On the Alignment of the Purposes and Views of Process Models in Project Management

Tyson R. Browning
Neeley School of Business
Texas Christian University
TCU Box 298530
Fort Worth, TX 76129 USA
t.browning@tcu.edu

This is a near-final version. The final version is published in the
Journal of Operations Management, **28**(4): 316-332, 2010.

Acknowledgements: Don Gerwin, Nitin Joglekar, Vish Krishnan, Christoph Loch, James Martin, Steve Sherwood, several individuals at the case study company, two associate editors, and three reviewers provided helpful comments on earlier versions of this paper. Marc Ortiz provided careful research assistance.

On the Alignment of the Purposes and Views of Process Models in Project Management

Abstract

A project manager makes decisions based on what he or she sees and understands. In large, complex projects (or programs), a manager cannot see the entire "territory" between project start and completion and therefore must rely on models or "maps" to support planning and decisions. When it comes to planning and coordinating work, project managers commonly use a variety of process model views such as flowcharts, Gantt charts, responsibility assignment matrices, and narrative descriptions. However, these views may not contain the right information to best support the purpose or decision at hand. This paper investigates the fit between model views (a kind of technology) and the managerial decisions (a kind of task) they support. Through analysis of the literature and case study data, this research identifies: (1) a set of 28 *purposes* for which managers draw upon process models for decision support, (2) a set of 15 *views* of process models, and (3) a set of 56 information *attributes* involved in supporting the purposes and provided by the views. The paper develops new measures of the *sufficiency* and *extraneousness* of the attributes for each purpose and view. Analysis of the evidence suggests substantial misalignment between managers' purposes and tools. Drawing on task-technology fit theory, the paper discusses the theoretical and managerial implications of these results and contributes a new construct, *purpose-view alignment*, which may help explain project success in future studies. The paper also presents insights for researchers and managers on how to develop customized views that are more suitable for particular managerial tasks.

Key Words: Project management; process modeling; task-technology fit; decision support

1. Introduction

A project is "a temporary endeavor undertaken to create a unique product, service, or result" (PMI 2008). In recent decades the number and importance of large, complex projects or programs (hereinafter, just "projects") has continued to grow significantly (Winter *et al.* 2006). Projects such as the development of ships, aircraft, spacecraft, or information technologies, or the construction of skyscrapers, airports, tunnels, or subways, entail thousands of activities, done by hundreds or even thousands of people, each producing results that enable other activities to occur. Yet, such projects are notorious for cost and schedule overruns, and insufficient management of them wastes the equivalent of billions of dollars around the world each year. Because of their size, complexity, novelty, and attraction of competing interests, such projects are challenging to understand in their intricacies, let alone manage.

To cope with these challenges, project managers and others commonly rely on process models to plan and coordinate project work. A process consists of all of the activities and interactions required to accomplish a project. Unlike many business and manufacturing processes, which strive to do exactly the same thing repeatedly, a project process seeks to do something new, once. Each project must plan and control its unique process (although some projects are unique in more ways than others). For large, complex projects, these managerial tasks cannot be done entirely in peoples' heads and require the help of models. A *process model* is an abstraction of a process that attempts to represent its important aspects. The information captured in a process model may be organized and conveyed to users (planners, managers, workers, etc.) through different *views*. A view captures a subset of a model's attributes and provides a guideline for their presentation (Browning and Ramasesh 2007). Examples of views include flowcharts, Gantt charts, various network diagrams, narrative procedures, etc.—although in current practice most models use a single view.

Project managers may use one or more process model views for various *purposes*, such as supporting decisions about what work to do, when, and with what resources. For example, they may use flowcharts to help analyze project duration and resource allocation, Gantt charts to assign tasks and report status, and narrative procedures to direct how work is done. Managers use more than one model view because each has its strengths and weaknesses: each abstracts a different subset of process information, emphasizing certain data while omitting others. Similarly, different managerial decisions require and benefit from different bits of process information. Ideally, the model view used to support any particular purpose will incorporate the salient information. However, what if this does not happen? What if the view used by a manager does not contain the necessary and sufficient information to support a particular decision? Or, what if the essential information to support a managerial decision is buried in extraneous information? In such cases, it is possible that the efficiency and effectiveness of the managerial decision could be compromised, which might contribute to problems such as cost and schedule overruns, quality shortfalls, or even project failure. According to Bendoly and Speier (2008), it would be valuable to direct research toward the topic of "What information to include/disregard when making specific decisions" (p. 169). What a manager decides depends on what he or she perceives and understands (Bendoly and Swink 2007), and much of this insight stems from the model views used. The proposition motivating this research is that perhaps managers do not use (or even have) model views (technologies) that are congruent with the purposes and decisions (tasks) they face.

This study draws on task-technology fit theory (e.g., Goodhue and Thompson 1995) as a basis for exploring the fit or alignment between (a) the purposes for which process models are used in project management and (b) many of the common model views. Based on literature reviews and case studies of several industrial projects, this research identified 28 purposes, 15 views, and 56 attributes of process information. Each purpose required, and each view provided, a subset of the 56 attributes. Next, the paper develops three measures of alignment. The first measures the extent to which each view provides the attributes required for each purpose (*sufficiency*), the second determines the extent to which each view contains superfluous attributes for each purpose (*extraneousness*), and the third combines these to arrive at a composite measure of *purpose-view alignment* (PVA). Alignment or congruence between a purpose and a view thus depends on the presence of a sufficient set of attributes and the absence of extraneous ones. Analysis of the evidence points to a significant misalignment between process model purposes and views.

This paper contributes to the project management literature in several ways. First, it extends *task-technology fit* theory to an important context, that of project management. Second, it introduces a new construct, process model PVA, which has the potential to help explain project success, especially in large, complex projects where managers' tacit, mental models are less likely to suffice. While existing studies have only examined whether or not a project used a particular tool (such as a view) or not, they have not controlled for a tool's appropriate use for a particular purpose. Thus, the study builds contingency theory in project management by moving beyond the question of mere tool usage to the match between tool and purpose. Third, the paper offers new measures and a technique for analyzing alignment based on both the sufficiency and extraneousness of information content. Fourth, the study provides insight into the future development of views which are better aligned with managerial purposes. The development of more appropriate and useful tools would seem to be a critical enabler of improved project management capability.

The remainder of the paper is organized as follows. The next section provides the theoretical foundation, after which §3 describes the research methodology. §4 reports on the study; §5 discusses its limitations, implications, and insights; and §6 concludes.

2. Theoretical Background

2.1 Process Models and Their Purposes

A *process* is "an organized group of related activities that work together to create a result of value" (Hammer 2001). In attempts to improve understanding of processes, researchers have developed numerous models that treat them as networks (see (Browning and Ramasesh 2007) for a review) composed of both *activities* (work packages, decisions, etc.) and *deliverables* (work products, information, data, documents, estimates, prototypes, materials, etc.) that represent the input-output relationships between activities.

A model is an abstract representation of reality that is built, verified, analyzed, and manipulated to support a particular purpose, even if that purpose is merely to increase understanding of a situation (Steiger 1998). "All models are wrong, but some are useful" (Box 1979). Models are "wrong" in the sense that none fully represents reality; each model selectively abstracts key information. Decision support models are essential for managers (Shane and Ulrich 2004), increasingly so as project complexity grows. However, project managers and participants often rely on greatly simplified and disparate models, or even "mental models" (Senge 1990), as they attempt to describe and control a project (Flanagan *et al.* 2006). According to Little (1970), models that managers tend to find useful are simple (easy to understand), complete (include important phenomena), robust (hard to get absurd answers from), adaptive (easy to adjust upon the acquisition of new information), easy to control (the user knows what input data would produce desired outputs), and easy to interact with (the manager can quickly and easily change inputs and obtain and understand the outputs). Several of these criteria conflict, such as the competing desires for simplicity and completeness addressed in this study.

Fitness for (or alignment with) a decision or purpose at hand is another important criterion of usefulness. A process model should include the attributes of a process which are deemed appropriate to describe it. However, this determination of appropriateness is always made (explicitly or not) in relation to a particular purpose. For instance, Engwall *et al.* (2005) found that project managers see canonical, prescriptive process models as having a variety of different purposes. Similarly, a process model fit for one purpose may not be appropriate for another (Browning *et al.* 2006; Crowston 2003; Dolk and Kottemann 1993). For example, a general process model, for use on all of a firm's projects, probably will not contain sufficient details for planning each unique project. Including all such details would be inappropriate for the general model, even if each project needs detailed plans. (The projects might get these details elsewhere.) Thus, the fitness of a process model depends on its alignment with what is appropriate to support a particular purpose.

Some scholars have suggested that managers and others use process models to help make better decisions by first using them merely to increase their understanding of situations. According to Perkin's theory of understanding (Perkins 1986), understanding requires three things: a purpose for analysis, a model of the process to be understood, and arguments about why the model serves the purpose. Evaluative arguments include model accuracy, simplicity, and conceptual validity and model component sufficiency, necessity, and consistency (Steiger 1998). In particular, the necessity and sufficiency of a model's components help determine the alignment between a managerial purpose and a model used to support it.

As an aside, it is important to distinguish the purpose of a process model from the purpose of a process itself, which is to accomplish some business result. A firm may have a variety of standard processes for work such as taking orders, developing products, and manufacturing—but these are the desired results or purposes of the processes themselves. Researchers have attempted to categorize processes according to their business purposes (Malone *et al.* 2003). In contrast, this study addresses the managerial purposes of process *models*. One or more process models (or views) may serve a variety of purposes within a project, such as enabling managers to estimate project completion times, allocate resources, etc. (Browning and Ramasesh 2007).

2.2 Process Models and Views

Attempting to digest all of the information in a model of a large, complex project will cause information overload (Farhoomand and Drury 2002) for individuals and groups, which can be worse than not disseminating the information at all (because of the erroneous assumption that communication occurred and was understood). Information overload occurs when a task's information processing demands exceed an individual's capacity to process the information within the available time (Schick *et al.* 1990). It deteriorates the quality of decisions (Pennington and Tuttle 2007; Stocks and Harrell 1995), it may prevent workers from locating what they need most, even causing them to overlook what they themselves would consider critical (Herbig and Kramer 1994), and it may also cause them to fail to use the relevant information at hand or known to be available (Wilson 1995). While the size and complexity of projects increases, and while process models grow in variety and richness, competitive pressures are decreasing the time available for making decisions (Bendoly and Speier 2008). This combination of challenges has brought increased attention to the concept of information overload.

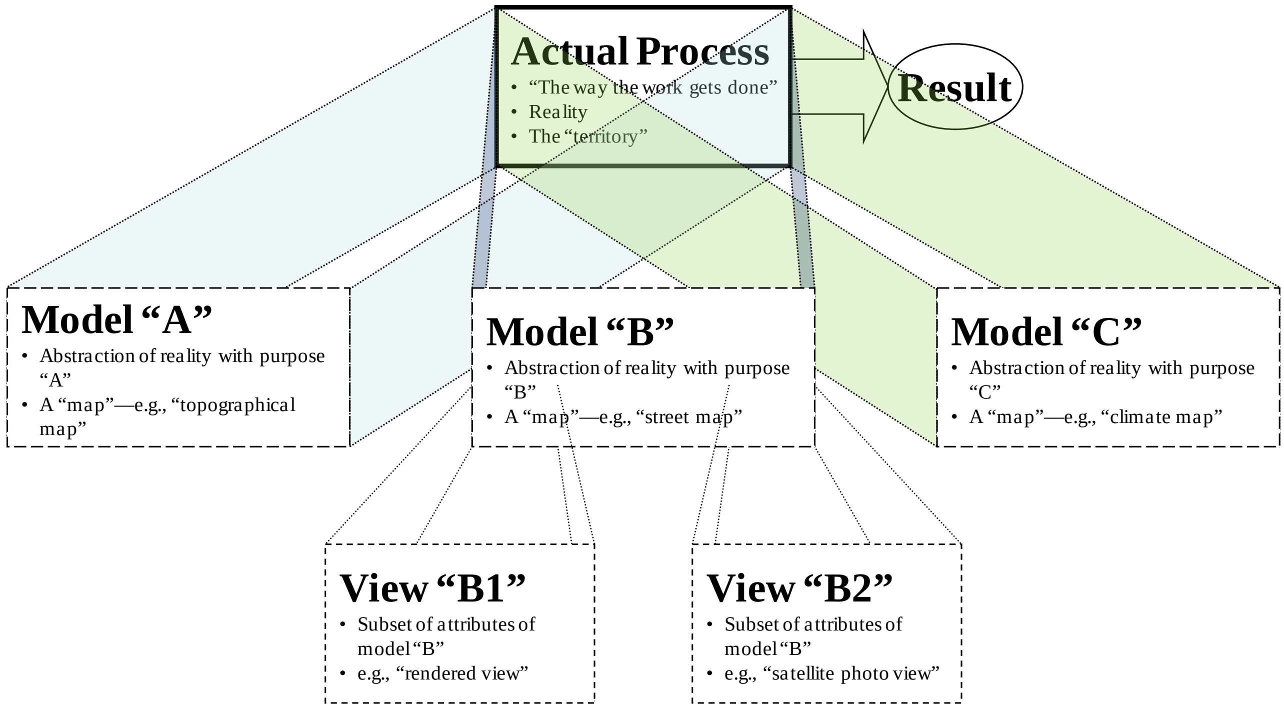


Figure 1: Relationships between a process, three models of it, and two views of one of the models

An alternative to providing a single, rich model to all project participants is to provide subgroups with subsets of a model's information in a format that facilitates the accomplishment of their particular activities and supports their timely decision making. However, achieving this approach requires identifying the subsets of information important to each group. This motivates the concept of a "view." Whereas a model is an abstraction from reality, a *view* is a second layer of abstraction, an arrangement of symbols, a table, or another depiction chosen to display a selected subset of a model's attributes and assumptions (Browning and Ramasesh 2007). For example, the actual process at the top of Figure 1 is the subject of three different process models, "A," "B," and "C." One may think of these models as three different maps of the same territory. In a non-process example, one might contrast a topographical map, a street map, and a climate map, each of which captures different attributes of the territory. In Figure 1, two *views*, "B1" and "B2," provide two lenses on model "B." Continuing the street map example, one might see such a map from a rendered (drawn) view or from a satellite view. View "B1" might display attributes such as addresses and business names that view "B2" might not.

Thus, returning to the example of a process, whereas a process model contains information about a process, a view presents a subset of that information in a chart, diagram, table, or other depiction. For another example, a Gantt chart is a process view that depicts activities and their temporal relationships. While a basic Gantt chart shows the activity attributes of name, duration, start time, and finish time, these may be supplemented with information such as the organizational unit responsible for an activity, resource requirements, precedence relationships (dependencies), activity percent complete, activity parent (or "roll up") activity, etc. However, including too much information would clutter the view, so one could deliberately choose not to show all of the information available in an underlying model of the process.

By distilling a subset of a model's attributes, a view enables users to focus on certain information and relationships. While many traditional models and views have a one-to-one correspondence (i.e., the subset shown by the view equals the full set of information in the model), a one-to-many relationship may actually exist between a model and its views, as various views each provide access to different subsets of the attributes captured in a rich model. Views leverage the principles of information hiding (e.g., Parnas 1972) to reduce complexity for decision makers. Ideally, a view should include all of those (and only those) attributes required for a purpose, such as making a certain type of decision. The way a view arranges and presents attributes may also facilitate a particular analysis. By reducing *perceived complexity* (or "complicatedness" (Tang and Salminen 2001)) and focusing on the specific needs of different users and purposes, better views can be a significant driver of innovation in system design (Alexander 1964; Keller *et al.* 2006; Schätz *et al.* 2002; Simon 1981; Zachman 1987), product development decisions (Krishnan and Ulrich 2001), and decision support systems in general (Basu *et al.* 1997). The concept of views also meshes with natural intelligence theory, where Minsky (2006) postulated that the human mind naturally maintains multiple models of a given system (e.g., physical, social, emotional, mnemonic, strategic, visual, and tactile) and rapidly switches among them depending on the current purpose. Because of their many benefits, the concept of multiple views of a complex model has recently gained traction in the engineering design literature (e.g., Browning 2009; Keller *et al.* 2005).

2.3 Task-Technology Fit Theory

Task-technology fit (TTF) theory (Goodhue 1998; Goodhue and Thompson 1995) argues that a technology (a means to accomplish a task) will improve a user's performance when it matches well with the task's requirements. Thus, all else being equal, as TTF increases, the effort required to achieve an outcome of similar quality (speed, accuracy, etc.) decreases, and vice-versa. The TTF-performance link stems from two main perspectives (Goodhue *et al.* 2000). First, organizational contingency theory (e.g., Donaldson 2001; Lawrence and Lorsch 1967; Van de Ven and Drazen 1985) and information processing theory (e.g., Galbraith 1973; Tushman and Nadler 1978) assert that performance will improve when an organization's design "fits" its task requirements and user capabilities. Second, at the personal level, research on cognitive costs and benefits contends that an individual will weigh the costs (mental efforts of acquiring and processing information) against the benefits (added quality, speed, accuracy, etc.) when choosing how to perform a task (Connolly and Thorn 1987). TTF theory has received attention in many areas but not in the project management literature.

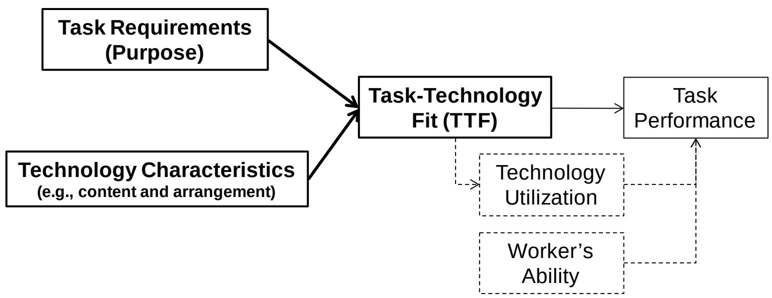


Figure 2: Main constructs in task-technology fit (TTF) theory

Figure 2 summarizes the main relationships in TTF theory, which scholars have extended to account explicitly for two other drivers of improved performance, technology utilization (Goodhue and Thompson 1995) and a worker's (or user's) ability (Goodhue *et al.* 2000; Jarupathirun and Zahedi 2007). While *technology characteristics* is a potentially broad factor, past TTF research has explored it mainly in terms of data representation—i.e., the way in which task- or decision-support data are *arranged for display*—most notably in research on the impact of graphs versus tables on decision-making performance. For example, Vessey (1991) argued that some tasks require extracting meaning through visualization and are best supported by graphs, while other tasks require exact values and are best supported by tables, and that a misalignment would slow decision-making performance and increase chances of error. Most prior studies focused on the form (arrangement) of the information rather than the appropriateness of the content itself. However, the presence or absence of appropriate information can also affect a technology's usefulness for a task (Jarupathirun and Zahedi 2007). (The quality, reliability, and timeliness of the content—and users' perceptions thereof—are also important characteristics of information technologies (Goodhue 1998).)

This paper explores the core of TTF theory (the emboldened parts of Figure 2) in terms of the alignment between the *purposes* (*task requirements*) for which project managers (and other types of users) use process model *views* and the types of data content (*technology characteristic*) ensconced in those views. For the technology characteristic, I specifically focus on content rather than arrangement, since past studies have not fully addressed the former. However, since both content and form are important, it remains for future research to synthesize these constructs and explore their joint effects. Nevertheless, this study extends the TTF literature to a new and important context, that of project management, and introduces a new construct, *PVA*, to include in future studies of project performance and success.

3. Research Approach

This initial study of the alignment between process model purposes and views is based on a combination of literature review and case studies. Case studies are advantageous for observing and describing a complicated research phenomenon in a way that increases understanding and provides a basis for further empirical research (Eisenhardt and Graebner 2007; Meredith 1998; Yin 2003). Operations management research has described the case study methodology as “essential … where theory exists but the environmental context is different” (Stuart *et al.* 2002, p. 423).

Seeking an “extreme case” where the phenomena of interest are more transparent (Eisenhardt 1989), I approached a U.S. Fortune 100 company that develops and produces multiple high-tech products. Management had divided the company into functional organizations (e.g., marketing, engineering, manufacturing, program management office, etc.) matrixed into large, complex projects. Each project developed a particular product that included both hardware and software, was organized into a number of cross-functional teams, and used process models to varying extents for planning and decision support. Most stakeholders viewed the projects as challenged to varying extents in terms of meeting all requirements within a schedule and a budget.

The first stage of the research was inductive and involved gathering empirical data on the *purposes* and *views* of process models through a synthesis of data from the literature and field work. In gathering data from the literature, two published reviews proved especially helpful. First, Browning and Ramasesh (2007) reviewed over 400 papers pertaining to activity networks in product development projects and distilled categories of major purposes of process models. Second, Browning *et al.* (2006) isolated a number of types of process models, model users, and model attributes. These reviews, as well as key papers they referenced, provided important grounding for the field work.

For the field work, I interviewed 12 individuals, reviewed a variety of internal company documents, and collected further data from secondary informants at the company in July-September, 2006. The 12 primary informants, listed in Table 1, represented six different projects and functional organizations and were selected with the help of company representatives based on their roles as key actors with significant experience (in the realm of 15-30 years each), their varied perspectives, and their diversity of backgrounds (Eisenhardt and Graebner 2007). The face-to-face interviews were semi-structured, beginning with a set of questions but also allowing for open-ended responses. I deliberately kept the questions general—worded in terms of the decisions and tasks that occurred when planning and coordinating work, and the tools that supported them—so as to ameliorate any potential prejudices towards (or misunderstandings of) words such as "process" or "model." Since voice recordings were not allowed, I took extensive notes at each interview. My research assistant accompanied me and also took notes, which I later compared to double-check accuracy. To encourage openness, I agreed not to attribute data or quotations to individuals unless specifically approved. Since the interviewees represented different areas of the organization, they provided alternative perspectives on the purposes and views of process models. The 12 interviewees were not all pre-selected. Rather, about three were selected at a time. Based on their responses, new questions would appear, or additional data would surface that I would seek to verify elsewhere. These discoveries prompted the selection of the next set of interviewees. This process allowed me to exercise "controlled opportunism" (Eisenhardt 1989, p. 539), the ability to respond flexibly to discoveries made while collecting data. Through four such rounds, the 12 interviews attained "theoretical saturation," the point of significant data recurrence and failure to surface new ideas (Glaser and Strauss 1967). Through additional meetings and conversations, other individuals (besides those listed in Table 1) from assorted organizations within the company and with varied backgrounds also provided inputs. The informants supplemented their responses with company records (reports, plans, briefings, archival data, etc.), which I reconciled with the interview data to triangulate multiple sources (Fielding and Fielding 1986; Jick 1979).

Table 1: Interviewees

1.	A software development manager working with a set of small, advanced projects
2.	A cross-functional team leader (technical project manager) in Large Program 1
3.	A program integrator[a] in Large Program 1
4.	A software quality assurance representative in Large Program 1
5.	A systems engineer in Large Program 2
6.	A program integrator in Large Program 2
7.	A software quality assurance representative in Large Program 2
8.	A systems engineer in the engineering functional organization
9.	A scheduling manager in the program management office (functional organization)
10.	An independent auditor for compliance with the ISO 9000[b] series of standards
11.	A CMMI[c] lead assessor (independently gauges level of organizational capability and maturity)
12.	The chair of a process integration working group in the engineering functional organization

[a]A program integrator is responsible for (1) coordinating support from subject matter experts on the programs into the development of the organization's standard processes and (2) planning and coordinating efforts to assess the impacts of standard process changes on the program's deployed processes.
[b]ISO is an abbreviation for the French name for International Organization for Standardization.
[c]Capability Maturity Model—Integrated is registered in the U.S. Patent and Trademark Office by Carnegie Mellon University.

I assembled the raw data, analyses, and preliminary results for several iterations of review and fact-checking by the company in October 2006. The diminishing number of comments and corrections received through the successive iterations of reviews gave reason to accept the evidence as sufficiently reliable and valid. Finally, the company approved a disguised version of the information for public release.

4. Data Analysis and Results

4.1 Stage 1: Identification of Process Model Purposes and Views

The first stage of the research sought to induce and organize two sets of data: a set of purposes for which workers use process models, and a set of views through which they perceive them. In both cases, the realistic aim was not to define these sets comprehensively (which would be impossible to verify) but to span the prominent purposes and views in the project management literature and those discovered in the field work. As it turned out, the field work was instrumental in discovering a number of previously unreported purposes but less so in uncovering new views, while the literature was more helpful for expanding the set of views.

4.1.1 Determining a Set of Purposes

The four categories of purposes for process models classified by Browning and Ramasesh (2007)—project visualization, planning, execution and control, and development (which includes continuous improvement, organizational learning, knowledge management, training, and compliance)—provided a starting point for the study. It became clear that a single project manager, especially in a multi-project organization, might not personally have all of these purposes. Thus, the scope of the interviews included a broad discussion of *potential* purposes (pertaining to planning and organizing project work) as well as current or previous purposes. Furthermore, since large organizations might assign project management sub-tasks to various individuals and groups, it also became clear that the data collection would similarly need to address a wide range of users (and potential users) of process models. Hence, I used literature reviews and the initial interviews to identify the five categories of users of process models listed in Table 2. These five categories of users are not submitted as comprehensive, as any employee or stakeholder may have an occasion to use a process model. However, these five categories are relatively broad, representing the multi-project enterprise as well as any customers and suppliers participating on a project (who may fit into one or more of the categories depending on their role). By ensuring that the full set of interviewees spanned these categories, the likelihood of accounting for a diverse set of perspectives greatly increased.

Table 2: Five categories of users of process models (adapted from (Browning 2009))

Category	Explanation
• Process owners	Process owners hail from functional organizations and are responsible for documenting and maintaining standard processes for accomplishing work; includes designated "authors" or "points of contact," executives and managers who fund process modeling (and supporting systems), and developers or maintainers of process modeling tools (internal or vendors)
• Project planners and schedulers	Experts with project management software tools who work (often full time) building and maintaining the plans and schedules of large projects (programs)
• Project managers and team leaders	Use process models primarily to support managerial decisions
• Engineers, designers, and other team members	Use process models intermittently in their daily work on cross-functional teams
• Process auditors, assessors, and appraisers	Seek to verify that the processes deployed to and used by various projects adhere to and comply with the company's standard processes

The interviews, the literature, and iterative analysis generated 28 ways in which process models are or could be useful to these categories of users, as summarized in Table 3. The use of iterative, qualitative analysis to devise categories or groups is a widely-used research method (e.g., Dutton and Dukerich 1991). I do not purport Tables 2 or 3 to be comprehensive. However, both lists are rather broad in scope, the former is used to expand the latter, they address not only the individual project but also the multi-project enterprise, and they proved sufficiently diverse to yield insights in subsequent analyses. Note that it is *not* imperative for all of the purposes to be mutually exclusive. Since they all pertain to the use of process models, it is unsurprising that their needs for process information overlap. However, as will be demonstrated later, each purpose is distinguished from another by at least one important attribute of process information. (Since a purpose may apply to more than one category of user, two purposes are shown twice, with the second occurrence of each being shaded.)

As a backdrop for the purposes listed in Table 3, it is helpful to clarify some potentially unfamiliar terms pertaining to process models in a multi-project enterprise. To increase the commonality of practices across projects, a multi-project enterprise may charge its functional organizations with defining and "owning" a set of *standard processes*. Executives would expect any new project to use the standard process as a starting point for its planning, with the understanding that the project's unique circumstances will necessitate some suitable tailoring of the standard process. The resulting, customized process is called the project's *deployed process*, and it must be jointly approved by the owners of the standard process (the functional organizations) and the project's management. Once approved, the project is expected to use the deployed process as the basis for further planning and scheduling, and auditors and assessors may periodically verify compliance. In some companies, this arrangement operates as a closed-loop system where best practices discovered in various projects feed back to the functional organizations, who update the standard processes. Thus, the standard processes ideally provide a kind of knowledge management mechanism for a learning organization

Table 3: 28 identified purposes of process models (adapted from (Browning 2009))

User	Purpose	Explanation
Process owner	• Define standard and preferred activities	The process model can document the work practices deemed appropriate by the functional organizations.
	• Define standard deliverables and quality standards	The process model can document the desired result(s) of each activity, including its measures of effectiveness and their acceptable levels.
	• Define standard handoffs and structure standard work flows	The process model can relate deliverables to activities via input-output lists, resulting in a sequenced flow of work.
	• Define standard tools and templates	A set of standard tools, templates, facilities, etc. can be associated with each activity.
	• Define standard staffing, roles, responsibilities, and skills	A set of roles to be filled and/or responsibilities to be held can be specified for each activity, along with the typical number of people, level of effort, and required skills to ensure that the activity is performed effectively.
	• Visualize, understand, analyze, and improve processes	Process owners desire ways to represent, examine, and improve processes.
	• Identify "ripple effects" of process changes	When multiple projects use a standard process model, the owner of the standard process faces a barrage of change requests, which he or she must be able to evaluate quickly, especially in terms of their potential effects on other, interdependent processes.
	• Organize knowledge about work	Process models can help structure the vast amount of information that exists in a large company about what work to do and how to do it.
Project planner and scheduler	• Tailor the standard process to suit project requirements	Project planners can partially derive their planned set of activities by tailoring the company's standard processes into a set of deployed processes. A deployed process is an instance of a standard process that has been customized (tailored) to the needs of a particular project.
	• Filter activities and deliverables (by hardware vs. software, project size and phase, contract type, etc.)	Tailoring requires clarity about which activities and deliverables apply to particular project situations and requirements.
	• Associate processes with elements of the project's work breakdown structure (WBS)	Since projects are typically organized according to a standard WBS, associating a standard process with each standard WBS item facilitates tailoring.
	• Identify appropriate activities and deliverables for the project	The deployed process results from tailoring the standard process to the particular circumstances of a project; it contains the basic set of activities and deliverables that the project will plan and schedule.
	• Import deployed process activities into a project scheduling tool	The activities and dependencies constituting the deployed process should be easily imported into a project scheduling tool (e.g., Microsoft Project™) for further use.
	• Define deployed deliverables and quality levels	Each deliverable in the deployed process can have a predetermined level of quality and/or risk against which to check its actual status; deviations portend downstream risks.
	• Choose tools and templates	A process can specify the tools and equipment needed to execute each activity so that planners can focus on acquiring and organizing these.
	• Set project schedule and secure formal commitments	The deployed process (planned activities and deliverables) can be elaborated to arrive at the project's actual schedule, handoffs, and work flows; the project manager or team leader responsible for each deliverable commits to providing it at a certain level of quality by a certain time.
	• Identify skill (or clearance) gaps in the workforce	If the staff assigned to a process does not meet the required skill or security level profile, then supplemental training activities can be planned.
	• Estimate project time, cost, quality, and risks	The set of planned activities can provide the basis for determining the critical path, the estimated time and cost of the project, cost and schedule risks, etc.; the deliverables also enable an assessment of quality and technical risks.
	• Allocate resources	Resource allocations govern activity costs and completion rates, so projects must allocate resources in conjunction with scheduling and budgeting.
Project manager or team leader	• Visualize planned work flows and integration points	Project managers need "situation visibility" and "look-ahead capability"; a scheduled set of linked activities facilitates both, as delays in scheduled activities portend downstream ripple effects.
	• Assign activity roles and responsibilities (staffing)	Managers make formal staffing assignments, hopefully aided by clear statements of the resource and skill requirements for each activity.
	• Estimate project time, cost, quality, and risks	(See above entry for Project Planner and Scheduler.)
	• Monitor project status in terms of activities and deliverables	Helpful status reports compare actual accomplishments of activities and deliverables to plans.
	• Renegotiate commitments where necessary	When activities are late, or deliverables do not meet quality expectations, project managers need the capability to rapidly renegotiate commitments and see the ramifications of changes on the rest of the project.
	• Allocate resources	(See above entry for Project Planner and Scheduler.)
Engineer, designer, team member	• Access knowledge about activities, tools, and deliverables	The typical worker on a project, once assigned to an activity, needs to be able to get additional information about the performance of that work and the production of its deliverable(s), including relevant tools, techniques, references, lessons learned, etc.
	• Deposit lessons learned	Each worker can be encouraged to add insights and experiences to the process knowledge base—e.g., risks encountered, common pitfalls, reasons for problems, etc.—for use in process improvement.
Auditor / assessor / appraiser	• View practices relevant to a given standard	Since an auditor must verify compliance with a particular standard (e.g., ISO 9000, CMMI, etc.), he or she wants to be able to determine quickly which subset of the planned activities are called for by the standard.
	• Confirm performance of requisite practices	Performance of requisite practices occurs if the implied activities are planned and executed.
	• Confirm production of appropriate deliverables	The expected deliverables are produced if the requisite activities are planned and executed and their results meet quality expectations.

(Browning and Ramasesh 2007; Crowston 2003). For further explanations of these practices and terms, see (Browning 2009).

4.1.2 Determining a Set of Views

Table 4 summarizes a set of 15 common views of process models. I limited the scope of this set to views that represent the primary objects in process models (i.e., activities and deliverables, as discussed in §2.1), and I consolidated some highly similar views into categories. As with Table 3, I report Table 4 as representative rather than comprehensive. The case study company actively used a minority of these views, and I found only one view (the last in the table) that was previously unreported in the literature.

4.2 Stage 2: Identification of Process Model Attributes Relating Purposes and Views

The literature and the interviews were instrumental in establishing the fairly rich sets of purposes and views. However, comparing the alignment between these sets required a third, intermediary set of mapping variables. As shown in Figure 3, decision support purposes require certain information *attributes* about project work and status. The models and views of the project process include various ones of these attributes. As discussed in §2.1, a process consists of at least two fundamental objects, activities (work packages) and their relationships, which one can define in terms of input and output deliverables (work products). Activities and deliverables each have properties or attributes. For example, an activity has attributes such as duration, cost, inputs, and outputs. A deliverable has attributes such as requirements, measures of satisfaction, maturity, etc.

Since purposes require views that show certain attributes, determining the alignment between purposes and views required defining a superset of common attributes. This superset must span the attributes required by all of the identified purposes and included in all of the identified views. Therefore, I initially assembled it by combining the attributes required for each purpose in Table 3 with the attributes shown by each view in Table 4. I then verified and expanded the set by comparing it with the list of process model attributes provided in the literature review by Browning *et al.* (2006). Finally, I expanded the list as needed upon the discovery of additional attributes during the discussions that occurred in Stages 3-5 (described below).

Table 4 (Part 1 of 2): 15 identified views of process model information (adapted from (Browning 2009))

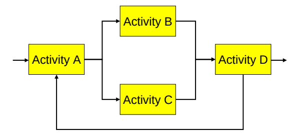
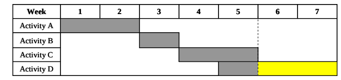
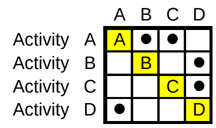
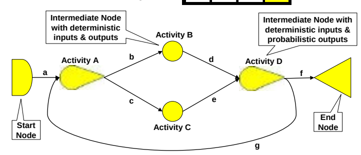
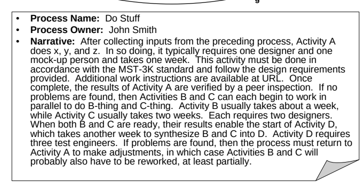
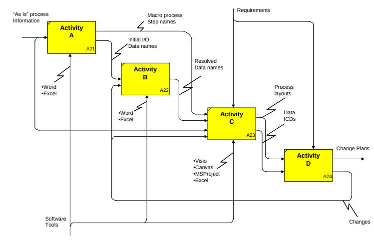
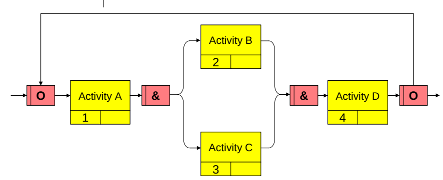
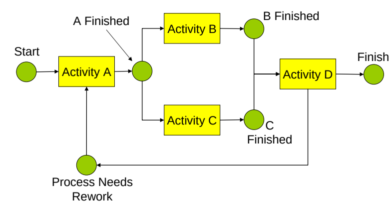
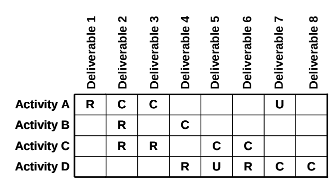
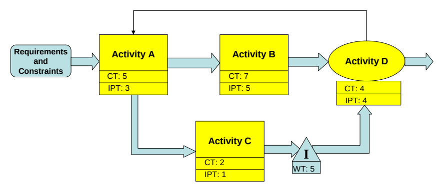
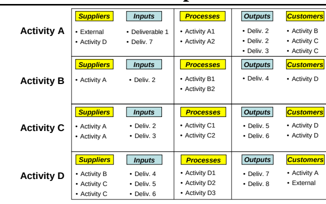
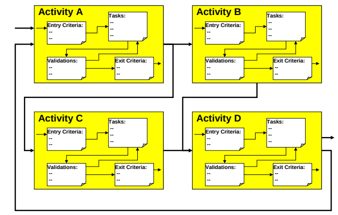
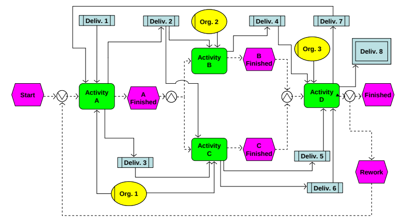
View	Reference	Description	Example
Process flowchart – Network diagram – PERT chart – Activity-on-node diagram	(IBM 1969) (Moder *et al.* 1983)	The classical process representation; activities in boxes and relationships on arrows (i.e., activity-on-node [AON] or Project Evaluation and Review Technique [PERT] chart); sometimes shows branching nodes using diamonds; often augmented according to local preferences and conventions	
Gantt Chart	(Gantt 1919)	The classical project management representation; depicts activities and their temporal relationships; may also indicate precedence relationships and activity status; sometimes augmented with additional activity attributes	
Design Structure Matrix (DSM)	(Browning 2001)	Square matrix of *N* activities on the diagonal, where marks in off-diagonal cells indicate an input/output relationship between activities; in the convention shown, feedback is shown below the diagonal, but the opposite convention (transpose of the matrix) is also used	
Graphical Evaluation and Review Technique (GERT) Diagram	(Pritsker and Happ 1966)	Extension to PERT that allows probabilistic branching between activities (nodes); arcs are lettered and have associated probabilities	
Textual Narrative	(SPC 1996, pp. 50f)	Process documentation that explains in words what is to be done and how	• **Process Name:** Do Stuff • **Process Owner:** John Smith • **Narrative:** After collecting inputs from the preceding process, Activity A does x, y, and z. In so doing, it typically requires one designer and one mock-up person and takes one week. This activity must be done in accordance with the MST-3K standard and follow the design requirements provided. Additional work instructions are available at URL. Once complete, the results of Activity A are verified by a peer inspection. If no problems are found, then Activities B and C can each begin to work in parallel to do B-thing and C-thing. Activity B usually takes about a week, while Activity C usually takes two weeks. Each requires two designers. When both B and C are ready, their results enable the start of Activity D, which takes another week to synthesize B and C into D. Activity D requires three test engineers. If problems are found, then the process must return to Activity A to make adjustments, in which case Activities B and C will probably also have to be reworked, at least partially.
IDEF0 Diagram	(NIST 1993)	IDEF0 stands for "Integrated Definition, Version 0"; there are more than 14 versions for various niche applications; emphasizes the input-output deliverables flowing among activities; activity boxes arranged diagonally on a single page; data inputs enter on the left of each box, control inputs enter from the top, mechanism inputs enter from the bottom; data outputs exit on the right of each box, while call outputs exit from the bottom; activity and deliverable hierarchies are also apparent	
IDEF3 Diagram	(Mayer *et al.* 1995)	A version of IDEF for "process description capture"; similar to flowchart, but with emphasis on flow junctions (And, Or, Xor; synchronous or asynchronous); activity identification numbers also shown	
State Diagram – Event graph – Markov chain – Data flow diagram – Directed graph	(Harel 1987)	Most state diagrams merely show the possible states (nodes), connected by transition paths ("edges," using the terminology of directed graphs); in process modeling, they may also show the intervening activities as a different type of node; used by Petri net and Unified Modeling Language (UML) models; project process applications require possibility of being in more than one state at a time	
Create-Read-Update-Delete (CRUD) Table	(Kilov 1990)	Shows activities' effects on deliverables; an activity can create, read (or retrieve) only (use), update (modify), and/or delete (or destroy) a deliverable; often used to model database and information system architectures	
Value Stream Map	(McManus 2005)	Recently adapted for modeling project processes; emphasizes activity cycle times (CT) and in-process times (IPT) and inter-activity wait times (WT); review activities shown as ovals instead of rectangles; intervening inventories shown as triangles; additional symbols also common; can also show additional features of process; emphasizes identifying sources of waste	

Table 4 (Part 2 of 2): 15 identified views of process model information (adapted from (Browning 2009))

View	Reference	Description	Example
Supplier-Input-Process-Output-Customer (SIPOC) Diagram – IPO diagram	(Browning *et al.* 2006)	For each activity, a table of its input deliverables and the source (supplier) of each, constituent activities (processes), and output deliverables and their destinations (customers); the first two columns have a one-to-one correspondence among the rows, as do the last two columns; the middle column does not have to map directly to the other columns	
Entry-Task-Validation-Exit (ETVX) Diagram	(Radice *et al.* 1985)	Perhaps more of a convention to ensure the inclusion of important activity attributes than a type of diagram, ETVX emphasizes the entry criteria, the sub-tasks to be done, the work validation methods (e.g., tests), and the exit criteria.	
Extended Event-driven Process Chain (eEPC) Diagram	(Scheer 1999)	The main "super view" provided by the ARIS (acronym based on the German term for "Architecture of Integrated Information Systems") method; includes functions (activities), events, information items and products (deliverables), and organizational units	
Responsibility Assignment Matrix (RAM) – RACI chart	(PMI 2008)	A table mapping activities to organizational units who fill roles on or have a responsibility for each activity; often uses a RACI format (R = responsible, A = accountable, C = consult, and I = inform)	(see matrix below)
Work Product Standard (WPS) database record	Practitioner-developed at case study company	Shows a database record (or a report thereof on a spreadsheet) of many deliverable attributes	(classic spreadsheet)

RAM example:

	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6	Person 7	Person 8
Activity A	A	C	C	I	R	I	A	A
Activity B	I	R	I	C	I	I	A	I
Activity C	I	A	R	I	C	C	I	I
Activity D	C	I	I	R	A	A	C	C

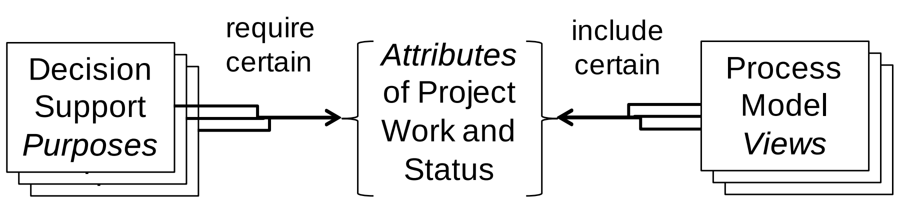


Figure 3: Purposes and views relate via a set of information attributes

Table 5 lists the finalized set of 56 process model attributes used in this study. Again, I do not submit this list as comprehensive, nor is it essential that it be so. One could certainly add other attributes if one found some use for them. However, the list in Table 5 spans the purposes and views discovered in this research and therefore proved sufficient for the subsequent analysis of alignment. Descriptions of each of these attributes are available in (Browning 2009).

4.3 Stage 3: Mapping Purposes to Attributes

The next analysis involved determining the relationships between the 28 purposes (Table 3) and the 56 attributes (Table 5). The left side of Table 6 describes the coding scheme, which was used in consultation with process experts at the company to arrive at Table 7. While coding the “0”s and “2”s was relatively straightforward, coding the “1”s was more challenging because a high degree of expertise is required to make judgment calls about certain relationships, and even process experts could debate just how “helpful” an attribute might be for supporting a purpose. However, any instances of coding discrepancies prompted discussions to resolve them, aided by consultation of the literature on particular purposes and attributes, where available. In the end, Table 7 provides a fairly rich picture of the diverse relationships between purposes and attributes, and “1”s represent less than 10% of the relationships. Table 7 is reminiscent of a Quality Function Deployment (QFD) matrix, which uses similar types of codings and which many have found to be a widely useful tool (e.g., Clausing 1994). Note that the two shaded rows in Table 7 indicate the second occurrences of two purposes that pertain to more than one category of user; these redundant rows were therefore consolidated in the subsequent analyses. The column of numbers to the right of Table 7 gives the row sums, while the rows below the table give the column sums, each attribute’s popularity ranking (by which the columns are sorted), and the percentage of purposes using the attribute.

Table 5: 56 potential information attributes identified for process models used in multi-project management (adapted from (Browning 2009))

Process/Activity (Work Package) Object Attributes		Deliverable (Work Product) Object Attributes	
• Name	• Standard Roles	• Name	• Standard Process Metrics
• Parent	• Deployed Roles	• Parent	• Deployed Process Metrics
• Constituents (“Children”)	• Basis for Requirement	• Constituents (“Children”)	• Format
• Mode	• Rules	• Mode	• Medium
• Shadowing	• References	• Shadowing	• Artifact
• Deployment	• Standard Risks	• Deployment	• Rules
• Version Number	• Deployed Risks	• Version Number	• References
• Brief Description	• Narrative Description	• Brief Description	• Narrative Description
• Inputs	• Tailoring Guidance	• Suppliers	• Tailoring Guidance
• Outputs	• System Identification Number	• Customers	• System Identification Number
• Entry Criteria	• WBS Element Association	• Key Criteria and Measures of Effectiveness	• WBS Element Association
• Exit Criteria	• Master Owner	• Requirements	• Change History
• Verifications	• Standard Owner	• Acceptance Criteria	• Change Notifications
• Standard Process Metrics	• Deployed Owner		
• Deployed Process Metrics	• Change History		
• Tools	• Change Notifications		

In observing Table 7, one can notice that process owners have the greatest needs for process information (and therefore rich views), as several of their purposes require most of the attributes (row sums close to the maximum possible, which is 112). Project planners and schedulers also have a purpose that requires most of the attributes (row sum 94 out of 112), and team members occasionally need the capability to browse most of the attributes. Despite these exceptions, most purposes use only a fraction of the attributes: aside from the purposes just mentioned, the row sums of the other purposes average 31 out of 112. (The average of all row sums is 46.3.) Thus, in an instance of the Pareto principle, roughly 20% of the purposes use over 80% of the attributes. The evidence suggests that a minority of the purposes require rather rich views that account for a wealth of process attributes, while the rest of the purposes need much simpler and sparser views.

Table 6: Coding Instructions and Schema

Purpose-Attribute Map (Table 7)	*View-Attribute Map (Table 9)*
First, gain familiarization with each of the 28 purposes and 56 attributes: • Purposes and their user types and explanations are given in Table 3. • Descriptions of the attributes listed in Table 5 are available in (Browning 2009). Second, for each purpose, go attribute by attribute, answering the following question: Which of the following statements best describes the relationship between the purpose and the information represented by the attribute? 0. The information provided by this attribute is *unneeded* for the purpose.Having the information provided by this attribute makes it easier to accomplish the purpose, but it is not essential for the purpose. The attribute is *helpful* but not required. 1. To accomplish the purpose, it is absolutely *essential* to have the information provided by this attribute. Enter the resulting number code into the table (Table 7).	First, gain familiarization with each of the 15 views and 56 attributes: • Views and their explanations are given in Table 4, where references are also available with additional background information. • Descriptions of the attributes listed in Table 5 are available in (Browning 2009). Second, for each view, go attribute by attribute, answering the following question: Which of the following statements best describes the relationship between the view and the information represented by the attribute? 0. The information provided by this attribute would not be easy to represent in this view, so it is practically *never* included.The information provided by this attribute could *potentially* be shown by this view, but it is *not typically* included. 1.5. The information provided by this attribute is *partially* (but not completely) shown by this view, *or* the information provided by this attribute is *sometimes* completely included in the view. 1. The information provided by this attribute is *usually* completely shown by the view. Enter the resulting number code into the table (Table 9).

Table 7 has the attributes (columns) sorted by column sum (for each object type). Unsurprisingly, the "Name" attribute of activities and deliverables is important for most purposes. However, tied for first place in activity attributes, and running a close second in deliverable attributes, is "Mode," an attribute for which most models or views do not explicitly account. (An activity mode is an alternative version of an activity—e.g., a fast, expensive mode or a slow, less-expensive mode.) The next-most frequently used sets of attributes (of both objects) deal with the object's relationships to other objects—hierarchical decomposition relationships (parents and children), flow relationships (inputs and outputs, or suppliers and customers), and instance relationships (deployment). At the other end of the spectrum, only a few purposes use the attribute "Version Number": most users apparently need to see only the latest version and expect any view to present this to them by default; they do not usually care about previous versions. Thus, in another instance of the Pareto principle, over 80% of the purposes use the same basic 20% of the attributes. The data suggest that a majority of the purposes require a common set of fundamental attributes.

Table 7: Mapping of process model purposes to attributes

Essential:	2
Helpful:	1
Unneeded:	0

Process/Activity Object Attributes

User	Purpose	Name	Mode	Parent	Constituents ("Children")	Deployment	Inputs	Outputs	Deployed Owner	Exit Criteria	Deployed Process Metrics	Deployed Roles	Brief Description	Entry Criteria	Tools	Standard Owner	Deployed Risks	Verifications	Rules	Shadowing	Standard Process Metrics	Basis for Requirement	Master Owner	Change Notifications	Standard Risks	WBS Element Association	Standard Roles	Narrative Description	Change History	References	Tailoring Guidance	Version Number
Process owner	Organize knowledge about work	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2
	Identify "ripple effects" of process changes	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	1	2	1
	Visualize, understand, analyze, and improve processes	2	2	2	2	2	2	2	1	2	2	1	1	2	1	1	2	2	2	2	2	2	1	2	2	1	1	1	2	1	1	
	Define standard and preferred activities	2	2	2	2	1	2	2	2	2	1	1	2	2	2	2	1	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2
	Define standard deliverables and quality standards																															
	Define standard handoffs and structure standard work flows	2	2	1	1	1	2	2		2				2		2				1			2									
	Define standard tools and templates	2	2										1		2	1							1					1				
	Define standard staffing, roles, responsibilities, and skills	2	2									1	1			1							1				2					
Project planner and scheduler	Tailor the standard process to suit project requirements	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	1	2	1	2	1	2	2	2	1	1		2	1
	Set project schedule and secure formal commitments	2	2	2	2	2	2	2	2	2			1	2										2								
	Identify appropriate activities and deliverables for the project	2	2	2	2	1	2	2		1	2	2	1	1						2	1					2						
	Define deployed deliverables and quality levels																															
	Choose tools and templates	2	2			2			1	2		2	1	1	2			2	2									1		2	1	
	Filter activities and deliverables	2	2	2	2	1							1							1						2						
	Associate processes with WBS elements	2	2	2	2															1						2						
	Estimate project time, cost, quality, and risks	2	2	2	2	2	2	2			2		1				2				2				2							
	Import deployed process activities into a project scheduling tool	2	2	2	2	2	2	2	2		2	2																				
	Allocate resources	2	2	2	2	2	2	2			2		1		2						1											
	Identify skill (or training) gaps in the workforce	2	2	1	1	2			1			2	1		1													1				
Project manager or team leader	Renegotiate commitments where necessary	2	2	2	2	2	2	2	2	2	2		1	2			2							2								
	Monitor project status in terms of activities and deliverables	2	2	2	2	2	2	2	2	2	2		1				2															
	Visualize planned work flows and integration points	2	2	2	2	2	2	2	2																							
	Estimate project time, cost, quality, and risks	2	2	2	2	2	2	2			2		1				2				2				2							
	Allocate resources	2	2	2	2	2	2	2			2		1		2						1											
	Assign activity roles and responsibilities (staffing)	2	2			2			2			2	1		1												2					
Auditor / assessor / appraiser	Confirm performance of requisite practices	2	2	2	2	2	2	2	2	2	1	1	1	1		1		2	2			2						2	2	1		2
	Confirm production of appropriate deliverables																															
	View practices relevant to a given standard	2	2	2	2	2			2							2						2	2									
Team member	Access knowledge about activities, tools, and deliverables	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	1	2	2	2	1	1	2	2	1	1
	Deposit lessons learned	2	2	2	2	2	2	2	2	2	2	2	1	2	1	2	2	2	2	2	1	2	1	2	2	1	1	2	2	2	2	
	Sum:	50	50	40	40	40	34	34	31	27	26	24	23	23	20	20	19	18	18	17	17	17	17	17	16	16	15	15	15	13	13	9
	Rank:	1	1	3	3	3	6	6	8	9	10	11	12	12	14	14	16	17	17	19	19	19	19	19	24	24	26	26	26	29	29	31
	Percent of purposes requiring:	89	89	71	71	71	61	61	55	48	46	43	41	41	36	36	34	32	32	30	30	30	30	30	29	29	27	27	27	23	23	16

Deliverable Object Attributes

User	Purpose	Name	Mode	Parent	Constituents ("Children")	Suppliers	Consumers	Deployment	Key Criteria and Measures of Effectiveness	Requirements	Acceptance Criteria	Deployed Process Metrics	Format	Medium	Rules	WBS Element Association	Shadowing	Artifact	Brief Description	Change Notifications	Tailoring Guidance	Change History	Standard Process Metrics	Narrative Description	References	Version Number	Row Sum
Process owner	Organize knowledge about work	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	110
	Identify "ripple effects" of process changes	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2	1	1	1	103
	Visualize, understand, analyze, and improve processes	2	2	2	2	2	2	2	2	2	2	2	1	1	2	1	2	1	1	2	1	2	2	1	1		89
	Define standard and preferred activities																										57
	Define standard deliverables and quality standards	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	49
	Define standard handoffs and structure standard work flows	2	2	2	2	2	2		2	2	2		2	2			2	2									46
	Define standard tools and templates																										10
	Define standard staffing, roles, responsibilities, and skills																										10
Project planner and scheduler	Tailor the standard process to suit project requirements	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	2	1	2	1		1	94
	Set project schedule and secure formal commitments	2	2	2	2	2	2	2	2	2	2	2	2	2	1			1	1	2							54
	Identify appropriate activities and deliverables for the project	2	2	2	2	2	2	2	1	1	1	2	1	1		2		1	1				1				51
	Define deployed deliverables and quality levels	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	1		2		1	1			38
	Choose tools and templates	2				1	1		1	1	1		1	1	1			1			1			1	1		37
	Filter activities and deliverables	2	2	2	2			2								2	1		1								27
	Associate processes with WBS elements	2	2	2	2			2								2	2		1								26
	Estimate project time, cost, quality, and risks																										23
	Import deployed process activities into a project scheduling tool																										20
	Allocate resources																										20
	Identify skill (or training) gaps in the workforce																										14
Project manager or team leader	Renegotiate commitments where necessary	2	2	2	2	2	2	2	2	2	2	2								2							51
	Monitor project status in terms of activities and deliverables	2	2	2	2	2	2	2	2	2	2	2						1									46
	Visualize planned work flows and integration points	2	2	1	1	2	2												1								27
	Estimate project time, cost, quality, and risks																										23
	Allocate resources																										20
	Assign activity roles and responsibilities (staffing)																										14
Auditor / assessor / appraiser	Confirm performance of requisite practices																										36
	Confirm production of appropriate deliverables	2	2			2	2	2	2	2	2	1			2				1			2		2		2	26
	View practices relevant to a given standard																										18
Team member	Access knowledge about activities, tools, and deliverables	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	1	2	1	1	2	2	102
	Deposit lessons learned	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	1	1	2	2	2	1	2	2		98
	Sum:	36	34	31	31	31	31	30	28	28	28	24	21	21	20	19	18	18	17	17	15	15	14	14	11	10	46.3
	Rank:	1	2	3	3	3	3	7	8	8	8	11	12	12	14	15	16	16	18	18	20	20	22	22	24	25	
	Percent of purposes requiring:	64	61	55	55	55	55	54	50	50	50	43	38	38	36	34	32	32	30	30	27	27	25	25	20	18	

Table 8: Purpose / attribute clusters

Essential:	2
Helpful:	1
Unneeded:	0

Process/Activity Object Attributes

Purpose	Name	Mode	Deployment	Parent	Constituents ("Children")	Inputs	Outputs	Deployed Owner	Exit Criteria	Deployed Process Metrics	Deployed Roles	Brief Description	Entry Criteria	Tools	Standard Owner	Deployed Risks	Verifications	Rules	Shadowing	Standard Process Metrics	Basis for Requirement	Master Owner	Change Notifications	Standard Risks	WBS Element Association	Standard Roles	Narrative Description	Change History	References	Tailoring Guidance	Version Number
Define standard and preferred activities	2	2	1	2	2	2	2	2	2	1	1	2	2	2	2	1	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2
Organize knowledge about work	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2
Access knowledge about activities, tools, and deliverables	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	1	2	2	2	1	1	2	2	1	1
Identify "ripple effects" of process changes	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	1	2	1
Deposit lessons learned	2	2	2	2	2	2	2	2	2	2	2	1	2	1	2	2	2	2	2	1	2	1	2	2	1	1	2	2	2	2	
Tailor the standard process to suit project requirements	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	1	2	1	2	1	2	2	2	1	1		2	1
Visualize, understand, analyze, and improve processes	2	2	2	2	2	2	2	1	2	2	1	1	2	1	1	2	2	2	2	2	2	1	2	2	1	1	1	2	1	1	
Define standard deliverables and quality standards																															
Define deployed deliverables and quality levels																															
Confirm production of appropriate deliverables																															
Confirm performance of requisite practices	2	2	2	2	2	2	2	2	2	1	1	1	1		1		2	2			2						2	2	1		2
Estimate project time, cost, quality, and risks	2	2	2	2	2	2	2			2		1				2				2				2							
Allocate resources	2	2	2	2	2	2	2			2		1		2						1											
Import deployed process activities into a project scheduling tool	2	2	2	2	2	2	2	2		2	2																				
View practices relevant to a given standard	2	2	2	2	2			2							2						2	2									
Identify skill (or training) gaps in the workforce	2	2	2	1	1			1			2	1		1													1				
Assign activity roles and responsibilities (staffing)	2	2	2					2			2	1		1												2					
Define standard staffing, roles, responsibilities, and skills	2	2									1	1			1							1				2					
Define standard tools and templates	2	2										1		2	1							1					1				
Identify appropriate activities and deliverables for the project	2	2	1	2	2	2	2		1	2	2	1	1						2	1					2						
Set project schedule and secure formal commitments	2	2	2	2	2	2	2	2	2			1	2										2								
Renegotiate commitments where necessary	2	2	2	2	2	2	2	2	2	2		1	2			2							2								
Monitor project status in terms of activities and deliverables	2	2	2	2	2	2	2	2	2	2		1				2															
Define standard handoffs and structure standard work flows	2	2	1	1	1	2	2		2				2		2				1			2									
Choose tools and templates	2	2	2					1	2		2	1	1	2			2	2									1		2	1	
Filter activities and deliverables	2	2	2	2	2							1							1						2						
Visualize planned work flows and integration points	2	2	2	2	2	2	2	2																							
Associate processes with WBS elements	2	2		2	2														1						2						
	50	50	41	40	40	34	34	31	27	26	24	23	23	20	20	19	18	18	17	17	17	17	17	16	16	15	15	15	13	13	9
	1	1	3	4	4	6	6	8	9	10	11	12	12	14	14	16	17	17	19	19	19	19	19	24	24	26	26	26	29	29	31

Deliverable Object Attributes

Purpose	Name	Mode	Parent	Constituents ("Children")	Suppliers	Consumers	Deployment	Key Criteria and Measures of Effectiveness	Requirements	Acceptance Criteria	Deployed Process Metrics	Format	Medium	WBS Element Association	Rules	Shadowing	Artifact	Brief Description	Change Notifications	Tailoring Guidance	Change History	Standard Process Metrics	Narrative Description	References	Version Number	Row Count (Activity Object)	Row Count (Deliverable Object)	Percent Populated (Activity Object)	Percent Populated (Deliverable Object)
Define standard and preferred activities																										57	0	92%	0%
Organize knowledge about work	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	61	49	98%	98%
Access knowledge about activities, tools, and deliverables	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	1	2	1	1	2	2	56	46	90%	92%
Identify "ripple effects" of process changes	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2	1	1	1	58	45	94%	90%
Deposit lessons learned	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	2	2	2	1	2	2		54	44	87%	88%
Tailor the standard process to suit project requirements	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	2	1	2	1		1	53	41	85%	82%
Visualize, understand, analyze, and improve processes	2	2	2	2	2	2	2	2	2	2	2	1	1	1	2	2	1	1	2	1	2	2	1	1		49	40	79%	80%
Define standard deliverables and quality standards	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	49	0%	98%
Define deployed deliverables and quality levels	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	1		2		1	1			0	38	0%	76%
Confirm production of appropriate deliverables	2	2			2	2	2	2	2	2	1				2			1			2		2		2	0	26	0%	52%
Confirm performance of requisite practices																										36	0	58%	0%
Estimate project time, cost, quality, and risks																										23	0	37%	0%
Allocate resources																										20	0	32%	0%
Import deployed process activities into a project scheduling tool																										20	0	32%	0%
View practices relevant to a given standard																										18	0	29%	0%
Identify skill (or training) gaps in the workforce																										14	0	23%	0%
Assign activity roles and responsibilities (staffing)																										14	0	23%	0%
Define standard staffing, roles, responsibilities, and skills														2												10	2	16%	4%
Define standard tools and templates																										10	0	16%	0%
Identify appropriate activities and deliverables for the project	2	2	2	2	2	2	2	1	1	1	2	1	1	2			1	1				1				25	26	40%	52%
Set project schedule and secure formal commitments	2	2	2	2	2	2	2	2	2	2	2	2	2		1		1	1	2							23	31	37%	62%
Renegotiate commitments where necessary	2	2	2	2	2	2	2	2	2	2	2								2							27	24	44%	48%
Monitor project status in terms of activities and deliverables	2	2	2	2	2	2	2	2	2	2	2						1									23	23	37%	46%
Define standard handoffs and structure standard work flows	2	2	2	2	2	2		2	2	2		2	2			2	2									20	26	32%	52%
Choose tools and templates	2				1	1		1	1	1		1	1		1		1			1			1	1		23	14	37%	28%
Filter activities and deliverables	2	2	2	2			2							2		1		1								14	14	23%	28%
Visualize planned work flows and integration points	2	2	1	1	2	2												1								16	11	26%	22%
Associate processes with WBS elements	2	2	2	2			2							2		2		1								11	15	18%	30%
	36	34	31	31	31	31	30	28	28	28	24	21	21	21	20	18	18	17	17	15	15	14	14	11	10				
	1	2	3	3	3	3	7	8	8	8	11	12	12	12	15	16	16	18	18	20	20	22	22	24	25				

Table 8 reorders the rows of Table 7 to identify attribute clusters. The first shaded cluster in the upper-left consists of seven purposes that use most of the activity attributes. The second shaded cluster, in the upper-right, includes nine purposes that use most of the deliverable attributes. These two clusters overlap. The third shaded cluster, in the middle-left, groups nine purposes with moderate to small needs for activity attributes and almost no needs for deliverable attributes. The last group of purposes, at the bottom, uses a moderate number of attributes from both objects. These clusters suggest the possibility of alternative groups or categories of purposes based on information needs (as opposed to the user-based categories from Table 3 used to organize Tables 5 and 7).

4.4 Stage 4: Mapping Views to Attributes

A similar approach was used to code the attributes shown by each of the 15 views, although here the literature guided the coding more than the case study data. Table 9 shows the converged results using the scale described on the right side of Table 6. Again, the "0"s and "2"s were the easiest to code with quick consensus, while the "1"s were the most difficult to code, because just how easy it would be to include an attribute in a view or not depends on assumptions about the view's practical capabilities and limitations. Nevertheless, I reached the reasonable and useful condensation in Table 9, which contains about 18% "1"s and "1.5"s (and from which we can therefore infer a coding reliability of at least 82%). Again, it is worth noting that other managerial and research models such as QFD produce highly useful results, despite using coding schemes with similar limitations. In the end, Table 9 provides a helpful synopsis of the information content of the views and enables several robust observations.

First, the textual narrative has the capability to include almost any desired attribute, although it is up to its authors to do so. However, the textual process documentation at the case study company was inconsistently detailed. Moreover, when a narrative includes many attributes, it becomes difficult to organize it in a way that facilitates users finding a particular piece of information, as filtering out subsets of information is difficult. A good search engine can get users to information quickly, but only if they know exactly what to look for. Therefore, simply determining whether or not a view can include an attribute does not tell the whole story (but it is a start). We will return to this point later. Second, the "WPS database record" view provides a means of potentially accessing a wide variety of information about the attributes of deliverables. This type of view—direct access to database objects (records) and their attributes (fields)—seemed attractive to expert users such as process owners at the case study company. However, effective use of this type of view requires a higher level of prior knowledge about an object and its context. Third, six attributes are not shown by any view,

Table 9: Mapping of process model views to attributes (adapted from (Browning 2009))

Usually: 2
Sometimes or Partially: 1.5
Potentially: 1
Never: 0

Activity Object Attributes

View	Name	Inputs	Outputs	Constituents ("Children")	Parent	Mode	Version Number	Master Owner	Standard Owner	Deployed Owner	Standard Process Metrics	Deployed Process Metrics	Standard Roles	Deployed Roles	Shadowing	Entry Criteria	Exit Criteria	Deployment	Verifications	Tools	Rules	Narrative Description	Brief Description	Standard Risks	Deployed Risks	Basis for Requirement	References	Tailoring Guidance	WBS Element Association	Change History	Change Notifications
Textual narrative	2	1	1	1.5	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1.5	1	1			
IDEF0 diagram	2	2	2	2	2	1	1	1	1	1	1	1			1			1		1.5	1.5										
SIPOC diagram	2	2	2	2	1	1	1	1	1	1					1			1		1			1								
IDEF3 diagram	2	1.5	1.5	2	2	1	1	1	1	1	1	1			1			1													
ETVX diagram	2	1.5	1.5				1	1	1	1						2	2		2												
Process flowchart	2	1.5	1.5	1.5	1.5	1	1	1	1	1	1	1			1																
Extended EPC diagram	2	2	2	1.5	1.5	1							1.5	1.5																	
DSM	2	1.5	1.5	1	1	1	1	1	1	1	1	1												1	1						
Gantt chart	2	1.5	1.5	1.5	1.5		1	1	1	1	1	1																			
RAM	2			1	1	1		1	1	1			2	2																	
Value Stream Map	2	1.5	1.5	1	1						1.5	1.5																			
GERT diagram	2	1.5	1.5	1	1	1	1																								
CRUD Table	2	1.5																													
State diagram	2															1	1														
WPS database record																															
Sum:	28	19	18	16	16	9	9	9	9	9	7.5	7.5	4.5	4.5	5	4	4	4	3	3.5	2.5	2	2	2	2	1.5	1	1	0	0	0
Rank:	1	2	3	4	5	6	6	6	6	6	11	11	14	14	13	16	16	16	20	19	21	22	22	22	22	26	27	27	29	29	29
% of views requiring:	62	42	39	36	34	20	20	20	20	20	17	17	10	10	11	9	9	9	7	8	6	4	4	4	4	3	2	2	0	0	0

Deliverable Object Attributes

View	Name	Suppliers	Mode	Requirements	Acceptance Criteria	Parent	Constituents ("Children")	Deployment	Consumers	Key Criteria and Measures of Effectiveness	Artifact	References	Narrative Description	Version Number	Brief Description	Standard Process Metrics	Deployed Process Metrics	Rules	Tailoring Guidance	Change Notifications	Format	Medium	Shadowing	WBS Element Association	Change History	Row Count (Activity Object)	Row Count (Deliverable Object)	Percent Populated (Activity Object)	Percent Populated (Deliverable Object)	Total Row Count
Textual narrative	1.5			1	1					1					1											32	5.5	34%	7%	37.5
IDEF0 diagram	2		1																							22	3	24%	4%	25
SIPOC diagram	2		1																							18	3	19%	4%	21
IDEF3 diagram																										18	0	19%	0%	18
ETVX diagram																										15	0	16%	0%	15
Process flowchart																										16	0	17%	0%	16
Extended EPC diagram	2	1.5	1			1.5	1.5		1.5																	13	9	14%	12%	22
DSM	1																									16	1	17%	1%	17
Gantt chart																										14	0	15%	0%	14
RAM																										12	0	13%	0%	12
Value Stream Map																1	1									10	2	11%	3%	12
GERT diagram																										9	0	10%	0%	9
CRUD Table	2																									3.5	2	4%	3%	5.5
State diagram																										4	0	4%	0%	4
WPS database record	2	2	1	2	2	1	1	2	1	1.5	2	2	2	1.5	1	1	1	1.5	1.5	1.5	1	1				0	32.5	0%	43%	32.5
Sum:	13	3.5	4	3	3	2.5	2.5	2	2.5	2.5	2	2	2	1.5	2	2	2	1.5	1.5	1.5	1	1	0	0	0					
Rank:	1	3	2	4	4	6	6	10	6	6	10	10	10	17	10	10	10	17	17	17	21	21	23	23	23					
% of views requiring:	28	8	9	7	7	6	6	4	6	6	4	4	4	3	4	4	4	3	3	3	2	2	0	0	0					

although one could expand some views to show them. However, doing so causes the views to become cluttered. Users might need additional views to represent these attributes. Fourth, I confirm the finding of Browning and Ramasesh (2007) that most views emphasize the activities but not the deliverables. At best, some views name the deliverables without elaborating on them, while many views only treat the deliverables implicitly. The eEPC diagram view provides the capability to emphasize deliverables, but, when it does so, the diagram becomes cluttered. Therefore, users might need separate views to emphasize the characteristics of deliverables.

4.5 Stage 5: Alignment of Purposes and Views

While the purpose-attribute and view-attribute tables yield some interesting findings in themselves, their primary purpose was to enable analysis of the alignment between the purposes and views, which occurs as follows. First, I defined two arrays of attributes, ***P*** and ***V***, for the purposes and views, respectively. The 28 purposes are indexed in *i*, the 15 views in *j*, and the 56 attributes in *k*. Second, I computed the *positive* difference, D_{ij}, between the arrays by summing the individual differences between their corresponding entries:

$$D_{ij} = \sum_{k=1}^{56} \mathrm{Max}\left(P_{ik} - V_{jk}, 0\right) \tag{1}$$

This difference indicates the absolute size of the gap between the attributes needed by purpose *i* and provided by view *j*.

Third, I defined the *sufficiency* of view *j* for purpose *i*, S_{ij}, as this difference normalized against the sum of all of the “essential” or “helpful” attributes for the purpose:

$$S_{ij} = 1 - \frac{D_{ij}}{\sum_{k=1}^{56} P_{ik}}. \tag{2}$$

S is a scalar index over the range [0,1] that compares the percentage of “essential” and “helpful” attributes for purpose *i* to their “usual,” “partial,” or “potential” provision by view *j*. When S_{ij} = 0%, then the view provides none of the “essential” or “helpful” attributes for the purpose. If S_{ij} = 100%, then the view provides all of them. Higher percentages are better. For example, the purpose “View practices relevant to a given standard” requires the attribute “Activity Name,” and the view “State diagram” provides it, so the difference between these entries is zero. However, this purpose also needs eight other attributes that the view does not provide, so $S = 1 – [(2 \times 8) / (2 \times 9)] = 11\%$. Table 10 shows the sufficiency of the attributes in each view for each purpose (with percentage signs removed). The columns are sorted by maximum sufficiency (bottom row), and the view with the greatest sufficiency for the purpose in each row is highlighted. Because of its ability to include a large set of attributes, the “Textual Narrative” view has the highest average sufficiency (which one might interpret as an indicator of its flexibility for a variety of purposes) and also often exhibits the best score for a particular purpose. Some other views also perform relatively well. However, *S* only accounts for the *inclusion* of the attributes required by a purpose; it says nothing about the inclusion of superfluous attributes or the view’s ease of use (i.e., how it arranges and displays attributes). Therefore, by itself, *S* provides insufficient guidance to the best view for a purpose. The main finding in Table 10 is the relatively low sufficiency exhibited by most of the views—meaning that those relying on them could be making important decisions without all of the necessary information.

Table 10: Sufficiency of the attributes in each view for each purpose

Sufficiency	Views															
Purposes	Textual narrative	RAM	WPS database record	IDEF0 diagram	SIPOC diagram	Extended EPC diagram	IDEF3 diagram	Process flowchart	DSM	Gantt chart	Value Stream Map	ETVX diagram	GERT diagram	CRUD Table	State diagram	Average
Organize knowledge about work	34	11	30	23	19	20	16	15	15	13	11	14	8	5	4	16
Identify “ripple effects” of process changes	35	12	28	24	20	21	17	16	17	14	12	15	9	5	4	17
Visualize, understand, analyze, and improve processes	40	11	31	26	22	24	19	17	18	15	13	16	9	6	4	18
Define standard and preferred activities	56	19	0	39	32	22	32	28	28	25	17	26	16	6	7	23
Define standard deliverables and quality standards	11	0	66	6	6	18	0	0	2	0	4	0	0	4	0	8
Define standard handoffs and structure standard work flows	38	15	38	35	35	39	26	24	24	20	15	24	17	12	9	25
Define standard tools and templates	80	50	0	65	70	30	50	50	50	40	20	40	30	20	20	41
Define standard staffing, roles, responsibilities, and skills	80	80	0	50	60	55	50	50	50	40	20	40	30	20	20	43
Tailor the standard process to suit project requirements	37	13	29	27	22	23	19	17	18	15	13	16	10	6	4	18
Set project schedule; determine actual handoffs and work flows…	35	11	43	30	30	35	22	19	19	17	15	19	15	10	7	22
Use the deployed process to identify appropriate activities and deliverables	43	14	37	35	31	40	27	24	22	20	23	14	16	11	8	24
Define deployed deliverables and quality levels	14	0	70	8	8	24	0	0	3	0	5	0	0	5	0	9
Choose tools and templates	53	16	38	27	24	23	14	11	14	8	5	22	8	11	11	19
Filter activities and deliverables by hardware vs. software, project size/phase…	44	19	30	44	44	44	33	26	22	19	15	7	19	15	7	26
Associate processes with WBS elements	38	19	31	42	38	46	31	27	23	19	15	8	19	15	8	25
Estimate project time, cost, quality, and risks	63	22	0	61	52	43	57	48	52	43	43	22	35	15	9	38
Import deployed process activities into a project scheduling tool	63	40	0	70	60	57	65	55	50	50	43	30	40	18	10	43
Allocate resources	68	25	0	77	65	50	65	55	50	50	48	25	40	18	10	43
Identify skill (or training) gaps in the workforce	79	57	0	57	64	46	50	43	43	36	29	21	36	14	14	39
Renegotiate commitments where necessary	39	12	35	33	31	37	25	22	24	20	19	20	16	11	8	23
Monitor project status in terms of activities and deliverables	41	13	38	37	35	41	28	24	26	22	21	17	17	12	7	25
Visualize planned work flows and integration points	48	22	33	59	56	67	44	37	37	33	26	22	30	20	7	36
Assign activity roles and responsibilities (staffing)	64	57	0	43	50	43	36	29	29	21	14	21	21	14	14	30
Confirm performance of requisite practices	67	22	0	49	42	31	42	36	33	33	22	36	25	10	11	31
Confirm production of appropriate deliverables	21	0	79	12	12	23	0	0	4	0	4	0	0	8	0	11
View practices relevant to a given standard (e.g., ISO 9000, CMMI, etc.)	67	44	0	61	56	33	61	50	44	44	22	28	28	11	11	37
Access knowledge about activities, tools, and deliverables	36	11	30	25	21	21	18	16	17	14	12	15	9	5	4	17
Deposit lessons learned	37	11	31	24	20	22	17	15	16	13	12	14	8	6	4	17
Average:	48	22	26	39	37	35	31	27	27	23	18	19	18	11	8	
Maximum:	80	80	79	77	70	67	65	55	52	50	48	40	40	20	20	

Fourth, I similarly computed the *negative* difference between ***P*** and ***V*** and summed these to determine the *extraneousness* of the attributes in view *j* for purpose *i*, E_{ij}—i.e., the degree to which the view provides superfluous attributes for each purpose:

$$E_{ij} = \frac{\sum_{k=1}^{56} \text{Max}\left(V_{jk} - P_{ik}, 0\right)}{\sum_{k=1}^{56} V_{jk}} \quad (3)$$

E is a scalar index over the range [0,1] that indicates the percentage of the attributes provided by view *j* which are *not* used by purpose *i*. When E_{ij} = 0%, then the view does not provide any extraneous attributes. If E_{ij} = 100%, then the view provides all of the attributes *not* required for the purpose. Therefore, lower percentages are better. For example, the view "IDEF0 diagram" can provide the attribute "Activity mode," and the purpose "View practices relevant to a given standard" requires it, so there is no difference between these entries. However, this view also provides ten other attributes that the purpose does not need, and *E* = 14 / 25 = 56%. Table 11 shows the extraneousness of the attributes in each view for each purpose, with columns sorted by average *E* (lower is better). The best (minimum) value of *E* is also highlighted in each row. Since the first

Table 11: Extraneousness of the attributes in each view for each purpose

	Extraneousness	Views: CRUD Table	GERT diagram	State diagram	SIPOC diagram	Extended EPC diagram	IDEF3 diagram	Process flowchart	Gantt chart	Value Stream Map	IDEF0 diagram	RAM	DSM	ETVX diagram	Textual narrative	WPS database record	Average
Purposes	Organize knowledge about work	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Identify "ripple effects" of process changes	0	0	0	0	0	0	0	0	0	0	0	0	0	3	11	1
	Visualize, understand, analyze, and improve processes	0	11	0	5	5	6	6	7	0	6	17	6	7	5	15	6
	Define standard and preferred activities	36	0	0	14	43	0	0	0	21	12	8	6	0	15	100	17
	Define standard deliverables and quality standards	64	100	100	86	59	100	100	100	83	88	100	94	100	85	0	84
	Define standard handoffs and structure standard work flows	0	11	0	24	18	33	31	36	42	36	42	35	27	53	46	29
	Define standard tools and templates	64	67	50	67	86	72	69	71	83	74	58	71	73	79	100	72
	Define standard staffing, roles, responsibilities, and skills	64	67	50	71	75	72	69	71	83	80	33	71	73	79	100	71
	Tailor the standard process to suit project requirements	0	0	0	0	0	0	0	0	0	0	0	0	0	7	15	1
	Set project schedule; determine actual handoffs and work flows…	0	11	0	24	14	33	38	36	33	36	50	41	33	49	29	29
	Use the deployed process to identify appropriate activities and deliverables	0	11	0	24	7	22	25	29	4	28	42	35	53	41	42	24
	Define deployed deliverables and quality levels	64	100	100	86	59	100	100	100	83	88	100	94	100	85	18	85
	Choose tools and templates	27	67	0	57	61	72	75	79	83	60	50	71	47	48	57	57
	Filter activities and deliverables by hardware vs. software, project size/phas	27	44	50	43	45	50	56	64	67	52	58	65	87	68	75	57
	Associate processes with WBS elements	27	44	50	52	45	56	56	64	67	56	58	65	87	73	75	58
	Estimate project time, cost, quality, and risks	36	11	50	43	55	28	31	29	17	44	58	29	67	61	100	44
	Import deployed process activities into a project scheduling tool	36	11	50	43	48	28	31	29	29	44	33	41	60	67	100	43
	Allocate resources	36	11	50	38	55	28	31	29	21	38	58	41	67	64	100	44
	Identify skill (or training) gaps in the workforce	64	44	50	57	70	61	63	64	67	68	33	65	80	71	100	64
	Renegotiate commitments where necessary	0	11	0	24	14	28	31	29	21	32	50	29	33	47	45	26
	Monitor project status in terms of activities and deliverables	0	11	25	24	14	28	31	29	21	32	50	29	47	49	46	29
	Visualize planned work flows and integration points	0	11	50	29	18	33	38	36	42	36	50	41	60	65	72	39
	Assign activity roles and responsibilities (staffing)	64	67	50	67	73	72	75	79	83	76	33	76	80	76	100	71
	Confirm performance of requisite practices	36	0	0	29	50	17	19	14	33	30	33	29	13	36	100	29
	Confirm production of appropriate deliverables	64	100	100	86	73	100	100	100	92	88	100	94	100	85	37	88
	View practices relevant to a given standard (e.g., ISO 9000, CMMI, etc.)	64	44	50	52	73	39	44	43	67	56	33	53	67	68	100	57
	Access knowledge about activities, tools, and deliverables	0	0	0	0	2	0	0	0	0	0	8	0	0	3	5	1
	Deposit lessons learned	0	11	0	5	2	6	6	7	4	6	8	6	7	3	8	5
	Average:	28	31	31	37	38	39	40	41	41	42	42	42	49	49	57	

purpose in the table ("Organize knowledge about work") requires every attribute, none of the views can contain any extraneous attributes, so they all score well. However, purposes that require only a few attributes, such as "Confirm production of appropriate deliverables," cause many of the views to perform poorly. Thus, *E* compensates for views that seem to perform well in *S* solely because they overwhelm users with information. High *E* indicates that a view provides a lot of irrelevant, potentially distracting information for a given purpose.

Finally, I combined *S* and *E* to arrive at a measure of the *alignment* between purpose *i* and view *j*:

$$PVA_{ij} = \frac{S_{ij} + \left(1 - E_{ij}\right)}{2} = \frac{S_{ij} - E_{ij} + 1}{2} \tag{4}$$

PVA is also a scalar index over the range [0,1], where 0% indicates complete misalignment ($S = 0$ and $E = 1$) and 100% implies perfect alignment ($S = 1$ and $E = 0$)—so higher scores are better. For example, the alignment between the purpose "Allocate resources" and the view "State diagram" is (10% – 50% + 1) / 2 = 30%. Since *PVA* depends on the chosen number and type of attributes used in this analysis, it is mainly useful in a relative sense, for comparison. The resulting *PVA* measures are shown in Table 12, which again highlights the best (highest) score in each row and sorts the columns by best *PVA*. While there are several 0% scores, indicating

Table 12: Overall alignment of the attributes required by purposes and provided by views (*PVA*)

	Alignment	Views: WPS database record	Extended EPC diagram	RAM	Textual narrative	IDEF0 diagram	IDEF3 diagram	GERT diagram	Process flowchart	SIPOC diagram	Value Stream Map	ETVX diagram	Gantt chart	DSM	CRUD Table	State diagram	Average
Purposes	Organize knowledge about work	65	60	55	67	61	58	54	57	60	55	57	56	58	52	52	58
	Identify "ripple effects" of process changes	59	61	56	66	62	59	54	58	60	56	57	57	58	53	52	58
	Visualize, understand, analyze, and improve processes	58	60	47	67	60	57	49	55	59	57	55	54	56	53	52	56
	Define standard and preferred activities	0	39	55	71	63	66	58	64	59	48	63	62	61	35	54	53
	Define standard deliverables and quality standards	83	30	0	13	9	0	0	0	10	10	0	0	4	20	0	12
	Define standard handoffs and structure standard work flows	46	60	37	42	49	46	53	46	55	37	49	42	44	56	54	48
	Define standard tools and templates	0	22	46	51	45	39	32	41	52	18	33	34	40	28	35	34
	Define standard staffing, roles, responsibilities, and skills	0	40	73	51	35	39	32	41	44	18	33	34	40	28	35	36
	Tailor the standard process to suit project requirements	57	62	56	65	63	60	55	59	61	56	58	57	59	53	52	58
	Set project schedule; determine actual handoffs and work flows…	57	61	31	43	47	44	52	41	53	41	43	40	39	55	54	47
	Use the deployed process to identify appropriate activities and deliverables	48	67	36	51	54	53	52	49	54	59	30	46	43	55	54	50
	Define deployed deliverables and quality levels	76	32	0	15	10	0	0	0	11	11	0	0	4	21	0	12
	Choose tools and templates	40	31	33	52	34	21	21	18	34	11	37	15	21	42	55	31
	Filter activities and deliverables by hardware vs. software, project size/phase…	27	49	30	38	46	42	37	35	51	24	10	27	29	44	29	35
	Associate processes with WBS elements	28	50	30	33	43	38	37	35	43	24	11	27	29	44	29	33
	Estimate project time, cost, quality, and risks	0	44	32	51	58	64	62	58	55	63	28	57	61	39	29	47
	Import deployed process activities into a project scheduling tool	0	55	53	48	63	69	64	62	59	57	35	61	54	41	30	50
	Allocate resources	0	48	33	52	70	69	64	62	63	63	29	61	54	41	30	49
	Identify skill (or training) gaps in the workforce	0	38	62	54	45	44	46	40	54	31	21	36	39	25	32	38
	Renegotiate commitments where necessary	45	62	31	46	51	49	52	45	54	49	43	46	47	55	54	49
	Monitor project status in terms of activities and deliverables	46	64	32	46	52	50	53	46	55	50	35	47	48	56	41	48
	Visualize planned work flows and integration points	31	74	36	41	62	56	59	50	63	42	31	49	48	60	29	49
	Assign activity roles and responsibilities (staffing)	0	35	62	44	33	32	27	27	42	15	21	21	26	25	32	30
	Confirm performance of requisite practices	0	40	44	65	59	63	63	59	57	44	61	60	52	37	56	51
	Confirm production of appropriate deliverables	71	25	0	18	12	0	0	0	13	6	0	0	5	22	0	11
	View practices relevant to a given standard (e.g., ISO 9000, CMMI, etc.)	0	30	56	49	53	61	42	53	52	28	31	51	46	24	31	40
	Access knowledge about activities, tools, and deliverables	63	59	51	67	62	59	54	58	60	56	57	57	58	53	52	58
	Deposit lessons learned	61	60	51	67	59	56	49	55	58	54	54	53	55	53	52	56
	Average:	34	49	40	49	49	46	44	43	50	39	35	41	42	42	38	
	Maximum:	83	74	73	71	70	69	64	64	63	63	63	62	61	60	56	

that a view is maximally "out of sync" with a purpose, the salient finding is the lack of any really good scores. In fact, the best score in the whole table is 83%, and the average of the best scores from all rows is 65%. These incongruities indicate that most purposes are inadequately supported by the common views. They also signal a potential benefit to be gained through developing more targeted views that better support particular purposes.

5. Discussion

Despite some challenges in determining the alignment between the purposes and views of project process models, the evidence and analysis are sufficiently suggestive to allow the extraction of several important implications and insights. This section discusses the study's limitations and then its implications and insights for researchers and managers.

5.1 Limitations

The present study has some methodological limitations, but it dodges others. If it were a deductive study, it would be seriously limited by the small number of cases at a single company. However, since its purpose was to induce sets of purposes, views, and attributes and explore their alignment—as a basis for building rather than testing theory—it drew on greater details from a smaller group of more in-depth cases and a thorough literature review. Many consider this approach to be best for inspiring and guiding theory development (Eisenhardt and Graebner 2007; Miles and Huberman 1984; Mintzberg 1979). Also, using case studies allowed me to address a rich phenomenon that required a deep understanding and was not immediately amenable to a broad survey. The study also faced the challenges of coding Tables 7 and 9, especially the "1"s. However, a discussion-based approach with process experts provided opportunities to hear alternative opinions and allowed for the emergence of a reasoned portrait of purpose-attribute and view-attribute relationships. On the other hand, I would have preferred to be able to spend even more time with each informant to observe more of their uses of process models in action. While I cannot yet claim generality, I can reasonably expect similar results in other contexts. And while it is too early to draw explicit prescriptive conclusions, this study has provided a valuable basis for further investigations.

The scope of the present study is limited to singular relationships between purposes and views via attributes. However, the value of an attribute to a purpose or a view might depend on the presence or absence of other attributes. Further research might identify "affinity groups" of attributes that provide greater value in combination. It might also be possible to support certain purposes with a combination of views. The present scope is also limited to activity network models of project processes. While these types of models are predominant, both in the literature and in practice, other types of models (e.g., parametric forecasting models) also serve some of the purposes addressed in this study (such as estimating the duration and cost of project work). Future studies could include other types of managerial models that address the purposes listed in Table 3.

Finally, this study determines PVA solely on the basis of information content, even though view effectiveness also depends on additional properties, such as the arrangement of the content and the cognitive capability and style of the user. Our study does not include a way to compare the much more subjective attributes of "intuitiveness" and "ease of use" that would also affect a view's fitness for a purpose. However, most prior studies of TTF have the same limitation, albeit on the "other side of the coin," by having focused on these perceptional aspects while ignoring the aspect of content. Thus, it remains as future research in all areas to synthesize the perceptional and content factors into a more holistic measure of TTF and PVA. Future studies could also endeavor to address the cognitive preferences and abilities of users. A textual narrative view, for example, might not appeal to users who prefer images, regardless of the information content.

5.2 Implications for Theory and Research

Despite its limitations, the present study suggests at least three important areas for theory development and future research. First, in being the first to apply TTF theory to the project management context, the study introduces a new construct, PVA, and suggests that project performance and success should improve with increased PVA. That is, increasing the alignment between the purposes and views of the models used to increase understanding and support decisions about "what work to do and when" should enable better and faster actions. Conversely, misalignment should decrease project performance. (These findings are consistent with socio-technical systems theory's principles of compatibility, minimal criteria specification, information flow, and support congruence (Closs *et al.* 2008).) One would expect other factors such as project novelty, size, complexity, and difficulty to amplify these effects. While existing studies have only examined whether or not a project used particular tools or not, they have not controlled for the tools' appropriate use for particular purposes. Thus, the study builds contingency theory in project management by moving beyond the question of mere tool usage to the match between tool and purpose.

It is likely to be important for managers to match the right view to the right decision, which is a more specific instance of the old admonition to use the right tool for a job. This study finds that the common views do not seem to provide appropriate support for the key purposes for which managers might use them. For instance, a project planner said how helpful it would be to be able to accomplish the purpose "Filter activities and deliverables," but that he did not know of any good tool to help him do so. Indeed, the best view in this study has a PVA of only 51% with that purpose. Furthermore, the case studies revealed anecdotal evidence of the use of poorly aligned views supposedly contributing to inefficiency and other problems. For instance, one project manager spent much time using a Gantt chart to try to convince a process auditor that a standard process was being followed, even though the names of the activities on the Gantt chart did not match those in the standard process narrative. Another project manager commented, "The biggest challenge is staffing—getting the right people assigned to the right activities." Staffing is one of the project manager's purposes, and this particular interviewee was using Gantt charts (which have a PVA of only 21% with that purpose) and having trouble. Furthermore, project breakdowns seemingly occurred because managers made scheduling or other decisions with overly simplified views. Several interviewees mentioned that some project teams would arrive at key milestone meetings without a common understanding of what exactly had to be done by then. One said, "Most failures seem to be attributable to a lack of integration of schedules." A view of the process that emphasized the activity entry and exit criteria, for example, might have helped prevent such occurrences. Thus, further empirical study could evaluate PVA (misalignment) as a potential contributor to project success (failure). It also seems likely that PVA will explain project success to a greater extent in large, complex projects where managers' tacit, mental models are less likely to suffice as substitutes for formal models and views. The ability to investigate PVA at the granular level of individual purposes and views opens the door to further comparative studies.

Second, it would be useful to understand *how* views and PVA facilitate innovation and good managerial decision making, and, conversely, how misaligned views contribute to poor decisions. For instance, since most purposes seem to require relatively simple views (i.e., views with a nominal amount of information content), one might expect projects using such views to outperform projects using more complicated views (when controlling for other factors such as user ability and project novelty, size, complexity, and difficulty).

Third, since this study disentangles the sufficiency and extraneousness aspects of alignment, it might also be fruitful to explore their effects separately. For instance, user ability and experience might compensate for a lack of filters in a view with extraneous attributes, whereas it might be more difficult to compensate for missing information. Having extraneous attributes might be a nuisance, but missing an essential attribute might be more detrimental. Equation (4) weights the contributions of S and E equally, but a weighting scheme that places a greater emphasis on *S* might be more appropriate. Future research could help clarify the implications of erring on the side of providing too little or too much information to decision makers.

5.3 Further Insights for Researchers and Managers

This study also provides insights that may help researchers and managers adjust the way they use process models. First, this study's approach and measures could be beneficial in themselves to those seeking to ascertain the fit between their tasks and tools. Second, while Little (1970) discusses a tradeoff between simplicity and completeness in models, using a menu or portfolio of views may allow managers to "have it both ways"—a relatively rich model of a complex process, accessed via a portfolio of comparatively simple views (or "portals"). While the underlying model would have the advantages of richness, integration, and synchronization, its various views could be the simple and easy-to-communicate-with type embraced by managers. Despite the complexity of contemporary projects, this approach would allow varied users to continue to use (apparently) simple views while providing behind-the-scenes integration of the information (in a model) (Browning 2009).

The various views used by different project participants indicate diverse needs for information and preferences for its presentation. Thus, *the drive towards a greater standardization of views pursued by some organizations might actually be counter-productive to project performance*. The deeper problem seems to be a lack of integration and synchronization of process information when it resides in disparate and redundant models. Understanding the specific information attributes of a process model provides a step towards the requisite integration of the various models currently in use. Perhaps the ideal would be a single model accessed through an integrated set of views, where proposed changes in one view are automatically checked against other views to enable faster project adaptation.

This study provides insight into the directions in which managers and information technologists might develop new, more purposeful views. By analyzing the required information content in certain decisions and tasks, managers (especially in project management offices) could develop views that target and align with specific purposes (or categories of users with similar purposes). Or, information technologists could make just the key information for certain purposes available and then let users customize and personalize their own views of that information (without sacrificing the benefits of a more complete underlying model). Users might also deliberately use multiple views to triangulate complex or uncertain decisions. With some centralized guidance on information content, the most useful and helpful arrangements of that content might emerge over time rather than being centrally developed or mandated.

6. Conclusion

The important decisions facing managers of large, complex projects require appropriate support from model views that filter and organize the relevant information. In contemporary projects, many of the common views both miss some of this information and include extraneous information. Experienced project managers may know how and when to use certain views and when not to. However, the literature contains no systematic evaluation of the alignment between activity network model views and the purposes they support. This paper has proposed a conceptual perspective, a new construct (PVA), and an analysis technique. Based on evidence from the literature and case studies, it finds a lack of content alignment, implying a need for more supportive views. The study and its results provide important benefits for researchers and practitioners.

Studying the alignment between the tools of project management and their uses provides fertile ground for building expanded theories of project performance. While performance is contingent on a great many factors, PVA is likely to influence project efficiency and effectiveness. After all, managerial decisions based on incomplete information seem more likely to be faulty, and managers inundated by extraneous data may find their decision processes slowed considerably or even misled. Getting the right tool for the job is important in any setting, but especially in the high-stakes management of large, complex projects.

7. References

Alexander, Christopher (1964) *Notes on the Synthesis of Form*, Cambridge, MA: Harvard University Press.

Basu, A., R.W. Blanning and A. Shtub (1997) "Metagraphs in Hierarchical Modeling," *Management Sci*, **43**(5): 623-639.

Bendoly, Elliot and Cheri Speier (2008) "Silver Bullet Junkies and the Codifiers That Love Them: Behavioral Roots Behind a Legacy of Bad Modeling and Use," *Decision Sciences*, **39**(2): 157-173.

Bendoly, Elliot and Morgan Swink (2007) "Moderating Effects of Information Access on Project Management Behavior, Performance and Perceptions," *Journal of Operations Management*, **25**(3): 604-622 .

Box, George E.P. (1979) "Robustness in Scientific Model Building," in Launer, R.L. and G.N. Wilkinson, Eds., *Robustness in Statistics*, New York: Academic Press, pp. 201-236.

Browning, Tyson R. (2001) "Applying the Design Structure Matrix to System Decomposition and Integration Problems: A Review and New Directions," *IEEE Transactions on Engineering Management*, **48**(3): 292-306.

Browning, Tyson R. (2009) "The Many Views of a Process: Towards a Process Architecture Framework for Product Development Processes," *Systems Engineering*, **12**(1): 69-90.

Browning, Tyson R., Ernst Fricke and Herbert Negele (2006) "Key Concepts in Modeling Product Development Processes," *Systems Engineering*, **9**(2): 104-128.

Browning, Tyson R. and Ranga V. Ramasesh (2007) "A Survey of Activity Network-Based Process Models for Managing Product Development Projects," *Production and Operations Management*, **16**(2): 217-240.

Clausing, Donald (1994) *Total Quality Development*, New York: ASME Press.

Closs, David J., Mark A. Jacobs, Morgan Swink and G. Scott Webb (2008) "Toward a Theory of Competencies for the

Management of Product Complexity: Six Case Studies," *Journal of Operations Management,* **26**(5): 590-610.

Connolly, Terry and Brian K. Thorn (1987) "Predecisional Information Acquisition: Effects of Task Variables on Suboptimal Search Strategies," *Organizational Behavior and Human Decision Processes,* **39**(3): 397-416.

Crowston, Kevin (2003) "Process as Theory in Information Systems Research," in Malone, Thomas W. *et al.*, Eds., *Organizing Business Knowledge*, Cambridge, MA: MIT Press, pp. 177-190.

Dolk, D.R. and J.E. Kottemann (1993) "Model Integration and a Theory of Models," *Decision Support Systems,* **9**(1): 51-63.

Donaldson, Lex (2001) *The Contingency Theory of Organizations*, Thousand Oaks, CA: Sage Publications.

Dutton, Jane E. and Janet M. Dukerich (1991) "Keeping an Eye on the Mirror: Image and Identity in Organizational Adaptation," *Academy of Management Journal,* **34**(3): 517-554.

Eisenhardt, K.M. and M.E. Graebner (2007) "Theory Building from Cases: Opportunities and Challenges," *Academy of Management Journal,* **50**(1): 25-32.

Eisenhardt, K.M. (1989) "Building Theories from Case Study Research," *Academy of Management Rev,* **14**(4): 532-550.

Engwall, Mats, Ragnar Kling and Andreas Werr (2005) "Models in Action: How Management Models are Interpreted in New Product Development," *R&D Management,* **35**(4): 427-439.

Farhoomand, Ali F. and Don H. Drury (2002) "Managerial Information Overload," *Comm of the ACM,* **45**(10): 127-131.

Fielding, N.G. and J.L. Fielding (1986) *Linking Data*, Newbury Park, CA: Sage.

Flanagan, Tomás , Claudia M. Eckert, René Keller and P. John Clarkson (2006) "Bridging the Gaps Between Project Plans and Reality: The Role of Overview," *Proceedings of the Tools and Methods of Competitive Engineering (TMCE) Conference*, Ljubljana, Slovenia, Apr 18-22, pp. 105-116.

Galbraith, Jay R. (1973) *Designing Complex Organizations*, Reading, MA: Addison-Wesley.

Gantt, Henry L. (1919) *Organizing for Work*, New York: Harcourt, Brace and Howe.

Glaser, B. and A. Strauss (1967) *The Discovery of Grounded Theory: Strategies for Qualitative Research*, London: Wiedenfeld and Nicholson.

Goodhue, Dale L. (1998) "Development and Measurement Validity of a Task-Technology Fit Instrument for User Evaluations of Information Systems," *Decision Sciences,* **29**(1): 105-138.

Goodhue, Dale L., Barbara D. Klein and Salvatore T. March (2000) "User Evaluations of IS as Surrogates for Objective Performance," *Information & Management,* **38**(2): 87-101.

Goodhue, D.L. and R.L. Thompson (1995) "Task-Technology Fit and Individual Performance," *MIS Quarterly,* **19**(2): 213-236.

Hammer, Michael (2001) "Seven Insights About Processes," *Proceedings of the conference The Strategic Power of Process: From Ensuring Survival to Creating Competitive Advantage,* Boston, Mar. 5-6.

Harel, D. (1987) "Statecharts: A Visual Formalism for Complex Systems," *Science of Computer Programming,* **8**(3): 231-274.

Herbig, Paul A. and Hugh Kramer (1994) "The Effect of Information Overload on the Innovation Choice Process: Innovation Overload," *Journal of Consumer Marketing,* **11**(2): 45-54.

IBM (1969) "Flowcharting Techniques," International Business Machines, Report GC20-8152-1.

Jarupathirun, Suprasith and Fatemeh "Mariam" Zahedi (2007) "Exploring the Influence of Perceptual Factors in the Success of Web-based Spatial DSS," *Decision Support Systems*, **43**(3): 933-951.

Jick, Todd D. (1979) "Mixing Qualitative and Quantitative Methods: Triangulation in Action," *Administrative Science Quarterly,* **24**: 602-611.

Keller, René, Claudia M. Eckert and P. John Clarkson (2005) "Viewpoints and Views in Engineering Change Management," *Proceedings of the 2nd Workshop on Complexity in Design and Engineering,* Glasgow, Scotland, Mar 10-12, pp. 188-192.

Keller, René, Tomás L. Flanagan, Claudia M. Eckert and P. John Clarkson (2006) "Two Sides of the Story: Visualising Products and Processes in Engineering Design," *Proceedings of the 10th International Conference on Information*

Visualisation, London, England, Jul. 5-7, pp. 362-367.

Kilov, Haim (1990) "From Semantic to Object-oriented Data Modeling," *Proceedings of the First International Conference on Systems Integration*, Morristown, NJ, Apr 23-26, pp. 385-393.

Krishnan, V. and Karl T. Ulrich (2001) "Product Development Decisions: A Review of the Literature," *Management Science*, **47**(1): 1-21.

Lawrence, Paul R. and Jay W. Lorsch (1967) *Organization and Environment*, Boston: Harvard Business School Press.

Little, John D.C. (1970) "Models and Managers: The Concept of a Decision Calculus," *Management Science,* **16**(8): B466-B485.

Malone, Thomas W., Kevin Crowston and George A. Herman, Eds. (2003) *Organizing Business Knowledge*, Cambridge, MA: MIT Press.

Mayer, Richard J., *et al.* (1995) "Information Integration for Concurrent Engineering (IICE) IDEF3 Process Description Capture Method Report," Knowledge Based Systems, Inc., .

McManus, Hugh L. (2005) *Product Development Value Stream Mapping (PDVSM) Manual*, Cambridge, MA: MIT Lean Aerospace Initiative.

Meredith, Jack R. (1998) "Building Operations Management Theory Through Case and Field Research," *Journal of Operations Management*, **16**(4): 441-454.

Miles, Matthew B. and Alan Michael Huberman (1984) *Qualitative Data Analysis*, Beverly Hills, CA: Sage Publications.

Minsky, Marvin (2006) *The Emotion Machine: Commonsense Thinking, Artificial Intelligence, and the Future of the Human Mind*: Simon & Schuster.

Mintzberg, Henry (1979) "An Emerging Strategy of 'Direct' Research," *Administrative Science Quarterly,* **24**(4): 582-589.

Moder, Joseph J., Cecil R. Phillips and Edward W. Davis (1983) *Project Management with CPM, PERT and Precedence Diagramming*, 3rd Edition, New York: Van Nostrand Reinhold.

NIST (1993) "Integration Definition for Function Modeling (IDEF0)," National Technical Information Service, U.S. Department of Commerce, Federal Information Processing Standards Publication 183 (FIPSPUB 183).

Parnas, D.L. (1972) "On the Criteria To Be Used in Decomposing Systems into Modules," *Communications of the ACM,* **15**(12): 1053-1058.

Pennington, Robin and Brad Tuttle (2007) "The Effects of Information Overload on Software Project Risk Assessment," *Decision Sciences,* **38**(3): 489-526.

Perkins, David B. (1986) *Knowledge as Design*, Hillsdale, NJ: Lawrence Erlbaum Associates.

PMI (2008) *A Guide to the Project Management Body of Knowledge*, 4th Edition, Newtown Square, PA: Project Management Institute.

Pritsker, A. Alan B. and W. William Happ (1966) "GERT: Graphical Evaluation and Review Technique: Part I. Fundamentals," *Journal of Industrial Engineering,* **17**(5): 267-274.

Radice, R.A., N.K. Roth, Jr. A.C. O'Hara and W.A. Ciarfella (1985) "A Programming Process Architecture," *IBM Systems Journal*, **24**(2): 79-90.

Schätz, Bernhard, Alexander Pretschner, Franz Huber and Jan Philipps (2002) "Model-based Development," Institut für Informatik, Technische Universität München, Technical Report TUM-I0204.

Scheer, August-Wilhelm (1999) *ARIS - Business Process Modeling*, 2nd Edition, New York: Springer.

Schick, G., L. Gordon and S. Haka (1990) "Information Overload: A Temporal Approach," *Accounting, Organizations and Society,* **15**(3): 199-220.

Senge, Peter M. (1990) *The Fifth Discipline*, New York: Currency Doubleday.

Shane, Scott A. and Karl T. Ulrich (2004) "Technological Innovation, Product Development, and Entrepreneurship in *Management Science*," *Management Science,* **50**(2): 133-144.

Simon, Herbert A. (1981) *The Sciences of the Artificial*, 2nd Edition, Cambridge, MA: MIT Press.

SPC (1996) *Improving the Software Process Through Process Definition and Modeling*, Boston, MA: Software Productivity Consortium, International Thomson Computer Press.

Steiger, David M. (1998) "Enhancing User Understanding in a Decision Support System: A Theoretical Basis and Framework," *Journal of Management Information Systems*, **15**(2): 199-220.

Stocks, M. and A. Harrell (1995) "The Impact of an Increase in Accounting Information Level on the Judgment Quality of Individuals and Groups," *Accounting, Organizations and Society*, **20**: 685-700.

Stuart, I., *et al.* (2002) "Effective Case Research in Operations Management: A Process Perspective," *Journal of Operations Management*, **20**: 419-433.

Tang, Victor and Vesa Salminen (2001) "Towards a Theory of Complicatedness: Framework for Complex Systems Analysis and Design," *Proceedings of the 13th International Conference on Engineering Design (ICED)*, Glasgow, Scotland, Aug..

Tushman, Michael L. and David A. Nadler (1978) "Information Processing as an Integrating Concept in Organizational Design," *Academy of Management Review*, **3**(3): 613-624.

Van de Ven, Andrew H. and R. Drazen (1985) "The Concept of Fit in Contingency Theory," in Cummings, L.L. and B.M. Staw, Eds., *Research in Organizational Behavior*, Greenwich, CT: JAI Press, 7, pp. 333-365.

Vessey, Iris (1991) "Cognitive Fit: A Theory-based Analysis of the Graphs Versus Tables Literature," *Decision Sciences*, **22**(2): 219-240.

Wilson, Patrick (1995) "Unused Relevant Information in Research and Development," *Journal of the American Society for Information Science*, **46**(1): 45-51.

Winter, Mark, Charles Smith, Peter Morris and Svetlana Cicmil (2006) "Directions for Future Research in Project Management: The Main Findings of a UK Government-Funded Research Network," *International Journal of Project Management*, **24**(8): 638-649.

Yin, Robert K. (2003) *Case Study Research: Design and Methods*, 3rd Edition, Newbury Park, CA: Sage.

Zachman, John A. (1987) "A Framework for Information Systems Architecture," *IBM Systems Journal*, **26**(3): 276-292.