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Technology Management Competencies

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TECHNOLOGY MANAGEMENT COMPETENCIES

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Abstract

In order to meet the increasing expectations of industry, technology management programs combine the application of technical skills with management competencies. The aim of the Association of Technology, Management, and Applied Engineering (ATMAE) is to develop professionals committed to solving complex technological problems, while advancing the technologist and applied engineering workforce. However, there is a wide variability of perceptions regarding the technologist and the technology manager. Clarity concerning the required competencies for an entry-level technology manager is essential. In order for technology management programs to be relevant, their competencies must be acknowledged and agreed upon. In addition, these technology management competencies must be aligned with accreditation and certification agencies within a body of knowledge. In this paper, the authors propose a set of common technology management core competencies. This research project sought to validate the competencies using reviews of literature with field, panel, and survey research. The findings indicated that the Technology Management Competency Model has both face and content validity with regard to applied and managerial contexts. Furthermore, the model identifies those competencies deemed most important by ATMAE members.

Introduction

With the increasing demands on organizations to do “more with less”, and produce acceptable market results, productivity and performance standards continually raise the expectations on competitive success. To meet these expectations, organizations frequently combine the application of technical management skills with the softer skills involved in people management. Technical managers with little training or past experience with non-technical skills often perform poorly in technical management positions [1]. Because this generation lives in a highly technical environment, managers need to be proficient in dealing with knowledge workers and systems; therefore, there is a growing emphasis on the application of management competencies [2]. Additionally, as the baby boomers shift from the marketplace to retirement, experienced technical leaders will be exiting the workplace. Within the next 10 years, the U.S. will experience a greater than threefold surge in leadership turnover in engineering and technical organizations, increasing the competition for a progressively scarce resource [3]. Competent technical managers will be a critical success factor for organizations to stay competitive.

Given that today’s labor market demands graduates competent in both technology and management, higher education has the opportunity to produce these graduates. For example, Dulaimi [4] highlighted the need for academic and professional development programs to provide the right balance of content and emphasis between the technical knowledge and the people management skills for young professionals. These technology professionals, or technologists, are described in various ways.

The National Research Council defined technology management as the link between science, engineering, and management, while ATMAE described it as the “field concerned with the supervision of personnel across the technical spectrum and a wide variety of complex technological systems” [5], [6]. The International Technology and Engineering Educators Association (ITEEA) identified the characteristics of a technologically literate person as an individual who has knowledge of processes to develop systems within practical contexts that solve problems and extend human capabilities [7]. With such a wide variance of characteristics used to describe the technologist (i.e., technical managers), a body of knowledge is not clearly defined for technology management. The authors of this current study support the development of a common technology management core with appropriate and defined competencies. The purpose of this study was to describe a core body of knowledge using competencies as a base for a technology management model. In order to accomplish the purpose, the authors asked the following questions:

- What is the core body of knowledge for an entry-level technology manager?
- What are the core competencies for an entry-level technology manager?

The "management of technology is the art and science of creating value by using technology together with other resources of an organization" [8]. A technology manager should have: 1) some minimum level of technical knowledge; 2) skills in one or more contextual areas; and, 3) applied abilities in system design, application, products, or processes [9]. Technology managers must have certain competencies that are agreed upon and measurable. At the university level, technology management programs are distinctly different from engineering or engineering technology programs (e.g., mechanical, electrical, civil, etc.). A required management curriculum is what distinguishes ATMAE-accredited four-year programs from two-year programs [10]. Minty [11] asserted that historical comparisons of the technological and managerial perspectives are closely aligned.

In order for technology management programs to succeed, they must produce graduates who possess the requisite knowledge, skills, and abilities (KSAs). The mission of the Association of Technology, Management, and Applied Engineering (ATMAE) is to solve complex technological problems and develop the competitive technologist and applied engineering workforce. The *ATMAE Accreditation Handbook* [10] lists content areas such as quality, finance, accounting, safety, legal, project management, and other courses consistent with the definition of industrial technology. Of these, what competencies are most important for a technology manager? Are there others? Without a recognized and accepted body of knowledge for technology management, the discipline of industrial technology, applied technology, and applied engineering will continue to be confused with other technical disciplines. Clarity regarding the required competencies for an entry-level technology manager is imperative.

Review of Literature

The need for a body of knowledge for technical-professional competencies is well documented, particularly with the advent of outcomes-based accreditation and industry's desire for certified employees (e.g., SME, ASQ, APICS, PMI, etc.). Meier et al. [12] and Meier and Brown [13] summarized the competencies essential for the success of new employees. Calhoun [14] created the Health Leadership Competency Model that identified outcomes, appropriate behaviors, and core technical-managerial competencies. Rifkin et al. [15] developed a competency model containing a hierarchical framework of the technical manager's role, critical accomplishments, work activities, skills, knowledge, and personal attributes. Other published literature regarding management competencies includes manufacturing and industrial management, general management, safety, project management, retail management, and sports administration [16-29].

As organizations advance technologically, the need for technical leaders will be vital. In benchmark companies like Rockwell Automation and GE Healthcare, the identification and development of the next generation of technical leaders is crucial [30]. Promoting individuals based solely on technical knowledge is becoming more difficult due to the need for sound managerial decisions across technically complex environments. Nair et al. [31] found a competency gap between engineering traits of graduates and the expectations of employers. They asserted that students need a combination of technical (hard), managerial (soft), and global (multicultural communication) competencies in order to be successful. Additionally, the Society of Manufacturing Engineers' (SME) Manufacturing Education Plan: Phase 1 and Phase 3 reported the following competency gaps in order of importance: business knowledge skills, project management, written communication, supply chain management, oral communication, international perspective, quality, problem solving, and teamwork [32], [33]. The proficiency of graduates is measured by entry into the job market and long-term career success. Education and professional development increase the proficiency of graduates and close the competency gaps.

Historically, higher education focused on the education process or the inputs into the systems. Now, higher education is increasingly asked to provide student outcomes or competencies [34]. At the university level, "Technology Management programs typically include instruction in production and operations management, project management, computer applications, quality control, safety and health issues, statistics, and general management principles" [10]. Increasingly, competencies are the basis for determining if programs are offering appropriate content and if students are meeting the competency criteria. Both ATMAE and ABET (the Accreditation Board for Engineering and Technology) [35] accreditations are based on students acquiring specific competencies, as measured by student outcomes.

The development of a common body of knowledge for technology management provides the rationale for a common core that distinguishes ATMAE-accredited four-year and graduate programs. Thus, a conceptual model is useful when attempting to describe the common elements. The American Society for Quality (ASQ), the Association for Operations Management (APICS), and the Project Management Institute (PMI) all have well-recognized bodies of knowledge for their professional constituents. However, ATMAE accrediting standards do not specify a core body of knowledge for management, only a range of required hours (12-24) and a broad list of potential subjects. In addition, the current content areas of production planning and control, quality, safety, and management on the Certified Technology Manager (CTM) exam are not aligned with the accrediting standards or with a recognized body of knowledge for technology management. Although there are ongoing revisions to both accreditation and certification standards, there is no coordinated effort to align these with a recognized body of knowledge.

Using published literature and previous studies, a common perspective of technology management is attainable within the discipline. However, as Minty [11] explained, this must be undertaken with knowledge that technology management is neither grounded in general business nor engineering, but is a unique body of knowledge grounded in socio-technical management. The term socio-technical refers to people and technology (or systems) [11]. Engineering and industrial technology programs have used terms associated with socio-technical theory such as six sigma, continuous improvement, autonomous teaming, and re-engineering [36]. Socio-technical systems reveal the interdependence of technology, people, the external environment, and the design of work [37]. As the authors gathered the information for a socio-technical framework, it was necessary to determine the appropriate competencies.

Competency modeling is an organized structure for defining the KSAs that students need to know in order to be proficient in their field of study and ultimately their career. Competence is a function of performance that goes beyond knowledge. Competencies can be defined as observable behaviors exhibited by technical mangers that are successful, both in terms of their results and the process or behavior for enabling those results [38].

Methodology

Phase One Model Development

The ATMAE Management Division formed a panel sub-group in 2010 to begin to define a technology management set of core competencies. The sub-group developed an initial competency model based on the group's interaction with industry, personal industry experience, and academic experience in technology management. The initial model was presented to industry professionals, group networks, advisory board members, and ATMAE members in 2011. In addition, the competency model was benchmarked against existing literature and research. This method was congruent with accepted approaches to competency model development that included selecting competencies from lists to field research. The panel method of research is a group of experts collaborating to develop a set of competencies [39].

After multiple revisions, based on input from educators, industry professionals, and research, a high-level technology management model was developed. The model showed the generic entry-level competencies for a technology manager within a category of knowledge for a specific managerial context. The competencies are applicable to systems, operations, processes, or projects and linked throughout by accepted leadership principles; see Figure 1 for an overview of the initial model.

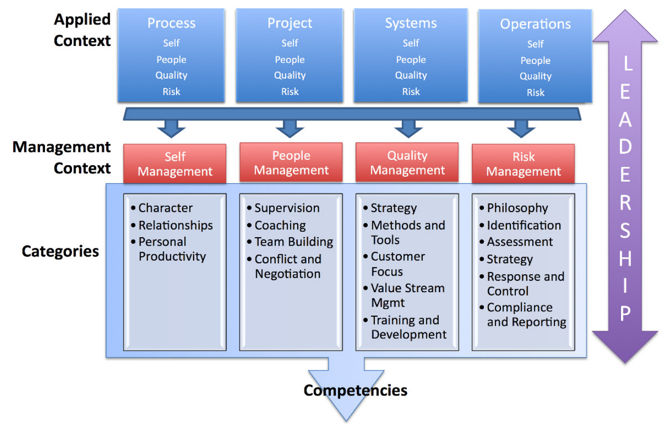

Figure 1. Initial Technology Management Competencies Model

To understand the model, it is important to define the contexts that are the situations or environments to which the competencies are applied. The project and process environments are most familiar with projects being the one-time application of processes to produce a unique product or service. Systems refer to the management of technology across disciplines and companies in an integrated fashion for the purpose of business venture and development, such as supply chain management. Operations are the management of technology within a specific specialty. Common industrial contexts would include those listed by the Bureau of Labor Statistics such as manufacturing, construction, telecommunications, or retail trade [40]. It is the assertion of the authors that the same competencies are utilized regardless of the applied context and can be classified into four management areas. The managerial context areas are self-management, people-management, quality-management, and risk-management, and are well-supported in literature. While the literature may refer to them using slightly different terms, they are frequently mentioned in leadership and management writings. For example, it is well accepted that in order to lead people effectively, managers must be able to manage themselves [41].

The other two threads that run consistently through the literature are managing quality and risk. Quality is a primary focus in the management of any endeavor, particularly technology, and is regularly ranked as a principal competency in literature. The management of risk is less familiar, but is still represented strongly in management theory. As related to process, project, systems, or operations, the assessment of risk and mitigation of uncertainty is applied to design, research, production processes, product development, mergers, and acquisitions from both quality and financial perspectives. For example, the National Aeronautics and Space Administration's (NASA) Leadership Development Program (LDP) measures results in three general areas: 1) mission success as substantial risk involved in space exploration, 2) project success through improved team leadership, and 3) organizational advancement within the NASA system [3].

Within each management context, the initial specific competencies were sorted into generic and recognizable themes. They are purposely broad to allow for flexibility and interpretation. The competencies may have popular synonyms that could be justifiably used instead. The intent of the model and initial competencies was to establish a baseline for further refinement; see Table 1 for the complete list of initial competencies sorted by category theme.

Phase Two Model Development

In order to refine the initial Technology Management Competencies Model, the authors developed a survey in February, 2012, that asked respondents to rank the importance of the competencies in defined contextual areas. The survey population was approximately 700 ATMAE members who were invited to participate using the professional member listserv. The ATMAE listserv consists of all ATMAE members who can send and receive email in order to share and gather information on current developments in the field of technology, technology management, and applied engineering.

The survey links were available for approximately four weeks. After weeks 1 and 2, a follow-up email reminder was sent. Qualtrics, a third-party survey software provider, automatically collected 93 anonymous responses. At the end of the survey period, 66 surveys were fully completed and validated (9-13% response rate). In April, 2012, faculty and industry professionals from engineering, engineering technology, technology, operations management, and advisory boards outside of ATMAE were invited to participate. Additional responses were collected until May, 2012, resulting in 124 total responses of which 75 were fully completed surveys.

Prior to the survey, participants were given a glossary of relevant terms. This was followed by questions that asked participants to check the competencies applicable to each context. The glossary of terms follows:

Technology Management Applied Contexts

- <u>Operations</u>—Management of technology within a specific industrial specialty.
- <u>Systems</u>—Management of technology across disciplines and companies in an integrated fashion for the purpose of business venture and development.
- <u>Project</u>—The one-time application of a process to produce a unique product or service.
- <u>Process</u>—The transformation of input elements into output elements with specific properties, within defined parameters or constraints.

Table 1. Initial Competencies by Category Theme

Self-Management Competencies	People Management Competencies	Quality Management Competencies	Risk Management Competencies
Character Values Integrity Responsible Capable Enthusiasm	Supervision Planning Organizing Staffing Leading Controls/ reporting Resource allocation Decision -making Listening	Philosophy Methods and Tools Frameworks Standards Customer focus Strategic planning Resources Measurement Training and development	Philosophy Culture and context Objectives Risk tolerance/ appetite
Relationships Communication Cooperation Emotional/ Social Spiritual Trust Influence	Team Building Mentoring Counseling Appraisal	Process Management Process design Control Improvement Value Stream Constraints	Identification Opportunities Tools and techniques Risk taxonomies
Personal Productivity Motivation Resourcefulness Discipline Knowledge Passion Vision	Coaching Facilitation Problem solving Group dynamics	Methods and Tools Lean sigma Safety and ergonomics Statistics SIPOC and PDCA Reliability	Assessment Analysis Drivers Prioritization
	Change Alignment Empowerment Respect Support		Treatment Treatment selection Action planning/ Mitigation
			Response and Control Policy deployment Governance Evaluation Compliance and reporting

Technology Management Managerial Contexts

- <u>Quality Management</u>- The use of quality assurance and control of processes and products to achieve consistent and predictable quality.
- <u>Risk Management</u>- The identification, assessment, and prioritization of risks followed by coordinated

and economical application of resources to minimize, monitor, and control their probability and/or impact.

- *Self-Management*- Methods, skills, and strategies by which individuals can effectively direct their own activities toward the achievement of goals and objectives.
- *People Management*- The deployment and handling of human resources to work together to accomplish desired goals and objectives using available resources efficiently and effectively.

Findings

Question 1. Select the applied context(s) of technology management. Select all that apply.

The purpose of this question was to validate the applied contexts. A total of 99 individuals responded to the question (see Figure 2). Eighty-four percent of the respondents checked systems and projects, while 83% checked processes and operations.

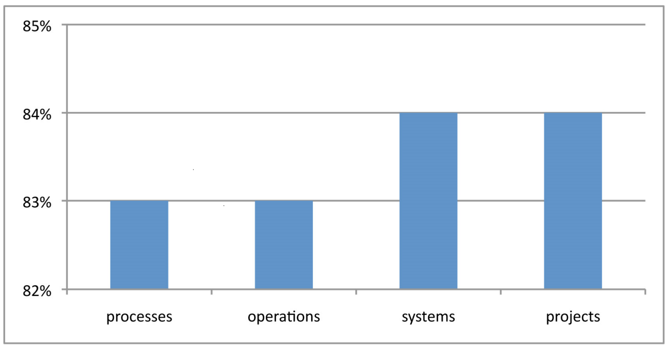

Figure 2. Applied Context of Technology Management

Question 2. Select the management context(s) that are applied to processes. Select all that apply.

The purpose of this question was to determine if quality management, risk management, people management, and self-management is applicable to processes. Seventy-seven individuals responded to the question (see Figure 3). Ninety-nine percent of the respondents checked quality management and 81% checked people management. Seventy-three percent checked risk management, while 55% checked self-management.

Question 3. Select the management context(s) that are applied to systems. Select all that apply.

The purpose of this question was to determine if technology management in the areas of quality, risk, people, and self is applicable to systems. Seventy-six individuals responded to the question (see Figure 4). Ninety-two percent of the respondents checked quality management and 80% checked people and risk management. Forty-two percent checked self-management.

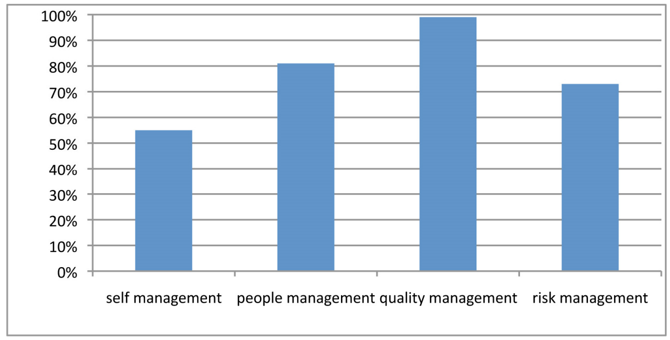

Figure 3. The Applicability of Specific Technology Management Contexts to Processes

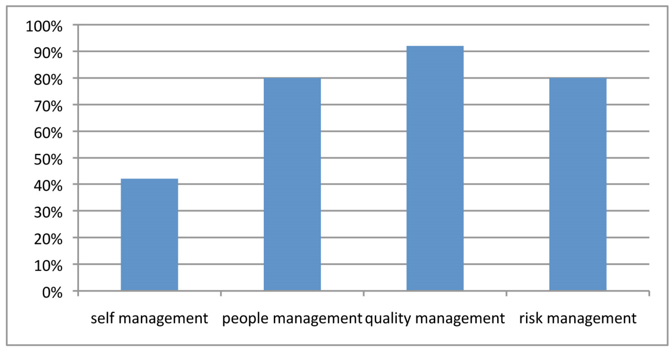

Figure 4. The Applicability of Specific Technology Management Contexts to Systems

Question 4. Select the management context(s) that are applied to operations. Select all that apply.

The purpose of this question was to determine if technology management in quality, risk, people, and self is applicable to operations. Seventy-five individuals responded to the question (see Figure 5). Ninety-two percent of the respondents checked people and quality. Seventy-seven percent checked risk management. Fifty-nine percent checked self-management.

Question 5. Select the management context(s) that are applied to projects. Select all that apply.

The purpose of this question was to determine if technology management in quality, risk, people, and self is applicable to projects. Seventy-six individuals responded to the question (see Figure 6). Eighty-nine percent checked people and 88% checked quality. Seventy-six percent checked self-management and 71% checked risk management.

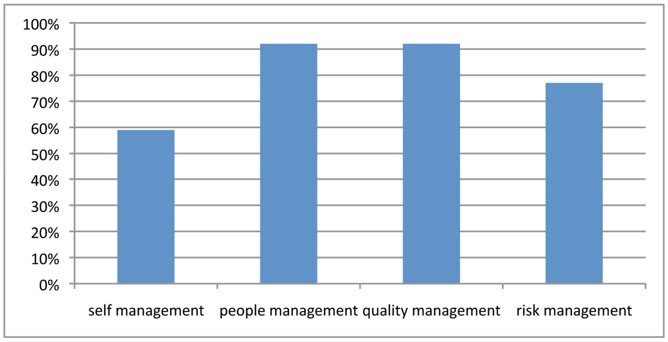

Figure 5. The Applicability of Specific Technology Management Contexts to Operations

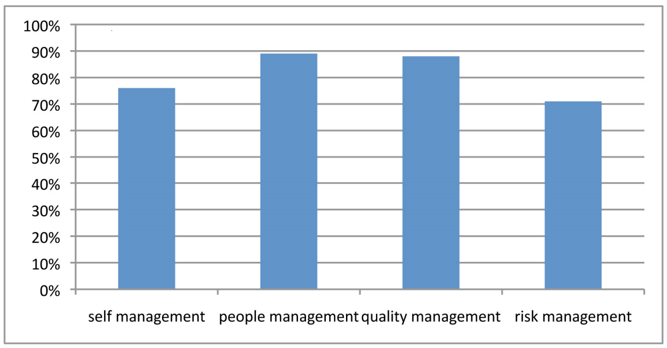

Figure 6. The Applicability of Specific Technology Management Contexts to Projects

Respondents were then given the opportunity to select the applicable entry-level technology management competencies in each of the management contextual areas (e.g., quality, risk, people, and self). These competencies were drawn from the initial Technology Management Model. Each contextual management area listed between 16 and 19 generic competencies and included a field labeled *other*, where respondents could add additional competencies. The purpose of these questions was to validate or refute the competencies and determine those perceived most important. For the contextual areas of self-management, people management, quality management, and risk management, the number of responses was 74, 72, 71, and 71, respectively.

Question 6. Select the following competencies that apply to self-management. Select all that apply.

In Figure 7, the percentage of responses is sorted from highest to lowest. Additional responses equating to five percent of the respondents were added: innovative, ethical, monitoring quality or the ability to discern quality, family, company, and society.

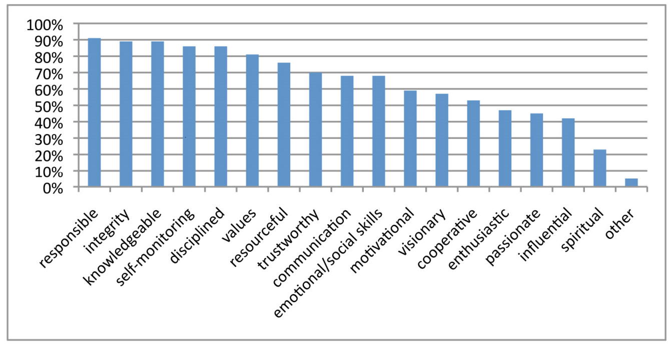

Figure 7. **Applicable Self-Management Competencies Sorted by Percentage of Responses**

Question 7. Select the following competencies that apply to people management. Select all that apply.

The sorted percentage of responses is shown in Figure 8. Additional competencies were added equating to four percent of the responses: open communications, training and development, personal needs, company, and society.

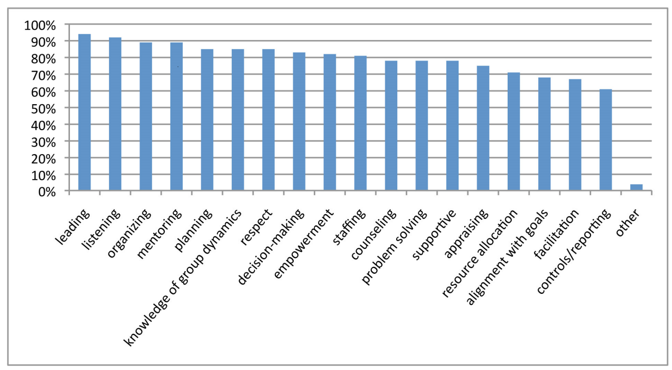

Figure 8. Applicable People Management Competencies Sorted by Percentage Response

Question 8. Select the following competencies that apply to quality management. Select all that apply.

The sorted percentage of responses is shown in Figure 9. Additional responses equating to four percent of respondents were added: teaming, benchmarking, communication, documentation/ISO 9000, compensation systems, ethics, tools of Ishikawa in addition to SPC, assessment, etc.; TQM is more than control or assurance; innovation, finance, environment, and responsibility.

Question 9. Select the following competencies that apply to risk management. Select all that apply.

The sorted percentage is shown in Figure 10. Three percent of respondents added that all of the above apply, but also that some are more important than others, such as people, society, and environment.

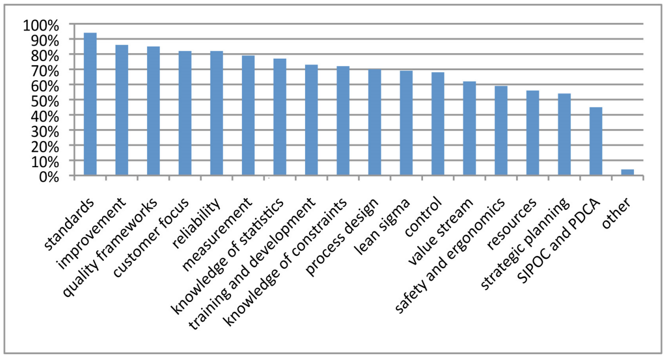

Figure 9. Applicable Quality Management Competencies Sorted by Percentage Response

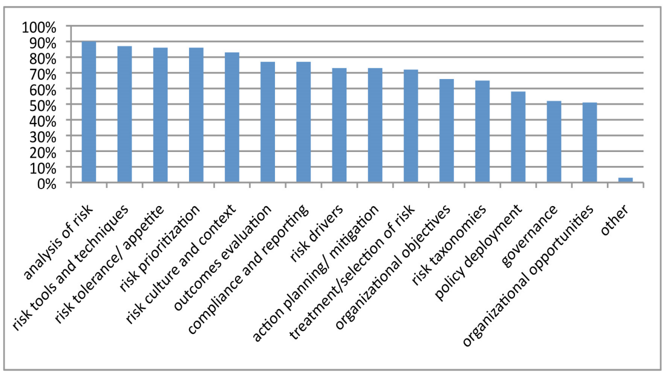

Figure 10. Applicable Risk Management Competencies Sorted by Percentage Response

The Technology Management Core Competency Model

Based upon the survey, a revised version of the Technology Management Competencies Model was created. The Technology Management Core Competency model is shown in Figure 11. It shows the generic entry-level competencies for a technology manager for a specific managerial context. The competencies are applicable to systems, operations, processes, and projects and linked throughout by accepted leadership principles. The findings indicate that the Technology Management Core Competency Model has both face and content validity, particularly with regard to the applied contexts of process, project, systems, and operations.

Respondents overwhelmingly agreed on the applied contexts. In terms of the quality, people, risk, and self-management contexts, a majority of the respondents agreed that they apply to process, project, systems, and operations. The only exception was the applicability of self-management to systems (defined as the management of technology across disciplines and companies in an integrated fashion for the purpose of business venture and development). However, over two-fifths of the respondents perceived a degree of applicability. Thus, the applied and management contexts of the model appear to have support from academic and industrial communities. The responses between the ATMAE and non-ATMAE participants were not significantly different.

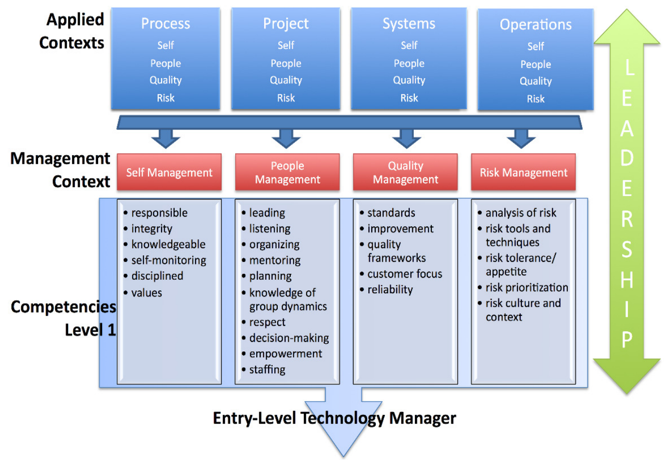

Figure 11. Technology Management Core Competency Model

The perceived relevance of the individual competencies varied. Any competency receiving less than a response of 50% was removed. The greatest response variation (23% to 91%) of the competencies was in the self-management context. The least response variation of competencies was in people management (61% to 94%). All competencies for risk and people management had greater than a response of 50%. For self-management, four competencies received less than 50% response. For quality management, only one competency received less than 50% response. Using the level of response, the authors then stratified the competencies.

The entry-level competencies for technology management are shown in Table 2. Competencies receiving a response of greater than 80% were categorized level one. Competencies receiving between 60% and 80% were designated level two, and competencies greater than 50% but less than 60% were labeled level three. This stacked ranking keeps the importance of the competencies at the forefront for outcomes assessment and reinforces the critical entry-level KSAs of technology managers. The competencies are purposely broad to allow flexibility, interpretation, and justification for the use of popular synonyms.

Table 2. Technology Management Core Competencies

	Competencies			
Level	*Self-Management*	*People Management*	*Quality Management*	*Risk Management*
1	responsible integrity knowledgeable self-monitoring disciplined values	leading listening organizing mentoring planning Knowledge of group dynamics respect Decision-making empowerment Staffing	standards improvement Quality frameworks Customer focus reliability	analysis of risk risk tools and techniques Risk tolerance/ appetite Risk prioritization risk culture and Context
2	resourceful trustworthy	counseling Problem solving supportive appraising Resource allocation	measurement Knowledge of statistics training and development Knowledge of constraints Process design	Outcomes evaluation Compliance and reporting risk drivers action planning/ mitigation Treatment/ selection of risk
3	communication emotional/ social skills motivational visionary Cooperative	Alignment with goals facilitation Controls/ reporting	lean sigma control value stream safety and ergonomics resources Strategic planning	Organizational objectives Risk taxonomies Policy deployment governance Organizational opportunities

Implications of the Research

ATMAE sets standards for academic program accreditation, professional certification, and development for educators and industry professionals involved in technology, leadership, and systems design [42]. The development of a common and recognized body of knowledge for the discipline starts with an understanding of technology management competencies. The operational effectiveness of accredited technology management programs depends on identifying competencies, measures, and outcomes. An agreed-upon set of technology management competencies tied to a body of knowledge will strengthen the discipline. In particular, the ATMAE Management Division must lead in the adoption of the technology management competencies and the corresponding body of knowledge. ATMAE membership and industry advisory boards should ratify and adopt these technology management competencies. The critical competencies within a body of knowledge should be congruent with ATMAE standards and certification. ATMAE should recognize and incorporate these competencies into accreditation and the Certified Technology Manager exam.

Although there is still much work needed to develop a comprehensive body of knowledge for technology management, efforts can now begin using the identified competencies as a starting point. Future research should capture and analyze the seminal published works regarding technology management and the textbooks being assigned by accredited ATMAE technology management programs. This starting point will provide the relevant body of knowledge needed to achieve the competencies. Additional areas of opportunity will be the development of measures and outcomes for the technology management competencies. This will close the loop for outcomes assessment and technology management program accreditation. The authors recognize that developing measures for these competencies will be difficult. However, both industry and academia use performance-based appraisals based on similar competencies. The field is ripe for further research and creative solutions.

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