (UL, 1997), reliability. Determinants of aesthetic quality may be harder to pin down since they include elements of style that are subjective and change with time. Nonetheless style often makes the difference between an exceptional and merely adequate design, with market consequences. Some aspects of style can be quite simple, though they may have significant manufacturing implications. For example, a dishwasher must fit within the physical geometry of the typical kitchen spaces, which are not as consistent as a superficial inspection might suggest.[2] The aforementioned quality standards are from the consumer perspective.

[2]Unfortunately, there are slightly different bench-top standards between different nations. Kick space, the recess of the cupboards at floor level, is particularly variable. Although this does not affect product function, it seriously and adversely affects style considerations since the appliance does not blend into the kitchen joinery. Circumventing the problem can have major design and production implications.

The producer also has important measures of quality, including takt time (production cycle time), cost, plant capital, design for manufacture, and warranty exposure.

The whiteware industries are sensitive to customer perspectives since the financial margins are usually slim, so market-sensitivity affects survival. Thus producers seek to hear the 'voice of the customer' and incorporate features into the design to 'delight the customer'. Thus product style is generally essential in NPD, particularly for consumer products, but is not covered in the PMBOK. Typical mechanisms to determine customer preferences are focus groups and market surveys. Formal methods may be used, such as the analytical hierarchy process (AHP) that permits pair-wise comparison of bundles of alternative product features (Calantone et al., 1999; Perego & Rangone, 1996). A favourite tool in NPD is quality function deployment (QFD, or 'house of quality'). This converts customer preferences into engineering specifications (Gustafsson, 1996; Kim, Moskowitz, Dhingra, & Evans, 2000; Sivaloganathan, Andrews, & Shahim, 2001). It is popular in NPD but does have limitations that are easy to overlook (Martin, Kmenta, & Ishii, 1998; Mill, 1994).

More recently there has been an attempt to transfer some of the knowledge of lean manufacturing to project management (thus 'lean project management'). Lean manufacturing was developed in the USA (over 1850-1950 by Whitney, Taylor, Gilbreth, Ford, Deming, and Juran), and subsequently in Japan (Ishikawa, Taguchi, Toyada, Ohno, and Shingo, and manufacturing organisations such as Toyota). The lean approach seeks primarily to reduce waste, improve the production process, and reduce inventory with just-in-time production. It is a production philosophy and partly an artefact of society (particularly cohesiveness between organisations), and therefore difficult to replicate simply by copying its externally visible features (Corbett & Yucesan, 1993; Keys, 1991).

A precise definition of lean is difficult as there is no single lean methodology, but rather a collection of methodologies that are used in concert, such as 'statistical process control', 'total quality management (TQM)', 'lean production', 'six-sigma', 'just-in-time (JIT)', and 'kaizen', among others. However, all embodiments of lean manufacturing tend to emphasise, to a greater of lesser degree, continuous improvement ('learning', suggestion systems, 'kaizen'), minimisation of inefficiencies and waste, worker empowerment (teams, cells), control of workflow (balancing production lines, variant models, customer push/pull), partnerships (with suppliers, banks), and concurrent engineering.

Lean project management embraces various of these concepts, such as the need to schedule work as late as possible (JIT), minimisation of inefficiencies (Freire & Alarcon, 2002), and control of workflow (Ballard, Koskela, Howell, & Tommelein, 2005; Chua, Shen, & Bok, 2003). Concurrent engineering is already accommodated since conventional project management has a natural emphasis on sequencing tasks in parallel to reduce total project duration.

However, lean PM is a developing rather than mature concept, and is currently loosely defined and variously implemented. There is a substantial volume of popular literature that acclaims lean PM, but a paucity of robust research. Thus whether or

not lean PM adds value to project management, and if so to which areas in particular and how to reliably achieve those benefits, is not yet entirely clear (Haque, 2003). Some elements of lean PM may fail to meet expectations in the longer term, i.e. there a risk of being a fad (Boaden, 1996; Fretty, 2005; Gibson & Tesone, 2001; Malone, 1997). Nonetheless, the little research that exists suggests that it may be a viable perspective particularly for the construction industry (Ballard et al., 2005; Chua et al., 2003; Freire & Alarcon, 2002). Perhaps this is not entirely unexpected, because that industry has been moving away from a craftmanship approach towards standardised construction processes similar to manufacturing production.

Thus lean PM may have potential for projects that use existing knowledge and techniques involving configuration (variant) design. In these cases the problem reduces to a production scheduling one in which the main uncertainties are in the supply chain (Chua et al., 2003; Freire & Alarcon, 2002). Even so, it may be necessary for construction project managers to move away from the dominant subcontracting arrangement into partnering relationships (Miles, 1996), as lean manufacturing has already found. Partnerships are built on deep inextricable commitment to common goals (Miles, 1996) and a shared understanding of risk, whereas subcontracting compartmentalises the goals and the risks to different organisations.

Whether lean PM is suitable for NPD is less clear. We tentatively conclude not, because it removes organisational slack (Smart et al., 2003), so projects (e.g. NPD) with uncertain and therefore dynamic structure may suffer. Furthermore, concurrent engineering is already well known in NPD, so lean PM does not add new value in that regard. In addition, some research suggests that lean does not (yet) provide a coherent method for design (Haque, 2003): design is in turn an essential activity within NPD.

4.6 Human Resource Management

Human resource (HR) management includes the assembly of the staff (definition of responsibilities, perhaps an organisation chart, workloads required) and the assignment of tasks to staff. Many of these outputs are available off the Gantt chart and other reports produced by project management software. The project manager will also need to manage the team, for example provide training and motivation, sort out conflicts, appraise staff performance, and help decision-making work effectively (see Figure 9-1 and 9-2, PMI, 2004). However, the PMBOK does not have much to say about the social and behavioural aspects, such as organisational culture, team dynamics, and leaderships styles, especially not for NPD.

The project team is an association of people from diverse backgrounds. They may be from the organisation or external consultants. They bring different skills, and have to be managed. The assignment of a person to a project team is usually temporary. However it may be disruptive to normal business operations because of the loss of staff, especially if no relief staff are provided. If the assignment is partial, i.e. a person is expected to contribute both to the normal job and the project, then this can

be stressful for the person and there may be a workload issue. Some projects may be long duration, in which case people may find that they have no job to go back to at project closure, since the normal business has compensated and made the position unnecessary. The expectation of this may lead to fear and reluctance to commit long-term to the project. None of these issues feature strongly in the PMBOK.

Team composition appears to be an important factor in NPD success. Matrix management is popular, but has been found to be problematic for research and development projects (deCotiis & Dyer, 1977). Research tentatively suggests that cross-functional new product development teams may be effective (Hong, Nahm, & Doll, 2004; Lantos, 2005; Sethi, Smith, & Park, 2001). However, this must be interpreted with caution, as other research suggests that cross functional teams do not work reliably since the members feel stressed, neglected by the organisation and unsure of the rewards they will receive:

> *'Overall, our results indicate that management entrusts NPD teams with work critical to the maintenance and future of their organizations, yet often fails to provide these hardworking teams and team members with the support necessary to help them fulfill their charge.'* (Barczak & Wilemon, 2003 p475)

This has important implications for how senior managers influence motivation of employees, e.g. through selection of appropriate financial and encouragement rewards (Jeffrey, Michael, & Shin, 2003).

The Project manager holds the team together. While individual team members need only know their part in the project, the Project Manager needs to create the project plans and keep the overall objectives in sight. The uncertainty and possibility of failure is very much more proximal in projects than in general management, creating stress in the position. Time and cost constraints are more intense than ongoing management. There is also less job security. In addition team members are more difficult to coordinate as they are from different professional backgrounds and may have no long-term relationships to maintain with colleagues. Also, the team may consist of people from both client and service provider organisations, with different and conflicting strategic objectives. It can be frustrating to have a task to do, but have to rely on other people to do their part when those others are not task focussed and not answerable to the project manager. However the project management position also has rewards, such as the opportunity to prove abilities. There is also excitement, challenge and a sense of accomplishment. All of these are real issues for project management in general and NPD in particular, but our current knowledge of these effects and how to manage them is very limited.

Most organisations design their HR practices to encourage certain desirable staff behaviours that are believed to contribute to organisational success. This design process is termed strategic human resource management (SHRM). The large, even immense, literature on SHRM has been only weakly integrated with PM, though it is better connected to NPD because both have interest in 'innovation'. The resource-based view (RBV) of SHRM is that the organisation gains competitive advantage from resources that are rare, valuable, and inimitable, further that human resources can provide these attributes (Barney, 1991). Unfortunately many incentives that are

intended to motivate staff and align them with the organisational purposes can have unintended consequences, e.g. workgroup competition suppresses knowledge sharing (Burgess, 2005). How SHRM practices affect people working on projects is an unclear area requiring further research.
Strong market orientation of staff is usually posited to be important in innovation but there is not a lot of research to confirm or deny this (Mavondo, Chimhanzi, & Stewart, 2005). NPD requires innovation, which is dependent on individual staff accepting the need for personal innovative behaviour (Klein & Knight, 2005), which in turn requires personal orientation to the organisational purpose, or at least to that of the team (Hoegl & Parboteeah, 2006). It is thus important that human resource management activities promote organisational commitment (Dorenbosch, van Engen, & Verhagen, 2005) and emphasise the organisation's appreciation of innovation (Klein & Knight, 2005). Unfortunately strategic HR practices have sometimes been found to be too harsh for this (Hailey, Farndale, & Truss, 2005).

The importance of style of project leadership in new product development has relatively recently been identified as important for success (Clift & Vandenbosch, 1999; Lewis et al., 2002; Swink, 2005). Thus different types of projects benefit from different types of leadership. Unfortunately, PM research has not yet made those relationships sufficiently clear that they can be reliably implemented in practical projects. However, what is clear is the necessity of selecting a project manager who has skills in all of technical, project management and interpersonal areas (Barczak & Wilemon, 2003). A participative leadership in the project leader has also been associated with NPD success (Jeffrey et al., 2003), although it also seems that the style of the project manager may have to change as a project progresses (Lewis et al., 2002).

While the PM research literature on project leadership is short, the SHRM literature is more comprehensive and some of the findings may be applicable also to the intersection of PM and NPD. Thus SHRM suggests that a manager would do well to create workplace relationships of trust by modelling trustworthy behaviour towards subordinates, providing intrinsic motivation opportunities for staff, providing visible support, and ensuring trusting relationships within teams (e.g. Follon, 1998; Lee & Choi, 2003; Mårtensson, 2000). Here then are some specific recommendations that project managers can implement.

Also, some SHRM research has showed that input control (selection and training) can facilitate product innovation, and output control (targets are set, appraisal, rewards, management by objectives) inhibit it (Liao, 2006) (Garcia, 2005). Though this is a SHRM finding, it can perhaps be applied to project management for NPD, in which case it suggests that selection of staff for NPD projects may be more important than conventional project management practices. Current PM practices are very much based on 'output control', which the SHRM literature identifies as inhibiting innovation (and hence presumably also inhibiting NPD). In a longitudinal study it was found that 'recruitment and selection, induction, appraisal and training - predict organizational innovation in products and production technology' (Shipton, Fay, West, Patterson, & Birdi, 2005, p118). One solution is hiring people with greater natural abilities in intelligence and creativity, though the latter is the more

difficult to measure. Fortunately, research has found that measures of divergent thinking adequately predict creativity (Scratchley & Hakstian, 2001), at least for managers. Managers may also develop the skills and experiences of staff, by training, cross functional project teams, diversity of work experiences, temporary assignments, etc.

To sum up, the project management perspective on human resource management, as encapsulated in the PMBOK, is of limited relevance to projects involving NPD or innovation. Managers of these projects are likely to be better informed by the SHRM literature instead. The above analysis has given some specific examples of the SHRM body of knowledge that impinge on PM, but this was of necessity only a brief review. There are further research opportunities at the intersection of SHRM and PM. For example, there is a need to better understand the way team behaviour and leadership styles contribute to project success. And are these the same effects as in general management, or are there HR features that are unique to projects?

4.7 Communications Management

Communications management includes the flow of information between the project manager and clients, superior managers, sub-contractors, and staff, all of whom have different reporting needs. The PMBOK calls for a communications management plan (p227), although some projects will not need this level of formal statement up front. Most important is the topic of performance reporting (p231), since clients and managers will generally want to be informed about project status (see Figure 10-1 and 10-2 PMI, 2004).

The PMBOK primarily focusses on reporting, particularly the external communication between team and stakeholders. Without wishing to diminish the importance of that, it is also clear that the PMBOK somewhat ignores the internal communication (within the team).

One component of this is communication that aids collaboration during the project. For NPD it is common to use various information technologies (e.g. computer aided design, document management systems, email) for the infrastructure on which communication occurs. Research continues into the development of other technologies, including for other areas such as construction (Chan & Leung, 2004).

Teams with better communication, specifically the ability to share knowledge inside and outside the group, have been associated with better performance (Hayashi, 2004), suggesting that organisations may benefit from creating structures that encourage such communication. A little conflict in a project team can be beneficial, but too much is detrimental to project success (Gobeli, Koenig, & Bechinger, 1998).

The skills developed during product development, and the technical knowledge gathered are an important component of future capability. Formalising that knowledge in some way, so that it can be used by the organisation for future projects

is not easily done, but has been identified as a potentially valuable activity (Marsh & Stock, 2003; Olsen & Reitz, 2002). Indeed, there is a substantial body of literature on organisational learning, including knowledge management (KM), in which 'communication' features prominently. Briefly, knowledge management consists of capturing and reusing the knowledge of individuals, thereby equipping the organisation for innovation (Brooking, 1998; Goh, 2005; Nonaka, 1994; Shipton et al., 2005; Sveiby, 2001). Thus there is likely to exist an intersection, as yet poorly explored, between PM and KM.

4.8 Risk Management

Risk management seeks to treat the hazards that could adversely affect project outcomes. Even routine projects have schedule and cost risks. Novel projects have those risks plus technology and quality risks.

The PMBOK approach to risk management (see Figure 11-1 and 11-2 PMI, 2004) involves Risk identification, Risk analysis (qualitatively or quantitatively), and Risk treatment. Suggested methods to respond to risks are avoidance, transfer to a third party, and mitigation (reduction in likelihood or consequence). Monitoring and control of risks is also included.

There is a large separate body of specialised knowledge on risk management, e.g. AS/NZ standard 4360 (AS/NZ 4360, 1999; AS/NZS 4360, 2004; SAA/SNZ HB436, 2004). There the process is generally perceived to be a progression of sequential tasks, and the main activities are to 'establish the context', 'identify risks', 'analyse risks', evaluate risks', and 'treat risks'. Collateral activities include 'communicate and consult' and 'monitor and review' (SAA/SNZ HB436, 2004). Thus:

(a) Identify risks
There are many mechanisms that may be used for identification of root causes, and these include scrutiny of field failures or warranty data, accelerated life testing, and hazard analyses. The latter include hazard and operability study (HAZOP), zonal analysis, failure mode and effect analysis (FMEA), and fault tree analysis (FTA).

(b) Analyse risks
Risk is the combination of consequence and likelihood, and these two factors have to be determined separately. It is first necessary to place a value on each system consequence, which may be either:
(1) qualitative, e.g. 'insignificant, minor, moderate, major, catastrophic' (AS/NZ 4360, 1999, Table E1), or
(2) quantitative, e.g. monetary value, number of injuries, human lives, value of life.
Another analysis will be required to provide the probability (or likelihood) of those system consequences.

(c) Evaluate risks

If both the consequence and probability are quantitative (i.e. on an interval or ratio scale (Ackoff, 1962)), then it is acceptable to determine risk as the simple product of consequence and probability. The risks of various outcomes can then be easily ranked. However, in the more general case where the probability is on an ordinal or nominal scale then a product operation cannot be readily defended and instead it is necessary to map probability vs consequence, perhaps in a matrix or plot (PMI, 2004, p245; SAA/SNZ HB436, 2004, p53). In such cases a cumulative probability value is also hard to justify.

(d) Treat risks
The primary activity for treatment of risk is to select the risk strategy(s), depending on the tolerable level of risk. This level will be variable between individuals and organisations. One strategy is to accept residual risk (implicitly or explicitly), and live with the consequences. There are three other approaches, which are to reduce either the *likelihood* of failure, or the *magnitude* of the consequences, or the *exposure* to consequences. Reduction of *likelihood* of failure may be achieved by increasing quality control (inspection, supervision, testing, audit, compliance, controls), or increasing quality generation (staff empowerment, motivation, better equipment, processes), or design for robustness. If the decision is to reduce the *magnitude* of the consequences, then provision of recovery systems on standby is appropriate. Reduced *exposure* to consequences is commonly achieved by transferring the risk to others through legal contract, joint venture, or insurance.

These concepts of risk management are well established in the NPD sector, because product development always has uncertain outcomes (hence risk), the more so if it involves a component of research. The PMBOK includes some, but not all of these concepts.

4.9 Procurement Management

Procurement refers to purchase of goods and services, including subcontracting or work packages. Consequently it is necessary to decide what work will be done in-house vs subcontracted. The external work packages may need contracts to ensure that the deliverables are correct in quality, time and cost. These contracts have to be managed and may need to be changed during the project to accommodate changes in scope or environmental factors (e.g. the cost of goods may increase during the project) (see Figure 12-1 and 12-2 PMI, 2004).

Applying this to NPD, the geographically dispersed nature of global engineering enterprise means that effective communication and procurement processes are essential for product development organisations (Amami, 2000; McDonough III, Kahn, & Barczak, 2001; Vijayan, 2005). Single organisations no longer have the capability to design and produce every component in a product, at least not within the window of opportunity presented by the short product life cycles for consumer products. Instead it is a strategic imperative that organisations leverage their links

with other organisations, forming partnering relationships (including but not limited to subcontracting and outsourcing) (Fraser, Farrukh, & Gregory, 2003) to provide pre-manufactured sub-components and specialised design expertise. This minimises the time to market, but it also provides other benefits including components with proven reliability and the possibility of minimised cost. In some cases it may be advantageous to support collaborative design too (Michel, 2004). There are many software applications that provide at least part solutions to this problem, such as collaborative computer aided design (CAD), and part document management (PDM). Project management applications are likewise developing greater capability for management of a distributed project (Pratim Ghosh & Chandy Varghese, 2004). However, NPD projects typically have many work packages, even thousands, which can be difficult to handle (Mesihovic, Malmqvist, & Pikosz, 2004).

The issue of product configuration (or build) arises with any product that is a complex assembly or has a long production life. The design changes in small ways over time, due to incremental quality improvement or production efficiencies. On its own this is beneficial, but it has the consequence that nominally similar products may not be interchangeable as regards parts (or even embedded software), so a larger inventory of parts is required. Most product manufacturers have sizable profit margins on spare parts, so the business is attractive, but not if inventory cost is excessive. At the end of production the organisation has to anticipate the life-time spares requirement and manufacture (and store) this before the tooling is decommissioned. Having multiple builds complicates this. At very least, it is essential for a manufacturer to have a robust method of tracking build, for example the capability to determine the build from the serial number. This can be summed up as a need to manage product families during NPD (Tatikonda, 1999; Tatikonda & Rosenthal, 2000).

5 Discussion

For this study MS Project software readily permitted creation of the work breakdown structure, estimates of duration, creation of links (sequences), imposition of milestones & deadlines, estimates of fixed and labour cost, and identification of resources (people, equipment, and consumables). See Figure 2 for a sample of the data. Reports, including the useful critical path and tracking Gantt, were readily available.

By focussing on the NPD domain, taking a case study, applying the PMBOK, and integrating research findings in the formal literature, it has been shown that there are significant gaps in the PMBOK, at least for NPD. Granted, NPD is a difficult area and the large uncertainties in project path sometimes decrease the effectiveness of project management (Herroelen & Leus, 2005; Leus & Herroelen, 2004). That aside, the problem seems to be more than just uncertain work packages, but a fundamental need for research on how to best apply PM to NPD.

Implications for managers

The main message of this paper to practitioners is that the PM method (including its

software tools and the PMBOK) provides a basic, but limited, tool for managing NPD. Thus the PMBOK provides several useful, but incomplete, perspectives on NPD. The Reader should not infer from this that the PMBOK or the PM method are useless: instead the results suggest that these methods on their own do not provide comprehensive cover of the project management issues within NPD.

There are many books, magazine articles, and advice from consultants at the intersection of PM and NPD, but it is surprising how little research has actually been done. The implication is that managers who need to manage real NPD projects might benefit from adopt new PM ideas as they appear, but need to do so with an open mind and not assume that following a consultant's prescription will automatically lead to success.

The outcomes of this study may generalise to other areas. It has been shown that there are significant gaps in the PMBOK for NPD. Examples of areas that are poorly covered include uncertain scope, team dynamics (organisational behaviour), organisational learning, quality, and partnerships. These are probably also important in areas other than NPD, (e.g. construction, pharmaceutical, aerospace), because many of the design and problem-solving processes are common.

The tentative recommendation from this study is that NPD practitioners should use, but not rely on, the PM method and the PMBOK.

Implications for research
The effectiveness of many of the popular PM methods for NPD, including lean project management and stage-gate, have not yet been thoroughly researched. These might be excellent methods, capable of reliably achieving all that their advocates claim. Or they might be appropriate only in certain situations. At worst they may be unreliable fads that could discredit other areas of PM. Research is urgently required to increase our knowledge of the effectiveness of these methods, and their causal relationships with project success.

The PM method needs to better cope with the uncertainties of NPD, and the PMBOK needs to provide more robust treatment of the critical success factors for NPD. Regarding the former, the method called 'design structure matrix' (DSM) (Denker, Steward, & Browning, 2001; Eppinger, 2001; A. Yassine, Falkenburg, & Chelst, 1999; A. A. Yassine & Falkenburg, 1999) has potential for better handling the task dependencies in NPD, but it is a prototype method that is not yet mature enough for complete project management.

This paper was founded on the assumption that it is appropriate to apply project management methods to new product development. However, it is worth noting that not all researchers agree with such a premise. Some suggest that NPD is too dominated by project management methodologies with their focus on planning and prescribing; that instead there should more trial-and-error, empathy and cooperation (Smulders, de Caluwé, & van Nieuwenhuizen, 2003). Of course NPD can lie anywhere on a continuum from incremental design improvement, to research, where the latter is characterised by vague objectives and high epistemic uncertainty.

Unfortunately, projects towards the research end of that scale are not easily managed with any methodology, and PM may be better than none.

Projects can have numerous perturbations during deployment, e.g. changing resource allocations (Leus & Herroelen, 2004) and technology barriers, and a degree of initiative and innovation is necessary from the project manager to solve these. This may explain why research suggests that rule breaking may be necessary for success (Olin & Wickenberg, 2001). So perhaps project management with its highly structured approach is not the best in every case? Hence another area for future research.

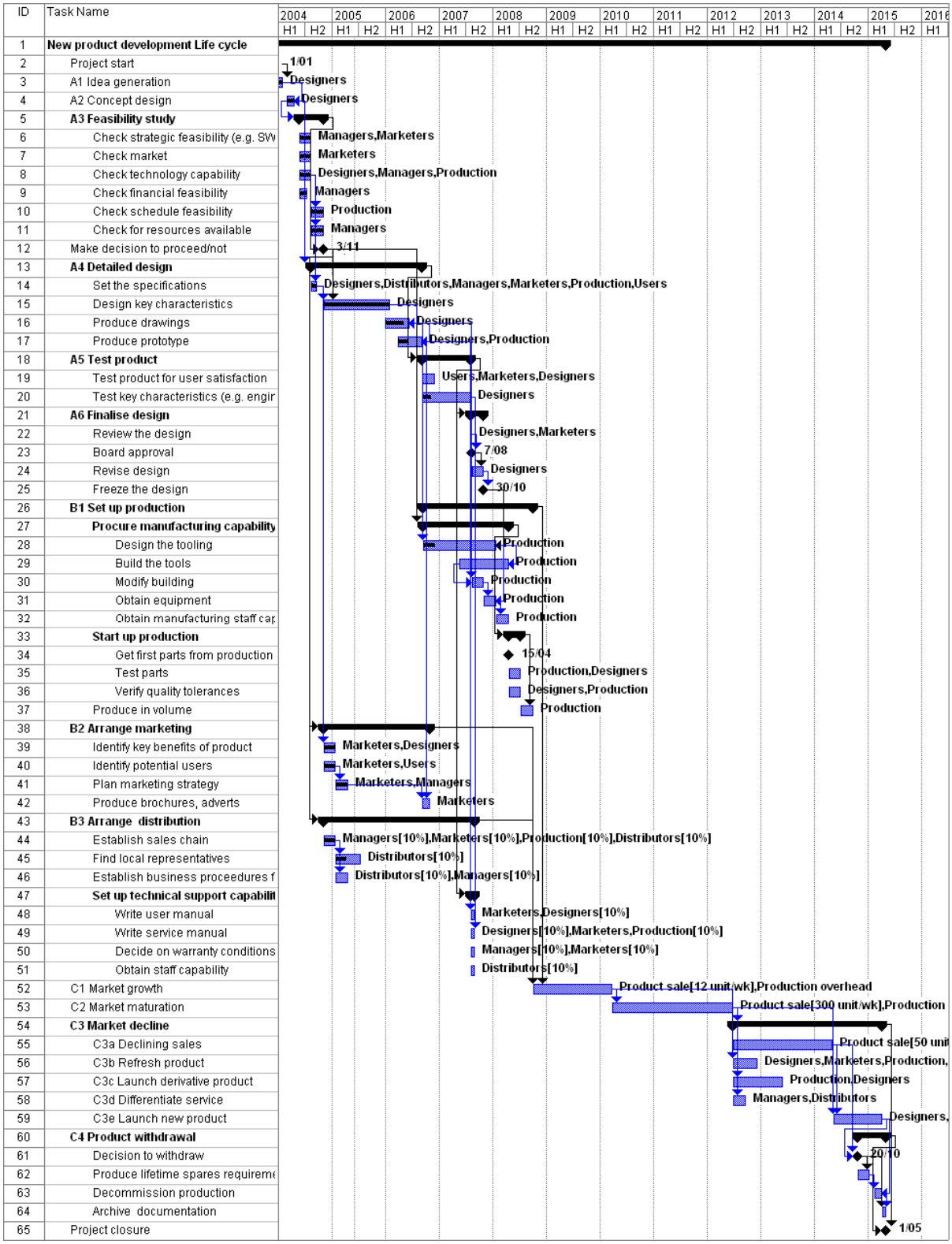

Figure 2: Gantt chart for project (baseline), showing the phases of the life cycle, the resources, and the schedule. The project commenced in 2005 and was due to complete 2015 with product withdrawal.

6 Conclusions

This paper examines the intersection of the project management (PM) body of knowledge with new product development (NPD). In general the PM method, with its structured task definition and software tools, is useful for managing NPD projects. However, in some areas PM incompletely meets the needs of NPD.

Specifically, NPD is characterised by complex interrelated activities and large uncertainties about precisely which solution path will be taken, such that the full scope of the project can often not be anticipated beforehand. Thus senior managers may need to change their expectations as to the certainty of the process, and be accommodating of changes to the work breakdown structure as the project unfolds. Also, whereas cost is the primary focus in PM (because conventional projects tend to only spend money), with NPD there is a need to consider both cost and income (from product sales) in making strategic decisions. Furthermore, in NPD a single-minded cost focus may distract designers away from creating other value in the product.

Communication and human resource management are important factors in NPD success, but existing project management perspectives on these are of limited relevance to NPD and innovation. There is a need to better understand the way team behaviour and leadership styles contribute to motivation and project success. While strategic human resource management can provide some initial solutions to these issues, there is still a need to understand how reliably the effects can be extrapolated from general management to project management. There is also likely to exist an intersection, as yet poorly explored, between PM and knowledge management, particularly for innovation processes such as NPD.

These findings are relevant to NPD practitioners because they need to know what aspects of NPD are well served by the project management method (including the PMBOK and software tools), and those that are not. For the areas of poorer coverage this paper has offered results, from other domains, that appear to be relevant and adaptable to management of NPD. Thus practitioners are provided with some tentative solutions for the areas where the PM method currently has gaps.

The relevance for researchers is that gaps have been identified in the PM method as it is applied to NPD. While some bridging material has been provided, it is nonetheless incomplete and there are several places where further research is required to (a) better understand the causality between factors (e.g. human resource management) and project success, and (b) adapt PM methods to better serve the NPD process.

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