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Engineering Management Competencies: A Framework for Present and Future Engineering Environments

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ABSTRACT

Managing and directing engineering requires engineering management competencies. Although perspectives may differ concerning competencies for engineering management, identifying competencies can direct and improve management. The purpose of this research is to develop a framework of competencies for engineering managers using an inductive research design. Development of this engineering management competency framework involves an exploration of three primary research questions. The first question is *'What are the current competencies for engineering managers?'* The response to this question provides a basis for the current state of competencies for engineering managers. The second research question, *'What are future engineering management competencies based on future perspectives and trends?*' seeks to establish the nature of engineering management competencies that project to the future. The third research question, *'What competency framework may be generated for engineering management competencies?*' establishes a rigorously grounded framework for engineering management competencies. This framework appreciates current competencies while being tempered to competencies required. The approach to explore research questions is based in a Grounded Theory Method (GTM) (Charmaz, 2014) that builds from research literature references qualified for inclusion (Katina, 2015). Based on qualification criteria, engineering management competencies are coded following the GTM to produce a theoretical framework for engineering management competencies. Results provide a framework of competency areas and competencies necessary for engineering management. This provides a significant approach to filling gaps in the body of knowledge related to competencies for the engineering management discipline. While other works identify competencies for engineering management, current literature is fragmented, aging, and not sufficiently developed to provide adequate developmental directions for engineering management practitioners. Multiple competencies and implications are discussed in this research along with context, environment, and human factors where competencies are identified within Systems Theory and gaps. This provides a vital base that places competency areas and competencies into a cohesive and coherent framework while projecting the existing state of engineering management competencies to the future. This may include the theoretical, methodical, and practical dimensions to advance the engineering management discipline. Therefore, the competency framework development may support and unite organizations proactively while providing opportunities to operations and overall performance which extends beyond a specialized area.

ACKNOWLEDGEMENTS

This paper is dedicated to engineering management professionals who value working with others in identifying competencies and life-long learning. This is important for me as I continue to notice improvements in technology while witnessing the internal problems many organizations face. Unfortunately, the call for many engineering management competencies has not been understood as our future focuses' acceptance and expansion toward education, knowledge, and technology. Although each area or specialty helps it does not remove the importance of engineering management competencies.

I want to thank Dr. Keating for working with me on this topic. Also, I acknowledge the reviews provided by engineering management professors as this has allowed a path forward for this topic.

Finally, I want to thank my wife and four children for their patience in supporting this work, which will hopefully allow me to bless their lives.

Thank You -
Chris

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CHAPTER I: INTRODUCTION

The purpose of this chapter is to establish the foundation for research while providing general direction and background information. This begins with competencies for engineering management and addressing a significant deficiency in the body of knowledge concerning a framework of competencies for engineering management. Today this is observed from a lack of information within organizations and research that captures engineering management competency framework. The root and confusion may be addressed by identifying engineering management competencies. Therefore, research represented in this thesis is based on engineering management competencies along with systems theory. The systems theory provides means of establishing criteria to the foundation for competency framework. This is important as competencies may depend on environment, human, and contextual elements at the foundation. Although these elements continually change an oversight to include these elements cannot be accepted for engineering efforts and future innovation. If we are not aware of competency requirements, then the result is a return to unsupported practices that do not ensure the success of an organization.

The future of engineering requires accurate information supported by engineering management competencies. A focus of engineering management competencies allows for a foundation and framework for organizations that would depend on competencies. Therefore, the following represents the purpose of this effort.

1.1 Statement of the Problem

Organizations continue to work in identifying current and future competencies for engineering management. The result has failed to provide structure and framework that can be supported in the engineering management profession.

1.2 Purpose

Identify a framework of competencies for engineering managers using an inductive research design to map competencies that support present and future projected work trends for management in engineering professions.

The initial effort was identified with a step-in providing framework to competencies required within engineering management. A holistic view is taken for the consideration of the environment, human factors, and systemic theory. This effort identifies a union between the current and future competencies while allowing opportunities to address a gap in the construct of engineering management competencies. This thesis provides the approach for the literature while addressing the questions that directed the reason for the research.

1.3 Research Questions

This section provides three research questions that are key to the development competency framework for engineering management. The first two questions provide the foundation of current and future competencies necessary, while the third question considers the competency framework. The following represent the research questions explored.

1. What are the current competencies for engineering managers?
2. What are future engineering management competencies based on future perspectives and trends?
3. What competency framework may be generated for engineering management competencies?

1.4 Research Significance

These questions direct the research considered to identify competencies and the development of a competency framework. This begins by addressing each research question and then identifying competency areas and competencies to structure a foundation. Identification of the competencies provides the foundation for competency framework.

The limitations to enable or restrict the framework will be found from the research and the qualification of the data used for the study. Further significance may relate to elements within the research but will require the acceptance along with a critique related to gaps within the research. This provides the primary significance of this research as held within two primary contributions. First, a rigorously developed framework for engineering competencies is established. This framework is built from the existing literature and serves to bring together several different sources identifying engineering management competencies to capture the present state. Second, the future for engineering management competencies is developed. This projects engineering management competencies to the future. This is significant as it can identify the overlap between current and future competencies.

Today's business management practices will not provide sufficient control or coordination to govern engineering management professionals. This theory is based on the current and future competencies for an engineering competency framework. This means that understanding present and future competencies will be required more for engineering. This is vital to the success of organizations as future research may capture the systemic problems prior to a premature exposure found in out of context management methods and applications. Unfortunately, an approach to identifying a competency framework for engineering management responsibilities is scarce. However, ignoring competencies will not be acceptable for engineering professionals as current and future innovation efforts continue. Ultimately, identifying and mapping relevant engineering management competencies to a framework may allow organizations to unite a knowledge and understanding of competencies required. Therefore, this

research may help remove a barrier or wall that seems to be found when competencies practiced do not align with the competencies required for what can be more effective and practical.

1.5 Summary

Identifying the sets of competencies necessary for a competency framework can relate to foundational context, environment, and human factors within an organization. An important contribution to this effort will be connecting the present and future competencies with systemic foundations that respect the emergent and complex environments of the future. This is important as competencies with a competency framework have not directly been discussed with systems theory. Therefore, this provides one of many significant reasons why research is beneficial as efforts continue toward an understanding of elements that support framework at the foundation of engineering organizations. Ultimately the target will capture multiple competencies for engineering managers and professionals that can expect emergence within an advanced technological field.

The foundation of this research was introduced with importance given to identifying engineering management competencies for the development of a competency framework. An understanding for this effort is taken from the problem statement, purpose of the research, and research questions. In short, the problem statement suggests that although competencies are valued within organizations currently a lack of competencies and structure exists for competencies required. This directs the purpose of the research to identifying framework of engineering management competencies to provide organizations with a support structure to direct various engineering environments. A key part of this effort begins with the three research questions. The first two questions direct what may be found with a set of present and future competencies. This is important as some may be unaware of their responsibility or simply becoming ignorant to competencies required for engineering management. Unfortunately, this is evident with organizations that lack a support for competency areas when continual awareness and support is required. This means that awareness to engineering management competencies are evident when not in place to support engineering professionals. Therefore, the competencies necessary must be in place for the third research question. This research question establishes a viable competency framework for engineering management while appreciating the state of current and future competencies. This directs the research focus to research questions for identifying engineering management competencies and framework.

The engineering management competencies necessary for a foundation to effective practices and implications will consequently be based on this competency framework. This includes information gathered for current and future competencies of engineering management. In addition, gaps and relations to systems theory will be reviewed with the research prior to the development of the competency framework. Therefore, a competency framework using an inductive research design to map competencies is discussed to support present and future work trends for management in the engineering profession. This

involves a research design and approach to improve awareness and competencies required for future engineering practices. Although this research of a competency framework will be subject to critique, other research may provide benefits for future topics on the structure, practice, and accountability measures. Ultimately, this may help provide information to improve competencies across organizations and eliminate confusion or conflict.

CHAPTER II: LITERATURE REVIEW

2.1 Introduction

This chapter provides an initial review of literature with the purpose of identifying various research paths taken regarding engineering management competencies. The approach directs areas or categories for competencies along with a structure for development. Ultimately the information within the research is dependent on the research literature available. This is the reason a review of literature is taken with terms and definitions, literature review results, criticism and gaps, synthesis, human/environment elements, and summary. This section provides a review and objective for the purpose of these areas.

2.2 Review of Literature

This section outlines what is known about the research topic along with related terms and definitions. These are given to provide the literature review and synthesis for the research. Specific areas are listed as an initial perspective for categorizing competency areas. This represents the initial consideration of competencies categorized in different areas. Criticisms and gaps related to the literature are discussed with further emphasis given to human and environment elements.

The aim of this section is to summarize background literature related to the foundational development of competencies for engineering management. This introduces Engineering Management Competencies (EMC) and Future Engineering Management Competencies (FEMC) projected for the engineering management professions with a summary of background literature. These foundational areas provide a foundation for consideration to support development of the competency framework and critique. Also, literature areas and system elements are considered in defining gaps that currently separate the identification and validation for a modern framework of competencies. The foundation of the elements and gaps existing in the current state of literature are also suggested as a critical part of mapping competencies to framework.

The literature review of engineering management competencies suggests fragmentation without support of a widely accepted framework of competencies for management in the engineering profession. Consequently, most literature identifying competencies tend to be area specific, as related to the various needs provided by subset discipline areas. An example from El-Baz & El-Sayegh (2007) states that "necessary core competencies which include a balance of technical skills with interpersonal and conceptual skills; mastering technical knowledge by itself is not enough to assure the engineering manager's success" (El-Baz & El-Syegh, 2007, p. 2). This suggests that competencies work together and that a focus specific business and engineering competencies may not account for all competencies required for engineering management (e.g. interpersonal & conceptual skills). This does not come as a surprise to anyone as organizations continue to discuss methods to control, manage, and govern with competencies. It is important to note that research from Westbrook (2005) found that "according to the

American Society of Engineering Management (ASEM) certification standards, the curriculum requirements include a balance between qualitative and quantitative courses and at least one third of the curriculum to be management or management related courses" (El-Baz & El-Syegh, 2007, p. 1). This provides merit to engineering management and organizations that seek joint foundational engineering management competencies without a focus of reductionism.

2.3 Terms and Definitions Supporting Research Effort

There are several terms that are necessary to ground the research perspective. While these terms may be subject to different definitions and perspectives, the following provides the definition of terms central for this research.

Competency **-** Demonstrated and measurable capability comprised of knowledge, skills, or abilities that is causally related to superior performance in a given job or situation. This definition is a synthesis derived from definitions by Lahti (1999); Mirabile (1985); Spencer & Spencer (1993); and Ulrich, Brockbank, Yeung, Lake (1995), T., Cerovsek, T. Zupancic, V. Kilar (2010) & (Slivinski et al., 1996).

Core or General Competency **-** A competency that applies to everyone in an organization across a variety of occupations. This definition is a synthesis derived from definitions by Hoge, Tondora, & Marrelli (2005) and the U.S. Office of Personnel Management (2011). An example is leadership.

Technical Competency **-** A competency tailored to particular knowledge, skills, or abilities that apply to everyone performing a specific type of service or job in an organization. This definition is a synthesis derived from definitions by Hoge, Tondora, & Marrelli (2005) and the U.S. Office of Personnel Management (2011).

Knowledge **-** A learned or acquired concrete or abstract awareness, understanding, or information that directly relates to the performance of a job. This definition is a synthesis derived from definitions by Hoge, et al. (2005), Lahti (1999), and Lucia and Lepsinger (1999).

Skill **-** A concrete or abstract potential or capacity to successfully perform physical or mental tasks using tools, equipment, or machinery. This definition is a synthesis derived from definitions by Hoge, et al. (2005), Lahti (1999), and Lucia and Lepsinger (1999). An example may be spreadsheet modeling.

Ability **-** An enduring cognitive or physical potential or capacity to successfully perform physical or mental tasks possessing a wide range of plausible results not necessarily involving tools, equipment, or machinery. This definition is a synthesis derived from definitions by Hoge, et al. (2005) and Lahti (1999). Examples may include analytical thinking or conducting a cost benefit analysis.

Theory -The supposition or belief of ideas used to explain an unknown. This may relate to an unknown phenomena, patterns and tendencies observed in real world systems Whitney et al. (2015, p.22).

Proposition – A large set of ideas that provide an assertion of knowledge for addressing a path or means that may exist to define a solution or result. This definition is a synthesis derived from definitions by Whitney et al. (2015), Adams et al. (2014). An example may be the ideas that move theory to the validation process.

Environment -The condition and stability balance of within the area of study. This definition is a synthesis derived from definitions by Whitney et al. (2015), Cannon (1929). An example may involve accounting for the known and unknown changes internal to a system.

Context – A set of circumstances, factors, and conditions that enable interpretation and insight for the supporting propositions. This definition is a synthesis derived from definitions by Whitney et al. (2015). An example of context extends to understanding values and patterns of an organization and gathering this information to study for interpretation.

Axiological Context – Context associated with elements of design, values, deployment, and maintainability of operations that often relate with the 'soft problem' issues. This definition is a synthesis derived from definitions by Keating & Gibson (1991).

A literature review focused specifically on competencies for engineering management to support building a competency framework. The review identified several themes. The key theme suggested that, while there were some strong area competencies, there was little to no literature related to a competency framework for engineering management. Some information identified a conceptual framework along with literature narrowing down specific requirements, however this existed at a very granular level and did not rise to provide a more generalized competency framework for engineering management. With respect to the current literature it seems many studies continue to focus on the 'how' engineering management is accomplished rather than 'what' is necessary with respect to competencies necessary to perform engineering management functions. Therefore, the literature review focused a search of conference papers, journal articles, journals, and texts that were considered related to engineering management competencies and supportive of a framework. This review identified a total set of 35 reference papers on specific area competencies (management) with little to support a wider ranging competency framework for engineering management. Also, sparse literature was found to question some area specific competencies and the emphasis of these areas is targeted in identifying essential requirements for a discipline (e.g. measure and assessment of competencies). Therefore, this literature supports expansion to the more generalized and higher-level engineering management competencies applicable to the higher 'managerial' levels of an organization. In summary, many competencies must be identified for a current and future competency framework. Table 1 represents this high-level literature summary with the consideration of associated gaps.

Table 1: Literature Summary Related to Inductive Research and Associated Gaps

Literature Area	Reference	Literature Gaps
Engineering Management Competencies (Current & Future Competencies)	Winxker, 1999; Doggett, 1999; Datta, 2018; Danneels, 2015; Liznkov et. al., 2015; Dekkers, 2000; Kasvi et. al., 2003; Ivanova, 2012; Warren & Langley, 1999; Backa, 2007; PMBoK, 2017; Hecker, 1996; Hafeez et. al., 2002; Guerri, 2008; Hutchin, 1992; Kendall et. al., 2018; KLETT, 2010; Veres, 2009; Rajagopal, 2003; Hahn, 2017; Ravesteijn et. al., 2011; Heston, 2019; Berghman et. al., 2006	•Competencies and hierarchy with supporting foundational elements. • Mapping future or unknown competencies to a viable framework.
Competency frameworks for engineering management.	Valente et. al., 2003; Linton & Jayaraman, 1829; Cerovsek et.al., 2010; El-Baz & El-Sayegh, 2007; Wu & Ying, 2012; Bertonceli et. al., 2009; Lenarz, 1985	• Identifying a competency framework for engineering management competencies.

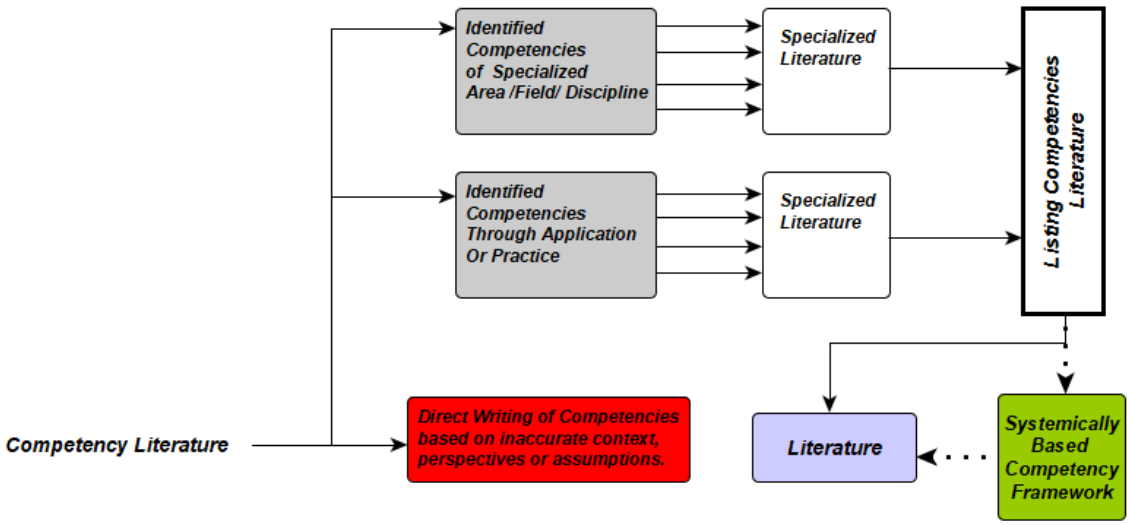
2.4 Scholarly Criticism of Literature Gaps for Engineering Management Competencies

The literature review can conclude with the major summary points: (1) there are a some suggested competencies for engineering management, (2) no set of competencies for engineering management provides acceptance as a definitive set upon which other literature claims as a foundational base, (3) there is no hierarchy related set of competencies that define a structure for relationships in competencies, (4) competencies for future engineering managers is not complete or lacking in the literature, and (5) a rigorously developed and more holistic competency framework for engineering management is not addressed in the literature. Literature gaps, stemming from the referenced materials, are suggested in Table 1. The existence of these gaps provides an opportunity to connect foundational competencies with a competency framework that integrates a fragmented literature related to present competencies. Additionally, this supports the projection for competencies for future consideration of engineering management discipline development. This will be discussed in the research design as to the path required for identification and mapping to a competency framework. The following sections move further into examination of literature gaps along with critique and the movement into the research design. An emphasis is given to these areas for the competency framework foundations upon which further development can be based.

Literature reviewed identifies competencies for specialized areas, diciplines or fields of study, where many of these are proven effective when based on foundational requirements related to the specific areas. However, an effective competency framework that exists beyond a narrowly defined area is challenged to be inclusive due to a wide ranging and complex environment. Identifying the competencies necessary to address the wider engineering management environment will necessarily allow for an effective integration of competencies across a range of technical, operational, social, and business practices. This requires a systemic based foundation that includes and appreciates not only the

competencies, but also the complex contexts within which those competencies must be applied. This means without the inclusion for context at the foundation then a selection of competencies may not meet necessary requirements for a competency framework. Therefore, while it is not difficult to find literature that lists many competencies, it is difficult to find literature that effectively integrated those competencies through a structure or map that describes interrelationships and linkages (e.g. a framework of competencies). Figure 1 represents the literature review map that identifies supporting paths for the current identification of competencies that is specialized to area/field/discipline. The broken (dotted line) paths position the gaps in the body of knowldege for engineeing management competencies that fail to recognized the interrelationships among competencies.

Figure 1: Literature Review Map of Broken Paths



2.5 Synthesis of literature

Foundational elements of engineering are identified at many levels. However, competencies have not been identified and separated for the purpose of an integrating and supporting framework. The lack of paths or steps in figure 1 represent gaps in the literature that do not support the necessary elements and coding required to map a competency framework. In addition, Systems Theory allows the inclusion of context which can be represented at the foundation to support an initial map to a more rigorously developed and comprehensive competency framework. Identifying the framework for engineering management competencies represents a significant step forward as a foundation for future based competencies that may be used to support development of future methods and applications.

The literature identified valuable engineering managerial competencies, however, without a respect for context, environment, and emergence a list of competencies may be limited in application or utility. Although a current literature review identifies some valuable competencies, a deeper identification

of competencies can be supported from a more robust systemic foundation. This is important as engineering management efforts must support and sustain the knowledge and resources necessary for operation. The following Table 2 provides a synthesis of literature for competency areas along with systemic elements that may be considered.

Table 2: Synthesis of Literature for Competencies and Related Elements

		Area Specific	Field or Discipline	Elements	References
Literature Review	Competency Framework	Competency Framework	Literature Review on Existing Framework of Competencies for Engineering Management.	• Environment • Emergence • Axiological Context	Valente et. al., 2003; Linton & Jayaraman, 1829; Cerovsek et.al., 2010; El-Baz & El-Sayegh, 2007; Wu & Ying, 2012; Bertonceli et. al,2009; Lenarz, 1985
	Engineering Management Competencies	Technical	Engineering Course Area Disciplines	• Knowledge	Winxker, 1999; Doggett, 1999;
		Operations	Estimating Proposals Planning Setting Objectives Information Management Impact Control & Monitoring	• Capacity • Control & Constraint • Viability • Knowledge	Datta, 2018; Ackoff, 1974 –'99;
		Human	Organizational Culture Communication Performance Management Social Mentoring Coaching Managing Creativity	• Human • Autonomy • Communication • Holism	Kasvi et. al., 2003; Ivanova, 2012; Warren & Langley, 1999; Backa, 2007; PMBoK, 2017; Hecker, 1996
		Business	Economics Legal	• Profitability • Inventory • Money	Hafeez et. al., 2002; Guerri, 2008;
		Management Competencies	Management (General Overview) Leadership	• Hierarchy • Requisite Parsimony	Danneels, 2015; Liznkov et. al., 2015; Dekkers, 2000; Odiorne, 1974; Ackoff, 1974 –'99; EMBoK, 2015;
		Engineering Competencies	Engineering (Manufacturing & Design)	• Area Specific Knowledge	Hutchin, 1992; Kendall et. al., 2018; KLETT, 2010; Veres, 2009; Rajagopal, 2003
	Future Competencies	Engineering Management Competencies	Innovation Educational Strategic Paths Artificial Intelligence (A.I.) Recruitment & Building Marketable Assessment	• Time • Resources • Iteration • Adaptation	Hahn, 2017; Ravesteijn et. al., 2011; Heston, 2019; Berghman et. al., 2006; Squires & Sofer, 2018; Andersen & Hansen, 2002, Jovanovic & Tomovic, 2008

2.5.1 Human Element of Competencies

Competencies required for engineering management involve effectively working with many individuals and groups at various levels of an organization. Although this may not always be noticed due to extremely busy schedules the minimum requirement involves the competencies of understanding the environment and what individuals can contribute. “The majority of operations management decision making takes place within the framework of a socio technical system in which decision makers need to take full account, not only of technical factors, but also of the needs of all individuals involved if they are to achieve meaningful and sustainable results” (D. Kirk, 1995). From a holistic perspective, understanding competencies as existing beyond purely technical considerations is essential. Therefore, management in the engineering management profession must be capable of the competencies that identify and support the human element. These competencies involve the knowledge and perspective that support the human element (e.g. context, emergence) prior to a viable implication effort. Therefore, “it has become clear that a method other than analysis is required for understanding the behavior and properties of systems” (Ackoff, 1999). In short, the interactions of system elements, including the human elements, may drive the effectiveness of the whole organization and require corresponding competencies appreciative of the holistic nature of engineering management. This is important as a set of competencies represented within a competency framework may be reviewed for change to effectively support the function related to the human element. The lack of awareness and approach to human element competencies can present an oversight of knowledge that drives a framework based on elements that misrepresent the organizational environment resulting with incorrect information and mislead employees.

2.5.2 Environment Element of Competencies

An emphasis and inclusion of the environment element is necessary to develop a competency framework that is relevant for supporting organizations. Environmental shifts may affect which competencies are used for the precise functions within many levels of an organization. Thus, the exclusion of competencies appreciative of the shifting nature of organizational environments may develop a limited competency framework. Therefore, suggesting a competency or set of competencies for engineering managers must involve the consideration of the environment and necessary adjustments. This allows the competencies or a set of competencies to respect the change or variety within the function of the organization. This means that importance must be given to an understanding and awareness of the environment, as environment element competencies may drive some predictability for the competency framework. Often it is common practice to monitor environments without emphasizing the different competencies required, however, it is apparent that competencies for the environment will depend on the depth of this effort. When failure is a result of unexpected environmental elements, then emergent conditions are considered along with gaps in the areas where competencies may have not been practiced.

This is where the hand off from information related to competencies required for the environmental element will improve the development of a competency framework. The inclusion of the competencies after failure provides insight to the foundation for the competency framework and systems theory. Although; research literature identifies competencies within systems theory, an in-depth understanding of these areas is only briefly mentioned with respect to system foundations and implications to direct future research (sections 5.4 and 6.6). In short, efforts to identify an understanding of gaps, cause of failure, and relations of elements ultimately help identify competencies or sets of competencies necessary for the development of competency framework.

2.6 Summary

This literature review considered the generation of different areas categorized to separate competencies with an emphasis given to the human and environment elements. This gives importance to the foundation for current and future competencies and competency framework. Additionally, the literature review provides information regarding the competency gaps for engineering management competencies and a competency framework. Depending on the information and approach, a direct path may be considered for engineering management competencies and framework based defining gaps, different areas, and elements related to competencies. In short, competencies link to gaps, environment conditions, and human factors will be considered. To support the research areas mentioned, terms and definitions provided as areas and elements researched may connect competencies, framework, gaps, and the broken path to a systemically based competency framework.

The scholarly criticism identified key points which was followed by a synthesis of the literature reviewed. While these areas reviewed present a challenge for competency framework, these sections covered expose valuable information from the literature review for the purpose of developing a competency framework for engineering management. The research will consider additional areas from the literature reviewed and the identification of gaps that separate competencies. Ultimately, this can link the categorized areas and gaps related to competencies to validate a competency framework. This involves the research to the extent of competencies linked back to the material gathered for this research.

CHAPTER III: RESEARCH PERSPECTIVE & METHODOLOGY

3.1 Introduction

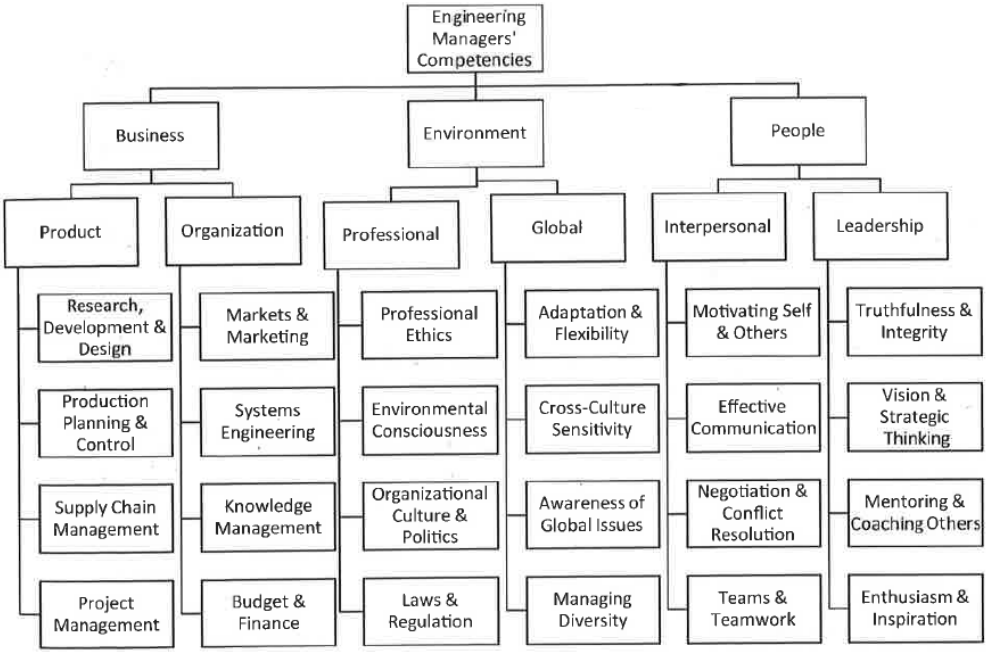
This chapter reviews perspective and methodology prior to the research and design. Although sections may lack information due to gaps and incomplete literature (broken paths) this provides a perspective and approach that extends between the research literature review and research design. This means information and competency areas briefly mentioned may identify key foundational elements for engineering management competencies. Therefore, the extent of the research perspective is that it helps direct an approach to review competency areas necessary and recollect missing competencies. Without a review of the research perspective and methodology the research design may be absent from opportunities that depend on grounding foundational elements.

3.2 The Research Perspective

The research perspective in table 2 of the literature review considers the identification and separation of competencies with the synthesis of the literature for competencies and related elements. Although this provides awareness of elements that may exist it is important to note that many competencies and related elements identified in research have not been developed as being integrally connected. Therefore, due to many different perspectives, competencies are identified best with direct text and context from the research. This directs the identification of competencies and removes ambiguity while respecting various perspectives from which research information was gathered for input to the engineering management competencies framework. This accounts for areas where a competency can be represented for both current and future engineering management competencies. Representing the current and future competencies is ultimately the focus of the research and provides valuable information in responding to the first two research questions.

Careful consideration is taken when identifying competencies as separation areas as these may differ depending on the perspective. A Guide to the Engineering Management Body of Knowledge provides the following figure 2 which represents a hierarchical structure of engineering management competencies as taken from El-Baz & El-Sayegh in 2007. The competencies listed are not separated into current and future engineering management competencies but rather competencies in general. In addition, the competency areas listed are Business, Environment, and People.

Figure 2: Hierarchical Structure of Engineering Management Competencies
(As represented from El-Baz & El-Sayegh)



3.3 The Researchers Role

The research perspective must consider the separation of competency areas beyond this example of business, environment, and people. In fact, the area separation of competencies may overlap other areas, which escape the representation in a hierarchical form. This can change the hierarchy with similar competencies and depends on the areas considered within the research. Certainly, the form of the hierarchical representation discounts differential weightings of context as well as the context free implications suggested. Therefore, the role of the researcher is to identify competency areas, respond to research questions, and present results as found in research text. In the instance of inductively building the research framework, the researcher plays an integral role in interpretation of materials, inductive interpretation through coding of different literature, and constructing the engineering management competencies framework.

3.4 Foundation of Research & Criticism

Researchers Morgan & Smircich (1980) recognize the social world as “fluid with activity driven by the transmission of information and with relationships being relative rather than real or fixed” (Bradley, 2014, p.30). This paper closely aligns with this perspective as consideration is given to research of engineering management competencies based on the research materials qualified for coding.

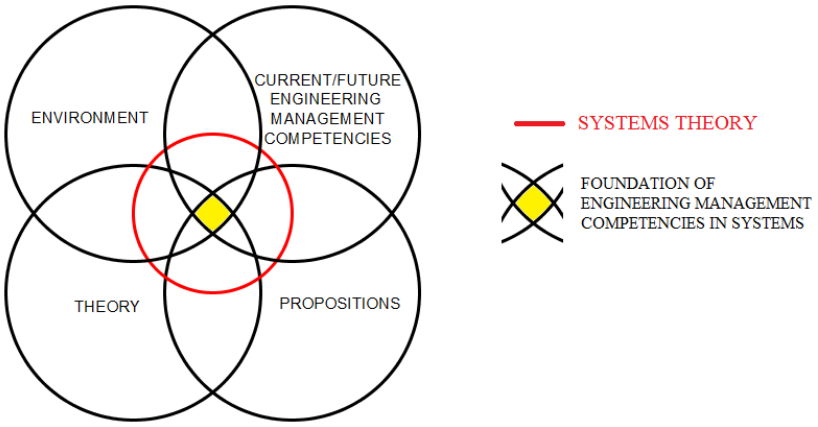
Separation of competency areas and identifying current and future competencies is dependent on the researcher's role throughout the identification process. To gather data with the objective of reducing bias, the precise text from the research was considered to direct perspective development and identification of current and future competencies for engineering managers.

Engineering management competencies and the framework rely on the foundation of research and are generated through the research phases based in coding in accordance with the Grounded Theory Method (Charmaz, 2014). With a focus toward research questions and development of a theoretical framework, the foundation and structure of this research was mapped. This is key in generating a framework for engineering management competencies. However, the competencies and framework identified will only be as good as the set of research information gathered. This is where criticism of competencies and the research is expected. This section of the paper considers the assessment of a foundation for competencies and framework where the defense is ultimately dependent on research supporting competencies and competency areas that may be fragmented at best. It is noteworthy that any competency framework is subject to evolution as new knowledge, new practices, and changes in the environment may force the continued relevance of any framework to be questioned. This means framework must always be considered as evolving and not a static delineation of competencies.

Identification of current and future engineering management competencies, mapping competencies, and interpreting the competency framework depends on what is provided as input data for coding, the coding process, and the representation/interpretation of results from the research. Many areas of separation for competencies exist in research. Identifying these areas help in organizing competencies, however, it is naïve to suggest that any competency framework will represent the definitive set of areas and competencies. In fact, these may overlap depending on the research and the areas associated with problems for engineering management. Therefore, where research literature does not specifically relate competencies to a current or future competency, a direct identification is found from a region that unites both current and future competencies as an intersection of present to future formulation of competencies. This reveals the gaps and strengths of this research with more information provided in chapter 4.

The direction and foundation for this research is built on research questions and the research that includes the consideration of systems theory. In systems, axioms are supported from propositions, theory, and environment. Adams et al., found these areas support a systems theory model that can lead to governance (Whitney, 2015). This does not only identify a valuable foundation link between systems and competency framework but from a systems perspective it involves selecting the necessary competencies required to precisely meet requirements. These would be competencies that satisfy proposition, theory, and environment for each system and its context. Figure 3 represents the area for this foundation of engineering management competencies.

Figure 3: Foundational Research of Competencies to Systems



Although many perspectives may be taken concerning competency framework, the areas represented are considered to relate competency framework to system foundations. Among the proposition are those that connect with communications, control, emergence, hierarchy, darkness, holism, viability, self-organization, recursion, and requisite variety. While these provide a construct useful to Systems and Complex System Governance (CSG) (Keating, 2015) they will not be studied since they go beyond this research. However, a complete understanding of systems and competencies, while a noble undertaking, is still a work in progress. This means that research may lack vital information for an engineering management competency framework or framework altogether due to fragmented research and current practices. Nevertheless, given that there is not such a framework currently in existence, the first generation of such a framework represents a significant first step forward. Ultimately, the application and utility of an engineering management competency framework will rely on identifying the problems and context prior to a targeted deployment for the framework required.

Therefore, the focus is directed at the location or area concerning where/how to structure an engineering management competency framework. The structure of this framework will undoubtedly require the consideration of emergence, environment, theory, and propositions as they influence, and are influenced by, the deployment of the framework. The difficulty and importance for this research can be represented as Santandreu-Mascarell et. al (2010) indicates:

> "Once we identify these competencies it is interesting to see if they adapt to the reality of business, because new titles are designed with the aim of providing competent and specialized workers. It's hard to make this comparison. First, because there are no studies of the competencies required by companies; instead, there are studies that evaluate workers for their skills. Secondly, because there is a lack of studies about competencies designed for degrees. Then, we use for comparison some of our previous works" (Santandreu-Mascarell et. al 2010, p. 15).

This means competencies are often acknowledged for the specialist at the technical level without any connection or interrelationship to the wider whole of engineering management. Therefore, this thesis seeks to add to the engineering management body of knowledge by consolidation of present works identifying competencies as well as projecting to a set of future based competencies. Some areas considered may connect with the similar human and environmental elements or research gaps. These are used to map a competency framework for engineering managers. In this effort the following section provides definitions used for primary concepts related to the research.

3.5 Construct and Theory

Appreciation of engineering competencies allows expansion on the competencies for engineering management along with respect to competency areas. Prior to engaging research, an initial high-level perspective is helpful in providing the basis for identifying competency areas and the competencies associated with each area. This serves to support a response to research questions and utilize Systems Theory to direct the identification of competencies and the construction of the framework. Although various competency areas and overlap can be considered, the identification of competencies is drawn from literature addressing competencies. This provides a consistent source for building competencies anchored in peer reviewed literature sources.

The gathering of competencies based from the source articles was mapped to identify the current and future engineering management competencies. An organized approach of sorting this data not only provided a structure for the competency framework but prioritized which competencies were classified as current and future. This can be significant when theory requires a rework to construct the competencies required. Ultimately, it is the elements for engineering management as identified in the source literature that supported the building of a foundation of competencies. Therefore, support of competencies is based on a foundation that considered environment, theory, and propositions as they related to engineering management competencies.

The current and future engineering management competencies were extremely valuable in the development of a competency framework and methodology to build that framework. Without understanding competencies required one cannot build a framework and without a framework it is difficult to drive a precise application.

3.6 Summary

The research perspective and requirements for the role of the researcher were discussed along with the foundational construct for the theory and criticism. This construct requires first the identification of the competencies as required to match the environment, context, theory, and propositions. This helps identify the conditions for each competency when developing the structure for a competency framework.

This is where the foundations and systems may establish relationships among elements and functionality with the competencies required. The researchers roll is critical throughout the research process to omit bias and gather accurate information. Therefore, the research perspective and competencies discussed in this research are identified directly from the research literature. Competency areas are listed prior to the identification of specific competencies within those areas. This is where research questions, research literature and systems support the development of a competency framework. Although information may be fragmented, the direction and foundation of this research is based on building the framework consistent with the research literature in response to the research questions. This implies that competency areas and competencies listed will be directly traceable to the source literature from which they have been constructed. These are the foundational areas that connect competency areas with systems and must be identified within the environment, theory, and propositions upon which the competencies are built. Ultimately, the competency framework is based on engineering management competencies which provides a foundation capable of supporting engineering management.

CHAPTER IV: RESEARCH DESIGN

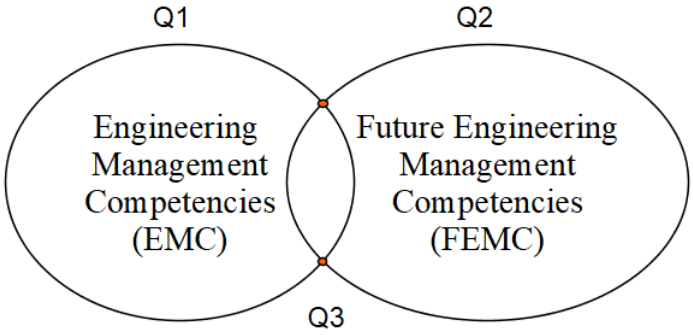
4.1 Introduction

The purpose of this chapter provides the research design that supports the research questions and competency framework. The current and future competency area is defined along with the overlap area that identifies connections and gaps. This directs the research phases and coding required for the identification and competency framework. Ultimately it is the competency framework that is supported by the competencies identified with the research design. This is based from the foundational research literature, questions, research paths, and coding.

4.2 Current and Future Engineering Management Competencies

Identifying a competency framework for engineering management involves the consideration of current and future competencies. Figure 4 represents the areas of current and future competencies along with the intersections and overlap where these paths may merge and interact. These areas will initialize the research paths to identify competencies, mapping, and a competency framework.

Figure 4: Current and Future Engineering Management Competencies



The research of multiple competencies and sets of competencies allows an opportunity to identify the overlap and streams of commonality between engineering competencies and future competencies. Sets of competencies may be determined on a hierarchy dependency and ultimately the function of the core competency of interest. These may trace back to systemic conditions, interactions, strategies, and consequences. Ultimately, the interest for this research is to gather research data that supports a set of competencies and a management competency framework. The competencies may be identified within competency areas or categories. In general, competency areas to consider may represent ’people skills’ and ’technical skill areas’. However, prior to identifying the separation of various competency area categories, an initial list of competencies needed to be gathered. The list can be grouped for the current and future competencies. The challenge is identifying the many competencies and support competency areas for mapping an engineering management framework. Therefore, the inductive research approach

with respect to literature related to current and future competencies, coupled with the coding of research data, allows an approach for aligning competencies and areas considered. The competency areas and lists generated is therefore part of the necessary identification to support construction of framework. This identifies suggested competencies and how an interaction between multiple competencies are considered and organized.

Figure 4 offers a guide to identify the level of importance for current and future engineering competencies. Therefore, the initial approach is a separation phase of the competency areas while making note of dependencies related to other competencies. This suggests that there is an overlap between present and future competencies, as they are not considered to be mutually exclusive and independent of one another. The level or hierarchy of competencies in general will be supported by competency sets within the structure of the framework. Table 3 represents an initial scan and review of literature with areas that consider the current, future and overlap of competencies found in figure 4.

Table 3: Literature Areas & Overlap to Associated Gaps from Initial Scan and Review

	Competency Fields of Study	**Gaps**	**References**
Engineering Competencies	Technical (Manufacturing & Design) Engineering I Management Leadership Operational Organizational Social Economic Risk Management	Foundational elements related to understanding contextual requirements, communication, equivocation, scanning and feedback.	Keating, 2003; Akoff, 1999; Hester & Adams, 2014; Clegg, 2000; Nittala & Jesiek, 2018
Overlap	Technological, Social, & Environment Developing Core Competencies -The Recruitment and Educational Management Competencies Strategy for Competencies Building Marketable Competencies Developing Engineering Retaining Core Competencies	Assesment of disorder and organization of areas related to the environment, viability, emergence and context. *Note:Future Competencies must allow control over this overlap region rather than allowing complete self organization.*	Keating, 2009; Crownover, 2005; Peterson and Rabadi, 2003; Krippendorff, 1986 Laszlo, 1996; Umpleby et.al., 1990; Skyttner, 2005; Jovanovic & Tomovic, 2008
Future Competencies	Innovation Risk Management Skills Artificial Intelligence	Gather foundational elements that support systems thinking, management cybernetics, autonomy, and constraints.	Jaradat et. al., 2018; Montano et. al, 2001; Clegg, 2000; Ackoff, 2006; Squires & Sofer, 2018, Andersen & Hansen, 2002

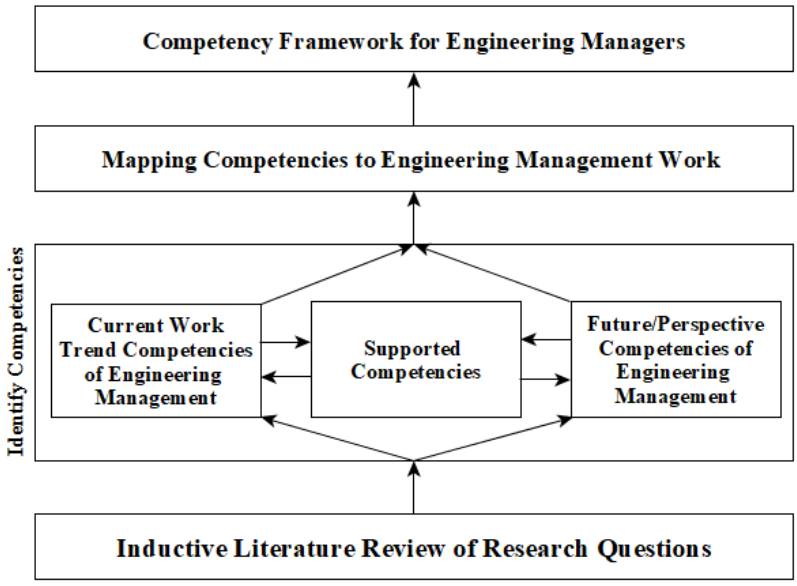
This table can direct the research design back to one of the three areas provided for the identification of competencies and separation areas within the research. The collection of data may then

provide specific competencies along with details for what is known and what needs further developed due to gaps within the literature (competency foundational framework, human, environment). The documentation phase of competencies, gaps, and areas of critique must follow the research and the research questions. The competencies within these areas provides an approach that considers numerus competencies that may be identified for an engineering management framework. This importance and appreciation for this approach connects research with the holistic perspective rather than placing efforts where a single competency focus is directed with a reductionist-based perspective.

4.3 Concept Path from Literature Review

The concept path for the literature reviewed is represented below in figure 5. The inductive research identifies the current and future competencies that are studied for the mapping and framework. The research effort focused on data gathered allows the consideration of gaps prior to collecting the detailed information relevant to engineering competencies and the competency framework. The basis of the information was determined by the research and literature that support the competency framework. Ultimatly, the purpose of this research is directed to construction of the engineering management competencies and competency framework that may be used by management in the engineering profession. The intial phase of this reseach offered the opportunity to be refined and studied at many levels. However, the reseach design is focused on development of the competencies and corresponding framework. Therefore, this effort is directed at providing the necessary competencies for the present state of engineering management while providing considerations based on the reseach for future competencies.

Figure 5: Concept Path from Literature Review



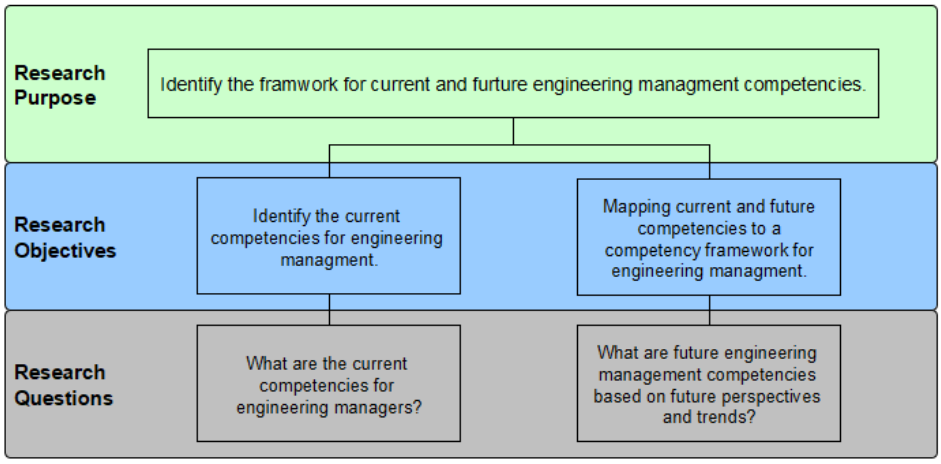
4.4 Area of Separation

Identifying current and future competencies from research provides data and context that support various levels of engineering management in an organization. Ultimately engineering management competencies and a competency framework are considered to provide a foundation that matches a variety of conditions to support a development for a framework of competencies. The competencies for managing engineering projects may then be directed toward the foundational framework along with the human and environment changes identified earlier. Under some circumstances a general hierarchy of competencies can be determined, however, the areas for which competencies are recognized must be further evaluated in the research phase with the coding of data. This coding of data provides a rigorous 'building' of competencies and their situation within a competency framework. Systems theory may then be introduced and considered based on foundational context, environment, and human factors to extend the depth of the competency framework. This approach was undertaken to possibly identify an order to the competencies required which supports a futher understanding of hierarchy along with the competency foundation for each area. The separation of research into common categories allows an additional search of all competencies related to the category. It is important to note that systems theory provides a relation to the design, operation, and maintenance while considering policies, standards, and perspectives as important to the formulation of competencies. This information provides the context for competency areas and competencies required with importance given to both hard and soft issues.

4.5 Research Questions, Objectives, and Purpose

The research phase and gathering of data initialized the identification and organization necessary for coding. The coding is an "essential piece that enables the researcher to structure data and clarify codes and their relationships" (Kelle, 2005; Strauss & Corbin, 1990; Strauss, 1987). This is to refine and develop the separation of current and future competencies along with a fragmented structure that can represent hierachy and gaps. This suggests the support of common categories, themes, properties, attributes, and subcategories (Leedy & Ormrod, 2010, p. 143) as central elements of Grounded Theory Method. Therefore, this open coding begins the process of organization of the data in the study for the generation of an acurate, traceable, and rigorous competency framework. An ontological perspective considers the elements of table 2 along with the reseach questions represented below in figure 6.

Figure 6: Research Questions, Objectives, and Purpose

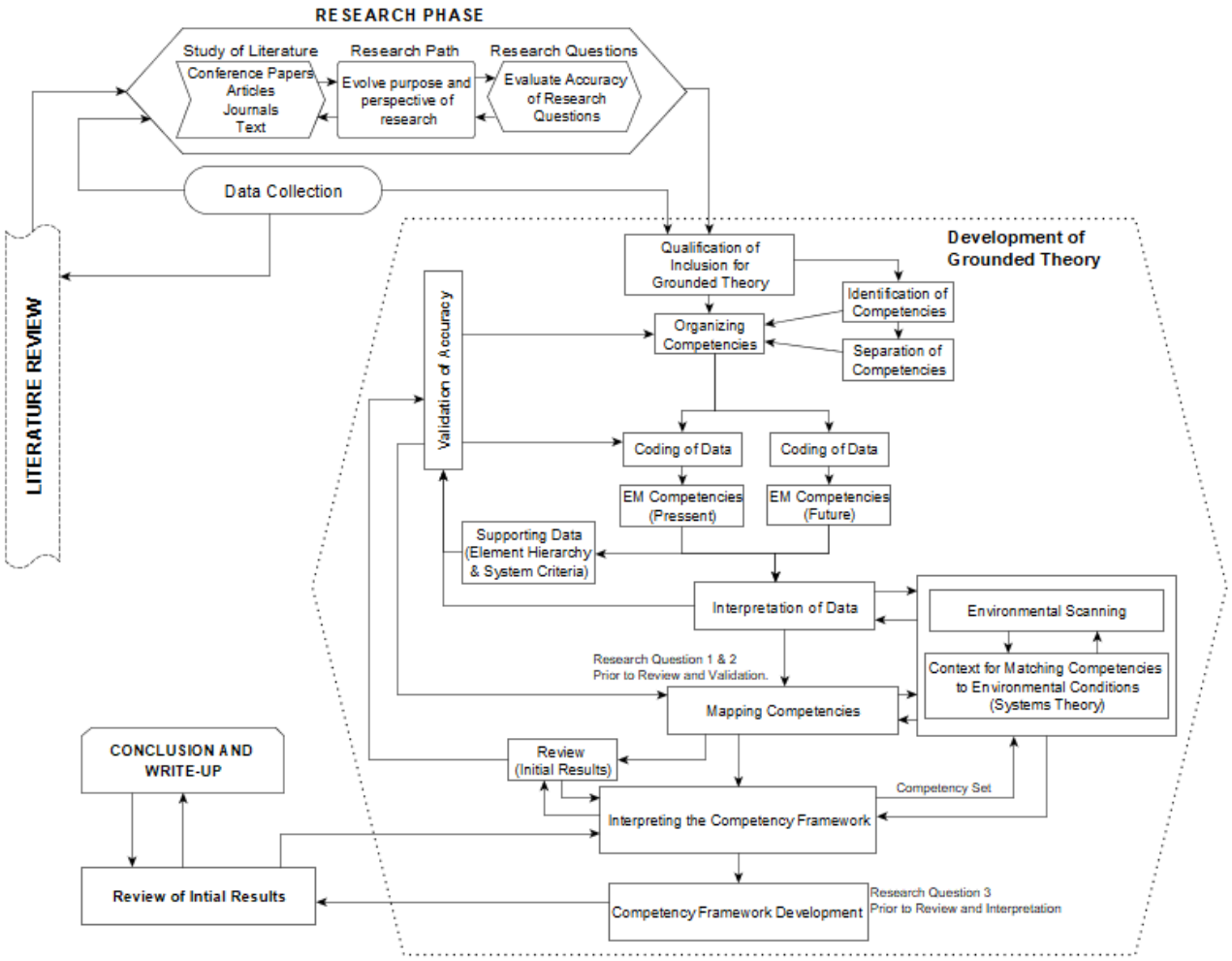


4.6 Research Phases and Approach

These questions identify the separation and further reseach to consider for the conditions and the development of the framework (e.g. including consideration of context and enviroment). Also, elements and interactions can be identified at many levels with a focus on the overlap region in figure 4. At this level an open coding approach allowed the gathering of all competencies from the literature prior to mapping a framework. Inductive research and reasoning directed the research based on the data and theory building phases achieved through coding. In part this follows an epistemological viewpoint provided by Charmaz (2014). This viewpoint as stated by researchers Siangchokyoo and Sousa-Poza (2012) is an "inductive reasoning process that takes the direction of going from data to the idea. Knowledge (ideas) is gained through the researcher's ability to derive meaning out of the data" (Baugh, egk 2019, p. 15).Therefore, this directs the foundational principles, dependencies, and structure that is necessary to support the building of framework. Additional areas and elements allowed the identification of gaps that separate the current and future competency areas. The areas and separation support the development of framework with a categorization for competencies. Also, with respect to research this effort establishes identification of a hierarchical list of competencies for the framework.

The research was conducted in 4 primary phases. These phases involved the data collection, identification, and research of required competencies in developing a grounded theory for engineering management competencies. Figure 7 represents the research phases for the research paths.

Figure 7: Research Phases



The research phases in figure 7 provide a path based on the utilization for the Grounded Theory Method (GTM) to develop a response to research questions. These phases provide a direct response to this research and direct the data collection for research phases and coding. Ultimately the result provides a direction to current and future engineering management competencies. Although this can be determined in the main topic headings of this research, Table 4 represents selected research phases and a development approach. This provides an information related to figure 7 development and design requirements with a connection to research questions. It is important to note that although the development and approach is valuable in directing a research path to competencies it does not represent appreciation for the identifying competencies. This identification takes place with each phase and involves the data collected from the research.

Table 4: Selected Research Phases and Development Approach

Research Phase	**Phase Development & Design Requirement**	**Completion Path to Research Questions**
Literature Review	A literature gathered focus which provide the design to identify a direction for the research path with respect to engineering management competencies and framework.	This was done by reviewing literature topics and information to categorize the intent of the literature and validate the purpose in relation to research questions.
Research Phase	This phase focuses on the approach and method of inductive research with the purpose of understanding the various competencies and the separation of competencies for research.	The research phase is completed with inductive research and the grounded theory method (GTM) which connects the research material with research questions.
Qualification of Inclusion for Grounded Theory	This focus is on research specific to 'engineering management competencies' and was designed for the separation of material required for the organizing competency phase.	The inclusion of material qualified for grounded theory is determined with completion of the research and review of material associated with engineering management competencies.
Organizing Competency	Organizing competency focused on competencies and was designed to separate the structure related to competency areas and engineering management competencies.	This is done by identifying main competency areas common within the research in relation to competencies that exist within these areas. Research questions guided information related to competency areas.
Coding of Data	This phase focused on competencies specific to current and future engineering management competencies with the intent to separate these from the research material.	An approach to represent identification of competencies that can be separated with research questions 1 & 2. An example is a text, context and purpose from research related to competencies.
Interpretation of Data	This phase focused on materials in the research and gathering of research data for the purpose of validating competencies identified.	This identifies competencies from research data as a response to research questions.
Mapping Competencies	The aim of this phase gathers categorized research data for the purpose of mapping competencies to a list.	The path completes the connecting of current and future competencies in research to provide a response to research questions 1 & 2.
Interpreting the Competency Framework	The intent of this phase was targeted at the interpretation of research data for the development of a competency framework for engineering management.	The was done by separating competency areas and competencies for a review of the framework structure related to the research questions.
Competency Framework Development	This phase targets the interpreting the competency framework phase for the development of a competency framework for engineering management.	The approach provides a competency separation with structured competency areas and competencies for the purpose of a competency framework aligned with research question 3.

Although the initial organization of research topics may direct some path to identify competencies, it does not represent appreciation of finding both the current and future competencies that may coexist under one topic. This is where a coding process is directed specifically to the research text for the purpose identifying competencies. This begins with the separation of each research phase and is directed further by the separation of research data. Therefore, each text that defines a competency within the research is searched to identify current, future or both current and future competencies. This text may

be a few words to an entire sentence. Each text in the research phase may or may not explicitly refer to the current or future engineering competencies. In fact, in many cases competencies are listed without the text classifying if the competency is a current or future competency. This is when the researcher must select the competency as relevant for current, future, both or exclude the text from direct relationship of competencies altogether. This may be considered for many competencies but for the purpose of clarity, current or future competencies are identified when the research refers to these as current or future. This provides the separation, qualification, and identification for the precise text from the research. Bringing out text from the research is the preference taken for this research as it identifies the competency base from the text and research literature. This instills the traceability for the interpretations made by the researcher. However, any engineering management competencies that are not explicitly directed to 'current' or 'future' competencies may be identified as shared competencies or classified based on the context of the literature. Therefore, classification depends on the context and research in identifying both current and future competencies. In addition, this represents the overlap region of figure 4 and identifies literature that shares parallel coding of competencies for the union of current and future competencies.

Separating areas and listing competencies with associated elements may identify interactions and dependencies within a set area for the framework. Although many levels of dependency may be necessary for competencies required, the separation may identify a relation through reduction and axial coding. As stated earlier, competency areas and the elements associated with competencies will continually be considered for the identification phase. This follows the research of Leedy and Ormrod (2010, p.143), as "the researcher moves back and forth among data collection, open coding, and axial coding, continually refining the categories and their interconnections as additional data are collected" (Katina, 2015). Therefore, respect and refining of data is dependent on the research for the competencies dependent at various levels (e.g. context, environment & emergent conditions, strategies, policies, and stakeholders). As stated earlier the gaps in literature can also provide a separation that may identify a lack of competencies.

Researchers Leedy and Ormrod (2010) report that "the theory depicts the evolving nature of the phenomenon and describes how certain conditions lead to certain actions or interactions, how these actions or interactions lead to other actions, and so on, with the typical sequence of events being laid out. No matter what form of the theory takes, it is based entirely on the data collected" (Katina, 2015). This means that initially theory and connections will evolve and always depend on the data. Figure 4 directs the research phases with the following data collection and analysis found in table 4. Table 5 provides the research phases and evolving criteria that depends on research data.

Table 5: Data Collection for Research Phases and Coding

RSH Phase		Data Collection Methods	Data Collection Reference	Data Analysis Methods	Data Analysis Reference	Expected Outputs	Relationship to Research Questions
Research	Study of Literature	Directed by RSH areas (Figure 2)	Archive List of Literature	Number count of resources.	List of Major competencies	Literature for the gathering data.	Area focus toward RSH questions.
	Research Path	Subject list of literature	List of Literature Reviewed	Support criteria for framework	Focus of literature to figure 2.	Competencies structure & examples	Competencies & Framework
	Research Questions		Questions 1, 2, & 3	Literature review			
Development of Grounded Theory	Raw Data	Research literature	Research literature list	Focus of literature to figure 2.	Focus of literature to figure 2.	Subject area literature list	Identified by RSH questions.
	Identification	List per literature selection	Research Questions 1, 2, & 3	Based on research questions.	List & link to specified questions	Competency list & link to questions	Raw list of competencies
	Separation	Competency list & link to organization support criteria.	Link to structure & elements	Literature based criteria	List of competencies & structure elements	Filter of Competencies per area (Figure 2)	Literature comparison with RSH Questions.
	Organizing Competencies	Select of area competencies	List of areas	Competency	Competency matrix	Organized competencies	Competency separation
	Coding	Research	Spreadsheet	Elements	Matrix	Mapping data	Link to Study
	Element & System Support Criteria	Competencies & Elements	Competency matrix	Inductive research data	Element hierarchy	Filter area competencies per support elements (Figure 2)	Framework structure & hierarchy
	Present Competencies	Research Literature	Research literature set	Competency elements	Competency matrix	Current list of competencies	Result for question 1
	Future Competencies	Research literature	Research literature set	Competency elements	Competency matrix	Future list of competencies	Result for question 2
	Interpretation	Matrix list	Matrix	Elements	Hierarchy	Hierarchy	Competencies
	Mapping	Current and future competency list	Competency list	Hierarchy and union of elements	List of competencies	Separation of Current and Future Competencies	List of current and future competencies
	Interpreting Competency Framework	Competency area list	Framework structure	Hierarchy	Framework structure	Initial framework	Framework
	Competency Framework Development	Competency structure	Competency area list	Inclusion Criteria	Framework	Competency framework	Framework
Review	Framework	Competency framework and Interpretation	Competency framework	Competency set and support of research	Competency element and hierarchy	Competency Sets for framework	Framework supported by research
Conclusion	Write-Up	Competency framework	Research paper			Competency framework	Current and future competency framework

The development of paths and actions taken in table 5 must be continually reviewed as it depends on emergence of what develops as the research design is executed. The review and efforts to structure lists, reduction areas, and competencies will remove confusion and criticism for developing a competency matrix of the research data. This effort will also avoid error from the coding paradigm. An example is from G Laser criticism that suggests "a researcher might 'force' categories into data rather than letting categories to 'emerge' from the data appears to have merit" (Katina, 2015). Therefore, research (Morse,1994) grounding theory through axial coding is be constantly reviewed since it may often seem to relate with unrelated logic, facts, and categories. This provides direction for the precise interpretation of data from the paths selected for the research phases and approach. In effect, this also provides for the tenets of qualitative research related to Trustworthiness. As stated earlier, competencies relevant to developing framework require support though each research phase. A deeper understanding defines the foundational construct supporting the identification, elements, and mapping. This provides the link between the separation areas and the many different competencies. Researchers Adams, et al. (2013) proposed a unified group of specific propositions from systems theory to form the construct for a system.

4.7 Summary

Engineering management competencies and a competency framework is the focus of this research with the aim for an approach to rigorously develop a competency framework. An important part of developing the framework begins with mapping competencies and the coding process. This involves the boundary of research literature from which competency areas and competencies will emerge through the analysis. Ultimately, this can help in the identification of competencies and areas of separation. Understanding competency areas and listing competencies with associated elements serves to identify the interactions and dependencies within a set area for the framework.

The research phases discussed insure the proper review and identification of current and future competencies. This involves competencies that share the overlap region in figure 4 but may reveal gaps between current and future competencies. This is key to structuring any framework as it respects both environment and emergence. Therefore, joining the coding process with figure 4 and research questions allows direction for the research. This allows for the research and direction associated with the concept path, area of separation, and the research purpose. The identification of current and future competencies is based on the research questions, objectives and purpose. Therefore, adherence to the Grounded Theory Method provides a rigorous, transparent, and repeatable approach to the construction of engineering management competencies through the coding process. This provides identification of engineering management competencies that may not be explicitly identified as current or future competencies. The identification of competencies is then used to build a competency-based framework with researched competency areas and the approach for competency gaps.

CHAPTER V: FINDINGS

5.1 Introduction

This chapter provides the findings from the research of competencies along with the competency framework development for engineering management professionals. The response to the research purpose, objectives, and organization follow the response to these findings. This is based on the identification of current and future engineering management competencies and the generation of a competency framework. These findings in this chapter follow the research phases and research questions.

This research found competency areas in Human/Relation/Leadership, Integration/Blending, Operation & Method, Financial, and Technical/Specialty. These areas were identified from the research related to competency areas or categories (e.g. Studies and research by James A. Lenarz and Hazim El-Baz et.al.). The American Society for Engineering Management (ASEM) published the Managerial Competency Inventory (MCI) which provided some examples of these competency areas (J., Lenarz, 1985). These areas do not represent individual competencies but the separation of competency areas (categories) for where competencies are recorded. The following represents the definition of these competency areas.

5.2 Terms and Definitions of Competency Areas

Human/Relation/Leadership – The competency area or category that allows for the related competencies associated with soft skills, communication, teamwork, leadership, cultural awareness, motivation, social & ethical responsibilities for engineering management professionals.

Integration/Blending – The competency area or category related to both the hard and soft competencies for engineering management which support or influence the integration and blending of work and teams within an organization.

Operational Method – The competency area or category related to the competencies for engineering management that support the method(s) of operation(s) within an organization.

Financial – The competency area or category related to the engineering management competencies necessary for the finance requirements of an organization (e.g. accounting, cost estimation, cost evaluation, economic analysis).

Technical & Specialty – The area of competence or category specifically focused on competencies within the engineering discipline (subject area(s)) and that is required for engineering management to make decisions within an organization as they relate to technical and specialty fields.

A list of competencies identified for each competency area is found in Appendix I. This section of the paper lists research materials along with the text identifying current and future engineering management competencies. An initial perspective provided the following order to competency areas;

however, without a method to normalize data this order may change depending on the engineering management boundary and environment. From a holistic perspective this means competency areas do not follow a prescriptive order as each is dependent on the competencies or sets of competencies required in different situations. Thus, although the order and weighting of importance may change, the competencies are expected to represent a stable set. Therefore, from a research perspective, competency areas provide an area of separation that is dependent on research literature included and the competencies required.

1. Human/Relation/Leadership
2. Integration/Blending
3. Operation & Method
4. Financial
5. Technical & Specialty

It is noteworthy that the competency areas represent a set at a point in time. This does not preclude their continued evolution over time and with the generation of new knowledge. It would be naïve, irrespective of how rigorously developed, to hold that competency areas would remain static. However, these categories or competency areas are represented in this research with current and future engineering management competencies as developed through the rigorous application of the research design. In Appendix I competencies are listed for each competency area with the number of occurrences related to current and future engineering management competencies. Also included are the number of occurrences related to gaps and systems. Each competency identified has a reference number for the intent of traceability to the reference list. It is important to note that a hierarchy that represents competency areas and competencies is taken from the number of competencies or the occurrence of each competency. This means that a hierarchy of current and future competencies will be provided for each competency area, but the list of current and future competencies will be different for a single competency area. An example is current and future engineering management competencies will not be the same for the financial competency area.

5.3 Engineering Management Competencies

The following represents the competency areas related to current engineering management competencies (EMC). The number of competencies listed in each competency area is identified from the order of the following list. The 109 refers to the number of competencies identified under the competency area of Human/Relation/Leadership and other competency areas followed with 45, 32, 15, and 9.

1. Human/Relation/Leadership (109)
2. Operation & Method (45)

3. Technical & Specialty (32)
4. Financial (15)
5. Integration/Blending (9)

The top five engineering management competencies (EMC) for each of these competency areas is represented in table 6. This highlights the first five competencies for current engineering management competencies. The list of additional competencies is found in appendix I.

Table 6: Engineering Management Competencies (EMC)

Human/Relation/ Leadership	**Operation & Method**	**Technical & Specialty**	**Financial**	**Integration/Blending**
• Effective Communication	• Operations Knowledge (Core & Enabling Processes - Capabilities)	• Technical Knowledge	• Business	• Effective Communication
• Multidisciplinary Teamwork	• Making Decisions regarding capability of operation.	• Measurement	• Economic Analysis & Evaluation	• Multidisciplinary Teamwork
• Mentoring	• Setting Realistic Goals	• Quality & Statistical Design	• Financial Analysis	• Mentoring
• Assessment of Others	• Knowledge of Resources	• Ability to Develop Projects (Product Development)	• Marketing	• Assessment of Others
• Managing People	• Knowledge of Working Environment (Rotation)	• Ability to Innovate	• Accounting	• Managing People

5.4 Future Engineering Management Competencies

The following is a list of future engineering management competencies (FEMC) represented by the number of occurrences referenced in the research. Future engineering competencies are listed under each of these areas as found in table 7.

1. Human/Relation/Leadership (109)
2. Technical & Specialty (36)
3. Operation & Method (26)
4. Integration/Blending (18)
5. Financial (12)

Table 7: Future Engineering Management Competencies (FEMC)

Human/Relation/ Leadership	**Technical & Specialty**	**Operation & Method**	**Integration/Blending**	**Financial**
• Understand & show an interest in development of life-long learning.	• Technical Knowledge	• Operations Knowledge (Core & Enabling Processes - Capabilities)	• Organizational Practices	• Business
• Effective Communication	• Knowledge of Science	• Product Life Extension (e.g. Knowledge of Product Life Cycle. Understand predictive, preventative maintenance, repair, recall, and recycling.)	• International Cooperation (Soft skill knowledge base to drive this work.)	• Knowledge of Business Relations (Government, Private Sector, & Foreign)
• Multidisciplinary Teamwork	• Measurement	• Controls	• Competencies	• Marketing
• Managing People	• Ability to Define a System Design Solution (Systems)	• Understand the Environment	• Understand how compensation ties to attainment of competencies	• Financial Knowledge
• Mentoring	• Ability to Innovate	• Minimizing Waste	• Driving Teamwork	• Economic Analysis & Evaluation

5.5 System Foundations & Engineering Management Competencies

The system foundation elements shown in figure 3 suggests a link to competencies only at the point where competencies are supported within theory, propositions, and the environment. In other words, an appropriate set of competencies will support areas of systems theory. However, an in-depth treatment, development, or complete list of competencies required for this union is beyond the scope of this research. However, the foundation of engineering management competencies considered within the structure of systems provides support to foundational competencies for further development. This analysis was based on engineering management practices and the alignment of competencies to competency areas from a Systems Theory perspective. From this research the following competency areas are listed from a study of systems. Integration/Blending and Financial are listed together and were not considered with the results due to a lack of information from the research. In relation to systems, a list of competencies for the first two competency areas is found in table 8.

1. Human/Relation/Leadership (20)
2. Operation & Method (13)
3. Technical & Specialty (5)
4. Integration/Blending & Financial

Table 8: Engineering Management Competencies in Relation to Systems

Human/Relation/Leadership	**Operation & Method**
• Systems Thinking • Holistic Perspective (System Vision) • Effective Communication	• Understanding System Boundaries & Problem Domain
• Knowledge and appreciation for different perspectives in solving problems. • Understand & show an interest in development of life-long learning • Understanding Human Capital Relationships (e.g. Intellectual Capital, Selection of the right people available for assignments) • Understanding & skills for knowledge that must be developed to bridge the gap in a firm or companies skill set. • Cultural Awareness • Understand Mistakes • Making Decisions without Adequate Information -foresight	• Understand a Needs or Problem Statement (Systems) • Knowledge of System Context • Understanding what Problems to Solve (Solving the Right Problems) • Understanding Constraints • Knowledge of System Output • Ability to Document or Record of Decisions Made • Ability to Monitor Decisions • Ability to Define and Manage Stakeholders expectations • Understanding & Supporting Infrastructure (e.g. processes, support systems, & functions) • Sustainability Knowledge • Product Life Extension (e.g. Knowledge of Product Life Cycle. Understand predictive, preventative maintenance, repair, recall, and recycling.)

The competencies listed do not precisely follow a hierarchy but direct the preparation for a competency framework that includes system elements. Therefore, it is important to note that competencies rooted to foundations grounded in engineering and systems may account for the engineering management competencies necessary for this competency framework. Depending on the competency areas required the identification of competencies will eventually form the structure and foundation for a competency framework. This means the foundational competencies identified in Table 8 are found to align with the following summary of areas found in figure 3. However, the extent of these areas is suggested to only connect to with the foundation of researched engineering management competencies. This allows a foundation of competencies related to these areas to be considered depending on the competency and engineering management environment.

• Real System Environment & Empirical Data
• Current and Future Engineering Management Competencies
• Propositions & Theory

This summary of foundational areas related to systems (figure 3) requires a competency related to systems (table 8) that aligns with the engineering management competencies researched. This provides the potential connections that exist in going back to the foundation for competency framework. Therefore, the validation of competencies related to systems is based on a match linking competencies identified from engineering management while respect is given to emergent conditions and the environment. This alignment provides the first-generation competency framework that can reduce the gap between current and future competencies.

5.6 Competency Areas to Hierarchy

Competencies required for engineering managers are dependent from many levels and continue to change due to emergence, context, and theory related to various engineering problems. This continual change provides a hierarchy that must be different for each engineering manager and contingent on the specific situation being 'managed'. For this research the interpretation for mapping engineering management competencies is directly taken from figure 4 along with additional considerations taken from the inclusion of systems. The results suggest that a hierarchy of competencies will not function without the consideration of current and future competencies along with the union of these and system competencies. This hierarchy is based on a foundation that supports the system environment, theory, and propositions for each competency. Unfortunately, a continuation for ranking a hierarchy is difficult for competencies listed as each competency is associated within a hierarchy level of competency areas and that ranking is beyond the scope of the present thesis. Therefore, an effective approach for competency hierarchy will be discussed in the section of this paper associated with the framework. Ultimately, the theory developed (engineering competency framework) is that an approach to hierarchy begins with a hierarchy of competency areas and then branches down to individual competencies. Specifics beyond this would not be borne out from research, but rather take a more speculative form. These specifics are beyond the boundaries established for the research. In short, this approach provides an actual report in consideration of environment, context, and theory for each area.

Considering a competency framework with systems theory provides a prerequisite for understanding engineering within any organization. This includes the understanding of communication control, emergence, hierarchy, darkness, holism, viability, self-organization, recursion, and requisite variety. The connection to these areas can directly relate to the results found in table 8. An example may involve the constraints required to control an outcome. In any case it is important to understand that "excessive control in a system , beyond that minimally necessary: (1) waste system resources that could be allocated to more value producing activities, (2) 'steals' autonomy form system entities that are excessively constrained, and (3) has high human cost associated with unnecessary surrender of autonomy (freedom and independence of decision, action, and interpretation)" (Keating & Gheorghe, 2016).

Therefore, organizations will benefit with an attempt for building a framework for engineering management competencies prior the supposition of results from self-organization or the implementation of efforts from a single person. This also extends to a single specialized area of an organization or the implementation of software. The reason behind this is based on the inclusion of others along with decisions that may require an engineering background. Engineers that have design and manufacturing experience have one part of the technical background but coupled with engineering management provides a finer path to a realization of competencies. This 'finer path' means that understanding multiple competency areas (e.g. The Human/Relation/Leadership and Technical & Specialty) allows knowledge and perspective for a competency hierarchy. With innovation and global interactions, engineers are required to understand many areas beyond the technical aspects of a problem/situation. Systems thinking is one area that provides a change in perspective and is recognized as a valuable engineering management competency. "Students stated that a general understanding of systems thinking is missing and that everyone needs to look beyond their own discipline" (Squires & Sofer, 2018). Ultimately, these provide important parts of the hierarchy that may be required for engineering management competencies. "Engineers, historically, have been adverse to political activity, unfortunately, politics, along with money, is what drives our nation. Unless we are willing to become politically active, we cannot expect to have an impact on decisions related to either our deteriorating infrastructure or our profession. Some of us must be willing to enter politics and/or to enter public service" (Hampton, 1992). Therefore, research suggests change is taking form but without an effort to understand competency areas and competencies which for development in business organizations result with obscurity to necessary opportune competencies.

5.7 Competency Gaps & Critique

The following represent the competency area gaps for the area competencies. Specific competencies related to these gaps are represented from the resarch competency gaps found in table 8.

1 Human/Relation/Leadership (53)
2 Operation & Method (14)
3 Integration/Blending (16)
5. Technical & Specialty (10)
6. Financial (9)

Competencies published from many articles and journals do not mean that they are adheard to within industry. Unique recommendations drive the implementation for some competencies without validation for future recommendations that acuratly provide control and drive change. This is expected by future competencies to drive the comercial, technological, and even political foundations. It is therfore viatal to emphasize engineering management competencies that do not systemically over constrain but rather validate competency areas and competencies within engineering management. This extends to

viability (continued existence) and governance (provision of regulatory capacity to maintain performance) at all levels of engineering management. It insures the viability of engineering products within a system based enviroment. However, who is doing this in industry today? The understanding of engineering management competencies goes far beyond the initial listing of employment with human resources. Research of engineering managers through human resource development found that some engineering managers would often "struggle to be effective engineering managers in terms of leading teams, delegating work, and communicating effectively" (Hittala & Jesiek, 2018). Unfortunately, today some human resource managers can be influenced by engineering managers that may have misdirected the organizational knowledge and goals for organizations. This can change the culture and enviroment of an organization and how talent is sought. Researcher F. Klett refers to the importance of defining organizatonal goals and assuring that goals intertwine with indivdual goals. "Currently most human resource management stakeholders have a vague notion of their existance and utility. Standards make learning, training, performance and competency technologies interoperate in a global network. They contribute to factors such as portability and scalability of systems" (Klett, 2010, p. 178). This requires the validation of competencies required for engineering management.

Validating competencies beyond a resume requires understanding the competency gap. Once this is found work can be done in "validating achievement of the competencies, and providing supporting documentation for promotion and certification recommendations" (Hahn, 2017, p. 426). Ackoff, understood competence as one of the essential properties of good management as he stated "In a rapidly changing business environment, such as we have, the most important competencies are (1) the readiness, willingness, and ability to change, and (2) the ability to innovate. The absence of these competencies is more likely to result in failure than the presence of other competencies is to assure success… The abilities to learn and adapt is the most important core competency an organization can have" (Ackoff, 2007, p. 151, f-law 76). However, "Mitroff [18] suggests that since real problems are unstructured and arbitrarily bounded, their resolution requires systemic inquiry. He concludes that, "All serious errors of management can be traced to one fundamental flaw: solving the wrong problem precisely, or muddled thinking" [17, p. 9] and that failure to think systemically is a primary contributor to these errors" (Keating & Gheorghe, 2016, p. 3). Therefore, "Managers who don't know how to measure what they want settle for wanting what they can measure" (Ackoff, 2007, p.101, f-law 51). The problem is then understanding what to measure and how it will solve the problem. Therefore, the bottleneck for many organizations can involve understanding the competencies required to access the physical manufacturing resources. In any case, suggested efforts to resolve and govern System problems, consistent with Systems Theory, provides consideration to the knowledge and support that aligns system elements, their resources, and engineering management competencies.

The research identified engineering management competency gaps (Table 9). In other words, these represent engineering management competencies that may be lacking.

Table 9: Engineering Management Competency Gaps

Human/Relation/ Leadership	**Operation & Method**	**Integration/Blending**	**Technical & Specialty**	**Financial**
• Effective Communication • Multidisciplinary Teamwork Managing People, Systems Thinking, Making Decisions, Understanding & skills for knowledge to bridge gaps, & Ability to delegate work	• Operations Knowledge (Core & Enabling Processes -Capabilities) & Project Management Problem Solving, Ability to document or record decisions made, Ability to monitor decisions, Strategic operations planning, Knowledge management, Changing management, Signals, Stakeholders	• Organizational Practices • International Cooperation • Understanding the input and inclusion of others (Involvement of Others) Integration competencies, Network Practices, Understand realistic expectations, Understand how compensation ties to attainment of competencies, Sharing objectives, Understand how competencies help to recruit qualified engineers.	• Technical Assessment, Appraisals, Software, Understanding feasibility, Ability to define technical system requirements, Ability to frame and re-frame problems, Ability to define a system design solution.	• Business Knowledge of Business Relations (government, private sector, & foreign), Marketing, Financial knowledge, Accounting, Understand the need of Investment to improve technologies, Cost assessment via database or systems.

The competencies represented for engineering management competency gaps align well with future engineering management competencies required (e.g. Human/Relation/Leadership: effective communication, teamwork, managing people; Operations Method: operations knowledge, documentation, controls; Integration/Blending: organizational practices, International cooperation, understanding inclusion of assets; Technical & Specialty: technical; and Financial: business & business relations). These similarities suggest the necessity for consideration of engineering management competency requirements within organizations. Any failure to meet the competency requirements suggested by the competency framework will create a 'competency gap' for engineering management in an organization and with the management practitioners. Therefore, the problem may be with an organization and the individual assuming responsibilities that require competencies that cannot be met. As an example, "Engineers who are nationals are expected to take on managerial responsibilities especially in the public sector at an early stage of their career without adequate managerial background from their undergraduate studies" (El-Baz & El-Sayegh, 2007). Another perspective is "Hiring for attitude (including loyalty) and training for skills (competence). Ackoff, values this as the way to go because the former is harder to get than the latter. Any business whose employees are loyal has a valuable asset. When loyalty is absent people are less committed" (Ackoff, 2007, p. 104, f-law 52). Ultimately, the approach is for an organization to

understand the competencies required with a willingness to train a new engineering manager consistent with the competencies required by their position and responsibilities. This means competencies must be supported at other levels and means until such time as they might be obtained by the new manager. Ultimately, many organizations must ensure engineering management competencies or mentor new engineering managers as this is often expected from day one and may only be questioned with problems.

Perspectives exist at many levels for exactly what competency gaps exist. These are determined based on the competencies required for the engineering management environment and problem. This means understanding the context and human element. Therefore, while some may consider knowledge management as the greatest competency gap, "knowledge utilization was perceived to be the best knowledge management competence" (JJ., Kasvi et.al, 2003). Also, continued challenges are that many organizations change knowledge requirements but fail to structure practices that align with all competencies required. The result can be unrealistic expectations for engineering management competencies and a lack of a structured competency framework. The research findings did not find evidence of the use of structured competency framework utilization in organizations for practicing engineering management positions. Often in these situations only the competency areas important to senior executives are given highest priority while other areas fail due to a neglect of competencies. If management at different levels can learn about these problems and share a responsibility to improve efforts, then engineering management professionals will better identify competencies. This is required to close the gap while helping many understand that responsibilities and breadth of perspectives increase when moving into management positions. This change was recognized by researchers Eisenhardt and Martin in 2000 when they identified *'dynamic competency*' as "the ability of a firm to alter its resource base, in one of three ways: adding new resources/competencies, recombining/reconfiguring these resources/competences, and dropping existing resources/competences" (Danneels, 2015, p. 2176).

If an organization is planning to train competencies then the "training and learning programs, and services needs a clear distinction from monitoring organizational processes" (Klett, 2010, p.175). This involves the proper pedagogical approach for developing engineering management competencies within organizations. This is particularly important for industry specialized areas that may not be taught in academic programs. It is important to note that instruction from the user (bottom up approach) must also be considered with the holistic management approach (top down approach). Ultimately, developing strong competencies allows organizations to produce new products (Hafeez et. al, 2002). Also, researcher F. Klett (2010) stated that "intellectual assets incorporate knowledge and skills and is quite often excluded of consideration that these assets involve also attitudes and behaviors" (Klett, 2010, p. 1). Often engineers are required to quickly transition into managerial and leadership roles while understanding this is a difficult transition for both engineers and employers (Nittala & Jesiek, 2018). The reason for this

transition is rooted from struggles that employers face to find talent for engineering management. In these management positions engineers struggle to delegate work, communicate effectively, and lead teams. Unfortunately, some organizations or engineering managers may believe they have success while only a focus is given strictly to hard technical details. Although, the technical competency area is important it does not ensure that a new engineering manager understands how to manage intellectual resources. This involves the soft and hard issues.

5.8 Building Hierarchy & Framework

Research provided the identification of many competencies within competency areas for engineering management. The American Society of Engineering Management (ASEM) along with research on engineering management competencies directed research into five areas. These areas include Technical, Management, Leadership, and Financial. No prescriptive path or hierarchy is recommended in regard to the order, but an assessment can be taken as to what areas of competency are more prevalent for the foundation of specific operations and projects. Competency areas and competencies will change in priority and applicability based on the context of specific applications. Therefore, the projection of a framework requires the application of that framework based on the specific circumstances and context to which the framework is applied. These are based in the foundations and variability across Environment, Context, Theory, Propositions, and Problem addressed. Table 9 represents a general framework for identifying engineering management competencies applicable to a specific context. Note that the Foundation Area 2 must be tailored to the specific nature of the point of application for the specific competencies necessary. For example, there are general competencies that might be appropriate from Foundation Area 1. However, there are also specific competencies that would be identified as appropriate and contingent on the local nature of the situation for which competencies are being identified.

Table 10: Competency Framework for Engineering Management

Foundational Area(s)	**Competency Area(s)**	**Competencies** (Research of EMC)	(Research of FEMC)
Foundational Area 1 (Research Example)	1. Human/Relation/Leadership (Research Example)	• Effective Communication • Multidisciplinary Teamwork • Mentoring • Assessment of Others • Managing People	• Understands interest in development of life-long learning. • Effective Communication • Multidisciplinary Teamwork • Managing People • Mentoring
	2. Integration/Blending (Research Example)	• Effective Communication • Multidisciplinary Teamwork • Mentoring • Assessment of Others • Managing People	• Organizational Practices • International Cooperation (Soft skill knowledge base to drive this work.) • Competencies • Understand how compensation ties to attainment of competencies • Driving Teamwork
	3. Operation & Method (Research Example)	• Operations Knowledge (Core & Enabling Processes Capabilities) • Making Decisions regarding capability of operation. • Setting Realistic Goals • Knowledge of Resources • Knowledge of Working Environment	• Operations Knowledge (Core & Enabling Processes -Capabilities) • Product Life Extension (e.g. Knowledge of Product Life Cycle. • Controls • Understand the Environment • Minimizing Waste
	4. Financial	• Business • Economic Analysis & Evaluation • Financial Analysis • Marketing • Accounting	• Business • Knowledge of Business Relations (Government, Private Sector, & Foreign) • Marketing • Financial Knowledge • Economic Analysis & Evaluation
	5. Technical & Specialty	• Technical Knowledge • Measurement • Quality & Statistical Design • Ability to Develop Projects (Product • Ability to Innovate	• Technical Knowledge • Knowledge of Science • Measurement • Ability to Define a System Design Solution (Systems) • Ability to Innovate
Foundational Area 2 (Foundational areas supported by the Environment, Context, Theory, Propositions, Problem Statement)	1. Competency Area 2	List of Engineering Management Competencies Required:	
	2. Competency Area 2	List of Engineering Management Competencies Required:	
	3. Competency Area 2	List of Engineering Management Competencies Required:	

Additional research may consider a match of competencies from one area to another. Researchers (Hazim S.El-Baz, Sameh M. ElSayegh) found engineering management competencies mainly focus on the task-specifics to the nature of effectively meeting engineering goals and building leadership from a person focused approach (W.Wu, M. Ying, XHe, 2012). This research combined the future and current engineering management competencies and systems allow for the development of a specific framework for each organization that can be extended based on the uniqueness that exist for the organization. Thus the framework is flexible, adaptable, and configurable based on the specific circumstances that define its application. Some direction extends to the documentation and signoff's required that would provide supporting evidence for benchmarking and maintaining competencies (Hessami, A. & Moore, M., 2007). This complements the documentation and assessment of competencies once they are identified. However, the real challenge for organizations is not only accepting the competencies required but identifying and

maintaining an awareness of all engineering management competencies. The Engineering Management Competencies framework developed provides a research based articulation of competencies for engineering management that appreciates: (1) derivation from the existing literature for engineering management competencies, (2) recognizes that there are general competencies applicable across engineering management positions and responsibilities, and (3) maintains the need for the framework to be adaptable based on the unique context for the engineering management position/responsibilities and recognition that the necessity/priority for situation specific competencies may shift over time in response to changes in circumstances, environment, or contexts.

5.9 Summary

This section of the paper provided the current and future engineering management competencies and competency areas identified from the research. The references found in Appendix I provided the findings for competencies and hierarchy. Although this hierarchy exists from the research it may be subject to critique and should therefore be valued at all five areas and recognized as not prescriptive. Therefore, the hierarchy represents an overall list of competencies which is the focus of the first two research questions. However, the approach for a competency framework is first directed at identifying the competency areas and then listing the competencies along with hierarchy. This is important but will change based on the foundation of context, environment, theory, propositions, and emergence inherent to the application of the framework in operational settings. Ultimately, the framework provides the basis to identify the competencies necessary for performance of engineering management in complex environments. Specific to current engineering management competencies this provides a hierarchy related to each competency area, significantly extending the literature related to engineering management competencies. This framework will continually allow an understanding of competencies while identifying opportunities to close gaps in the existing competencies identified in the literature.

Current engineering management competencies identified represent competencies associated with traditional engineering management practices of the past. These competencies are represented within the five competency areas along with related elements within the foundation of systems. Additional competencies and relations beyond tables 5 and 7 can be found in Appendix I. Future competencies provide an extended perspective, which includes an emphasis on the human element as well as the technical/specialty, operations & method, integration and blending and the financial. Therefore, from a systems perspective, the framework provides a more robust and ‘systemic’ view as to the competencies and their interrelationships.

CHAPTER VI: CONCLUSION AND IMPLICATIONS

6.1 Introduction

This chapter reviews research areas and provides a conclusion along with implications for current and future engineering management competencies. This directs the importance of research findings beyond the identification of current and future competencies. Therefore, the aim provides consideration and importance to the competencies and the development of the competency framework. The identification of research areas along with implications for competencies are not limited to this research and may be expanded in the future. This is where the future of identifying competencies and a foundation that supports required competencies is necessary. Ultimately, organizations that develop a successful framework, tailored to their specific circumstances and desired utility, will continue to support practical competencies that are necessary for successful engineering management professionals and organizations.

6.2 Research Areas

This research identified competencies along with an area of separation between current and future competencies. Ultimately, competencies are at the foundation of the research and direct the current and future engineering management competencies along with competency areas, gaps, and areas related to system theory. The research areas direct a path for identifying the foundation and structure for a competency framework. It is important to note that future research may expand these areas and that a continual assessment of these areas is required for developing and maintaining a competency framework. Various implications for future research will be discussed later in this chapter as consideration may easily be given to multiple research areas. In fact, significant to this research is the identification of areas related to gaps and systems. This relates to the foundation of current and future competencies. The gap in current and future competencies along with environment, theory, and systems propositions will provide research areas that can be expanded. The significance of identifying these research areas provides consideration for continued evolution of a competency framework using the current research as a foundation. Obviously, one would not proceed if a thorough effort had not been considered for the context of competencies required. The structure for a competency framework is the reason for developing an understanding of the research areas considered. This means that identifying the context and unique competencies for an organization is essential prior to establishing a tailored competency framework and selection of the methodology (approach) to guide that tailored competency development. Therefore, justification of competencies required must come prior to framework or implication efforts. Those who claim supporting framework or methods without understanding foundational competencies will not understand the approach to framework or methods necessary to achieve intended utility suggested by the research.

6.3 Implications for Current Engineering Management Competencies

Current engineering management competencies suggest practical implications that are important for organizations. These practical implications are important since the technological and digital future will not remove or resolve the requirement for developing and maintaining current engineering management competencies. These involve foundational competencies related to the human/relation/leadership competency area along with Operation & Method, Technical & Specialty, Financial, and Integration/Blending (Refer to Appendix I and table 9 for a list of competencies). "In today's knowledge-based economy, different resources are used in creating new value and a broader circle of participants is involved than in the past. Human capital is becoming more important than economic capital" (Bertoncelj et. al, 2009, p. 1). And "often what appears to be a technical problem turns out to have a large behavioral dimension. In particular, any aspect of operational management which involves the management of technology has both hard and soft aspects. By ignoring soft elements of a system, particularly those related to organizational factors, this has often led to the failure of new systems" (Kirk, 1995, p. 15). Therefore, implications to improve current engineering management competencies must involve an active effort within industry and among new and experienced engineering management. Unfortunately, this starts with the common and basic practice of respect and communication. Hampton (1992, p.236) amplifies this point:

> "Others watch how engineers treat each other, and in too many instances we show a lack of respect for one another, damaging our public image. Some of us force our subconsultants to bid for professional services while we proclaim to our clients the virtue of selection on the basis of qualifications. Some of us subject our subconsultants to unfair contractual terms. Some of us demean our competitors to our clients. If we want to improve our image, we have to treat each other fairly and with respect, and present to the public a much more cohesive and unified front on issues of importance to our profession and the nation. For example, the verbal genuflecting members of the medical profession do to each other gets nauseous sometimes, but it clearly demonstrates to the public the respect physicians have for themselves and their profession. Engineers need to demonstrate the same."

Ultimately, this involves respect along with giving credit where credit is due as engineering continues to provide the creation, maintenance, stability, and access to resources and services needed across the globe. Currently many inexperienced engineering managers tend to optimize a focus in technical areas without any support to context related to foundational competencies. And if context is considered it may only be selectively taken from one vantage point. This explains why researchers Kumar & Hsiao (2007) and Sommers et al. (2004) found that "engineers are overlooked to senior management positions and attributed that to the lack of education in communication, leadership and management skills" (El-Baz & El-Sayegh, 2007, p. 1). Therefore, an effort to identify implications may start with pathologies (aberrations from normal or healthy conditions) related to competency failures. Often current engineering management competencies and representation frameworks will direct an understanding for

the cause and effect of issues related to ineffective efforts. This often suggests that engineering management impacts both technical processes and people since the foundation identifies the data and context selected to direct and govern. This is important as some organizations may require reframing of competencies and methods due to a legacy of inaccurate information and an overemphasis on more limited formulations and applications of engineering management competencies (e.g. technical based competencies only).

6.4 Implications for Future Engineering Management Competencies

Currently many engineers seldom have engineering management experience beyond a deep immersion in technical areas related to their profession. This is where competencies required at the foundation may be considered to structure a competency framework, particularly in consideration of the range of competencies that exist beyond the purely technical realm. An example found from research states "communication, teamwork, networking and adaptability are among the competencies with highest priority" (Ivanova, 2012, p. 1). While another researcher emphasizes the three competencies recommended as "instrumental, strategic and communicative competencies" (Raventeijn et. al, 2011, p. 8). The instrumental relating to the general basics of engineering work while strategic dealing with the economic and political goals. And unfortunately, communication often exists as the weak area. Currently these, along with other competencies provided by the research exist as recommendations. Although each of these competencies may be necessary, without a common practice to review and implement a competency framework, specific to an environment, then the most current competencies identified may not be relevant. Although each of these competencies may be necessary, without a common practice to review a competency framework specific to context and environment, then competencies may not be relevant, or those 'most' important not surfacing for assessment/development. This is important when identifying a focus toward an important set of competencies. Therefore, it is of value to recognize the effort made to identify competencies, structure a competency framework, and how an unfortunate result can relate back to a type II error by Mitroff. This stated in section 5.6 this refers to solving the wrong problem precisely.

The future will not allow ignorance of engineering management competencies to go without accountability (performance degradation), as industry business practices depend on both the human and technical elements. This means all organizations will face the increasing necessity for identification and implementation for future engineering management competencies. This extends to an understanding of priorities, constraints, and compensation as part of governance. Ignoring these issues may result in a loss of control, priorities, and values for a business operation. Regarding practical implications in a knowledge-based economy, requires resources at various levels to create new value with a broad circle for involvement. In fact, the future requires more knowledge and understanding for the evolving roll of

engineering management professionals. If not taken seriously poor decisions can be made along with an improper respect for the roll of engineering professionals. The acknowledgement of these aspects exists within the engineering management competencies framework.

Researchers Jumar and Hsiao stated “Currently, engineers learn leadership and management skills while working-learning soft skills the hard way” (H. El-Baz et.al, 2007, p. 1). This follows that “if much of the future of American industry is dependent on effective management of the engineering/technical community, then we need to do some strategic thinking about development of engineering managers” (Lenarz, 1983, p. 83). The strategic approach here involves the consideration of competency areas, competencies and framework before those who may rapidly suggest request a list of unsupported competencies. Although the future involves the human/relations/leadership competency areas it also extends to the technical & specialty, operations & methods, integration/blending, and financial competency areas. Some future competencies from this research include an understanding for lifelong learning, technical knowledge, operations knowledge, organizational practices, and knowledge of business relations (government, private sector & foreign). This relates to cultural, technical, and communication competencies (Refer to Appendix I and table 9 for a list of competencies). Therefore, “Global engineers of the future need to understand the foundations of systems theory and science and be exposed to challenges that help them mature their knowledge, skills, abilities, and attitudes (competencies) about applying a systems approach” (Squires & Sofer, 2018, p.1). This suggests practical implications for future engineering management competencies may be found within a foundation that relates to specific competencies required. This begins with structuring a foundation for an engineering management competency framework with a direct focus toward competency areas and foundations (theory, propositions, and environment) prior to identifying specific competencies required for the engineering manager. The importance of this point for the utility of engineering management competencies framework cannot be overstated. The movement from general competencies to specific situational related specific competencies, as well as the shifts over time and circumstances, is indicative of a tailored and systemic approach to application of the framework.

6.5 Implications for Engineering Management Practice

Engineering management competencies for the future may be implemented when accurate and available information is based at the foundational structure for the required competencies. It is important to emphasize that this builds a future competency framework only when the competencies required match the variation required by the environment, context, theory, and propositions. This is why management must be involved with engineering management professionals, since organizational goals can direct a focus toward fair assessments of engineering management performance, which are the result of effective instantiation of competencies. This means that an active awareness must be taken by owners and

management to be involved with the development and propagation of engineering management competencies. If an active awareness and involvement is not taken, then organizations may fail to realize opportunities for success or may lose ownership to some engineering managers that choose to invest in business opportunities. Therefore, Change (2005) recommends "To meet the challenges of the 21st century, engineering managers need to manage the inside of the company as well as the outside, to lead from the present to future, and to act locally and think globally (El-Baz & El-Sayegh, 2007, p. 2). Ultimately, this can provide some high-level perspective and understanding of information necessary for the future foundation and competency areas required to meet the goals of an organization.

The implications of engineering management framework for practice are found in a framework that identifies competencies within competency areas. Listing different competency areas must be done prior to identifying individual constituent competencies. Lacking an effort to define competencies can leads to the consequences of unstable management practices, operations, and organizations. An example can be found with organizations that strive for quality management systems but only ensure competencies of those who are not part of management. This may assume that engineering management practices within an organization do not require assessment. On the contrary, a review of engineering management competencies can identify a path for management professionals while improving performance, effectiveness and a path forward for development of other professionals. Ultimately, organizations may define competency areas, competencies, and training plans, but appreciation, awareness, and an active effort must be taken to enhance practice. Unfortunately, many organizations do not place an awareness or continual practice application in reviewing the competencies necessary for engineering management. Evidence of this can be found in effective performance reviews or the lack of reviews. When done properly, reviews can help develop good working relationships that are necessary at all levels of an organization. The engineering management competencies, and the exercise of those competencies, are certainly capable of providing an effective basis for performance evaluation and professional development goals.

Supporting engineering management competencies will be necessary for all engineering management professionals and organizations, and certainly may escalate in the future. This is particularly the case as engineering management environments continue to see increasing complexity, uncertainty, ambiguity, and contextual influences. This extends to the challenges within the technical areas of engineering design to the support of working professionals across the globe. Hayes and Pisano (1994) found that "Only when we link core competencies to decision-making, we will find a manufacturing strategy presenting guidelines for decision-making on resource acquisition and capacity management" (Dekkers, 2000, p. 4087). Therefore, developing relationships and supporting working professionals and organizations is significant when founded on competencies. This provides a high-level future practice

since “researchers Canós and Santandreu (2010) determined that competencies wanted by companies and their staff involved shared vision, understanding of various job tasks (rotation), access to information, and teamwork” (Santandreu-Mascarell et. al, 2010, p. 22). Unfortunately, many organizations have only learned to make an attempt without a focus toward a competency framework and follow-up to build competencies. If this is a common practice, then it represents a practice that is incomplete for engineering management. Therefore, practice may require a new perspective for developing engineering management competencies. Researchers Bertonclj et.al (2009) indicate:

> “knowledgeable and empowered individuals with high learning capacity have become a key competitive advantage of an organization and it is outdated to treat employees as labor cost only. Intangible items such as creativity, talent, expertise, commitment and relationship cannot always be measured but they are key success factors of today’s economy” (Bertoncelj et. al, 2009, p. 1509).

This changes our awareness to the “short-term economic gains give way to long-term economic and social effects” (Bertoncelj et. al, 2009, p. 1509). Although challenges will continue with leadership and managing social responsibilities, an assessment of engineering management competencies will provide structure to support to technical and social area development for enhanced organizational performance. In practice an effort can be made to identify the competency areas and competencies required to unify understanding and further development. This gives way to recognize management requests that may be unrealistic due to the problem(s). This is where the competency framework provides a valuable approach for identifying competencies to drive future implications which are not solely based on the literature, but competencies specifically identified with actual problems. Verification of competencies with competency framework may then be supported with further development of theories, hierarchy, and framework. Ultimately this represents part of further development in moving research to validate implementation.

6.6 Implications to Direct Future Research

The research areas in this paper focus on engineering management competencies and competency areas that structure an engineering management competency framework. This requires a knowledge of competency areas for the effective implication of engineering management competencies. Although organizations will differ on the inclusion of competencies, a concerted involvement along with multiple perspectives can help implement a structure for competency framework utilization to improve organizational and specific practitioner performance. This provides opportunities for the future research of competencies and opportunities to understand gaps that may enable or limit successful practices. An example may involve the improvement and benefits of identifying competencies and tailoring a context specific development framework. This may also involve the operational success of an organization

dependent on the complexity and framework of engineering management competencies. This is effectively how engineering management competencies will resolve problems (hard or soft) within organizations. Regardless of the problem(s), the focus will continue to be rooted at the competency foundation of problems that need solved for an organization. This suggests that future research might be effectively targeted to: (1) further development of competencies identified in the engineering management framework, (2) deployment in operational settings to provide for enhanced validation of the framework, and (3) focus on development of deployment methodologies that allow for the use of the framework through appropriate tools, methods, and technologies.

Although problems continually change due to emergence, the awareness and efforts made can direct the importance of identifying the extent of competencies and framework. This can be considered in future research since many organizations may continually face an oversight of competencies. This is where researchers have considered how "the laws of nature should also apply to organizations where people are the key creators and operators, regardless of the level of automation, normalization and assumed appearance" (Bertoncelj et al., 2019, p. 1515). Therefore, although "strategy writers and managers have recognized the importance of strategic resources and competence, these factors need to be operationalized if they are to explain the scale and rate of change in competitive advantage" (Warren & Langley, 1999, p.397). In short, rules for routing codes and defining the limits of technology are not found with explicit paths absent from the inclusion of the human element. This hopefully emphasizes the importance of competencies, particularly those that range beyond the specific technical aspects of engineering. The current and future engineering management competencies support the competency areas and identify areas and gaps. This provides opportunities to continually review the inclusion of competencies and competency areas. Researchers Vrazhnova & Shatia (2013) indicate:

> "For a modern engineer, the presence of organizational and management competences becomes more important, which implies totality of acquired special knowledge, skills and habits, socially relevant and professionally important personal qualities. They are expressed in ambition, readiness and ability to professionally solve management problems, make effective management decisions and allow to be successful and competitive in the profession" (Vrazhnova & Shatia, 2013, p. 1).

This further directs the value of knowledge and skills for future engineering professionals. This extends to reason why "Ulrich (1998) argues that human capital as part of intellectual capital can be observed through competencies" (Bertoncelj et. al, 2019, p. 1513). It is interesting to note that regardless of the future research direction the foundation for where competencies are identified and the approach to utilization of the framework will continue. Eschenbach and Ra (1997) explained that a program mission must balance concepts, skills, and knowledge. The concept area emphasizes the ability to visualize the big picture. The skills area includes teamwork, communication, and analytical skills. The knowledge area

includes both managerial and technical knowledge (Danneels, 2015). While the future for engineering management is fraught with challenges, further research into the nature, definition, and utilization of competencies can play a vital role in ensuring increasingly effectiveness of organizations and engineering management practitioners.

As the foundational competencies for engineering management practitioners are identified, future research into systems may highlight competency for the future while identifying elements for current competencies that have been neglected. Continuing the focus may direct a path to strengthen the system foundation for competencies presented in figure 3. This is a foundation that may move a holistic approach for the theory related to research of competencies as the structure is based on theory, propositions, environment, and current & future competencies. One key research area focus may suggest a study of the gaps that are found from mistakes due to oversight and lack of competencies (e.g. competencies for the human element based on cause and effect, emotional intelligence, systems thinking, system pathologies). Therefore, the foundation of competencies considered may be based on a selection of research that connects engineering management competencies to System foundations. It is important to note that other fields of study may be researched and explored to strengthen the competency framework for engineering professionals. One area for research may involve the nine areas of Complex System Governance (CSG). These would involve identifying competencies that support the areas of Information & Communication, Environmental Scanning, Learning & Transformation, System Context, Policy & Identity, Strategic Monitoring, System Development, System Operations, and Operational Performance. In short, any research that improves the practice for engineering management and provides a connection to competency framework is worth consideration. This perspective is supported by practicing organizations or those involved with Systems theory.

6.7 Summary

The current and future competencies identified in this research through the development of the framework help to develop foundational competencies necessary for advancing understanding and possibilities for application for engineering management. This research identifies current and future engineering management competencies that must be in place to meet engineering management competency requirements. This is where the environment, theory, and propositions support competencies that provide the basis to better prepare future professionals and organizations to take responsibility in providing the support, development, and practice of competencies. Therefore, from a systems perspective an essential competency will provide a more capable response to deal with turbulence and emergence stemming from increasingly complex environments. This means that the engineering management competency framework can be developed depending on information available and a continual review of foundation elements for required competencies. In effect, the framework is a ‘living framework’ that

should be continually challenged as new knowledge and understanding emerges in the engineering management discipline. The initial research phase provided a literature review with relevant competency areas and then moved to identifying each competency from the research.

The effort to develop competency framework follows an approach to identify engineering management competencies and identify overlap and competency gaps that require support and suggests future based competencies. Awareness and actions taken to identifying competencies provides the approach to a relevant list of competencies within the framework. Also, identifying engineering management competencies may be linked to the boundaries of engineering management as competencies continue to evolve as the environment and circumstances for the engineering management discipline. The acknowledgement of the present competencies in relationship to future emerging competencies suggests the gap to be bridged to meet the technological world of the future with the proper order of management practices. The awareness to adjust for change and bridge gaps is based with the foundation and structure for a competency framework. Also, it is important to note that the topic of competencies has been around for years and although current competencies are published, it has not given reason or resonance to influence practice in any substantial way. However, the future may force adherence and change out of necessity for survival, regardless of any formal or informal approach. It will undoubtedly be unfortunate if learning efforts are made without the support of implementing and assessing engineering management competencies -learning the hard way (e.g. accretion, self-organization).

The engineering management competencies identified in this research are not represented with a hierarchy in the competency framework. This is based on the extent of the research and lack of validating the competencies beyond the research literature. In practice, empirical data or tests may be considered to validate this area hierarchy with respect to the foundation for the study. Therefore, depending on the foundation, core competencies for engineering management can be reviewed prior to defining an operational framework, methodology or flow for organizational practice. Thus, implications to move forward point toward working with the human element which will remain a key factor within management. This will be difficult if respect and information is not given a proper place as competencies and implications cannot be discovered anywhere without a corresponding emphasis on governance (design, execution, and evolution of systems) and inclusion of multiple points of view. Ultimately, the significance in identifying competency areas, competencies, and framework is to direct engineering management professionals and unite organizational environments and operations. This means that organizations must actively consider engineering management practices with a foundation for competencies and framework. This is not done with a single focus at one competency area or set of competencies but requires structure for the engineering management framework. An example may be the single focus of engineering technical and business skills working to resolve all problems without an

understanding of the human and integration/blending elements. This means that an inclusion of all competencies areas and competencies are required to improve control and coordination required for engineering management professionals. Therefore, organizations will require a foundation for engineering management competencies since expectations for accurate information and direction are required.

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Appendix I

This appendix provides a list of research literature along with a reference number for the purpose of representing competencies identified within the competency areas of this research. This links the competencies to competency areas with traceability from reference numbers back to research literature.

Author	Topic	Reference
A., Andersen, J., Hansen (2002)	Engineers of Tomorrow and beyond Knowledge	1
A., Bertoncelj, D., Kovac, R., Bertoncel (2009)	Success Factors & Competencies in Organizational Evolution	2
A., Squires, A., Sofer (2018)	Maturing System Competencies to Engineer a Better World	3
ABM- S., Poulo	ABM Attribute and Competencies	4
ASEM, (2015)	A Guide to EMBOK 4th edition	5
BR.Rubenstein-Montano et. al (2001)	A System Thinking Framework for Knowledge Management	6
C., Cook, T., Ferris (2007)	Re-Evaluating Systems Engineering as a Framework for Tackling System Issues	7
C., Keating, W., Peterson, G., Rabadi (2008)	Framing of Complex System of System Engineering Problems	8
C.B., Keating, A.V., Gheorghe (2016)	Systems Thinking	9
Competence Matters More than Knowledge	Competence Matters More than Knowledge	10
Competencies and Skills for Future Industrial Engineers	Competencies and Skills for Future Industrial Engineers	11
S.W., Goehring, D.D., Strouble, A.E. Thal Jr. (2009)	Competencies for Successful R&D Program Management	12
D. Hampton (1992)	Critical Issues for Engineers	13
D., Huejnagic, A., Sluga (2015)	A Conceptual Framework for ubiquitous autonomous work system in the engineer-to-order environment	14
D., Kirk (1995)	Hard and Soft Systems	15
D.H., Winzker (1999)	Leadership & Management Competencies for Technology Organizations in Developing Countries	16
E., Danneels (2015)	Surve Measures of First & Second Order Competencies, Statigic Managment	17
E.A., Guerri (2008)	Managers Guide to Successful Day-to-Day Employee Relations	18
F., Klett (2010)	The Interrelationship Between Quality & Competency Managment	19
S., Wadhwa, K.S., Rao (2000)	Flexability: -an emerging meta-competence for managing high technology	20
G.,Valente & A.,Rigallo (2003)	An Innovative Approach for Managing Competence: An Operational Knowledge Management Framework	21
G.S., Odiorne (1974)	Management By Objectives	22
H., El-Baz & S.M., El-Sayegh (2007)	Developing Engineering Managment Core Competencies	23
H.A., Hahn (2017)	Recruitment & Educational Alignment Use Cases for Competency Framework	24
H.Kumar & S.Raghavendran	Not By Money Alone	25
J.A. Lenarz et. al (1985)	Engineering Managerial Competencies in a Changing World	26
J.J., Kasvi, M., Vartiainen, M., Hailikari (2003)	Managing Knowledge & Knowledge Competencies in Projects & Project Organizations	27
JD.Liton & V.Jayaraman (1829)	different modes of product life extension	28
K., Hafeez, Y., Zhang, N., Malak (2002)	Core Competence for Sustainable Competitive Advantage	29
K., Rajagopal (2003)	Retain Core Competencies	30
K., Warren, P., Langley (1999)	The Effective Communication of System Dynamics to Improve Insight and Learing in Management Education	31
K.Whitney et.al (2015)	Systems Theory as a Foundation for governance of complex systems	32
L., Berghman, P., Matthyssens, K., Vanderbempt (2006)	Building competencies for new customer value creation	33
M., Doggett et.al (1999)	Technology Management Competencies	34
M., Ivanova (2012)	Social Competencies Identification for Realizationof Successful Engineering Practice	35
M., Kendall, C., Salas, E., Martinez, R., Gonzalez (2018)	Integrating Engineering Leadership Through an Undergraduate Engineering Degree	36
M., Vrazhnova, A., Shastina (2013)	Development Needs of Engineers Relating to Organizational & Managerial Competencies	37
P.A., Hecker (1996)	Human Resouces Strategies for Successful Consulting Engineering Firms	38
P.F., Katina (2015)	Systems Theory-Based Construct for Identifying MetaSystem Pathologies for Complex System Governance	39
P.P., Datta (2018)	Developing Competencies to Lead Innovation in India Manufacturing	40
Project Managment Institute, (2017)	PMBOK	41
R., Dekkers, (2000)	Decision Models for Outsourcing and Core Competencies in Manufacturing	42
R.L., Ackoff (1974)	Managment f-Laws	43
R.L., Ackoff (1999)	Ackoff's Best	44
R.L., Ackoff (2006)	Why Few Organizations Adopt Systems Thinking	45
R.M., Jaradat, C.B. Keating, J.M., Braley (2018)	Individual Capacity & Organizational Competency for Systems Thinking	46
S., Nittala, B.K.,Jesiek (2018)	Work Experiences of Engineering Managers: Challlenges, Strategies, Competencies	47
T., Cerovek et. al (2010)	A Framework Model-Based Competency Management for Design in Physical and Virtual Worlds	48
T., Heston (2019)	Remember your best boss?	49
T., Hutchin (1992)	Developing Competencies in Engineering: The Challenge of the 90s'	50
V., Jovanovic, M., Tomovic (2008)	A Competency Gap In The Comprehensive Design Education	51
V., Liznkov, V., Marchuk, E., Podzorova (2015)	Identification of Criteria, Features and Levels of Economic and Managerial Competencies Development for BS in Mechanical Engineering	52
W., Ravesteijn, E., De Graaff, O., Kroesen (2011)	Engineering the Future: The Social Necessity of Communicative Engineers	53
W., Wu, M., Ying, X., He (2012)	Index System & Benchmark of Competencies in Engineering Management	54
W.R., Peterson, R.E., Landaeta (2005)	Certification of Engineering Managers?	55
W.T., Winklbauer (2012)	Dissertation -Identifying Operations Research Systems Analysts* Technical Competencies	56
Z., Veres (2009)	Competence-Based Risk Preception In Project Buisness	57

Competency Area 1 **Financial Competencies**	**Occurrences Related to EMC**	**Reference to EMC**	**Occurrences Related to FEMC**	**Reference to FEMC**	**Occurrences Related to GAPS**	**Reference to GAPS**
Knowledge of Business Relations (Government, Private Sector, & Foreign)			2	13, 23	1	5
Business	4	26, 15, 3, 18	3	51, 18, 30	3	51, 5, 30
Accounting	1	26,			1	34
Financial Knowledge	1	23	1	23	1	5
Financial Analysis	2	26				
Economic Analysis & Evaluation	3	26, 23, 54	1	53		
Cost Estimation	1	26,				
Ability to forecast and estimate demand of products & services.			1	28		
Marketing	2	29, 48	2	29, 48	1	48
Sales	1	29	1	29		
Understand the Need of Investment to improve technologies					1	40
Knowledge of Impact related to recall of product due to repair or failure (e.g. Max 8 Boeing Aircraft)			1	28		
Cost Assessment via database or systems					1	19

Competency Area 2 **Operation & Method Competencies**	**Occurrences Related to EMC**	**Reference to EMC**	**Occurrences Related to FEMC**	**Reference to FEMC**	**Occurrences Related to GAPS**	**Reference to GAPS**	**Occurrences Related to Systems**	**Reference to Systems**
Operations Knowledge (Core & Enabling Processes -Capabilities)	8	21, 23, 29,50, 54, 36, 42, 34	6	40, 31, 36, 42, 34, 30	2	5, 30		
Controls	2	50, 34	2	34, 30	1	30		
Minimizing Waste	1	10	1	11				
Problem Solving	1	54			1	34		
Risk Assessment	1	23						
Making Decisions regarding capability of operation.	3	29, 37, 42	1	42				
Ability to Document or Record of Decisions Made			1	45	1	45	1	45
Ability to Monitor Decisions	1	45	1	45	1	45	1	45
Strategic Operations Planning	1			23	1	27		
Setting Realistic Goals	3	10, 5, 22						
Knowledge Management	1	27	1	26	1	6		
Project Management	2	23	1	51	2	51, 34		
Sustainability Knowledge			1	40			1	46
Changing Management	1	26			1	5		
Just In Time (JIT) Management	1	50	1	50				
Understanding Constraints	1	50	1	50			1	8
Understand Benchmark Expectations	1	49	1	49				
Understanding benefits of being proactive and creative	2	5, 44			1	44		
Understanding that routines may limit the comprehension of new signals along with the ability to respond.					1	26		
Product Life Extension (e.g. Knowledge of Product Life Cycle. Understand predictive, preventative maintenance, repair, recall, and recycling.)	2	23, 28	3	23, 28			1	8
Understand the Environment			2	28, 29				
Technical Marketing	1	50						
Planning	2	54, 5						
Organizing	1	5						
Ability to Define and Manage Stakeholders expectations			1	3	1	5	1	8
Human Resource Planning & Selection	1	50						
Knowledge of Resources	3	17, 29, 37						
Knowledge of Working Environment (Rotation)	3	26, 21, 27						
Understand a Needs or Problem Statement (Systems)			1	3			1	8
Governance (Systems)	1	54						
Understanding Autonomy	1	25	1	25				
Understanding System Boundaries & Problem Domain							2	8, 46
Knowledge of System Context							1	46
Knowledge of System Output							1	9
Understanding what Problems to Solve (Solving the Right Problems)							1	9
Understanding & Supporting Infrastructure (e.g. processes, support systems, & functions)							1	46

Competency Area 3 **Human/ Relation/ Leadership Competencies**	**Occurrences Related to EMC**	**Reference to EMC**	**Occurrences Related to FEMC**	**Reference to FEMC**	**Occurrences Related to GAPS**	**Reference to GAPS**	**Occurrences Related to Systems**	**Reference to Systems**
Understanding Human Capital Relationships (e.g. Intellectual Capital, Selection of the right people available for assignments)	2	25, 5	2	2, 10	1	19	1	8
Not afraid to tackle Problems	1	1						
Ability of Organization Skills	1	37			1	37		
Concern & Understanding for Others	2	37	1	1				
Making Decisions without Adequate Information -foresight	4	23, 37, 54, 45	2	45, 30	3	45, 5, 30	1	45
Ability to Delegate work	1	47	1	1				
Ability to Adapt to changing conditions	2	37, 35						
Time Management	1	54			1	19		
Understand Emergence			1	3	1	40		
Understanding of Tacit Knowledge			1	2				
Vision	3	23, 50, 34	1	11				
Holistic Perspective (System Vision)			3	3, 2, 51	2	51, 46	4	8, 7, 9, 46
Systems Thinking	2	43, 45	3	3, 43, 45	3	45, 46, 9	6	45, 6, 8, 7, 9, 46
Thinking (Cognitive Component)	3	2, 19, 23	3	26, 23, 40				
Knowledge and appreciation for different perspectives in solving problems							1	8
Knowledge on how to find and select relevant material	2	1, 37			2	27, 40		
Knowledge to align Engineering Management goals & business goals.	2	34, 5	2	19, 23	2	27, 40		
Managing People	5	23, 37, 50, 54, 34	6	1, 23, 40, 34, 34	3	23, 37, 5		
Coordinating & Scheduling	3	15, 37, 50	1	25				
Negotiation	1	26						
Mentoring	6	26, 10, 43, 36, 49, 34	5	1, 43, 36, 49, 34				
Ability to direct	1	5	1	23				
Understand the importance of management involvement (Involvement with workers)	1	25	3	11, 25, 35				
Understanding the Organizational Culture					1	6		
Ability to ask questions					1	19		
Understand & show an interest in development of life-long learning.	3	4, 43, 36	11	1,4, 13, 37, 40, 25, 31, 35, 43, 36, 45	2	37,45	2	45, 46
Assessment of Others	6	26, 37, 25, 49, 18	2	49, 18	1	24		
Understanding tools & metrics used to manage					1	5		
Understanding & skills for knowledge that must be developed to bridge the gap in a firm or companies skill set.					3	28, 37, 45	1	45
Multidisciplinary Teamwork (Working with others in Forming & leading teams.)	8	4, 35, 48	7	1, 4, 11, 23, 35, 51, 48	4	51,48,34, 5		
Ethics & Social Responsibility	2	50, 18	3	13, 35, 18	1	5		
Motivation	4	10, 26, 54, 34						
Cultural Awareness	1	50	4	1, 3, 35	1	5	1	6
Social Competencies	2	26, 35	4	1, 3, 29, 35				
Political			1	53				
Honesty	2	26, 49	1	49				
Loyalty	1	26	1	35				
Trustworthy	1	1						
Responsible	3	1, 34, 22	2	1, 40	1	23		
Behavior & Attitudes	4	15, 19, 37, 54	5	3, 2, 40, 25, 35	1	5		
Ability to Interact with people			1	35	1	19		
Emotional Control	2	54, 34			1	23		
Understands Accountability (Including Self)	2	49, 22	2	25, 49	1	34		
Understand Mistakes	2	43, 49	3	43, 45, 49	1	45	1	45
Understands flexibility for work & schedule			2	25,20	1	20		
Understand Standards, Agreements, Rights	1	18	1	18				
Understand Ready and Willingness	1	43	1	43				
Understand Leadership Traits (e.g. Integrity, self discipline, commitment, persistence, mentor, value others)	1	36	2	23, 36	1	23		
Effective Communication	12	1, 4, 19, 23, 47, 54,35, 43, 48, 34, 5	10	1, 4, 23, 35, 53, 51, 43, 45, 48, 34	6	23, 51, 45,48, 34	2	45, 9
Read	1	1						
Write	1	1	2	1, 51	2	51, 34		
Speak	1	1	1	51	2	51, 34		
Listening			2	1, 51	1	51		
Ability to Explain	1	37	1	1				
Ability to Describe System			1	3				
Ability to Understand	1	50	1	1				
Managing Communication	1	1	1	1				
Foreign Language	2	1, 54	1	1				

Competency Area 4 **Integration/Blending Competencies**	**Occurrences Related to EMC**	**Reference to EMC**	**Occurrences Related to FEMC**	**Reference to FEMC**	**Occurrences Related to GAPS**	**Reference to GAPS**
Managing Activities (e.g. balance of soft & hard, qualitative & quantitative.)	1	11	2	23, 40	1	23
Organizational Practices			3	27, 33, 30	5	24, 37, 47, 5, 30
Understand Policies			1	23		
Network Practices			1	33	1	5
Teaching (transmitting Knowledge)	1	11				
Understand Impact of Environment	1	11				
Understanding the input and inclusion of others (Involvement of Others)	1	15			2	19, 40
Understand realistic expectations					1	19
Iteration	1	15				
Understand how compensation ties to attainment of competencies			2	24, 25	1	24, 22
Driving Teamwork	2	15, 23	2	23, 51		
Not afraid of unstructured situations in teamwork			1	1		
Sharing Objectives	1	15			1	24
International Cooperation (Soft skill knowledge base to drive this work.)			3	1, 13, 30	3	34, 5, 30
Knowledge of cognitive & political problems that occur in team work			1	1		
Understand how competencies help to recruit qualified engineers (e.g. HR)	1	25	2	24, 25	1	19

Competency Area 5 **Technical & Specialty Area Competencies**	**Occurrences Related to EMC**	**Reference to EMC**	**Occurrences Related to FEMC**	**Reference to FEMC**	**Occurrences Related to GAPS**	**Reference to GAPS**	**Occurrences Related to Systems**	**Reference to Systems**
Technical Knowledge	6	23, 54, 50, 42, 49, 34	18	1, 3, 14, 26, 21, 23, 29, 25, 35,50, 53, 51, 42, 48, 49,20, 34	3	12, 51,48		
Ability to Inovate	1	43	1	43				
Ability to Draft Projects	1	50						
Ability to Develop Projects	2	11, 23						
Knowledge of Materials	1	11						
Knowledge of Science	1	10	2	3, 14				
Design Knowledge	1	34						
Knowledge of the empirical Domain	1	10						
Measurement	3	11, 43, 34	2	43, 34				
Calculations	1	11						
Assessment	1	11			1	24		
Appraisals	1	11			1	24		
Surveys	1	11						
Studies	1	11						
Reports	1	11						
Standards, Specifications, Regulations	1	11						
Quality & Statistical Design	3	11,15, 34	1	34				
Software			1	48	1	48		
Reliability	1	34	1	34				
Optimization Analysis	1	1	1	14				
Understanding Feasablity					1	46		
Understand Global Risks			1	3				
Creative Approach	1	35						
Systems			1	3				
Ability to Compare & Contrast System Models to Meet a Balanced Solution.			1	3				
Create System Architecture (e.g. System Foundations)			1	3			1	46
Ability to define technical System requirements.	1	34	1	3	1	47		
Ability to Logically Decompose a System			1	3				
Ability to Identify Interactions, Relationships, and Patterns							1	8
Ability to Frame and Re-Frame Problems					1	8	1	8
Ability to Define a System Design Solution.			2	3, 51	1	51	1	7
Ability to Change	1	43	1	43			1	46

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EDUCATION

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B.S. Mechanical Engineering, Apr 2008
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A.S. Pre-Engineering, May 2005
Salt Lake Community College, Taylorsville, UT, USA
A.S. General Studies, Aug 2001
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PROFESSIONAL EXPERIENCE

Manufacturing Engineer and Planner, Complex Fabricators, Salt Lake City, UT	2016 – Present
R&D Engineer, Bullfrog Spas, Bluffdale, UT	2015 – 2016
Engineer & Design/Drafter, Bonneville Machine, Salt Lake City, UT	2014 – 2015
Mechanical Engineer, ITT Corporation, North Salt Lake City, UT	2011 – 2014
Reliability Engineer, Utah Kennecott Copper, Salt Lake City, UT	2008 – 2010
Internship (BYU Capstone), American Railcar Ind, St. Charles, MO	2007 – 2008
Mathematics Tutor & Instructor, Salt Lake Community College, Taylorsville, UT	2003 – 2011