THE USE OF SYSTEMS THINKING BY THE INDUSTRIAL ENGINEER AS ORGANIZATIONAL LEADER

by

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ABSTRACT

While industrial engineers are important to operations, the macro changes in the nature of the economic environment have created the opportunity for their profession to evolve. This evolution has provided the opportunity for industrial engineers to rise into leadership positions. In terms of organizational performance, the focus of systems thinking is a holistic attitude, working to guarantee the success of the organization by concentrating on quality, productivity, and profit, and how these components work together. Systems thinking is a framework for seeing interrelationships rather than seeing components separately. A review of literature examined the theory of systems, the background and growth of systems thinking usage in current organizations, and the historical role of industrial engineering. The study serves as a meaningful contribution to the profession of industrial engineering and the framework of systems thinking skills.

In order to investigate the relationship of systems thinking skills and technical industrial engineering skills to managerial transition success, 376 members of the Institute of Industrial Engineers were surveyed using the Systems Thinking and Technical Skills Use survey instrument. An analysis of the data showed positive significant correlation between systems thinking skills and technical industrial engineering skills to transition success among industrial engineers. The study also showed there is a relationship between factors, created by combining systems thinking skills and technical industrial engineering skills, and transition success. Finally, a regression model was developed for industrial engineers to utilize for successful transition to management. Industrial engineers who seek to make a successful transition to management will benefit from the valuable insights and conclusions derived in this research study.

Keywords: Systems thinking, industrial engineering, transition, management

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Background

Industrial engineers do more than just perform time studies; they are active contributors to bottom line performance. A number of current and former Fortune 500 CEOs have industrial engineering backgrounds: Timothy Cook, CEO Apple; Edward Whitacre, former CEO at AT&T and GM; Lido “Lee” Iacocca, former Chrysler CEO; and Michael Duke, former CEO Walmart. Additionally, an increasing number of industrial engineers are moving into leadership roles at all levels in various industries: Joseph Girardi, New York Yankees manager; Shahid Khan, Jacksonville Jaguars owner; and Joe Barton, Texas Congressman.

In its 2008-2018 National Employment Matrix, the U.S. Bureau of Labor Statistics indicated the level of growth for industrial engineers would increase by 20% in the ten-year time frame between 2008-2018, significantly faster than mechanical, civil, environmental, and electrical engineers as shown in Table 1. All other major engineering disciplines grew a total 16.5% with no discipline greater than 5.5% growth.

Table 1

Management employment by industry, occupation, and percent distribution, 2008 and projected 2018

Management of companies and enterprises	2008		Projected 2018		Change, 2008-2018	
	Management Employment (thousands)	Percent of Occupation	Management Employment (thousands)	Percent of Occupation	Management Employment (thousands)	Percent of Occupation
Industrial Engineering	10.1	4.71	12.2	4.95	2.0	20.0
Environmental Engineering	1.0	1.82	1.0	1.47	0.1	5.5
Electrical Engineering	3.4	2.17	3.6	2.22	0.1	4.4
Mechanical Engineering	6.2	2.60	6.5	2.56	0.3	4.4
Civil Engineering	1.8	0.66	1.9	0.55	0.0	2.2

Created by author with information from *United States Bureau of Labor Statistics (2012).*

Not only are organizations beginning to realize the value of industrial engineers, but the profession's premier professional society, the Institute of Industrial Engineers, has also recognized the changing role of its members. Founded in 1948, "The Institute of Industrial Engineers is an international, nonprofit association that provides leadership for the application, education, training, research, and development of industrial engineering" (Institute of Industrial Engineers, 2012a, para. 1). It "is the world's largest professional society dedicated solely to the support of the industrial engineering profession and individuals involved with improving quality and productivity" (Institute of Industrial Engineers, 2012a, para. 1).

Historically, industrial engineering was "concerned with the design, improvement, and installation of integrated systems of people, materials, equipment, and energy. It drew upon specialized knowledge and skills in the mathematical, physical and social sciences together with the principles and methods of engineering analysis and design to specify, predict, and evaluate the results to be obtained from such systems" (Martin-Vega, 2001, p. 1.11).

In contrast to the historical definition, during the 2010 annual Institute of Industrial Engineers conference, papers were requested on the transition from technical industrial engineers to industrial engineers in management. While industrial engineers are important to manufacturing operations, the macro changes in the nature of the economic environment have created the opportunity for the industrial engineering profession to evolve, including the opportunity for industrial engineers to rise into leadership and management positions. For example, according to the United States Bureau of Labor Statistics (2012), 10,100 industrial engineers were working as managers of companies and enterprises. In 2018, the forecasted number will rise to 12,200, a 21% increase. The other engineering disciplines average a percent increase of only 4.1% with environmental engineering ranking highest at 5.5%.

Starting in the 1950s, corporations in North America and Western Europe found themselves operating within a new environment as advanced societies began—slowly at first and then ever more rapidly—to make the transition from industrial age to knowledge age economies. Stewart (1997) wrote, in a knowledge age economy, knowledge plays a more direct and greater role in wealth creation, and the leaders and managers of organizations in this type of economy must be able to lead and manage the acquisition, creation, and competitive use of knowledge effectively. Successful knowledge age organizations are complex, open, and adaptive; learning systems and systems thinking is an essential tool for leading and managing such organizations.

In this new environment, industrial engineers also have found themselves making a transition from their traditional technical industrial engineering role to the new managerial industrial engineering role because transformational firms are using them in unique and changing ways. For example, industrial engineers have “combined their technical skills with people skills, which have proven to be important in project and people management” (Boggs, 1996, p. 14). Despite being faced “with a very different set of circumstances than those encountered by their predecessors three decades ago,” industrial engineers are able to prosper and to attain leadership and management roles by transitioning from technical industrial engineers to industrial engineers in management (Merino & Farr, 2010, p. 246).

Industrial engineers have many skills to contribute to organizational performance in contemporary organizations, including systems thinking skills, which are “thinking skills that requires intensive practice and patience” (Richmond, 2000, pp. 3-4). This study uses Barry Richmond’s (2000) seven essential systems thinking skills—dynamic thinking, system-as-cause thinking, forest thinking, operational thinking, closed-loop thinking, quantitative thinking, and scientific thinking. The study investigates the extent to which systems thinking contributes to the success among industrial engineers in various states of transitioning into leadership and management positions within their current organizations. Additionally, the study adopts those skills considered by the Institute of Industrial Engineers to be the fundamental concepts and principles of industrial engineering. These ten skills include time studies, statistical analysis, simulation modeling and analysis, ergonomics, project management, process improvement, engineering economics, production planning and control, performance metrics, and logistics. The study also uses the three levels of management identified by Badawy (1982) with an additional level of engineers who have not transitioned to management. These levels include industrial engineer, junior industrial engineer, senior industrial engineers or principal industrial engineer; supervisor, or manager; director, section manager, or unit manager; and president or vice-president.

Purpose of Study

The purpose of this study was to explore the theory of systems that relates systems thinking to transition success into organizational management among industrial engineers. The population includes members of the Institute of Industrial Engineers that have been or are currently employed in any industry. Currently, there is little research on the industrial engineer's use of systems thinking skills, and this study will help to address this deficiency. Industrial engineering provides a foundation of skills rooted in scientific management. The principal object of this theory of management was securing "the maximum prosperity for the employer, coupled with the maximum prosperity for each employee" (Wren, 2005, p. 145). The researcher theorizes that by incorporating systems thinking skills into their work activities as industrial engineers, they are able to successfully transition into management and organizational leadership.

Systems thinking skills enable users in knowledge-intensive organizations to see "the world in new, more dynamic and holistic ways, which is really the most powerful advantage that systems thinking offers" (Richmond, 2000, p. 3). Furthermore, according to Merino and Farr (2010), "systems thinking can provide a valuable capability for engineering managers to more effectively deal with complex problems" (p. 265). A review of the relevant literature strengthens the researcher's position that industrial engineers are systems thinkers, and that industrial engineers leverage systems thinking skills in both technical and managerial roles within organizations. By investigating the link between systems thinking and the transition success of industrial engineers, this researcher provides evidence explaining why industrial engineers appear to have greater facility in transitioning into management and leadership roles in today's organizations. The results of this study also provide greater direction for upward mobility, education, and on-the-job training of industrial engineers.

Rationale of the Study

The Industrial Revolution changed society in very fundamental ways. The move from an agrarian society to a mechanized society gave rise to new occupations. During the Industrial Revolution time period, managers were boss-centered, namely autocratic in their leadership style, and they managed from the top down with little or no input from those whom they managed. McGregor (1960) expanded "the idea that managerial assumptions about human nature and human behavior were all important in determining manager's styles of operating" (p. 33). The Industrial Revolution gave rise to a number of leadership styles such as McGregor's Theory X (boss-centered) and Theory Y (employee-centered), where employee-centered leaders accepted the input of others into management decisions.

Umpleby and Dent (1999) found that with globalization, "there is an emphasis on increasing the autonomy of the workers, reducing hierarchical relationships, increasing feedback throughout the production process, having good relationships with customers and suppliers, measuring results, and testing innovations on a small scale" (p. 90). Emphasis grew for quality control and process-improvement data, which typically were generated by the industrial engineers of the organization. Consequently, industrial engineers were able to provide information to management from all areas of the organization, and managers were then able to make more informed data-based decisions.

At the point when systems thinking originated in the 1950s, “knowledge had become the primary ingredient of what we make, do, buy and sell” (Stewart, 1997, p. 12). Eventually, Stewart (1997) argued knowledge became “the preeminent economic resource— more important than raw material; more important, often, than money” (p. 6). Upon the introduction of systems thinking, emphasis shifted from dissecting a problem or an organization into its parts to considering the organization as a whole, as something greater than the sum of its parts. Systems thinking was not introduced as a proverbial “silver bullet”; rather, it is a sound philosophy that “has been around in forms dating to the time of Aristotle, suggesting that in the whole we find something not found in the parts” (Merino & Farr, 2010, p. 250). While there is no universally accepted definition of systems thinking, there are several common themes: a way of thinking, holism versus reductionism, interrelationships, patterns, context, and environment (Merino & Farr, 2010, p. 251).

Systems thinking is applicable to many intellectual domains beyond engineering including biological, economic, social, organizational, and managerial studies. Subsequently, Merino and Farr (2010) found “there is a need to arm future engineering managers with the capabilities and skills that will increase the probability of success in managing” (p. 246). Engineers with a mastery of these capabilities and skills will quickly rise to the top of any organization in the drastically changing landscape of the 21st century leader and manager. A reason for this success in upward mobility may be because of the use and extent of systems thinking experiences of current managers. Atwater, Kannan, and Stephens (2008) noted “it is important to assess how effectively managers are being prepared to face these ever increasing challenges…” and the “…development of systemic thinking skills is an essential evolution in management education” (Atwater, Kannan, & Stephens, 2008, pp. 9-10).

Because industrial engineers are making a successful transition to the management side of the organization, the Institute of Industrial Engineers, in 2008, proposed its institutional name be changed to the Institute of Industrial and Systems Engineers. The Institute of Industrial Engineers leadership argued that adding “systems” to its name reflects the added value and importance of systems thinking in the field of industrial engineering. The name change was presented to the Institute’s membership and a debate ensued on whether 1) incorporating “systems” into the name “would bring clarity and cohesion to the Institute of Industrial Engineers and the profession” or 2) by not changing the name, the Institute of Industrial Engineers can “claim and promote all the jobs and techniques that [industrial engineers] perform, including systems thinking” (Elliott, 2008, p. 46).

This name change was given strong consideration; however, the proposal failed because members believed that “the word ‘industrial’ holds traditional roots” (Elliott, 2008, p. 46). “The Institute has grown and prospered under its current name and has a rich history filled with professional pioneers such as Frederick Taylor and Frank and Lillian Gilbreth” (Elliott, 2008, p. 47). Institute of Industrial Engineers Executive Director Don Greene stated, “With this vote [to reject the name change], the members have affirmed the breadth of industrial engineering. Although our profession undoubtedly encompasses a systems approach, it isn't necessary to communicate the broad reach that IE has through our name alone” (Fraser & Gosavi, 2010, p. 1-2). As of 2014, the Institute of Industrial Engineers has not moved to include systems in their name. However, by acknowledging the importance of systems and systems thinking in its proposed name, the Institute of Industrial Engineers acknowledged the role that both industrial and systems engineers and systems thinking have in organizations.

The significance of this study is that it will provide research on the use of technical and systems thinking skills by industrial engineers. The research of the study can be used directly by industrial engineering practitioners to further develop their skill set and drive them toward management roles in their organizations. “As [industrial engineers] have gradually branched out into various types of industries, it has been harder and harder to define succinctly what [they] do” (Elliott, 2008, para. 2). Consequently, industrial engineers see themselves as having great impact on the organization, and many possess a desire to move up in the organizational ranks, but often they do not have a clear understanding of what they need to understand and do to get there. The researcher hypothesizes that today’s industrial engineers do not have a clear understanding of the extent to which systems thinking helps them reach their goal of management in the organization.

Problem Statement

Even though industrial engineers have systems thinking skills to contribute to organizational performance, the problem is today’s industrial engineers, who aspire to become organizational managers, lack knowledge of the scope of systems thinking skills used with their technical engineering activities and the extent to which each are applied in their organizations for advancement into management and leadership positions. The purpose of this study is to explore the theory of systems that relates systems thinking to transition success into organizational management among industrial engineers. The engineers used in the study are members of the Institute of Industrial Engineers and currently employed in any industry.

The independent variables, systems thinking and technical industrial engineering skills, will be defined as the seven systems thinking skills identified by Barry Richmond (2000) and the ten technical industrial engineering skills identified by the Institute of Industrial Engineers. The dependent variable, transition success, will be defined using the three levels of management identified by Badawy (1982) and one non-management level of engineers. Badawy's management levels begin with supervisor. In order to capture the working level engineer, the researcher added a Level 0. Level 0 is considered non-management and provides a skill usage prior to managerial transition.

Research Questions

There are four research questions that will be used to determine the relationship between the independent variables and the dependent variable and thereby to address the overarching problem statement. These questions are:

1. What systems thinking skills correlate with the industrial engineer's successful transition to management?
2. What technical industrial engineering skills correlate with the industrial engineer's successful transition to management?
3. Do systems thinking skills and technical industrial engineering skills contribute to the industrial engineer's successful transition to management?

4. Is skill in systems thinking a predictor of organizational management transition success among industrial engineers?

CHAPTER 2: REVIEW OF LITERATURE

Literature Overview

There is extensive literature related to the theory of systems, systems thinking, and transition success to management. This literature review begins by providing an overview on the evolution of systems theory in understanding and leading organizations. It explores the influence of systems thinking on the engineering profession and reasons why the use of systems thinking is especially important in the effort to lead complex, hyper-dynamic, and globally-oriented organizations of the 21st century. Then, the review presents the development of the industrial engineering profession and the skills used among technical industrial engineers. Seven systems thinking skills and ten technical industrial engineering skills serve as the independent variables for this study. This review of the literature then focuses on research related to the dependent variable described as transition success to management and concludes with this study's problem statement and research questions.

The Evolution of Systems Theory

In his work, *Metaphysics*, Aristotle noted, "the totality is not, as it were, a mere heap, but the whole is something besides the parts" (Aristotle, trans. 1994, Book 8 Part 6). However, in the scientific revolution initiated by Sir Isaac Newton in the 17th century, Aristotle's concept became obscured by the typically static ontology and by the analytical and reductionist approach of the scientific method as it evolved in the 18th, 19th, and 20th centuries. Although systems thinking has been around since Aristotle and employed by

Aquinas and others, it had a rebirth in the 1920s when biologists noted the complexity of the organisms they were studying. These biologists began to focus more on the organism as a whole system, openly related to other systems in the larger environment. In essence, Aristotle's idea, commonly expressed today as "the whole is greater than the sum of its parts" (*Metaphysics*) became a major driver in shifting focus to the system. The idea of using a system to understand most any phenomenon of reality is attributed to biologist Ludwig von Bertalanffy's work (1968). The Austrian born biologist developed general systems theory (GST) in 1954 and his goal was to "find a unity of science for all complex living things on earth" (Haines, 2010, p. 1).

GST began as an "idea that systems had general characteristics independent of the scientific areas to which they belonged" (Skyttner, 2005, p. 39). Von Bertalanffy was one of the first to argue that a traditional closed system model based on classical science was not applicable to the characteristics of a dynamic, living system. The "theory of open systems was advanced, based on the rather trivial fact that the organism happened to be an open system" (von Bertalanffy, 1968, p. 13). It was von Bertalanffy "who suggested generalizing the thinking to refer to any kind of whole, not simply to biological systems" (Checkland, 1999b, p. 75). He thought it completely reasonable to ask "for a theory, not of systems of a more or less special kind, but of universal principles applying to systems in general" (von Bertalanffy, 1968, p. 32). Instead of explaining observable phenomena by investigating the units independently of each other, GST is rooted in wholeness and the interrelationships between units.

General systems theory has three main aspects that are based on relationships and are distinguishable by their intention. The first aspect is systems science, which is “scientific exploration and theory of ‘systems’ in the various sciences and general systems theory as the doctrine of principles applying to all systems” (von Bertalanffy, 1972, p. 414). General systems theory is often described as “the skeleton of science in that it attempts to provide a framework of systems” (Boulding, 1956, p. 208) so that other subjects can be organized and derived from the general body of systemic knowledge. The second aspect is systems technology, “arising in modern technology and society, including both ‘hardware’ and ‘software’” (von Bertalanffy, 1972, p. 420). Even at the time von Bertalanffy developed GST, modern technology and society had become so complex that traditional branches of technology were no longer sufficient; thus, the shift to a holistic or system-based general focus became prominent. The third and final aspect is systems philosophy, which is reorienting thought and world view to encompass the system as a new way of thinking (von Bertalanffy, 1972, p. 421). The concept of a system constituted a new paradigm or a new philosophy of nature that contrasted with the existing blind laws of nature and introduced the world as a great organization.

In his works, von Bertalanffy saw systems as mostly organic. Since his work, systems have been additionally described as mechanical and social. For example, Ackoff (1994) saw organizations as social systems and described a system as a whole consisting of two or more parts and each part “can affect the performance or properties of the whole, none of which can have an independent effect on the whole, and no subgroup of which can have an independent effect on the whole” (p. 175). By classifying the organization as a social system, leaders and managers who are capable of systems thinking can recognize the essential role that people play, which can be understood and managed. General systems theory was revolutionary for its time, because it emphasized the interrelatedness of reality. It was a “way of seeing things which were previously overlooked or bypassed” (von Bertalanffy, 1972, p. 424). GST provided the impetus for what eventually became systems thinking, which is thriving today.

Another theory developed about the same time as GST is von Foerster’s work on second order cybernetics in which he examines complex systems using mathematics. GST studies systems at the general level whereas “cybernetics focuses more specifically on goal-directed, functional systems which have some form of control relation” (Heylighen & Joslyn, 2001, p. 2).

Autopoesis developed by Maturana and Varela in the early 1970s is another attempt at explaining the nature of living systems, including social systems. A theory that began in an attempt to discover what distinguishes living systems from other non-living systems ended by transcending “a common systems distinction between hard and soft, beginning, as it does, with natural science” (Mingers, 1995, p. 5).

Social systems theory is also a forerunner of systems thinking. Developed by Niklas Luhmann (1984/1995), there are three main topics: systems theory as societal theory, communication theory and evolution theory. Luhmann's theory on social systems opened a “radical new perspective on society, with its subsystems like economy, law, politics, science, art, education, and even love” (Kieser, 2007, p. 991). Luhmann argued that “each of these systems performs a specific function and develops its specific communication mode” (Kieser, 2007, p. 991).

Another important systems theory is complex adaptive systems (CAS) that focuses on the macroscopic properties of the system. “Cas [complex adaptive systems] are systems that have a large number of components, often called agents that interact and adapt or learn" (Holland, 2006, p. 1). In addition, "complex adaptive systems—systems that involve many components that adapt or learn as they interact—are at the heart of important contemporary problems" (Holland, 2006, p. 1). The CAS theory as well as autopoesis, second order cybernetics, and social systems theory all play a role in moving from von Bertalanffy's GST to an understanding of systems thinking. These theories all attempt to explain the role of systems with regards to living, biological systems as well as organizational systems.

Systems Thinking

This section of the review focuses on scholarly research related to systems thinking in influencing social systems, particularly organizational leadership and management. Recent key figures include W.E. Deming and Peter Senge, two individuals who used systems thinking in their consulting with top CEOs and government leaders, influencing both leadership and management thinking, respectively.

W. Edwards Deming's most notable contributions were the utilization of systems thinking as an important component of good management practices, including his 14 points of management (1986, pp. 23-24) and seven deadly sins of business (1986, pp. 97-98). By providing management with an innovative approach to business, he saved the post WWII nation of Japan from economic ruin and put the United States on the fast track to business success. His life, work, philosophy, and methods remain some of the greatest business innovations.

Systems thinking is a major component of the "system of profound knowledge" used extensively by Deming (2000). This way of thinking addressed the need for the transformation needed in industry, education, and government. Deming and other systems thinkers "focus on the whole, paying attention to the interactions between the parts rather than the parts themselves" (Prevette, 2003, p. 33). Systems thinking has evolved over the past 50 years as systems thinkers continue to build upon the work of others.

Systems thinking has been defined in many ways. In terms of leadership and management, there is an emphasis on "increasing the autonomy of workers, reducing hierarchical relationships, increasing feedback throughout the production process, having good relationships with customers and suppliers, measuring results, and testing innovations on a small scale" (Umpleby & Dent, 1999, p. 91). In terms of organizational quality performance, the focus is with a holistic attitude, working to guarantee the success of the organization by concentrating on quality, productivity, profit, and how these components work together. According to Senge (2006), "systems thinking is a conceptual framework, a body of knowledge and tools to make the full patterns clearer, for seeing interrelationships rather than seeing components separately" (p. 7).

The use of systems thinking in the leadership and management of organizations "is characterized by long-term vision and achievement of long-term profits" (Prevette, 2003, p. 33). It requires organizations to focus on the long-term and the life-cycle costs of a product. A system is made up of a set of parts and systems thinkers realize that each part can affect the system and each part has an effect on other parts. Systems thinkers operate under the principle that "no part can have an independent effect on the whole" (Prevette, 2003, p. 33). Deming attained worldwide recognition by teaching Japanese engineers and their top management "statistical methods and how to view production as a system that included suppliers and consumers" (Landesberg, 1999, p. 59).

At the heart of W. Edwards Deming's management model lie 14 points on which his philosophies are based, and they form "the basis for transformation of American industry" (Deming, 1986, p. 23). In *Out of the Crisis* (1986), Deming introduced the 14 points for management which relate to the leadership and management of an organization from a systems perspective in several ways. Deming believed that "the job of management is not supervision, but leadership" (1986, p. 54). Deming believed that success was only possible through a leader who does not treat every fault as a special case; rather, the entire system must be understood. Furthermore, leaders must create and foster a secure environment. "No one can put in his best performance unless he feels secure" (Deming, 1986, p. 59). Most importantly, organizations with a systems perspective cannot fear knowledge. "There is widespread resistance of knowledge. . . . A better outlook is of course to embrace new knowledge because it might help us to do a better job" (Deming, 1986, p. 60).

According to Deming (2000), a system "is a network of interdependent components that work together to try to accomplish the aim of the system" (p. 50). A system must have an aim, and this "aim must be clear to everyone in the system and include plans for the future" (Deming, 2000, p. 40). However, the components of the system need not all be clearly defined or documented as "people may merely do what needs to be done" (Deming, 2000, p. 50). The system must be managed though because the components are naturally competitive. Cooperation is the key, and it is leadership's and management's job "to direct the efforts of all components toward the aim of the system" (Deming, 2000, p. 50).

Perhaps the most profound result of systems thinking is that complexity is reduced and an overwhelming number of intangible benefits are gained. These intangible benefits "were what brought about the unexpectedly larger increases in productivity, on top of what could have been expected in gains out of what was worked on directly" (Delavigne & Robertson, 1994, p. 89). In other words, by focusing upon improving the system as a whole, systems thinkers gain a ripple effect and a compounding effect of benefits through the interaction of improved parts with one another and with the whole.

Another important figure, Peter Senge, a professor at M.I.T, received a B.S. in aerospace engineering from Stanford University, an M.S. in social systems modeling, and a Ph.D. in management from M.I.T. An engineer by training, Senge extensively wrote about what he and others learned from pioneering consulting work with Ford, Chrysler, Shell, AT&T, Hannover Insurance, and Harley Davidson. He first achieved notoriety in the 1990s when he emerged as a major figure in organizational development with his book, *The Fifth Discipline*. In the book, he further developed the idea of the "learning organization," which is dependent for success upon the fifth discipline of the learning organization, viz., systems thinking. In this book, Senge thought of organizations as dynamic systems in a state of continuous improvement.

Senge (2006) determined that "systems thinking is a conceptual framework, a body of knowledge and tools that has been developed over the past fifty years, to make the full patterns clearer, and to help us see how to change them effectively" (p. 7). Senge (2006) claimed that "the prevailing system of management is, at its core, dedicated to mediocrity" (p. xviii). The learning organization is one that is able to pull itself away from mediocrity and instead focus on several core ideas as outlined in *The Fifth Discipline*. First, Senge thought "working together is more satisfying and more productive than the prevailing system of management" (2006, p. xviii). Second, organizations work on the basis of how their members think and interact, and at the heart of successful organizational change is its people. Finally "in building learning organizations, there is no ultimate destination or end state, only a lifelong journey" (Senge, 2006, p. xviii). Senge concluded that "systems thinking" is a management paradigm that is desperately needed because people love to put together a puzzle and see the whole emerge. He argues that "the unhealthiness of our world today is in direct proportion to our inability to see it as a whole" (Senge, 2006, p. 68). Senge (2006) further noted of systems thinking, "it is a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static 'snapshots'" (p. 68).

By viewing knowledge, people, and organizations as living systems, Senge showed it is possible to get people to work together to create value. Along these same lines, Senge determined that successful systems thinkers are able to impact the core of the organization. By impacting the core, change comes from the inside out. Programs that work from the top down or from the outside in cause "many in the organization to feel threatened or manipulated" (Senge, 1999, p. 14). Senge has chosen to focus on the internal leaders to avoid these feelings of mistrust induced from outside. This does not mean top managers, it means "leadership as the capacity of a human community to shape its future, and specifically to sustain the significant processes of change required to do so" (Senge, 1999, p. 16). Senge observed that systems thinking developed over the course of many decades and spans a diverse group of fields including the natural and social sciences, engineering, and management. Overall, he views systems thinking as sensible and claims it is needed now more than ever because our society is overwhelmed by complexity. It “is the antidote to this sense of helplessness that many feel as we enter the ‘age of interdependence’” (Senge, 2006, p. 69).

In his work, *The Fifth Discipline,* Peter Senge (2006) posited systems thinking to be the cornerstone of his five learning disciplines of how learning organizations think about their world. Real systems thinking does not allow people to fight complexity with complexity or devise complex solutions to increasingly complex problems. Systems thinking will ultimately simplify life “by helping us see the deeper patterns lying behind the events and the details” (Senge, 2006, p. 73). Systems thinking all starts with an understanding of feedback. By understanding feedback, systems thinkers can begin to build learning and recognize when things recur again and again.

“Reinforcing and balancing feedback loops and delays are the building blocks of systems thinking” (Senge, 2006, p. 79). In the past, many situations required no more than a simple linear description. However, feedback processes are essential when dealing with the dynamic and complex problems in today’s environment. Senge (2006) states “the systems viewpoint is geared toward the long-term view. This is why feedback loops are so important” (p. 91). In the short term, delays and feedback can be ignored, but they always catch up. “That’s one of the lessons of balancing loops with delays: that aggressive action often produces exactly the opposite of what is intended” (Senge, 2006, p. 91). Systems thinking, using feedback loops and delays, teaches us again and again that certain patterns of structure keep returning.

Senge and Deming proposed that successful leadership required something special from the leader. They all also indicated that this special talent can be taught later in life, but it will not be totally mastered unless it is intrinsic and comes up the leadership and management chain with the leader. Most people have “been socialized in ways of thinking and acting that were embedded in their most formative institutional experiences,” (Senge, 2006, p. xiii) and this non-systems oriented socialization sometimes makes it difficult for some people to learn to think with a systems perspective. Systems thinking can and should be part of the educational experience beginning in the primary years, according to both Deming and Senge, so that future generations find this way of thinking to be second nature. Until that time when the schools of thought developed by these important figures becomes second nature, it is important to continue developing, understanding, and implementing a systems mindset wherever possible. Industrial engineers, by nature, are trained systems thinkers and key players in this process of systems thinking.

Because of systems thinking, Ion Georgiou (2007) said he gained “a lifelong motivation which propels one to continue to learn, to write, to exchange the most intangible human product of them all and yet one with profoundly tangible consequences: ideas” (p. xi). Georgiou (2007) wrote that contrary to the seemingly scapegoating use of the word, “systemic” problems really can exist with the system as a whole. No one part can be blamed for failure or praised for success. However, this goes against the grain of the innate desire to “point the finger,” “quelch the anger,” and “take the blame” (Georgiou, 2007, p. 6). Instead of handing out blame, systems thinking attempts to redesign the situation so that “blame takes a back seat in systemic problem resolution—if it has any at all—and the demanding search for systemic causes begins" (Georgiou, 2007, p. 6). Systems thinking allows the practitioner to step back from the situation and consider the very real possibility that the situation itself enabled the problem to arise.

There is surely much value to be gained by employing systems thinking. Perhaps most importantly, "the systems approach reveals how a system causes its own behavior and thus points the way towards resolving undesirable consequences stemming from this self-induced cause" (Georgiou, 2007, p. 11). By gaining an understanding of the system, the systems thinker can model and solve problems by mapping out the interrelationships of a situation, inviting consensus, and demanding more of those affected by the system. A holistic, or systemic, approach to problem solving can have dramatic and lasting effects on the organization. Those systems thinkers that bring their holistic knowledge to the leadership level are able to affect lasting and profound change in the organization.

Related Systems Theories

Industrial engineers use operations research as "a systematic approach to solving problems, which uses one or more analytical tools in the process of analysis" (Rajgopal, 2001, p. 11.29). Therefore, operations research is an important related theory to the systems thinking skills used by industrial engineers. Operations research comes in two distinct varieties, hard operations research and soft operations research, and both of these are important related theories in the system methodologies world.

In the 1960s, operations research began to show that well-structured recurring situations could be modeled quantitatively and that modeling offered useful results to aid decision making. Hard operations research was thought to be that which is quantifiable and able to be modeled. Soft operations research was more of an approach to problem solving. In relation to hard operations research and soft operations research, system dynamics is most usually classified as hard, whereas, Soft Systems Methodology and systems thinking are considered soft.

System dynamics, developed by Jay Wright Forrester in the 1950s, is directly related to systems thinking. System dynamics was developed because, according to Forrester, there was “no widespread realization of the complexity of social systems, people are easily beguiled into believing that systems thinking is sufficient” (2010, p. 1). Forrester took offense to the belief that system dynamics along with soft operations research evolved “as a reaction against the inability of classical or ‘hard’ operations research to deal with the major issues of interest to managers and political leaders” (Forrester, 1994, p. 8). He held the belief that “ineffectiveness of hard [operations research] arose, not from differences between physical and social systems, but from two aspects of the operations research practice” (Forrester, 1994, p. 8). The two aspects include the adoption of inappropriate mathematical methods by hard operations research and that “hard [operations research] became an academic discipline rather than a practical profession” (Forrester, 1994, p. 8).

Through his work experiences, Forrester (1999) realized “change is more the essence of the manager’s environment” (p.1). It was clear to him that nonlinear relationships that control the course of events were more significant and interrelationships of factors more complex than those challenges that the normal engineer faced. Because of this complexity, Forrester (1999) saw management as art based on “an underlying structure of principles and science” (p. 1). Forrester developed system dynamics to assist working engineers and managers alike in understanding and solving the organization’s problems. System dynamics “provides a basis for the design of more effective industrial and economic systems” and “provides a single framework for integrating the functional areas of management, marketing, production, accounting, research and development, and capital investment” (Forrester, 1999, p. 13). Most importantly, and a major distinguishing characteristic, “it is a quantitative and experimental approach for relating organizational structure and corporate policy to industrial growth and stability” (Forrester, 1999, p. 13).

In Forrester’s view, there is some distinction that can be made between systems thinking and system dynamics. While both are based on the system, the two are independent theories. Systems thinking developed out of the management field, whereas, system dynamics developed from engineering and attempts to “contribute rigor and clarity to systems thinking and soft [operations research]” (Forrester, 1994, p. 1). This study focuses on how industrial engineers move through management, not how they employ the skills of systems dynamics. Forrester (2007a) viewed systems thinking as a small management-focused subset of system dynamics, a door opener that “calls attention to the existence of systems” (p. 355). However, system dynamics does not shy away from major real-world issues but, without a plethora of training, many are unable to reach the full potential of system dynamics.

It is hard to deny that the overlap of systems dynamics and systems thinking is “very substantial, and the differences are more in orientation and emphasis than in essence” (Richmond, 1994, p. 1). By pushing the envelope and thinking outside the box, systems thinkers are able to focus on grander and continually improving interactions.

Soft systems methodology is another related theory that serves as a background to the systems thinking approach. Soft systems methodology "was developed as a result of the failure of [traditional systems engineering] in many management situations" (Mingers & White, 2010, p. 1151). Soft systems methodology can be thought of in terms of its three part functionality: "the recording of an understanding of a problematic situation, the identification of the required changes to enable resolution, and the design of models for operationalizing these changes" (Georgiou, 2011, p. 6). Incorporating the components of soft systems methodology, systems thinking developed as a methodology due to researchers "attempting to use the ideas of 'hard' systems thinking in 'soft' problems, moving away from the 'hard' engineering tradition when forced to do so by the difficulties of actual situations" (Checkland, 1999a, p. 189). Checkland (1999a) explained "the main difference between 'hard' and 'soft' approaches as that where the former can start by asking 'What system has to be engineered to solve the problem?'… and can take the problem or the need as 'given', the latter has to allow completely unexpected answers to emerge at later stages" (pp. 190-191).

System Thinking Skills

When systems thinking is viewed as a discipline, Barry Richmond, a former student under Jay Forrester at MIT, claimed that systems thinking "requires mastering a whole package of thinking skills that requires intensive practice and patience" (Richmond, 2000, pp. 3-4). Richmond worked to build the capacity of people to understand systems thinking. In order to practice the discipline of systems thinking, Richmond (2000) developed a series of "seven different cognitive processes that seasoned systems thinkers employ as they address problems or concerns from a systems thinking perspective” (Richmond, 2000, p. 3). Several studies (Brewster, 2011; Davidz, Nightingale & Rhodes, 2004; and Maani & Maharaj, 2004) have used Richmond’s seven essential systems thinking skills.

Richmond (2000) noted that there are seven essential skills: dynamic thinking, system-as-cause thinking, forest thinking, operational thinking, closed-loop thinking, quantitative thinking, and scientific thinking. These seven skills, which serve as independent variables in this study, are listed below in the order in which they should be mastered because, according to Richmond (2000), one must develop each precedent skill in order to use those that follow. Richmond’s (2000) definitions of the skills were used to construct the questions in the survey instrument. The list of system thinking skills used in the study can be found in Figure 1.

Systems Thinking Skills

1. Dynamic Thinking
2. System-as-Cause Thinking
3. Forest Thinking
4. Operational Thinking
5. Closed-Loop Thinking
6. Quantitative Thinking
7. Scientific Thinking

Figure 1. Systems thinking skills according to Richmond (2000)

Dynamic thinking is the first of the systems thinking skills because a practitioner must be able to think dynamically in order to use the other six skills. Dynamic thinking enables systems thinkers “to frame a problem or issue in terms of a pattern of behavior over time" (Richmond, 2000, p. 5). Mastering this skill allows systems thinkers to put the current situation in the context of how the problem occurred as well as where the organization is heading. Richmond (2000) believed that dynamic thinking is "the easiest of the systems thinking skills to master, [but] it does not develop naturally for most people" (p. 10). Static thinking tends to be the normal default for most people. Static thinkers "tend to see change as 'jumping' from the current state to a future desired state—with little happening between the two points" (Richmond, 2000, p. 10). In contrast to static thinking, dynamic thinkers consider the trajectory leading to the current state as well as the pathway from the current state to the future condition. "Dynamic thinking encourages people to use the past to both generate insights and guide inquiry into what produced the current state" (Richmond, 2000, p. 10).

Those who master the dynamic thinking skill generally see the path forward as nonlinear and assume the organization is more like an organism that will adapt to and resist change. Systems thinkers, through dynamic thinking, "understand how the behavior of a system arises from the interaction of its agents over time" (Sweeney & Sterman, 2000, p. 250). They are willing to invest and take a short-term decline before climbing out of the current state hole and improving performance. To hone dynamic thinking, Richmond suggests using reference behavior pattern, which is a behavior-over-time graph. By developing a behavior-over-time graph, thinkers can capture the essence of the issue that needs to be addressed. Developing a reference behavior pattern at the start of a performance improvement effort is one way to focus the organization's energy and encourage dynamic thinking.

Dynamic thinking revolves around collecting information, and industrial engineers employ dynamic thinking in several ways. First, “interviews are the most common informal technique to gather task information,” second, “surveys are particularly useful task-analysis tools when it is important to determine specific task characteristics,” and third, they use “observation during task activity or shadowing workers throughout their daily work activities” (Stanney, Smith, Carayon, & Salvendy, 2001, p. 1209).

To measure the dynamic thinking construct this study will ask respondents to reply to the following three statements using a Likert scale:

1. In my current position, I frame such things as issues, challenges, and opportunities in terms of a set of patterns that unfold over time.
2. In my current position, I investigate how variables of interest have changed in the past, how they’re doing now, and how I expect them to change in the future.
3. In my current position, I look closely at the underlying relationships between the variables of interest to shape and time a desirable path forward.

System-as-Cause Thinking is the next systems thinking skill to develop. Dynamic thinking allows systems thinkers to consider the issue as part of a pattern of historical behavior. System-as-cause thinking “can help you determine which underlying set of relationships are most relevant for improving the behavior pattern of interest” (Richmond, 2000, p. 12). This skill also means “viewing a system’s behavior as the result of the system and as such under the control of decision makers” (Maani & Maharaj, 2004, p. 23). System-as-cause thinking involves constructing a model to explain how behavior arises. The opposite of system-as-cause thinking is system-as-effect thinking.

This perspective views a system's performance as "the result of a set of forces that lie outside the control of decision makers within the system" (Richmond, 2000, p. 12). System-as-cause encourages systems thinkers to "view the system itself as the cause of its behavior it is exhibiting" (Richmond, 2000, p. 12) instead of seeing the system as a victim with behavior outside of its control. System-as-cause thinkers are proactive and "they seek either to alter the relationships that are causing the blow, or to change their internal structure so as to cause the force to have a less destructive impact on them" (Richmond, 2000, p. 12).

To develop this skill, a systems thinker needs to work at consciously reframing perceptions. Behavior formally attributed to outside forces needs to be viewed as a result of relationships within the control of decision makers. Understanding the organization's history, paying close attention during meetings, and viewing outcomes as being caused by controllable relationships will all contribute towards developing this skill. The biggest challenge to developing this skill lies "in identifying those variables that are partially under management's control" (Richmond, 2000, p. 13). Making this distinction is important because the variables which management controls are often high-leverage points. System-as-cause Thinking is vital for developing a personal responsibility perspective for performance.

Industrial engineers are tasked with finding the internal causes of problems and "the cause and effect diagram is a tool for organizing a group's current knowledge about causes of a problem" (Provost, 2001, p. 1816). Brainstorming is also "particularly helpful in the identification of issue formulation elements based on principles of collective inquiry" (Sage, 2001, p. 127). In addition, "failure mode and effects analysis is used to identify all conceivable and potential failure modes and determine the effect of each failure mode on system performance" (Kapur, 2001, p. 1940).

The three survey statements to determine how industrial engineers use system-as-cause thinking include:

1. In my current position, I focus upon identifying the set of forces that lie inside the control of decision-makers as the primary drivers of behavior and performance.
2. In my current position, I seek to identify actions that produce desirable behavior patterns rather than trying to predict which behavior patterns are likely to "happen to us."
3. In my current position, I try to identify how the relevant decision-makers are responsible for behavior and performance in a given situation.

Forest thinking is seeing the big picture. It "gives us the ability to rise above functional silos and view the system of relationships that link the component parts" (Maani & Maharaj, 2004, p. 23). The first two skills help to cast issues as a dynamic pattern of behavior and focus on those relationships, which can be influenced. Forest thinking "helps you finalize the breadth and depth that your hypothesis, or model, will have" (Richmond, 2000, p. 14). It is "the view from 10,000 meters" and is comparable to the experience of looking at the ground while at cruising altitude in an airplane (Richmond, 2000, p. 14). Forest thinking is in direct opposition to the more typical viewpoint, which is tree-by-tree thinking. This is the more natural viewpoint "because of our small physical stature and limited perceptual reach relative to the expansive boundaries of the systems within which we must operate" (Richmond, 2000, p. 14). Tree thinkers often get to know particular trees very well and in extreme detail. They are able to gain intimate knowledge of individual trees. However, these thinkers are unable to see the interactions between the trees or the role each one plays in the whole forest.

In contrast, Richmond (2000) stated “forest thinking gives the ability to rise above the local well-known trees and view the links connecting the different parts of the forest” (p. 14). Forest thinking “gives a broader overview of ‘the big picture,’ it also necessarily gives us a shallower view of the organization than we would get from employing a tree-by-tree perspective” (Richmond, 2000, p. 14). Tree-by-tree thinking tends to produce a narrow, highly disaggregated model with a lot of variables to relationships. Forest thinking tends to yield a broad, highly aggregated model with few relationship variables. Developing the forest thinking skill involves starting to consciously notice where perceived boundaries currently lie in the organization. In addition, looking for similarities rather than differences in people, situations, companies, and problems will develop the ability to filter out the trees from the forest. By employing a more penetrating gaze, systems thinkers can train their minds to see what is most important. Forest thinking completes “the trio of skills you need for defining an effective scope and level of detail for mental models” (Richmond, 2000, p. 15).

Industrial engineers use forest thinking in several ways, including SIPOC (supplier, input, process, output, and customer) charts, value stream mapping, and layout construction. SIPOC charts allow a process to be “viewed as a structure of activities designed for action with a focus on end customers and on the dynamic management of flows” (Lambert & Siecienski, 2001, p. 2123). Value stream mapping is used to illustrate problems by “showing the present flow of material and equipment locations of areas under study" (Hays, 2001, p. 13.49). "Facility layout is the planning, designing, and physical arrangement of processing and support areas within a facility; the goal is to create a design that supports company and operating strategies" (Wrennall, 2001, p. 8.21).

The three statements used to measure the forest thinking construct include:

1. In my current position, I investigate the connections between distinct parts and knit them together into a larger whole in order to see new connections.
2. In my current position, I find boundaries and seek to transcend them in my thinking in order to gain an elevated perspective.
3. In my current position, I look for similarities rather than differences in people, situations, problems, and organizations so that I can identify what is essential, simple, and important.

While the first three systems thinking skills help to establish the breadth, depth, and density of systems (or mental) models, the next four skills help to specify the relationships that exist within the established boundaries of these models. Operational thinking, which according to Richmond (2000), "is one of the most powerful systems thinking skills. Yet, unfortunately, it also appears to be one of the most difficult to master" (p. 16). It is so difficult because correlational thinking is so deeply ingrained. Instead of driving for the influencing factors, operational thinking queries for what exactly caused a particular outcome. Operational thinkers master the ability to think causally not correlational. The two most important benefits to operational thinking include supporting more effective communication and identifying leverage points for improving performance. This skill encourages "telling it like it is" and because of this, "it imposes a substantially higher degree of precision in the use of words and thereby reduces the likelihood of misinterpretation" (Richmond, 2000, p. 16).

Operational thinking helps "to recognize the notion of interdependence" and "looks at the structure or 'physics' of relationships, at how one variable affects another, not just that they affect each other" (Maani & Maharaj, 2004, p. 23). The first step in honing operational thinking is becoming aware of when systems thinkers are not thinking operationally. Instead of making lists of critical factors or drivers, operational thinkers must slow down and drive for what really causes a phenomenon or how something actually works. In thinking about how something works, it is important to look for two production functions: stock-generated and flow-generated. Stock generated refers to the specific objects that produce the output, i.e. the cows are the stock in the production of milk. The flow-generated are harder to identify but just as vital; they include "the stream of experiences that generates learning" (Richmond, 2000, p. 17). These functions yield the central nerve of the model and give it shape and structure. Operational thinkers that are able to look for these important production functions will force them to think in operational terms about what is really going on in the current situation.

Industrial engineers employ operational thinking when developing models. "Run charts and control charts are important when determining whether data is stable or trending" (Provost, 2001, p. 1822). A relationship chart like a "cause and effect diagram could give insights as to which variables should be plotted together" (Provost, 2001, p. 1822). The two-way table (similar to a scatter plot) is "a tabular representation of the relationship between pairs of variables or categories" (Provost, 2001, p. 1822). Planned experimentation is "a set of tools for understanding the causes of variation in a variable of interest. It is of particular interest when there are several factors that all contributed considerably to the variation under study" (Provost, 2001, p. 1822).

The three statements used to measure the operational thinking construct include:

1. In my current position, I seek out and identify the causes of a given behavior or performance, rather than merely its correlation.
2. In my current position, I think in terms of stock-generated and flow-generated production functions in order to understand the activities I am examining.
3. In my current position, when I am seeking to understand a particular event, trend, or process, I ask, "How does this actually work?"

Closed-loop thinking helps to specify the relationships within the constructed model. "If operational thinking produces the spinal cords, closed-loop thinking adds the nerves that radiate signals out to the various parts of the body that carry signals back to the brain for processing" (Richmond, 2000, p. 18). Closed-loop thinking brings life to the structure and enables the dynamics of the model to unfold. Straight-line thinking is focused on one-way causality whereas closed-loop thinking "means seeing causal relationships in circular terms—as two-way, rather than one-way streets" (Richmond, 2000, p. 19).

Closed-loop thinking increases the likelihood that the intended results will be achieved and sustained. It also raises awareness of unintended consequences. Instead of just seeing direct consequences, the closed-loop thinker will also "begin to anticipate unintended outcomes and the associated closed-loop relationships often set in motion" (Richmond, 2000, p. 19). Closed-loop thinking is one of the easiest skills to hone because the opportunities for developing this skill are abundant. Straight-line thinking is everywhere, but by listening carefully whenever causality is at issue, thinkers begin to "supply the connections that link stocks with flows to form feedback loops in the model" (Richmond, 2000, p. 19).

Closed-loop thinking is a dynamic, on-going process that is critical in creating and sustaining desired consequences. When employing closed-loop thinking, industrial engineers use matrix diagrams, "to arrange data to help the user understand important relationships" (Provost, 2001, p. 1819). In addition, "a control chart is a tool for studying variation in data, distinguishing between common cause and special cause variation" and, "along with diagrams, is especially useful for gaining information about the stability of a process" (Provost, 2001, p. 1821).

To test the closed-loop thinking construct, the study uses three statements:

1. In my current position, I see causal relationships in circular terms, as two-way streets rather than one-way streets.
2. In my current position, I study the feedback processes set in motion by actions in order to identify unintended consequences.
3. In my current position, I use feedback processes to help me identify high-leverage initiatives capable of creating and sustaining the outcomes I seek.

Quantitative thinking ensures quantification moves the systems thinker beyond mental simulation to the more rigorous testing of assumptions afforded by computer simulation. Quantitative thinking means outfitting structural assumptions with numbers. This comes down to: "(1) providing numerical values for constants, (2) choosing initial magnitudes for stocks, and (3) specifying numerical values for graphical function relationships" (Richmond, 2000, p. 20). Quantitative thinking can take the other systems thinking skills to the next level by increasing clarity and boosting the level of rigor in the systems thinker's assumptions. Quantitative thinking involves numeration but not necessarily measurement as you can quantify nearly anything but you can precisely measure very little. Quantifying offers substantial benefits but systems thinkers must move past the feeling that they must have precise numbers to accurately forecast the future. "Unfortunately, no one has succeeded in translating more precise numbers into more accurate predictions" (Richmond, 2000, p. 21).

To refine quantitative thinking, computer simulation is essential. The discipline associated with quantitative thinking leads to much sounder models that can be simulated on a computer and produce results with a much greater confidence level. Industrial engineers frequently use operational thinking when developing simulations. "Simulation modeling has been applied in a large number of industries in solving problems in the strategic, tactical, and operational levels of management" (Ulgen & Williams, 2001, p. 11.107). Industrial engineers use operations research as "a systematic approach to solving problems, which uses one or more analytical tools in the process of analysis" (Rajgopal, 2001, p. 11.29). Industrial engineers also use decision trees in quantitative thinking "to represent knowledge for the purpose of classification" (Jones, Yih, & Wallace, 2001 p. 1776).

The study measures this construct with three statements:

1. In my current position, I outfit my measureable and non-measurable assumptions about how something works with numbers in order to increase clarity and boost the rigor of my thinking about it.

2. In my current position, I sharpen my thinking about how something works by providing numerical values for constants, choose initial magnitudes for stocks, and specify numerical values for graphical function relationships.
3. In my current position, I quantify my understanding of the dynamics in a situation in order to discover effective leverage points for change.

Scientific thinking is most applicable after you have constructed a model, using the first six systems thinking skills. Richmond (2000) stated scientific thinking is "vital for ensuring that models deliver on their ultimate promise: to help build a better shared understanding of a system for the purpose of improving its performance" (p. 22). Many people seek to prove a model is true. Much effort surrounding models consists of people using statistical techniques to track actual against historical results. This is considered proving-truth thinking. By contrast, "scientific thinking seeks to systematically build confidence that a model is useful for developing insights into how to improve performance" (Richmond, 2000, p. 22). It involves testing face validity and robustness. Face-validity tests assess "how well the structures of a model matches the structure of the reality the model is intended to represent" (Richmond, 2000, p. 12). Robustness tests assess how realistically a model behaves. Scientific thinking deviates from predicting the future to creating the future based on modeling. To best sharpen these skills, systems thinkers revisit spreadsheet and regression analysis. These models constitute the analytical "artifacts of most organizations' planning efforts" (Richmond, 2000, p. 23).

Scientific thinking shifts systems thinkers from a "predict and prepare" mindset to a "what can we do to improve performance under a range of possible conditions" mindset (Richmond, 2000, p. 23). Similar to the other six systems thinking skills, scientific thinking focuses responsibility for performance on those within the organization rather than on the uncontrollable outside forces. “Statistical methods enable the industrial engineer to make better decisions in the context of the variability inherent to engineering processes” (Slate, 2001, p. 11.3).

Industrial engineers employ statistical analysis when practicing scientific thinking, “the key statistical concepts are obtaining and graphically displaying sampled process data, selecting an appropriate probability model for the data, and using the model to draw conclusions of interest” (Slate, 2001, p. 11.3). Regression analysis is “a technique for measuring and explaining (reducing unexplained) variability in a system” (Parvez & Fusaro, 2001, p. 2265). Statistical hypothesis testing is a way of testing “to see whether or not some assumed value is ‘reasonable’ under normal operating or assumed conditions” (Phillips & Garcia-Diaz, 2001, p. 2243).

The study uses three statements to measure the scientific thinking construct:

1. In my current position, I seek simulation results that test for model robustness, face validity, and “goodness-of-fit.”
2. In my current position, I simulate model results under a range of possible conditions in order to discover ways to improve real-world behavior and performance.
3. In my current position, I examine model-generated behavior patterns so that I can identify levers for creating the future, rather than predicting it.

General system theory, second order cybernetics, autopoesis, social systems theory, complex adaptive systems, hard operations research, system dynamics, soft operations research, and soft systems methodology have all played a role in making systems thinking everything that it is today. While each one is unique and make unique contributions, together, they draw importance to systems and to the value of developing an understanding of the intricacies of any given system. Subsequently, systems thinking was not developed in isolation and certainly draws key points from all of the theories and methodologies that came before it.

In this study, this researcher is using the term “systems thinking” in much the same way as Senge (2006), viz., it is the overarching term that refers to the family of theories and methodologies we have discussed above.

While Aristotle may be among the first to compare the whole to its parts, it is people like von Bertalanffy (1968), Deming (1986), Luhmann (1984, 1995), Maturana and Varela (1987), Forrester (2007a), Forrester (2007b), Checkland (1999a), Checkland (1999b), and Senge (1999) that developed this idea into a functional way of thinking. General systems theory, developed by von Bertalanffy, brought to light the value of the system and considering the whole instead of just the parts. Deming and Senge became avid users of systems thinking in a management setting, and Senge continues to promote its vital role in knowledge age organizations. The gradual development and use of systems thinking allow those who lead and manage to understand that business and human endeavors are also systems, and that “they, too, are bound by invisible fabrics of interrelated actions, which often take years to fully play out their effects on each other” (Senge, 2006, p. 7). Due to the work of key figures and their theories, systems thinking has become “a conceptual framework, a body of knowledge and tools that has been developed over the past fifty years, to make the full patterns clearer, and to help us see how to change them effectively” (Senge, 2006, p. 7).

Development of the Industrial Engineering Profession

After millennia of agrarian-based societies, the Industrial Revolution began in Great Britain in the later part of the 18th century. From about 1760 to about 1950, almost every aspect of society and daily life in Europe and North America changed as technological advancements enabled a transition toward greater reliance upon machine and factory-based production, rather than upon human and animal-based labor. Regarding the industrial revolution, Martin-Vega (2001) observes: “The events of this era dramatically changed manufacturing practices and served as the genesis for many concepts that influenced the scientific birth of [industrial engineering] a century later” (p. 1.4). An important component of the industrial age was the philosophy of scientific management that had a tremendous impact on production systems and included Frederick Taylor, Frank and Lillian Gilbreth, and Henry Gantt as key historical figures.

Industrial engineering found its roots in the scientific management movement, which paved the way for the knowledge age. During the latter half of the nineteenth century, the final stage of the industrial age focused on technological advances, changing power sources, evolving labor-management relations, and a need to bring these factors together with some sort of new management practice. Frederick Taylor, the father of industrial engineering, was able to look beyond the technical side of manufacturing, and his views became central to the scientific management efforts within the factory. Before Taylor, important figures such as Adam Smith, Henri Fayol, and Henry Ford also made an impact with theories that would eventually contribute components to the science of industrial engineering.

Historical Figures

Born in 1723, Adam Smith is famous for his work *The Wealth of Nations*, which is considered the first modern work on economics. Also known as the father of economics and capitalism, Smith was the first to expound on the “invisible hand” and on the “economics of self-reliance grounded in ‘the desire of bettering our condition’” (Spiegel, 1991, p. 24). Smith’s invisible hand of the market is the term that economists have come to use as a way of describing the self-regulating nature of the marketplace. Every economist since Smith has disagreed over how powerful the invisible hand is, but only a few argue that it does not exist.

Smith created a conceptual and societal context that influenced later thinkers and practitioners like Fayol, Ford, and Taylor, and some of Smith’s concepts would eventually find a permanent home in industrial engineering. For example, Taylor translated Smith’s laissez-faire system into the industrial world and more generally into the organization. “Smith drove home the demand for laissez faire, a system of natural liberty, as the best means of bringing about the wealth of nations” (Spiegel, 1991, p. 241). Smith believed that individuals in the laissez faire system would pursue their own self-interest and that this would naturally turn into the interests of society or, in Taylor’s case, the organization. While Smith focused upon the laissez faire nature of the macroeconomic system qua market, his thought influenced Taylor’s focus upon managing the microeconomic system of the firm. For example, Smith laid the groundwork for later understandings of specialization, standardization, the “one right way,” and the resulting manifold leaps in productivity through his discourse explaining his famous illustration of production in the “pin factory.”

Adam Smith illustrated division of labor when he described pin making in *The Wealth of Nations*. In this example, Smith discussed the ability of one person to make upwards of 4,800 pins in one day when working together within a group of ten people who are each specialized to a different facet of pin making. “But, if they all had wrought separately and independently, and without any of them having been educated to this peculiar business, they certainly could not each of them have made twenty, perhaps not one pin in a day” (Spiegel, 1991, p. 245). Smith illustrated the favorable effects of the division of labor. Furthermore, he “visualize[d] technological innovation as being made mainly by workmen who have become specialists along certain narrow lines of operation” (Spiegel, 1991, p. 245-246). To Smith, specialization and standardization by occupation, function, firm and industry capitalize on human abilities and provide a greater good to the organization in the form of greater output.

Smith’s illustration of the “pin factory” connected the principles of specialization and standardization with the later theories and practices of Fayol, Ford, and Taylor as they became endemic to the industrial engineering profession. Fayolism, the thinking, practices, and writings of Henri Fayol, constitutes one of the first comprehensive statements of a general theory of management. Not incidentally, Fayol was educated as an engineer and spent time working as an engineer at a mining company. He eventually became a managing director at the company and held the position for over 30 years. Fayol believed that one could develop a general management theory, and his was published in 1916 as *General and Industrial Management*.

Although Fayol believed in controlling the workers in order to achieve productivity, he introduced a “flexible approach to management” that could be applied to any circumstance, home, workplace, or state—a jolting concept, for the time. Fayol developed 14 principles including the one most related to the work of industrial engineering, which is the “division of work.” Similar to Adam Smith’s division of labor and Taylor’s scientific management, Fayol “recognizes that there are limits to the division of work” and that “where the degree of specialization is excessive, people become bored and alienated, with the result that staff turnover may rise” (Kitchin, 2010, p. 150). While Taylor dealt with the efficient organization of production in a competitive environment with a bottom-up approach, Fayol took a top-down approach.

Henry Ford and Fordism are also loosely tied to the development of industrial engineering. Introduced around the same time as scientific management, Fordism is the general term used to describe Henry Ford’s development of an unprecedented method of production and marketing that brought automobiles to the masses. Ford denied any acquaintance with Taylor: and Taylor, on a tour of the Highland Park manufacturing plant “expressed surprise to find that Detroit industrialists had undertaken to install the principles of scientific management without the aid of experts” (Sorensen, 1956, p. 41). While Taylor was not alone in the field of process analysis and synthesis. Henry Ford developed “a model of economic expansion and technological progress based on mass production: the manufacture of standardized products in huge volumes using special purpose machinery and unskilled labour” (Tolliday & Zeitline, 1987, p. 1-2). The hallmark of Fordism is standardization: it “is the necessary foundation on which tomorrow’s improvements will be based” (Liker, 2004, p. 141).

Ford worked toward standardization by pioneering the use of the moving assembly line. The assembly line involves the achievement of efficiency and productivity through a better use of time and motion. Ford and other inventors worked from Adam Smith's idea of specialization and standardization to the concept of interchangeable parts and subassemblies. Between 1908 and 1915, Ford developed a moving assembly line for the Model T automobile. This brought with it a focus on understanding the most economical way of operating the line and gave industrial engineers a chance to exploit their skills in motion and time studies. At the time the assembly line was introduced, industrial engineering focused on the development of standards, and standardization became critical to the organization of work.

The direct and immediate origins of industrial engineering can be traced to several people of notable interest. Frederick Winslow Taylor is most often considered "the father of industrial engineering" (Copley, 1969, p. 452). Frederick Taylor, 1856-1915, began his career as an engineer on the factory floor at Midvale Steel Company in Philadelphia. Ultimately, he became the first man to work as a manual worker and then to study manual work. Despite his eventual success, his factory occupation was far from the dreams he had of being a successful lawyer. Devoid of training in management, Taylor relied on his own observations as to how things should be done. He brought his experience on the worker side of things into his management roles. He understood ineffective incentives, and he estimated worker output at only one-third of what he thought was possible. Taylor was motivated by "the desire to free the worker from the burden of heavy toil, destructive of body and soul" (Drucker, 2008, pp. 14-15. "Taylor was the first person in history who did not take work for granted, but looked at it and studied it" (Drucker, 2008, p. 14).

Taylor sought to overcome output deficiencies by careful investigation and the setting of performance standards. Taylor determined "what workers should be able to do with the equipment and materials, and this became the beginning of scientific management" (Wren, 2005, p. 124). "Time study became the foundation of the Taylor system," and he believed that such scientific study on the job would provide "a vastly closer approximation as to time than we ever had before" (Wren & Bedeian, 2009, p. 125). Taylor's time study was used for analytical purposes and focused on future uses rather than past uses. Many believe that Taylor was responsible for an impersonal workplace. However, "in reality, Taylor dealt with each worker as an individual. He actively encouraged a manager's positive personal interaction with each worker. Impersonality in the workplace comes from sources other than Taylor" (Brogan, 2011, p. 42).

Ultimately, Taylor put the responsibility on management to take charge, accept responsibility, and move away from the old system into a new age. The industrial engineer became an integral part of the operation but had yet to cross the barrier into management. He "applied his wonderful inventive genius to the invention of management methods" (Copley, 1969, p. 148). Taylor believed that the industrial age lacked standardization and was made up of poor management practices that were used to design jobs improperly and offered improper incentives. Even in 1911, he believed that "in the past, the man was first, in the future, the system must be first" (Taylor, 1967, p. 7). Taylor's ideas and theory were in opposition to what was "for many years, the prevailing maxim of management [that] stated: 'management is getting work done through others'"

(Wheatley, 1994, p. 144). Taylor began to notice that *people* were working for them, and he helped bring recognition to the role that humans play in the organization.

Given that his methods involved more managerial level involvement, many were never implemented. From “a historical standpoint, Taylor’s enduring importance would seem to derive from his leadership in the introduction of the scientific method into the area of work” (Kakar, 1970, p.182). Following his development of time studies, Frederick Taylor provided the major thrust for “an era characterized by a search for efficiency and systematization in management thought” (Wren, 2005, p. 119).

Frederick Taylor’s theory of management is “characterized by a search for efficiency and systematization in management thought” (Wren, 2005, p. 119). Taylor summarized scientific management as “science, not rule of thumb; harmony, not discord; cooperation, not individualism; maximum output in place of restricted output; and the development of each man to his greatest efficiency and prosperity” (Brogan, 2011, p. 43). It seeks out management in which harmony is the rule instead of discord. Also known as Taylorism, the theory is guided by four main principles. First, Taylor “sought to replace rule of thumb work with methods based on scientific study. Second, he sought to scientifically select, train, and develop the workman rather than passively allowing them to train themselves as best they could. Next, the theory seeks to provide detailed instruction and supervision of each worker so as to ensure all of the work being done is in accordance with the principles of science. Finally, scientific management seeks to divide work nearly equally between managers and workers so that the managers apply scientific management principles to planning the work and the workers actually perform the tasks” (Taylor, 1998, p. 15-16).

However, hindsight shows that Taylor was simply ahead of his time. Taylor, the father of industrial engineering, saw himself as an industrial peacemaker and scientific management as “a great ‘mental revolution’” (Kakar, 1970, p. 21). In addition to coining the terms management and consultant, Peter Drucker credits Taylor with having an impact greater than Henry Ford and even Marxism. “Scientific management (and its successor, industrial engineering) is the one American philosophy that has swept the world—more so even than the Constitution and the Federalist Papers” (Drucker, 2008, p. 194).

Henry Gantt, an associate of Frederick Taylor, was another pioneer in the development of scientific management. He worked several years with Frederick Taylor as a consulting management engineer developing methods of planning. While working with Taylor, Gantt came to realize that industrial engineers had potential far beyond conducting time studies. He pushed industrial engineers to move past concern for simple factory matters and sought reform at all levels. In many respects, this was the beginning of a continuing expansion in the role and influence of industrial engineers within organizations.

After Taylor’s death, Gantt began to develop different ideas on the role of the industrial engineer and the firm as an institution. According to Gantt’s theory, “the industrial engineer, not the financier nor the labor leader, would be the new leader, because only the engineer could cope with the U.S. problem of production as the creation of wealth” (Wren, 2005, p. 160). Due in part to his work, industrial engineers of the time proved themselves as persons of few opinions and many facts who should be afforded a position of economic leadership.

Frank and Lillian Gilbreth also performed core work in the field of industrial engineering. While tied to the scientific management movement, the couple moved the field beyond time studies and focused on motion studies. Frank was a bricklayer by trade who wanted to make his trade faster and easier. After developing a management consulting company, he developed motion studies to reduce fatigue and improve productivity. As a brick-layer's apprentice, Frank began writing on the best ways to lay bricks, handle materials and train apprentices, among other things. His works led to the development of motion studies.

Similar to Taylor's time studies, motion studies measured the same activities with the objective of eliminating motion to reduce fatigue and improve productivity. By moving beyond simply a study of time, Frank was able to provide industrial engineers with not only a survey of work performed but concrete alternatives to increase performance. Frank clearly saw the value of industrial engineers, and he made a great name for the profession. In fact, he became an integral part of history.

Lillian Gilbreth, also known as the "First Lady of Engineering" (Lancaster, 2004, p. 7), received some 22 honorary degrees for her work. She added a vital psychological component to industrial engineering that allowed the organization to see the human satisfaction and fulfillment available to workers and managers through implementing industrial engineering practices. Her doctoral thesis, *The Psychology of Management*, greatly contributes to understanding the human factor in industry. In fact, her dissertation detailed how psychology should be a part of scientific management by structuring management authority to provide dignity to each employee. Due to the Gilbreth's work, industrial engineers added another component—i.e., the psychological and human satisfaction and fulfillment component—to their toolbox that would enable them in their transition to leadership.

All of these historical figures recognized the importance of the human factor. Additionally, they recommended that industrial engineers assume their rightful place in management where the human contributions to the workforce could find a voice and actively contribute to organizational efficiency. The introduction of scientific management altered the path of the industrial revolution and the industrial age. During the time of scientific management, "the gospel of efficiency had its doctrine, but changing times would bring new emphases" (Wren, 2005, p. 183). As the era of the knowledge age has begun to dawn, it is ushering in a host of new emphases and organizational imperatives, and it is influencing an evolution in the necessary skills of the industrial engineer as a leader.

Reengineering Industrial Engineering

The leadership competencies practiced during the industrial age included "forcefulness, being a motivator, decisiveness, willfulness, assertiveness, being result-and bottom-lined-oriented, being task-oriented, and having integrity and practicing diplomacy" (Scholtes, 1998, p. 18-19). At the core of these competencies lays the concept that bosses used their personality traits and skills to manage the workers. The first competency is that it is a manager's responsibility to control the workforce. Forcefulness was seen as necessary to getting people to respond. Next, on the softer side of forcefulness, managers were expected to serve as the motivators to the workers. From here, the competencies of decisiveness, willfulness, and assertiveness played important roles in industrial age management approaches.

Progress during the industrial age eventually gave birth to the information age or the knowledge age as it is most often called today. Commonly believed to have begun around 1950, this age is dominated by the philosophy of the biological sciences. This economic age views “knowledge, people, and organizations as living systems” and focuses on the whole rather than the parts (Senge, 2006, p. 271). It represents a drastic change in thought from the prior industrial age because “in this new era, wealth is the product of knowledge. Knowledge and information—not just scientific knowledge, but news, advice, entertainment, communication, service—have become the economy’s primary raw materials and its most important products” (Stewart, 1997, p. x). During this age, the role of knowledge in driving economic and societal development intensifies and knowledge becomes the most important economic resource. The industrial age did much to foster new understandings, and it became more knowledge-intensive. Since approximately 1950, “knowledge has become the primary ingredient of what we make, do, buy, and sell. As a result, managing it—finding and growing intellectual capital, storing it, selling it, sharing it—has become the most important economic task of individuals, businesses, and nations” (Stewart, 1997, p. 12). By 1960, it was knowledge and intellectual capital, more than the machine, which became the focus of the modern organization. Today, the corporations with the largest capitalization and fastest growth rate tend to be organizations such as Apple and Microsoft, more so than corporations such as U.S. Steel and General Motors.

This change in organizational focus has required a corresponding change in the way organizations are managed. Knowledge production by knowledge workers is not managed quite like widget production by machines is managed. For example, while the mentality of the physical sciences dominated the management approaches of the industrial age, the mentality of the biological sciences dominates the management approaches that work best in the knowledge age. This philosophy “views knowledge, people, and organizations as living systems,” (Senge, 2006, p. 271) which are always complex, open, adaptive and dynamic.

There are many important differences between the economic dynamics, and effective management approaches, of the industrial age and the knowledge age. During the industrial age, work tended to be planned in advance with written instructions and means to accomplish the work. Managers led from the top down with no feedback. In contrast, in the knowledge age, productive work tends to occur across many functions with all workers as active participants working together for a common purpose. The living systems approach of the knowledge age appears to be forcing a shift away from industrial age thinking. This shift occurs in all facets of work: there has been “a shift in the focus from parts to whole, from focusing on categorization to focusing on integration, from focusing on individuals to interactions, and from focusing on systems outside the observer to focusing on systems that include the observer” (Senge, 2006, p. 271).

During the knowledge age, the focus of operations has turned to the whole rather than the parts. “Managers now must supervise many people… They must manage across functions… And they must be agents of change, champions of the latest re-engineering or reorganization…” (Davenport, 1999, p. 130). Members of the organization in the knowledge age are all active participants who play an essential role. Workers are now thought of as human capital and owners of knowledge, so there is a critical need to learn how to lead and manage them effectively. Unlike the industrial age, knowledge age leaders and managers perceive that even those fulfilling the worker role can and do have an impact on the organization. The knowledge age is essentially forcing all members of the organization to rediscover organizations as living systems and "rediscover what it actually means to us as human beings to work together for a purpose that really matters" (Senge, 2006, p. 271).

Beyond focusing upon work as a whole rather than parts, the knowledge age differs from the industrial age also in the area of autonomy. There was little to no empowerment during the industrial age. In fact, "the empowerment movement is an effort to break the enduring shackles of Frederick Taylor's scientific management" (Davenport, 1999, p. 128). Managerial influence has changed and adapted in the knowledge age, due in part to workers who make their own decisions. The knowledge age ushers in a contrast between control and influence. Managers are less concerned with exerting power and control and more in achieving an influential role in which all members of the organization can work in harmony towards a desired goal. In return for this autonomy, they are more likely to cooperate with management's policies. Through autonomy and empowerment, the investment in human capital as well as performance is greatly increased.

During the industrial age, the transfer of knowledge was very important, and knowledge concerning new innovations spread by several means. Workers who were trained in a specific skill often moved to new employers or were tempted to new organizations. Additionally, study tours were conducted by nearly all countries involved in the revolution. Records made by those who conducted tours remain an important source of information about the methods of this time. The workers sought to control more of their experience in the changing economy and unionized. They then began to shape their destiny and role in the revolutionized economy. Because knowledge was extremely important in the making of the industrial age, including its continuing expansion globally, both managers and workers were involved in the goal to increase knowledge and competitiveness.

The competencies needed to excel in the industrial age and knowledge age differs in emphasis. The core of the new competencies is the concept that managers use their knowledge of systems thinking to manage the system. The “leadership philosophy begun by Deming in Tokyo in 1950 is the first fundamentally new management philosophy since 1840,” (Scholtes, 1998, p. 18) and Deming’s approach to leading and managing organizations laid important foundations for the new management approach in the new age. A greater emphasis is placed upon some new competencies that are more appropriate for leadership in the knowledge age. “The new competencies are different in nature. They are based on very different premises, assumptions, and beliefs about people and organizations” (Scholtes, 1998, p. 19). According to Scholtes (1998), these competencies include:

1. The ability to think in terms of systems and knowing how to lead systems.
2. The ability to understand the variability of work in planning and problem solving.
3. Understanding how we learn, develop, and improve, and leading true learning and improvements.
4. Understanding people and why they behave as they do.

5. Understanding the interdependence and interaction between systems, variation, learning, and human behavior. Knowing how each affects the others.
6. Giving vision, meaning, direction, and focus to the organization (p. 21).

The new competencies are covered generally in W.E. Deming's system of profound knowledge, and they are important to management in the knowledge age. The first competency is "the ability to think in terms of systems and knowing how to lead systems" (Scholtes, 1998, p. 21). By thinking on the systems level, the organization is able to avoid "overly simplistic interpretations and solutions to complex problems" (Scholtes, 1998, p. 24). In addition, "the ability to understand the variability of work in planning and problem solving" (Scholtes, 1998, p. 24) is very important in the knowledge age; an accurate understanding of data is required to successfully run the knowledge organization. Next, there is a new focus on understanding people, our behavior and how we learn, develop, and improve.

It is clear that people are no longer motivated through a combination of promised reward and threat of punishment. In fact, the use of these during the industrial age was actually detrimental to the relationships of the time. Knowledge age management also brings about a special focus on understanding the interdependence and interaction between systems, variation, learning, and human behavior. In other words, knowing how each affects the other. Finally, there is great emphasis on "giving vision, meaning, direction, and focus to the organization" (Scholtes, 1998, p. 46). Members need to understand these things in order for the organization to remain cohesive. Not only are these new competencies innovative, but they also changed the face of both Eastern and

Western business methodologies. Business was transformed by shifting the focus of the organization from its parts to the whole and from an emphasis upon command-and-control methods to an emphasis upon designing, leading, and managing complex, adaptive, organizational systems.

The industrial age leader and manager was primarily a boss of people, the knowledge age leader and manager is primarily the architect of the system qua organization. Industrial engineers are especially well-suited to fulfill this role in the organizations of the emerging new economic order, because of their possession of systems thinking skills.

Technical Industrial Engineering Skills

The Institute of Industrial Engineers (2012a) defines industrial engineers as "being concerned with the design, improvement, and installation of integrated systems" (Institute of Industrial Engineers, para. 2). Industrial engineers draw "upon specialized knowledge and skills in the mathematical, physical, and social sciences, together with the principles and methods of engineering analysis and design to specify, predict, and evaluate the results to be obtained from such systems" (Billings, Junguzza, Poirier, & Saeed, 2001, p. 1.23). In essence, the field of industrial engineering is rooted in technical skills, and ten skills, deemed necessary and valuable by the Institute of Industrial Engineers will serve as independent variables in this study. These skills are considered by the Institute of Industrial Engineers to be the fundamental concepts and principles of industrial engineering. These ten skills include time studies, statistical analysis, simulation modeling and analysis, ergonomics, project management, process improvement, engineering economics, production planning and control, performance metrics, and logistics. The survey instrument draws upon the definitions and characteristics of the industrial engineering skills presented in the edited works of Salvendy (2001) and Zandin (2001) and the Institute of Industrial Engineers (2011) Fundamentals of Industrial Engineering course description. The visual representation of these skills is found in Figure 2.

Technical Industrial
Engineering Skills

1. Time Studies
2. Statistical Analysis
3. Simulation Modeling & Analysis
4. Ergonomics
5. Project Management
6. Process Improvement
7. Engineering Economics
8. Production Planning & Control
9. Performance Metrics
10. Logistics

Figure 2. Technical industrial engineering skills

Time studies are the most widely recognized technical skill of industrial engineers today. A time study is "used to determine time standards (targets) for planning, costing, scheduling, hiring, productivity evaluation, pay plans, and the like" (Sellie, 2001, p. 17.21). Time studies are used worldwide to determine the time required to do work. While the time study is being conducted, it is desirable for the industrial engineer to look for opportunities for methods improvement.

The following three survey statements will be used to measure the time study construct:

1. In my current position, I collect time study data to determine reliable time standards for all work.
2. In my current position, I analyze time study data to determine operator productivity for the efficient and effective management of operations.
3. In my current position, I make recommendations to optimize workflows at a defined level of performance based on time study data.

Statistical analysis is also used regularly by industrial engineers and plays an important role in data collection and reporting. “Statistical methods enable the industrial engineer to make better decisions in the context of the variability inherent to engineering processes” (Slate, 2001, p. 11.3). There are several facets to statistical process analysis including data collection, “relating data files for input, process, and product parameters”, and graphically displaying data to obtain “visual representation of the sequence of working steps or processes carried out by an individual or organization” (Jahn, Lohr, & Richter, 2001, p. 14.40). Industrial engineers are able to use statistical analysis to not only obtain estimates of process outcomes but to measure uncertainty and as a result, “they can precisely predict (or control) a process” (Slate, 2001, p. 11.3).

The statements used to measure this construct include:

1. In my current position, I analyze data collected through surveys or interviews to determine specific task characteristics such as frequency.
2. In my current position, I graphically display sampled process data using charts or graphs to determine trends in the data.

3. In my current position, I select an appropriate probability model for collected data to predict the probability of future outcomes.

Simulation modeling and analysis was, formerly, “the province of mathematicians and computer science specialists” (Ulgen & Williams, 2001, 11.101). Now, simulation methods of analysis have gained acceptance as an indispensable aid to engineers. Organizations recognize the use of simulation for “increased global competition, cost reduction efforts, improved decision making, effective problem diagnosis, and prediction and explanation capabilities” (Ulgen & Williams, 2001, p. 11.102). Industrial engineers have a proven ability to use simulation “to attack a wide range of problems and investigations” (Ulgen & Williams, 2001, 11.101).

The three statements used in the survey to measure this construct include:

1. In my current position, I create models to predict the performance of a new system.
2. In my current position, I run simulations to generate and analyze sample model behavior.
3. In my current position, I interpret simulation results to predict performance of model parameters.

Ergonomic*s* is “an applied science where the characteristics of people are used in designing jobs, tools, equipment, buildings, and environments with safety, quality, and high productivity as the goals” (Cerovec & Wilk, 2001, p. 6.205). Throughout time, industry has become increasingly concerned with the negative effects of poor ergonomics. Industrial engineers have “the responsibility for designing workplaces, methods, and tooling for a wide variety of tasks in industry” (Cerovec & Wilk, 2001, p.

6.205). Safety is a primary goal in ergonomic design. “After designing for safety, design for performance, then worker comfort, and, finally, worker higher wants” (Konz, 2001, p. 1354).

There are three statements in the survey to measure the ergonomics construct:

1. In my current position, I design solutions with safety as a goal to minimize operator injuries.
2. In my current position, I design solutions with quality as a goal to reduce production errors and variation.
3. In my current position, I design solutions with high operator productivity as a goal.

Project management is another technical skill for industrial engineers. It has changed substantially over the past fifty years and industrial engineers have been exposed to the new concepts and techniques. “Excellence in project management is based on the ability of individuals to initiate, plan, execute, control, and terminate the project scope and product scope successfully” (Shtub, 2001, p. 1250). Industrial engineers bring efficiency and effectiveness to project management through project planning and execution. “Industrial engineers have the opportunity to lead their organization in the application of modern project management to manage all projects” (Webster, 2001, p. 17.161).

The three statements used to measure this construct include:

1. In my current position, I utilize critical path modeling to accommodate unexpected changes and ensure there are no delays in the project.

2. In my current position, I develop project timelines using Gantt charts to ensure projects are completed on schedule.
3. In my current position, I assign resources to projects when needed to ensure project deliverables and milestones are achieved.

Process improvement is comprised of many different skills including Six Sigma and lean initiatives. Industrial engineers are able to obtain “the benefits of integrating continuous improvement initiatives that incorporate variation, risk, and waste reduction methodologies” (Institute of Industrial Engineers, 2011, para. 1). While most companies feel that further improvement is impossible, industrial engineers are able to show that “substantial improvement of workplaces is always possible if the perspectives and concepts regarding work are changed” (Hirai, 2001, p. 4.21).

The survey statements for this construct are:

1. In my current position, I use CQI (Continuous Quality Improvement) tools or techniques to reduce non-value added activities while improving operator productivity.
2. In my current position, I benchmark industry standards or use best practices to improve workplace processes or operator productivity.
3. In my current position, I use six sigma related tools or techniques to promote continuous process improvement for lean operations in the workplace.

Engineering economics “determine whether engineering projects are economically viable” (Hartman, 2001, p. 2396). Regardless of the application or situation, industrial engineers are able to estimate the relevant cash flows and their conversion to some common denominator to make a decision. Being skilled in engineering economics allows industrial engineers to use a number of different statistics to measure the riskiness of proposed plans, programs, and projects. “If performance cannot be measured effectively on a real-time basis, failure will likely occur” (Marrs & Mundt, 2001, p. 49).

There are three statements to measure the engineering economics construct:

1. In my current position, I adopt forecasting techniques that make the best use of historical data, accuracy desired, time period, and value to the organization.
2. In my current position, I supply inputs and forecasts for the planning and budgeting process to ensure accurate planning information is available for the organization.
3. In my current position, I perform labor analysis to record, measure, and control costs in an effort to manage labor resources.

Production planning and control is essential because “the industrial engineer’s work of designing a plant’s manufacturing process involves design of both production processes and infrastructural processes” (Lankford, 2001, p. 9.143). “Production planning and scheduling are important functions in operating the manufacturing facility” (Chang & Less, 2001, p. 451). Planning, scheduling, communication, and control all involve different techniques—all working in harmony due to the industrial engineers oversight and involvement.

The survey statements used to measure this construct include:

1. In my current position, I use material requirements planning to ensure that products are produced at the right time and in the right quantities.

2. In my current position, I design facility and work cell layouts to promote just-in-time inventory operations.
3. In my current position, I conduct audits to promote consistency, accountability, and integrity for standard operating procedures.

Performance metrics that monitor performance will change and most people work on implementing subsystems to enable the change. By creating, monitoring, and adapting performance metrics, industrial engineers provide valuable data for management decisions. “Managing performance must include an effort to align goals, both against performance challenges and across the various parts of the organization” (Finegan & Smith, 2001, p. 1006). Organizational leaders need many kinds of metrics and since “financial measures alone will not be enough to manage the future manufacturing enterprise,” industrial engineers and their ability to create performance metrics will “be useful for management of a future manufacturing enterprise” (Preiss, Patterson & Field, 2001, p. 1.157).

The three survey statements that will be used to measure the performance metrics construct are:

1. In my current position, I utilize SMART (specific, measurable, attainable, relevant, time bound) goals to help establish organizational operating objectives.
2. In my current position, I develop metrics to measure outcomes or results achieved against predetermined standards to help organizations manage performance.

3. In my current position, I provide feedback or variance analysis on metrics to assist organizations in improving its desired outcome.

Logistics is of fundamental importance to industrial engineers, because industrial engineers play an important role “in reducing transportation cost, as distinct from the unit rate, [and] should examine a different set of factors than the rate negotiator” (Davis, 2001, p. 10.84). Industrial engineers use “the same techniques of data gathering, analysis, observation, and study to improve transportation systems that they use to improve manufacturing operations” (Davis, 2001, p. 10.85). Industrial engineers are part of the state of the art modeling that has become logistics management.

The three survey statements for this construct include:

1. In my current position, I order and schedule materials to arrive according to production requirements to avoid bottlenecks and idle production times.
2. In my current position, I conduct material handling or storage analysis to ensure that the movements of materials or supplies within a facility are practical and cost effective.
3. In my current position, I communicate with suppliers and vendors to understand their processes and material handling capabilities for an efficient supply chain management system.

Transition Success from Technical Industrial Engineer to Management

Attaining a management position is often the desired career path of an industrial engineer. In 1982, Badawy, a student of W.E. Deming and Peter Drucker, stated that “management is the process of getting things done with and through others… Managing is a task or an activity—a process—requiring the performance of several functions by individuals possessing a specific set of skills" (p. 4-5). Badawy (1982) wrote that "knowledge, skills, and attitudes are the three interrelated components of managerial competency" (p. 20). The managerial skill mix consisting of technical, administrative, and interpersonal skills are all "closely related and can be significant in determining your success in management" (Badawy, 1982, p. 20).

In essence, since a manager is a person who manages, the core difference between an executive, manager, or supervisor relates to the scope of the job to be performed and the skill mix. The dependent variable of this study is a successful transition to management. "To be effective, managers must possess the authority that comes with knowledge and skills, and be able to exercise the charismatic authority that is derived from their own personalities" (Badawy, 1982, p. 20). Given the demand for "a technical approach to management accompanied by an understanding of modern complex organizations as sociotechnical systems," it is normal for a large number of engineers to encounter managerial responsibilities at some point in their career (Badawy, 1982, p. 33). Given that all technologists will not become managers, "engineers seem to be particularly suited for managerial positions," because the engineer is familiar with analytical skills and has a strong pragmatic orientation (Badawy, 1982, p. 34). Finally, Badawy (1982) wrote: "the typical engineer is actually a manager or an 'organization man.' This is why many engineers tend to see management as a natural path for career development" (p. 34).

For the purpose of this study, the dependent variable, transition success will be based on Badawy's three levels of management with an additional level of engineers who have not yet transitioned to management. More specifically, the dependent variable, transition success, is defined by job titles clustered into four levels: industrial engineer, Jr. IE, Sr. IE, or principal IE (Level 0); supervisor, or manager (Level 1); director, section manager, or unit manager (Level 2); and president or vice-president (Level 3). Badawy (1995) gave a greater description of his levels of management, supervisors (Level 1) is "the only one whose subordinates are nonmanagers. Rather, they are professional specialists in technical fields" (p. 11).

It is crucial to better understand the relationship between systems thinking skills and technical industrial engineering skills and transition success to management as industrial engineers take advantage of expanded opportunities being afforded them in the knowledge age. Badawy (1995) addressed the managerial skill mix, technical, administrative, and interpersonal, for managerial effectiveness. He found an inverse relationship between technical skills and management level: "they are most important at lower management levels, but that importance tends to decrease as you advance to higher levels in the organization" (Badawy, 1995, p. 32). As an engineer progresses through the management level, he or she will find "that while technical skills decrease in relative importance, the importance of administrative skills increases" (Badawy, 1995, p. 32). Furthermore, Badawy asserts that "managerial success on upper-management levels, then, is determined by [one's] vision and ability to understand how the entire system works (the conceptual skill) as well as [one's] capacity for organization and coordination among various divisions (the administrative skills)" (1995, pp. 33-34). Technical as well as administrative skills both hold some degree of importance at all levels of management while technical skills "are of enormous importance for success in engineering" at the Level 0, or non-management level, used in this study (Badawy, 1995, p. 34). So, Badawy introduced management levels and then, in a later work, discussed the importance of the skills involved in the levels of management. In this study, the managerial levels of Badawy are considered the dependent variable along with the added Level 0 for non-managers. Skill employment serves as the independent variable, system thinking and technical skills. Figure 3 shows the conceptual framework for the relationship between the variables of the study.

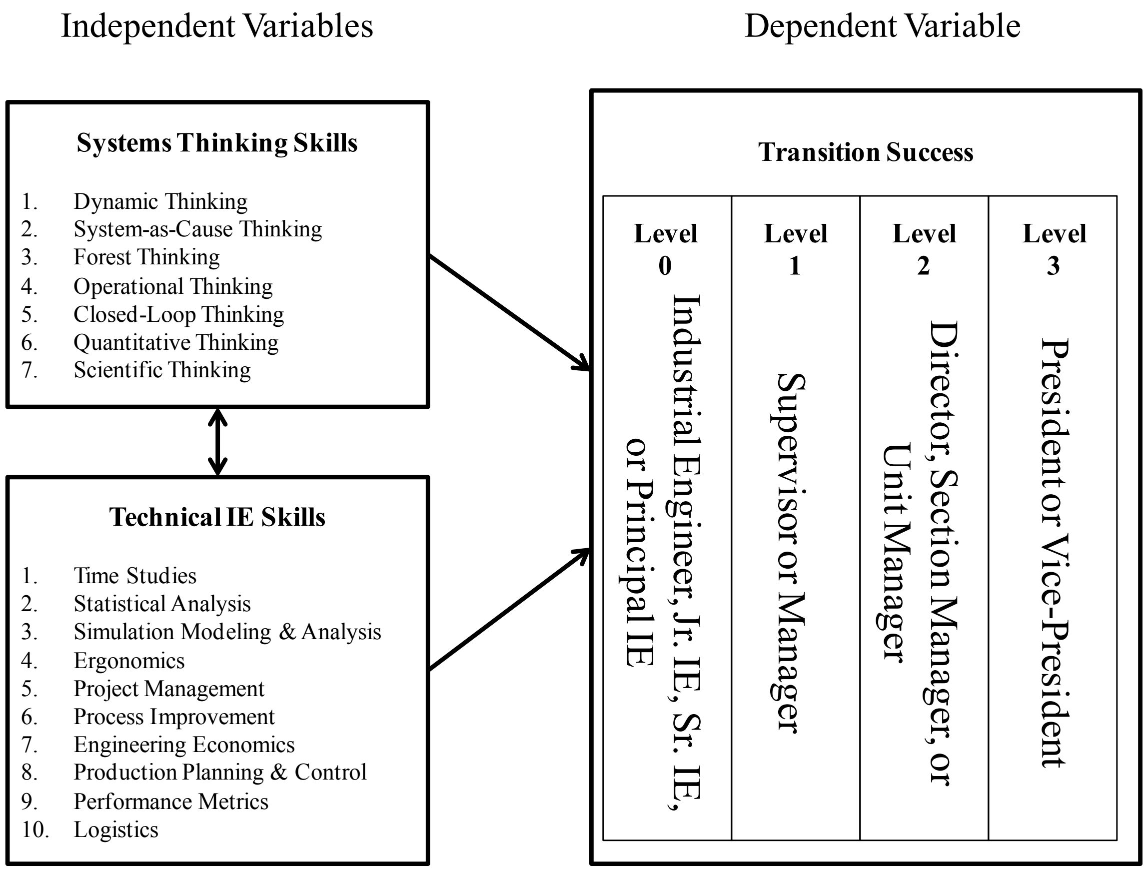

Figure 3. Conceptual framework for the independent and dependent variables used in this study

Summary of Key Concepts

The accuracy of this research depends on understanding the terms in the survey research instrument and in this investigation. The summaries of key concepts are presented below:

- Systems thinking: "Systems thinking is a conceptual framework, a body of knowledge and tools that has been developed over the past fifty years, to make the full patterns [of change] clearer, and to help us see how to change them effectively" (Senge, 2006, p. 7). Richmond (2000) defined seven essential skills, necessary to engage in systems thinking, which he described as "a set of tools…that help us map and explore dynamic complexity" (p. 3). The seven systems thinking skills defining this study's independent variable are:
    1. Dynamic thinking: "To frame a problem or issue in terms of a pattern of behavior over time" (Richmond, 2000, p. 5). Using the past "to generate insights and guide inquiry into what has produced the current state" (Richmond, 2000, p. 10).
    2. System-as-Cause thinking: "Determin[ing] which underlying set of relationships are most relevant for improving the behavior pattern of interest" (Richmond, 2000, p. 12). The ability to construct a model to explain how behavior arises through the identification of the variables within the control of decision makers.
    3. Forest thinking: Viewing the interactions between variables and the role each plays in the entire organization. Rising above the "functional silos

and view[ing] the system of relationships that link the component parts" (Maani & Maharaj, 2004, p. 23).

4. Operational thinking: Querying for what exactly caused a particular outcome, thinking causally not correlationally. Identifying leverage points for improving performance and recognizing the notion of interdependence. It "looks at the structure of 'physics' or relationships, at *how* one variable affects another, not just that they affect each other" (Maani & Maharaj, 2004, p. 23)
5. Closed-Loop thinking: Specifying the relationships within the constructed model. Brings life to the structure and enables the dynamics of the model to unfold. "Seeing causal relationships in circular terms—as *two-way*, rather than one-way streets" (Richmond, 2000, p. 19).
6. Quantitative thinking: Outfitting structural assumptions with numbers. The skill consists of "providing numerical values for constants, choosing initial magnitudes for stocks, and specifying numerical values for graphical function relationship" (Richmond, 2000, p. 20).
7. Scientific thinking: Most applicable after a model has been constructed, it builds "a better shared understanding of a system for the purpose of improving its performance" (Richmond, 2000, p. 22). Involves testing two qualities of a model: "face validity, which relates to model structure, and robustness, which has to do with model behavior" (Richmond, 2000, p. 22).

- The technical industrial engineering skills defining this study's independent variables are:
    1. Time studies: "A procedure used to measure the time required by a qualified operator working at the normal performance level to perform a given task in accordance with a specified method" (Sellie, 2001, 17.21).
    2. Statistical analysis: "Quantifying and explaining variability in sampled data and appropriately accommodating this variability when drawing conclusions" (Slate, 2001, 11.3). Key statistical concepts include: obtaining and graphically displaying sampled process data, selecting an appropriate probability model for the data, and using the model to draw conclusions of interest.
    3. Simulation modeling and analysis: "The imitation of a system with all its dynamic processes in an experimental model which is used to establish new insights and to ascertain whether these insights can be transferred to real situations" (Schraft, Neugebauer, & Schmid, 2001, p. 378).
    4. Ergonomics: "An applied science where the characteristics of people are used in designing jobs, tools, equipment, buildings, and environments with safety, quality, and high productivity as the goals" (Cerovec, 2001, p. 6.206).
    5. Project management: "The planning, organizing, guiding, and monitoring of organizational resources that are necessary to successfully produce one or more desired outputs or outcomes. It encompasses management of

project risks, issues, and changes, as well as product/deliverable configuration and quality" (Mundt & Smith, 2001, p. 1333).

6. Process improvement: "Assessing process performance and interrelationships with other processes. Such assessments lead directly to the identification and design of process changes that will improve the performance for the process as well as the enterprise as a whole" (Marrs & Mundt, 2001, p. 30).
7. Engineering economics: The use of "project budgeting, forecasting, progress monitoring, cash flow analysis and other financial basics [to] maximize cash flow and improve bottom line results" (Institute of Industrial Engineers, 2012b, para. 1).
8. Production planning and control: "Consists of a set of logistic functions that support the timely and effective processing of production operations" (Lankford, 2001, p. 9.143).
9. Performance metrics: Using standards to understand and manage the work to help an organization achieve its goals. Engineered standards are "useful for planning resources, setting realistic goals, measuring performance, and providing feedback" (Broderick, 2001, p. 2.55).
10. Logistics: "The group of activities concerned with the control, movement, and storage of materials" (Davis, 2001, p. 10.74). The five major functions of physical distribution include: order entry and customer service, warehousing, transportation, inventory management, and distribution administration.

- Transition Success: Four career levels through which industrial engineers progress define the dependent variable used in this study. Badawy (1982) defined the management levels as: "first level (supervisors and technical engineers), second level (middle-management managers), and third level (top management executives)" (1982, p. 7). For this study, it is important to consider the habits and skills of non-managers. So, a fourth level (Level 0) was added to include these practitioners. More specifically, this study further defines these four levels as:
    1. Zero level (engineers): Industrial engineers, Jr. IEs, Sr. IEs, and principal IEs (the "troops").
    2. First level (supervisors): Supervisor and manager. Those who directly supervise other professionals doing technical work.
    3. Second level (middle-management managers): Unit Manager (subsection), Section Manager, and Director. Charged with functional responsibilities but who do not directly supervise other professionals in the conduct of technical work.
    4. Third level (top management executives): Vice President and President. Executives are those in the highest management level of an organization who are responsible for its overall direction and management.

Study Research Questions

There is a great deal of research and literature surrounding systems thinking as well as industrial engineering; however, the problem is there is little research on industrial engineers as systems thinkers, even though the Institute of Industrial Engineers considered changing the name of the profession to “industrial and systems engineering.” More research is needed on systems thinking among industrial engineers and this study will help fill the need for discovering more about how systems thinking and technical industrial engineering skills influence both the role and leadership capabilities of industrial engineers.

This study proposed four research questions that will provide valuable insights towards understanding to what extent industrial engineers adapt their use of systems thinking skills and technical industrial engineering skills as they transition from technical to managerial roles. The research questions are as follows:

1. What systems thinking skills correlate with the industrial engineer’s successful transition to management?
2. What technical industrial engineering skills correlate with the industrial engineer’s successful transition to management?
3. Do systems thinking skills and technical industrial engineering skills contribute to the industrial engineer’s successful transition to management?
4. Is skill in systems thinking a predictor of organizational management transition success among industrial engineers?

While this researcher’s review of the literature explored the history, nature, and theories related to systems thinking and industrial engineering, a need exists in trying to relate the two to each other and to transition success into management positions in work organizations. By analyzing data collected from industrial engineers, this research study tested the relationship among systems thinking and technical engineering skills and transition success. Furthermore, this research study described more clearly how industrial engineers are able to successfully leverage systems thinking in both technical and managerial roles. Lastly, recommendations for further research resulted from the findings and conclusions of this research that could help enhance the transition success of industrial engineers into leadership and managerial roles at higher rates than other engineers, given the nature of 21st century organizations in the knowledge age.

Summary of Literature

The hunter-gatherer age gave way to the agrarian age, which gave way to the industrial age, which led to the present knowledge age, and through these evolutionary shifts in the economic nature of society the necessary competencies of organizational leaders have also changed. Similarly, the role of the industrial engineer has transitioned as the world has evolved. Scientific management, developed during the industrial age, gave rise to the industrial engineering profession, which now relies heavily on systems thinking. As the economic structures of society have transitioned from primarily industry-based to increasingly knowledge-based, the role of technical industrial engineers has increasingly incorporated systems thinking skills into their arsenal of engineering competencies. The inclusion of systems thinking skills appears to be one of the factors that often propel industrial engineers' career transitions from technicians within their organizations to leaders and managers of their organizations.

The origin of industrial engineering as a discipline is quite complex. The roots of this discipline come from mathematics and military engineering. Eventually, these two areas gave birth to the more commonly known engineering disciplines of electrical, mechanical, and chemical engineering. Mechanical engineering was greatly affected by the era of the scientific management of manufacturing operations, whereas electrical engineering was influenced by control theory. All three sciences converge on systems thinking and management philosophy. With this convergence, industrial and systems engineering was born. Figure 4 is a visual representation created by Turner, Mize, Case, & Nazemetz (1992) of the relationship and transition between other disciplines and industrial and systems engineering.

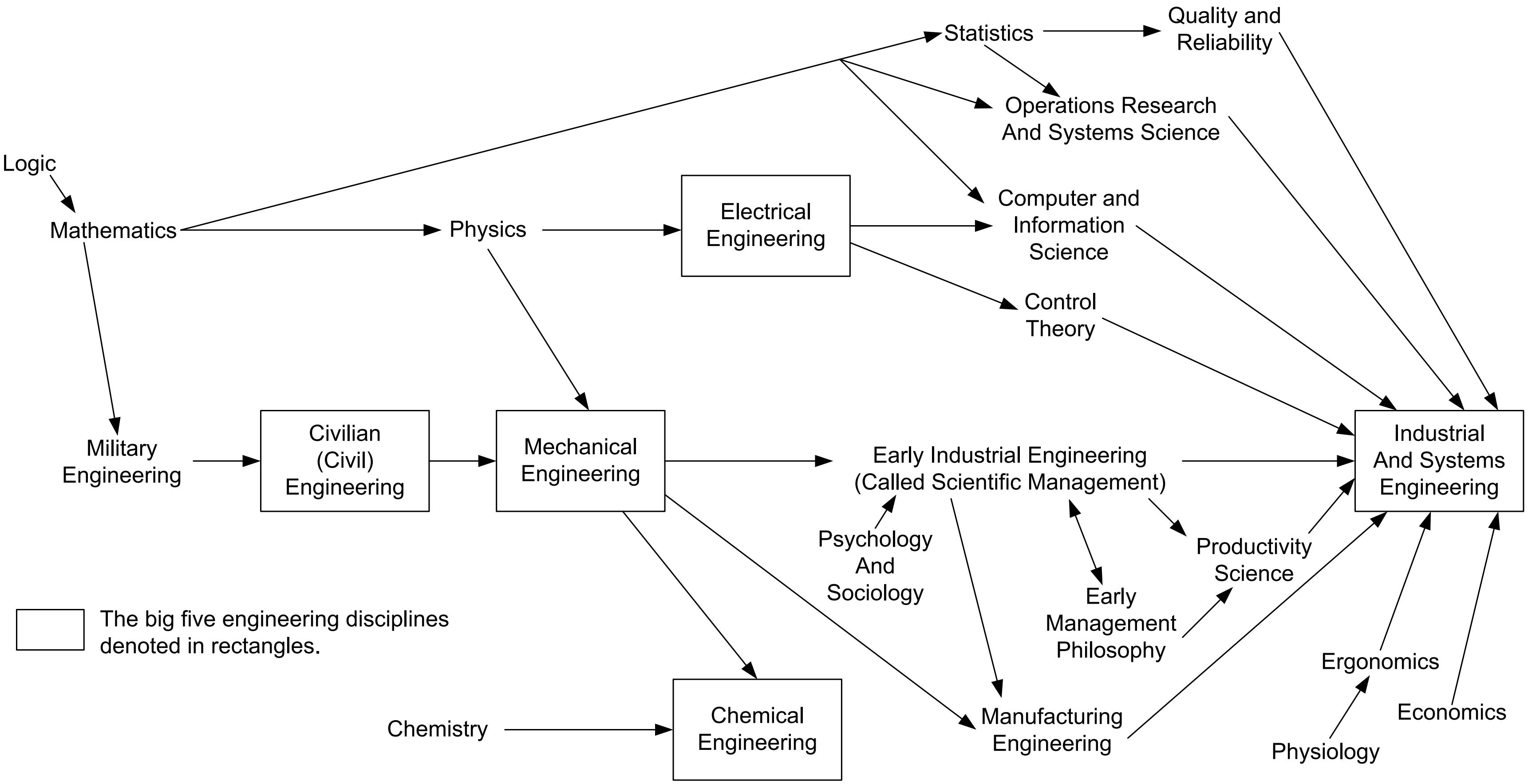

Figure 4. Representation of the relationship and transitions between industrial and systems engineering to other disciplines. Reprinted from *Introduction to Industrial and Systems Engineering*, 3rd edition (p. 22), by W.C. Turner, J.H. Mize, K.E. Case, & J.W. Nazemtz, 1992, Upper Saddle River, NJ: Prentice Hall. Copyright 1993 by Pearson Education, Inc. Reprinted with permission. (Appendix A)

During the industrial age and the era of scientific management, industrial engineers proved that they “are talented at cutting costs, producing efficiencies, and improving productivity” (Brandt, 2009, p. 34). By aptitude, training, and experience, industrial engineers are adept at systems thinking, at how to generate knowledge within an organization, and at how to use knowledge effectively and practically to improve continuously the performance of any organization. In other words, industrial engineers are especially well-equipped to lead the “learning organizations” of the knowledge age.

Industrial engineers are quickly finding their place within the knowledge age’s learning organizations. Since its establishment as a standalone degree, industrial engineering education has grown to incorporate some systems thinking concepts, methodologies, and techniques. “An industrial engineer who can view an organization as a whole—as a system of interdependent components—and who can help others within the organization do the same has tremendous potential” (Gaboury, 1999, p. 20). By stating that “traditional tools combined with the ability to recognize, study, and understand interdependencies enable [industrial engineers] to gain insight into factors that drive organizational business,” Gaboury is making clear that there is a distinct and quantifiable relationship between industrial engineering skills and systems thinking skills (1999, p. 20).

Since 1960, the approximate date many have used to mark the beginning of the knowledge age, the industrial engineering profession has seen unprecedented growth and the future job demand for industrial engineers is very promising. The National Bureau of Labor Statistics projects that “the number of industrial engineers is expected to grow by 6 percent between 2010 to 2020” (Louisiana State University, 2014, para. 5). The growing opportunity is even present "when many companies suffer fiscal hits and feel compelled to seek refuge by immediately cutting their work forces, opportunities for industrial engineering—at least on an operational level—appear plentiful" (Brandt, 2009, p. 34).. The knowledge age organization is facing a host of challenges on all fronts, and "the successful resolution of these challenges will require the broad systems thinking that is the hallmark of the industrial engineer" (Thorn & Rogerson, 2002, p. 40).

The technical skills needed for the work activities of an industrial engineer are acquired through an engineering education and on-the-job experiences. These are the basics of the profession. In addition, Billings et al. (2001) identified systems thinking as one factor that is "evident in those organizations in which industrial engineers have enjoyed much success," and it is a key success factor "for ensuring the effectiveness of the industrial engineer's role" (p. 1.27). Furthermore, "systems thinking is a skill that every industrial engineer should possess" (Billings et al., 2001, p. 1.27). While technical skills serve industrial engineers quite well, they alone are not significant enough to propel industrial engineers into general management positions, but they do give industrial engineers special aptitudes and proclivities for knowledge age management. Industrial engineers, moreover, have proven themselves adept at morphing and at retooling their skill sets. In addition, Badiru claimed: "industrial and systems engineers are perhaps the most preferred engineering professionals because of their ability to manage complex organizations" (2006, p. 8-1).

It is crucial to understand better the relationship between systems thinking skills and technical industrial engineering skills in order to understand the industrial engineers successful transition to management, as industrial engineers take advantage of expanded opportunities being afforded them in the knowledge age. The literature presented in this review clearly shows that systems thinking skills are unique. From literature, it is also clear that the industrial engineering profession developed out of necessity and continues to refine itself, making the industrial engineer very useful to the organization. The original research of this study will attempt to discover if the use of systems thinking is an essential skill possessed and used to great effect in transitioning to managerial and leadership positions in today's organizations by industrial engineers.

CHAPTER 3: METHODOLOGY

Overview of Research and Hypotheses

This chapter provides an overview of the research methodology used in this quantitative study to test the relationship of systems thinking skills and technical engineering skills among industrial engineers in transitioning from technical to management roles. The review of the literature described systems thinking as a way of thinking that looks at the whole first and then the parts of the system second. Systems thinking can be used to help individuals understand how systems work and to treat systems more effectively. A number of researchers, Russell Ackoff (1994), Peter Scholtes (1998), and Peter Senge (1999), found systems thinking encourages individuals "to look for patterns of interaction and underlying structures that shape the emergent patterns of systems behavior" (Morgan, 2005, p. 4). In addition, Morgan (2005) wrote, "All systems have a story. Part of the challenge is helping people see it. If they can grasp the whole system in action, their perspective changes as well as their actions" (p.16).

Can we, then, assume system thinking skills learned by industrial engineers today, knowingly or unknowingly, changed how they solve problems and are a reason why more industrial engineers are successfully transitioning into management at all levels of the organization? Assuming transition success of industrial engineers into management within the organization is influenced by systems thinking, then there is a need to examine systems thinking and transition success in work organizations.

Problem Statement

The problem is today's industrial engineers, who aspire to become organizational managers, lack knowledge of the scope of systems thinking skills used with their technical industrial engineering activities and the extent to which each are applied in their organizations for advancement into management or leadership positions. The purpose of this study was to explore the theory of systems that relates systems thinking to transition success into organizational management among industrial engineers. The engineers who participated in the study were members of the Institute of Industrial Engineers and employed in any industry.

Study Variables

In this research study, Barry Richmond's (2000) seven essential systems thinking skills—dynamic thinking, system-as-cause thinking, forest thinking, operational thinking, closed-loop thinking, quantitative thinking, and scientific thinking—serve to define the first of two independent variables, viz., systems thinking. Technical industrial engineering skills—time studies, statistical analysis, simulation modeling and analysis, ergonomics, project management, process improvement, engineering economics, production planning and control, performance metrics, and logistics—serve to define the second independent variable used in this study, viz., technical industrial engineering skills. The dependent variable, transition success, will be defined using level 0, industrial engineer, junior industrial engineer, senior industrial engineer or principal industrial engineer, as well as the three levels of management identified by Badawy (1982), viz., 1) supervisors and managers (supervisors), 2) director, section manager, or unit manager (middle-management managers), and 3) president or vice-president (top management executives).

Hypotheses

There are four hypotheses for this research study. All four revolve around what skills industrial engineers use and whether there is a relationship between skill usage and transition success and whether these skills are predictive of managerial transition success. The following hypotheses are relevant to determining the relationship between skill usage and managerial transition success:

1. There is no significant relationship between systems thinking skills and managerial transition success among industrial engineers.
2. There is no significant relationship between technical industrial engineering skills and managerial transition success among industrial engineers.

If systems thinking skills and technical industrial engineering skills are predictive to managerial transition success then can the study make predictions that systems thinking skills and technical industrial engineering skills predict transition success? The following hypothesis is relevant to determining how certain one can be in making that prediction:

3. There is a significant contribution made by systems thinking skills and technical industrial engineering skills to managerial transition success among industrial engineers.

If there is a relationship between systems thinking skills and transition success among industrial engineers, is there a predictive relationship between systems thinking skills and managerial transition success among industrial engineers? The following hypothesis is relevant to determining the predictive relationship between systems thinking and managerial transition success:

4. There is a predictive relationship between systems thinking skills and managerial transition success among industrial engineers.

By providing insights towards answering these questions and testing these hypotheses, this study assists industrial engineers and students in gaining an understanding of the important role systems thinking and industrial engineering technical skills play in the industrial engineer's transition to management. The study also eliminates the ambiguity many industrial engineers exhibit early in their career on how to advance from technical positions to management and executive leadership positions within their organizations.

Study Method

There are many types of data collection instruments that were appropriate for a study of this size and style. These include personal interviews, telephone interviews, mail surveys, and Internet surveys.

Personal interviews have the benefit of increased respondent participation, but cost is high, the rate of data collection is slow, and geographic flexibility is low. This methodology was rejected of the difficulty of being able to obtain personal interviews with the number of respondents needed to make the study statistically significant. Telephone interviews provide for fast data collection, assuming good respondent cooperation. However, the financial cost and time consumed to reach the sample size targeted for this study were significant challenges for this researcher. Mail surveys were also rejected both in terms of costs and delivery time. The rejected methodologies have the added drawback of requiring a great deal of data input once responses are collected.

The Internet survey was the chosen methodology of this study, because there is typically a high response rate due to the ease of use and high geographic and industry flexibility. Further, this researcher was able to send the survey out to the entire population of the study. Because the Internet survey was taken in electronic format, the data was more easily compiled for statistical analysis.

Strengths and Weaknesses of Study Method

An online survey was the chosen methodology for collecting data for this research study. There are many advantages as well as several disadvantages to using a survey. “Surveys provide a quick, inexpensive, efficient, and accurate means of assessing information about the population” (Zikmund, 2003, p. 175). According to Zikmund (2003), an Internet survey, specifically, has unique advantages and disadvantages. The advantages include the following: speed of data collection, high geographic flexibility, versatility of questioning, customizable questionnaire length, no item non-response rate, no degree of interviewer influence on answers, respondents can be anonymous or known, low cost, and allowance for graphics and animation. According to Zikmund (2003), the disadvantages include the following: “variable respondent cooperation, a high possibility for respondent misunderstanding, and inability to callback or follow-up unless e-mail address is known” (p. 228).

Given the advantages and disadvantages of an Internet survey, there were several distinct challenges in using this methodology. First and foremost, there was no way to guarantee the number of responses; however, an Internet survey generally provides greater ease of use for respondents, which hopefully encouraged their participation. Furthermore, this study was dependent on receiving responses from technical and manager level industrial engineers; thus a second challenge was that there was no way to ensure equal representation from both groups.

Population

Members of the Institute of Industrial Engineers, the premiere professional organization for industrial engineers, were participants in this study. As a member of the Institute of Industrial Engineers, the researcher requested and was granted permission by the Institute of Industrial Engineers to utilize its membership directory to electronically survey a judgment sample from its 3,300 United States-based members. Demographics of the population include U.S.-based members who were manager and non-manager engineers, excluding students and professors. The permission to solicit participation of Institute of Industrial Engineers members can be found in Appendix B.

Sample

This study viewed ease of access, proximity, and the likelihood of participation as critical in the decision of whom to sample. For purposes of this study, a judgment sample was employed to obtain respondents who are manager and non-manager members of the Institute of Industrial Engineers, and represented a number of geographic locations, industries, and organizations nationally. Judgment sampling is “a nonprobability sampling technique in which an experienced individual selects the sample based on his or her judgment about some appropriate characteristic required of the sample members” (Zikmund, 2003, p. 382). In this study, the required characteristic of each sample member was experience in the industrial engineering field.

Sample Size

Establishing a minimum desirable level of sample size for factor analysis was a challenge. In a review of 60 exploratory factor analysis studies in four journals: *Educational and Psychological Measurement, Journal of Educational Psychology, Personality and Individual Differences*, and *Psychological Assessment*, Henson and Roberts (2006) reported a minimum sample size of 42 and a minimum STV ratio of 3.25:1 with 11.86% of reviewed studies using a ratio less than 5:1. In this study, there are 21 observed variables measuring 7 latent variables in systems thinking skills and 30 observed variables measuring 10 latent variables in technical industrial engineering skills. To perform an exploratory factor analysis, Urdan (2010) wrote, “a general rule of thumb is that you need 30 cases for the first observed variable and 10 cases for each additional observed variable in a factor analysis” (p. 169). Consequently, an exploratory factor analysis on a set of 21 observable variables in the survey related to systems thinking skills required a minimum of 230 respondents. For the 30 observable variables in the survey related to technical industrial engineering skills, a minimum of 320 respondents were needed.

Using a software sample calculator, with a 5% margin of error, confidence level of 95%, a population size of 3,300 Institute of Industrial Engineers members, and assuming a 50% response distribution, a sample size of 345 was recommended, which was consistent with Urdan (Raosoft, Inc., 2013). In looking at the minimum sample size for multiple regression, the minimum required sample size, given a desired probability level of .05, 2 predictors, an anticipated effect size (r^2) of .15, and a desired statistical power level of .8 required a minimum sample size of 67 (Soper, 2013). For this study, the minimum sample size was 345 and 376 was achieved. Since the categories of the dependent variable were well represented, a stratified random sample of the returns was not conducted.

Instrument: The STTSU Questionnaire

The data collection instrument, the Systems Thinking and Technical Skills Use (STTSU) questionnaire, was a web-based survey developed by the principal investigator and was unique to this study. It was created using Qualtrics, a tool developed in the 1990s to provide an uncomplicated way of conducting research. An initial email (Appendix C) was sent to the population requesting participation. Participants had two weeks to complete their responses. One week after the initial email, a second email reminded the entire population to take the survey and thanked those who had already taken it. Three days before the close of the survey, a final reminder email asked for participation and again thanked those who had already taken it. Copies of these emails are found in Appendix C. Before beginning the survey, participants were asked to read and acknowledge the letter of informed consent found in Appendix D. Survey participants were asked demographic questions such as gender, age, current and previous role, industry, years of relevant (or related) industrial engineering experience, and education level. Despite having collected this data, the researcher did not use this information in the analysis because there were not enough responses for a statistically significant analysis for each individual demographic. Instead of an analysis of each demographic, responses were analyzed in aggregate.

The STTSU questionnaire was used to obtain data on the extent to which industrial engineers perform 21 tasks related to seven systems thinking skill constructs and 30 tasks related to ten technical industrial engineering skill constructs. The survey asked respondents to determine the frequency with which they employ the skills in their current position. The data was obtained by asking each Institute of Industrial Engineers' member a series of statements in a format similar to the statement found in Figure 5.

STATEMENT:
In my current position, I collect time study data to
determine reliable time standards for all work.

☐ Never
☐ Rarely
☐ Sometimes
☐ Often
☐ Always

Figure 5. Sample survey statement

The response choices, in standard Likert fashion, ranged from never to always. Once developed, the survey statements were reviewed for comprehension by several IE practitioners representing the four levels of transition success for the study. These survey statements were edited based on the feedback received. A matrix showing survey statement alignment with both technical industrial engineering and system thinking skills is in Appendix E. The questions in this matrix align with the questions found in the survey instrument found in Appendix F.

Pilot Study

A pilot test involving 20 respondents was completed and Cronbach's Alpha calculated to test the reliability of the instrument. This pilot study along with input from expert practitioners and the work of Richmond (2000), Institute of Industrial Engineers

(2011), and the edited works of Zandin (2001), and Salvendy (2001), further strengthened the survey statements used in this study. The pilot study exposed the minimal discomfort or risk associated with participation which included a time investment of approximately 15-20 minutes. A copy of the STTSU survey instrument is in Appendix F.

Research Design

There are a variety of research methods and designs available to researchers. One such design is the correlational research design. Urdan (2010) wrote, “In this type of research, participants are not usually randomly assigned to groups. In addition, the researcher typically does not manipulate anything” (p.5). However, Urdan (2010) noted, “Correlational studies can only tell us whether variables are related to each other; they cannot lead to conclusions about causality” (p. 5).

For purposes of this study, the correlational research design was selected because this design explores the relationship between variables and allows researchers to predict scores on one variable from respondents’ scores on other variables. Also, the study sample was a judgment sample, not a random sample. A judgment sample was employed to obtain responses from manager and non-manager engineers who are members of the Institute of Industrial Engineers, and represented a number of geographic locations, industries, and organizations nationally. The required characteristic of each sample member was experience in the industrial engineering field. As opposed to descriptive and quasi-experimental research designs, correlational research design allowed the researcher to analyze the relationship among a large number of variables. In addition, it provided the degree and direction of the relationships, and this was not available through the other types of research designs.

Three survey questions (observable variables) were identified for each of the seven latent variables (or constructs) that defined systems thinking skills and for each of the ten latent variables that defined technical industrial engineering skills. A total of 21 and 30 observable variables were created for systems thinking skills and technical industrial management skills, respectively.

To determine the underlying structure of the 21 observed variables used in this study to define the first independent variable, systems thinking skills, a reliability analysis using Cronbach's alpha was conducted followed by an exploratory factor analysis. The same process was used to determine the underlying structure and reliability of the 30 observed variables used in this study to define the second independent variable, technical industrial engineering skills. It generated similar factors aligning with the seven latent variables (or constructs) that define systems thinking skills and the ten latent variables (or constructs) that define technical industrial engineering skills. In addition, the items that defined each construct, as a group, demonstrated positive correlation.

Exploratory Factor Analysis (EFA)

Item scores on the systems thinking and technical industrial engineering skill constructs were analyzed using factor and reliability analysis. Because this study used three items (or measures) to represent a single construct, exploratory factor analysis (EFA) was used to determine how well these items go together, as well as how well the items that are supposed to represent a given construct separate from the items that are supposed to represent a different construct.

Zikmund (2003) explained, "exploratory factor analysis (EFA) is used to summarize the information contained in a large number of variables into a smaller number of factors" and the statistical purpose of EFA is "to determine linear combinations of variables that aid in investigating the interrelationships" (p. 586). In essence, EFA extracted factors from the set of 51 survey items until there were no more meaningful factors to be extracted. The factors had an eigenvalue that indicated the amount of variation in the items accounted for by each factor. By examining the eigenvalues, the researcher distinguished the major underlying factors in the study from the error variation.

The next step in EFA was obtaining factor scores for those factors that the eigenvalues identified as accounting for most of the variance. The scores represented each observation's calculated value on each of the factors. Next, the researcher determined the factor loadings. In this study, factor loadings were obtained using image factoring in the researcher's chosen statistical software, Statistical Package for the Social Sciences (SPSS). "In essence, the factor analysis process involves extracting factors from a set of items until there are no more meaningful factors to be extracted" (Urdan, 2010, p. 171). The final step of EFA was rotation, completed by SPSS, of the factor loadings. The researcher then conducted multiple regression analysis on the rotated data to answer the four hypotheses for the study.

Cronbach's Alpha

Zikmund (2003) stated, "reliability is the degree to which measures are free from error and therefore yield consistent results" (p. 300). In this study, reliability analysis was conducted using Cronbach's alpha. Cronbach's alpha "uses the associations among a set of items to indicate how well the items, as a group, hold together" (Urdan, 2010, p. 178). For purposes of this study, the researcher wanted to know if all the items in the survey questionnaire that are supposed to measure a single underlying construct were answered in a similar way by respondents. Based on the Cronbach's alpha scores, the questionnaire was deemed reliable.

Test of Hypotheses

To test Hypothesis 1 and Hypothesis 2, the relationship between systems thinking skills and technical industrial engineering skills to managerial transition success among industrial engineers, Spearman rho analysis was used. The independent variables, systems thinking skills and technical industrial engineering skills, were defined as those seven systems thinking skills identified by Barry Richmond (2000) and the ten technical industrial engineering skills identified by the Institute of Industrial Engineers. The dependent variable, transition success, was defined using the three levels of management identified by Badawy (1982) and one non-management level of engineers.

To test Hypothesis 3, the contribution between systems thinking skills and technical industrial engineering skills to managerial transition success among industrial engineers, multiple regression analysis was used. The independent variables, systems thinking skills and technical industrial engineering skills, were defined as those seven systems thinking skills identified by Barry Richmond (2000) and the ten technical industrial engineering skills identified by the Institute of Industrial Engineers. The dependent variable, transition success, was defined using the three levels of management identified by Badawy (1982) and one non-management level of engineers.

To test Hypothesis 4, the predictive relationship between systems thinking skills and managerial transition success among industrial engineers, multiple regression analysis was used. The independent variable, systems thinking skills were defined as those seven systems thinking skills identified by Barry Richmond (2000). The dependent variable, transition success, was defined using the three levels of management identified by Badawy (1982) and one non-management level of engineers.

Multiple Regression Analysis

Multiple regression analysis was used to test two of this study's four hypotheses. Multiple regression analysis as defined by Zikmund (2003) is "an extension of bivariate regression analysis, which allows for the simultaneous investigation of the effect of two or more independent variables on a single interval-scaled dependent variable" (p. 576). Multiple regression provided three components that the researcher utilized in answering the research questions: Correlations among variables (r), Multiple Correlation coefficient (R), and Coefficient of Determination (R^2); ANOVA table; and regression coefficients table.

The Spearman rho correlations among variables helped explain whether or not the two predictor variables (systems thinking skills and technical industrial engineering skills) are strongly correlated with the dependent variable, transition success. The multiple regression coefficient (R) measured the correlation between systems thinking and technical industrial engineering skills combined and transition success. The coefficient of determination (R^2) provided the variance explained for the combined independent variables and dependent variable.

Multiple regression analysis also provided an ANOVA table that informed the researcher whether the overall regression model was statistically significant. In essence, it told whether or not the relationship between this study's predictor variables (systems thinking and technical industrial engineering skills) and dependent variable (transition success) was statistically significant. The regression coefficients table allowed the researcher to determine whether each predictor variable was statistically significant to the dependent variable, transition success, while controlling for the other predictor variable.

Multiple regression analysis was chosen because of its "ability to examine the relations between variables, the relative predictive power of independent variables on the dependent variable, and the unique contributions of one or more independent variables" (Urdan, 2010, p. 145). Urdan (2010) argued that "multiple regression analysis provides much more than a simple correlation analysis" (p. 146), such as a Pearson correlation coefficient, or a simple linear regression analysis. Urdan (2010) continued by arguing that a Pearson correlation coefficient, for example, does not distinguish "between independent and dependent variables, while in regression analysis there is always a designated predictor variable and a designated dependent variable" (p. 146). This is because "the purpose of regression analysis is to make predictions about the value of the dependent variable given certain values of the predictor variable" (Urdan, 2010, p. 145). When conducting multiple regression analyses using SPSS, Urdan (2010) recommended "the sample, at a minimum, be 30 cases, plus 10 for each predictor variable" (p. 153). However, the researcher is aware that the accuracy of the regression model is dependent on the correlation values of the constructs. In this study, the correlation values are low so the model has limited accuracy. The multiple regression analysis was selected given the multiple independent variables in this study because a simple regression analysis, like simple correlation analysis, involved a single independent (or predictor) variable and a single dependent variable.

IRB Procedures

The research conducted in the course of this study was subject to approval by the Institutional Review Board (IRB) of Walsh College which reviewed the following related to the use of human subjects:

a. Respondents were asked to read an email with the survey link (Appendix C). By accessing the link provided in the cover letter, the participants were given the opportunity to read the survey letter of consent (Appendix D). A radio button was provided to indicate consent. If a participant chose not to consent, the survey ended. If participants chose to consent the survey advanced and participants were able to submit their responses to the researcher.

b. In protecting their anonymity, the cover letter stated that identifying information such as email address or IP address was not to be collected.

c. In eliminating or minimizing physical and/or psychological risks, the cover letter stated that the most obvious risk was a time commitment of less than 20 minutes.

d. In assuring complete anonymity of the data obtained, each respondent's questionnaire was processed in aggregate.

e. The researcher gained approval from the Walsh College Institutional Review Board (IRB) prior to beginning any research.

Research subjects were acquired through the assistance of the Institute of Industrial Engineers at the expense of the researcher. No personal identifying information was collected. Care and accuracy in the data collection procedure were ensured through the use of Qualtrics, an academically respected data collection instrument. Since this study had minimal risk, it fell under the exempt review procedures, meaning that it involved human subjects but did not require ongoing review from the IRB. The project was not amended in such a way that it no longer met the exemption criteria.

The researcher completed all requirements to serve as a principle investigator per Walsh College guidelines. This included completion of an online certification through The Collaborative Institutional Training Initiative (CITI) as well as required coursework. Additionally, the researcher worked under sponsorship of a Walsh College faculty member and no student research assistants were employed. All Walsh College publication policies and copyright policies were followed in the course of the study. A submission including all required documents was submitted for institutional review board approval in a timely manner consistent in completing the research study. Finally, no adverse incidents occurred in the course of conducting research. The institutional review board approved the researcher’s request and the survey of subjects commenced immediately.

Summary of Data Analysis

This study aids in understanding the relationship between systems thinking skills and technical industrial engineering skills and transition success to management, as industrial engineers take advantage of expanded opportunities being afforded them in the knowledge age. The literature presented in this review illustrated systems thinking skills as a unique skill set. Furthermore, the industrial engineering profession developed out of necessity and continues to refine itself, making the industrial engineer very useful to the organization.

The research of this study explored the theory of systems that relates systems thinking to transition success into organizational management among industrial engineers, who are members of the Institute of Industrial Engineers and have been or are currently employed in any industry. The data collected through the survey questionnaire used in this study was analyzed by the researcher to draw findings and conclusions. The researcher employed exploratory factor and reliability analyses as well as multiple regression analysis to determine the relationship between the independent and dependent variables of the study.

CHAPTER 4: RESULTS AND DISCUSSION

Overview of Results

This study sought to understand the relationship between systems thinking skills and technical industrial engineering skills and transition success to management among industrial engineers. All statistical analysis was completed with the Statistical Package for Social Sciences (SPSS). A 51-item internet survey questionnaire was created to measure 17 different underlying constructs measuring the independent variables; seven for systems thinking and ten for technical industrial engineering skills. The dependent variable, transition success, was measured using a Likert-type scale. Using Cronbach's alpha, the questionnaire was tested for reliability in a pilot study involving 20 industrial engineers as expert participants. The pilot study confirmed acceptable reliability for all items in the questionnaire, and the researcher launched the survey to the Institute of Industrial Engineers distribution list. Data from 376 respondents was collected over a two-week period and used in the study, exceeding the required sample size of 345.

Demographic Analysis

While demographic information was collected, it was not statistically significant for inclusion in the analysis of the study. Sample size was adequate for aggregate analysis, however; the demographic sampling was not large enough to be analyzed on an individual level.

Table 2 shows the gender demographics of the survey participants. The total number of participants was 376. Of this total, 86 or 22.9% were women and 290 or 77.1% were men.

Table 2

Gender demographics of survey participants

Gender	Industrial engineer, jr. industrial engineer, sr. industrial engineer, or principal industrial engineer (Level 0)	Supervisor or manager (Level 1)	Section manager, unit manager, or director (Level 2)	Vice-president or president (Level 3)	Total	Percent to Total
Male	106	53	69	62	290	77.1%
Female	41	25	13	7	86	22.9%
Total	147	78	82	69	376	100.0%
Percent to Total	39.1%	20.7%	21.8%	18.4%		

Table 3 shows the age demographics of the survey participants. The largest age group was 51-60 years of age with 105 respondents or 27.9%. The next largest group was 41-50 years of age at 80 or 21.3%. Over 70 years of age was the smallest group at 4.5% followed by 21-30 years of age with 51 or 13.6%.

Table 3

Age demographics of survey participants

Years of Age	Industrial engineer, jr. industrial engineer, sr. industrial engineer, or principal industrial engineer (Level 0)	Supervisor or manager (Level 1)	Section manager, unit manager, or director (Level 2)	Vice-president or president (Level 3)	Total	Percent to Total
21-30 years of age	42	6	2	1	51	13.6%
31-40 years of age	33	16	13	4	66	17.6%
41-50 years of age	26	19	26	9	80	21.3%
51-60 years of age	26	22	24	33	105	27.9%
61-70 years of age	18	10	15	14	57	15.2%
Over 70 years of age	2	5	2	8	17	4.5%
Total	147	78	82	69	376	100.0%
Percent to Total	39.1%	20.7%	21.8%	18.4%		

Table 4 shows the years of experience of the survey participants. The largest group was those with 1-10 years of experience with a total of 119 or 31.6%. The smallest groups were over 50 years at 1.3% and 41-50 years at 3.7%. The overwhelming majority of participants had 1-30 years of experience and comprised 77.1% of the participant total.

Table 4

Years of experience demographics of survey participants

Years of Experience	Industrial engineer, jr. industrial engineer, sr. industrial engineer, or principal industrial engineer (Level 0)	Supervisor or manager (Level 1)	Section manager, unit manager, or director (Level 2)	Vice-president or president (Level 3)	Total	Percent to Total
1-10 years	74	21	14	10	119	31.6%
11-20 years	36	21	18	8	83	22.1%
21-30 years	21	20	29	18	88	23.4%
31-40 years	12	12	17	26	67	17.8%
41-50 years	3	4	3	4	14	3.7%
Over 50 years	1	0	1	3	5	1.3%
Total	147	78	82	69	376	100.0%
Percent to Total	39.1%	20.7%	21.8%	18.4%		

Table 5 shows the highest degree obtained by the survey participants. 213 participants or 56.6% of the total had a Master degree. 91.8% of all survey participants had either a Bachelor or Master degree.

Table 5

Highest obtained degree demographics of survey participants

Highest Obtained Degree	Industrial engineer, jr. industrial engineer, sr. industrial engineer, or principal industrial engineer (Level 0)	Supervisor or manager (Level 1)	Section manager, unit manager, or director (Level 2)	Vice-president or president (Level 3)	Total	Percent to Total
High school diploma	1	0	0	1	2	0.5%
Associate degree	1	1	0	0	2	0.5%
Bachelor degree	64	33	25	10	132	35.1%
Master degree	74	39	55	45	213	56.6%
Doctorate/PhD	7	5	2	13	27	7.2%
Total	147	78	82	69	376	100.0%
Percent to Total	39.1%	20.7%	21.8%	18.4%		

The discipline of the highest degree obtained by the survey participants is shown in Table 6. 62.5% of participants held their highest degree in industrial engineering. Business administration was the next highest total with 24.5% of the participants holding this degree.

Table 6

Discipline of highest degree demographics of survey participants

Discipline of Highest Obtained Degree	Industrial engineer, jr. industrial engineer, sr. industrial engineer, or principal industrial engineer (Level 0)	Supervisor or manager (Level 1)	Section manager, unit manager, or director (Level 2)	Vice-president or president (Level 3)	Total	Percent to Total
Engineering, except industrial	11	4	5	1	21	5.6%
Industrial Engineering	105	44	48	38	235	62.5%
Business Administration	25	22	24	21	92	24.5%
Arts and Sciences	1	3	0	3	7	1.9%
Other	5	5	5	6	21	5.6%
Total	147	78	82	69	376	100.0%
Percent to Total	39.1%	20.7%	21.8%	18.4%		

The demographic data shows that for the Level 0 engineer, the majority of respondents were male industrial engineers, 21-40 years of age, with less than 10 years of work experience, and a Master degree in industrial engineering. At Level 1supervisor or manager, the majority of respondents were males ages 41-60 with 11-30 years of experience and a Master degree in industrial engineering. While the majority were male, roughly one-third were female. At Level 2 directors, the majority of respondents were male aged 41-60 with 21-30 years of experience and a Master degree in industrial engineering. At Level 3, president, the majority of respondents were males aged 51-60 with 31-40 years of experience and a Master degree in industrial engineering. Overall, females accounted for nearly 30% of respondents while 40% of respondents were from the Level 0. Given the demographics, the analysis of data segmented into demographic was not statistically significant.

The analysis phase of the study began by testing the reliability of the 51-item survey instrument using the judgment sample population. Again, the Cronbach's alpha scores showed an acceptable level of internal consistency for all items in the questionnaire. Next, the researcher used SPSS to calculate the Spearman rho correlation analyses to test hypotheses 1 and 2 followed by factor and multiple regression analyses to test hypotheses 3 and 4. The results were then interpreted and reported by the researcher in answering the four hypotheses developed for the study.

Results and Interpretation of Data

Pilot Study

Prior to the initiation of the data collection process, the Systems Thinking and Technical Skills Use (STTSU) survey questionnaire created by the researcher was tested for internal consistency using Cronbach's alpha test of reliability. The researcher selected 20 expert practitioners in industrial engineering, five representing each level of transition success, and they agreed to participate in the pilot study. The data collected from the pilot study was analyzed against a minimum alpha level of 0.7 to determine acceptable reliability for each variable. With all coefficients at or higher than the 0.7 minimum alpha level, the instrument was deemed reliable. The resulting Cronbach's alpha scores for this study are found in Table 7.

Table 7

Cronbach's alpha for the pilot study

Systems Thinking Skills	Pilot Study
1. Dynamic Thinking (DT)	0.782
2. System-as-Cause Thinking (SCT)	0.761
3. Forest Thinking (FT)	0.738
4. Operational Thinking (OT)	0.726
5. Closed-Loop Thinking (CLT)	0.726
6. Quantitative Thinking (QT)	0.778
7. Scientific Thinking (ST)	0.835

Industrial Engineering Skills	Pilot Study
1. Time Study (TS)	0.943
2. Statistical Analysis (SA)	0.690
3. Simulation Modeling & Analysis (SMA)	0.870
4. Ergonomics (E)	0.944
5. Project Management (PM)	0.699
6. Process Improvement (PI)	0.724
7. Engineering Economics (EE)	0.893
8. Production Planning & Control (PPC)	0.880
9. Performance Metrics (PEM)	0.719
10. Logistics (L)	0.903

Based on the acceptable Cronbach's alpha values, the researcher proceeded with the study without making any changes or excluding any observable variables. Institutional review board approval was obtained prior to conducting the pilot test. The pilot test showed that the survey was consistent and reliable.

Study Reliability

After institutional review board approval and completing the pilot study, the researcher used Qualtrics to electronically survey 3,316 Institute of Industrial Engineers members listed in the membership directory. After a two-week time period for survey completion, the researcher received 388 responses (11.7%) with 12 surveys incomplete, resulting in a sample population of 376 completed surveys. The calculated sample size for this study of 345 was exceeded providing an adequate amount of data to perform factor and multiple regression analyses. The analysis phase of the study began by testing the reliability of the 51-item survey instrument using the sample population. Again, the Cronbach's alpha scores showed an acceptable level of internal consistency for all items in the questionnaire exceeding the desired threshold of 0.7 as shown in Table 8.

Table 8

Cronbach's alpha for the study

Systems Thinking Skills	Full Study
1. Dynamic Thinking (DT)	0.735
2. System-as-Cause Thinking (SCT)	0.742
3. Forest Thinking (FT)	0.786
4. Operational Thinking (OT)	0.756
5. Closed-Loop Thinking (CLT)	0.754
6. Quantitative Thinking (QT)	0.786
7. Scientific Thinking (ST)	0.785

Industrial Engineering Skills	Full Study
1. Time Study (TS)	0.887
2. Statistical Analysis (SA)	0.701
3. Simulation Modeling & Analysis (SMA)	0.864
4. Ergonomics (E)	0.840
5. Project Management (PM)	0.746
6. Process Improvement (PI)	0.708
7. Engineering Economics (EE)	0.807
8. Production Planning & Control (PPC)	0.803
9. Performance Metrics (PEM)	0.797
10. Logistics (L)	0.830

A breakdown of the responses by transition success level shows the following: 147 for level 0, Engineer; 78 for level 1, Manager; 82 for level 2, Director; and 69 for level 3, Vice-President/President.

Research Question 1

Continuing with the statistical analysis of the study, the researcher analyzed the survey data based on the four research questions developed for the study. Research Question 1 asked what systems thinking skills correlate with the industrial engineer's successful transition to management. As a result, Hypothesis 1 was created stating there is no significant relationship between systems thinking skills and managerial transition success among industrial engineers. A test of Hypothesis 1 was conducted using Spearman rho correlation analysis.

The Spearman rho test measured the correlation between systems thinking skills and transition success and the significance of the relationship between the variables. As shown in Table 9, the findings show that dynamic thinking (DT), forest thinking (FT), and quantitative thinking (QT) were significant at the 0.05 level while system-as-cause thinking (SCT) and closed-loop thinking (CLT) were significant at the 0.01 level.

Table 9

Spearman rho values for systems thinking skills

	Transition Success	DT	SCT	FT	OT	CLT	QT	ST
Correlation Coefficient	1.000	.118*	.197**	.101*	.022	.173**	.103*	.054
Sig. (2-tailed)	-	.022	.000	.050	.677	.001	.046	.297
N	376	376	376	376	376	376	376	376

*-Correlation is significant at the 0.05 level (2-tailed).
**-Correlation is significant at the 0.01 level (2-tailed).

Operational thinking (OT) and scientific thinking (ST), while positive in correlation, were insignificantly correlated with transition success. Although evidenced by weak to low strength in their relationship, five of seven systems thinking skills reflected statistically significant positive correlations to transition success, rejecting the null hypothesis. As a result, it can be argued that as dynamic thinking, system-as-cause thinking, forest thinking, closed-loop thinking and quantitative thinking increases in the workplace among industrial engineers, their transition success into management increases.

Research Question 2

Research Question 2 asked what technical industrial engineering skills correlate with managerial transition success among industrial engineers. As a result, Hypothesis 2 was created stating there is no significant relationship between technical industrial engineering skills and managerial transition success among industrial engineers. A test of Hypothesis 2 was conducted using Spearman rho correlation analysis.

The Spearman rho test measured the correlation between technical industrial engineering skills and transition success and the significance of the relationship between the variables. As shown in Table 10, the inverse relationship between time study (TS) and transition success was significantly correlated at level 0.01.

Table 10

Spearman rho values for industrial engineering skills

	Transition Success	TS	SA	SMA	E	PM	PI	EE	PPC	PEM	L
Correlation Coefficient	1.000	-.163**	-.012	-.007	-.035	.284**	-.004	.119*	.103*	.058	.115*
Sig. (2-tailed)	-	.002	.820	.886	.493	.000	.944	.021	.045	.258	.026
N	376	376	376	376	376	376	376	376	376	376	376

*-Correlation is significant at the 0.05 level (2-tailed).
**-Correlation is significant at the 0.01 level (2-tailed).

It was also found that the inverse relationships between transition success and four independent variables [statistical analysis (SA), simulation modeling and analysis (SMA), ergonomics (E), and process improvement (PI)] did not significantly correlate. In addition, significantly positive correlation existed between transition success and project management (PM) at the 0.01 level, while significantly positive correlations existed between transition success and engineering economics (EE), production planning and control (PPC), and logistics (L) at the 0.05 level. The positive correlation between performance metrics (PEM) and transition success was not found to be statistically significant.

Although evidenced by weak to low strength in their relationship, five of the ten technical industrial engineering skills included in this study correlated significantly with transition success rejecting the null hypothesis. As a result, it can be argued that decreases in time study skills as expected complemented with increases in project management, production planning and control, engineering economics, and logistics skills in the workplace among industrial engineers increased their transition success into management.

Research Question 3

Research Question 3 asked whether those industrial engineers who rely heavily on their systems thinking skills and technical industrial engineering skills are less likely to transition successfully into managerial and executive leadership positions. As a result, Hypothesis 3 was created stating that there is a significant contribution made by systems thinking skills and technical industrial engineering skills to managerial transition success among industrial engineers. To test Hypothesis 3, exploratory factor analysis, Cronbach's alpha, and step-wise multiple regression analysis were performed on the sample population data (N=376) to determine statistical significance (R) and practical significance (R^2) among systems thinking and technical industrial engineering skills and managerial transition success.

A principal component analysis (PCA) was run on a 51-item questionnaire that measured the relationship between systems thinking and technical industrial engineering skills with managerial transition success. A varimax orthogonal rotation was employed to aid interpretability with the rotated solution exhibiting simple structure. Nine rotated factors are shown in Table 11, explaining 62.1% of the total variance.

Table 11

Factor analysis for the systems thinking and industrial engineering skills

	Component										Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	1	2	3	4	5	6	7	8	9		Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
QuantitativeT3	.688										14.601	28.629	28.629	14.601	28.629	28.629	6.777	13.288	13.288
ForestT1	.670										4.196	8.227	36.856	4.196	8.227	36.856	5.039	9.881	23.169
DynamicT3	.651										3.504	6.870	43.726	3.504	6.870	43.726	3.975	7.794	30.963
ClosLoopT1	.641										2.212	4.337	48.063	2.212	4.337	48.063	3.587	7.033	37.996
QuantitativeT1	.636										1.755	3.441	51.504	1.755	3.441	51.504	3.217	6.308	44.304
QuantitativeT2	.628										1.617	3.170	54.674	1.617	3.170	54.674	2.332	4.574	48.878
ForestT2	.616										1.388	2.721	57.396	1.388	2.721	57.396	2.272	4.455	53.333
DynamicT1	.613										1.278	2.505	59.901	1.278	2.505	59.901	2.268	4.448	57.781
DynamicT2	.590										1.096	2.148	62.049	1.096	2.148	62.049	2.177	4.269	62.049
SysAsCauseT3	.574										.992	1.946	63.995						
SysAsCauseT1	.562										.910	1.784	65.779						
ClosLoopT2	.539										.886	1.738	67.517						
ForestT3	.521										.843	1.652	69.169						
SysAsCauseT2											.807	1.582	70.752						
ClosLoopT3											.756	1.483	72.234						
SMA2		.873									.705	1.383	73.617						
SMA3		.849									.680	1.333	74.950						
ST1		.808									.659	1.292	76.242						
ST2		.791									.626	1.228	77.470						
SMA1		.714									.606	1.188	78.658						
ST3		.608									.569	1.115	79.774						
SA3		.545									.533	1.046	80.819						
PEM1			.680								.530	1.039	81.859						
PI1			.658								.513	1.005	82.864						
PEM2			.635								.502	.985	83.849						
SA2			.608								.486	.954	84.802						
PI3			.604								.461	.904	85.707						
PEM3			.576								.443	.869	86.576						
PI2			.522								.438	.860	87.435						
SA1											.428	.840	88.275						
L3				.784							.413	.809	89.084						
L1				.781							.405	.794	89.879						
L2				.754							.377	.739	90.618						

Table 11 (continued)

	Component									Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	1	2	3	4	5	6	7	8	9	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
PPC1				.599						.372	.729	91.347						
PPC2				.564						.363	.711	92.058						
PPC3										.359	.703	92.761						
TS1					.807					.334	.655	93.416						
TS2					.797					.323	.634	94.050						
TS3					.744					.311	.611	94.660						
PM3						.793				.294	.577	95.237						
PM2						.701				.281	.552	95.789						
PM1						.675				.276	.541	96.329						
OperationalT2							.701			.266	.522	96.851						
OperationalT1							.648			.240	.470	97.321						
OperationalT3							.603			.231	.453	97.774						
EE2								.795		.222	.434	98.208						
EE1								.707		.214	.419	98.627						
EE3								.676		.192	.377	99.005						
E1									.725	.187	.367	99.371						
E2									.683	.167	.328	99.699						
E3									.663	.153	.301	100.000						

To interpret the rotated factors, they must be relabeled based on research of the content of the variables. SPSS does not label the variables, but does clump together like items with common themes. The underlying theme of the survey items included in each component in Table 10 was analyzed by the researcher and each component relabeled as follows:

Component 1: Systems Approach (SyAp)
Component 2: Modeling (M)
Component 3: Continuous Improvement (CI)
Component 4: Supply Chain (SC)
Component 5: Time Study (TS)
Component 6: Project Management (PM)
Component 7: Operational Thinking (OT)
Component 8: Engineering Economics (EE)
Component 9: Ergonomics (E)

Cronbach's alpha was again calculated for each component to ensure reliability among the survey questions for each rotated factor. The Cronbach's alpha values again reflected acceptable reliability and are shown in Table 12.

Table 12

Cronbach's alpha for the factors of the systems thinking and industrial engineering skills

Component	Label	Cronbach's Alpha
1	Systems Approach (SyAp)	0.899
2	Modeling (M)	0.907
3	Continuous Improvement (CI)	0.834
4	Supply Chain (SC)	0.852
5	Time Study (TS)	0.887
6	Project Management (PM)	0.746
7	Operational Thinking (OT)	0.756
8	Engineering Economics (EE)	0.807
9	Ergonomics (E)	0.840

With acceptable reliability, a step-wise multiple regression was conducted to evaluate how well the above nine renamed variables predict transition success. Using the respondent's current transition level as the dependent variable and the rotated factor scores identified through the factor analysis as the independent variable, nine variables were introduced into the regression analysis in a step-wise fashion, ending at step 5, which is defined as Regression Model 5 in Table 13, regression model variables entered and removed.

Table 13

Regression model variables entered and removed

Model[a]		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	SyAp	.178[b]	3.608	.000	.184	1.000
	M	-.056[b]	-1.118	.264	-.058	1.000
	CI	-.016[b]	-.320	.749	-.017	1.000
	SC	.156[b]	3.153	.002	.161	1.000
	PM	.252[b]	5.203	.000	.260	1.000
	OT	-.069[b]	-1.384	.167	-.071	1.000
	EE	.113[b]	2.277	.023	.117	1.000
	E	-.037[b]	-.745	.457	-.039	1.000
2	SyAp	.178[c]	3.736	.000	.190	1.000
	M	-.056[c]	-1.157	.248	-.060	1.000
	CI	-.016[c]	-.331	.741	-.017	1.000
	SC	.156[c]	3.264	.001	.167	1.000
	OT	-.069[c]	-1.432	.153	-.074	1.000
	EE	.113[c]	2.356	.019	.121	1.000
	E	-.037[c]	-.770	.442	-.040	1.000
3	M	-.056[d]	-1.177	.240	-.061	1.000
	CI	-.016[d]	-.337	.736	-.017	1.000
	SC	.156[d]	3.322	.001	.170	1.000
	OT	-.069[d]	-1.457	.146	-.075	1.000
	EE	.113[d]	2.397	.017	.123	1.000
	E	-.037[d]	-.784	.434	-.041	1.000
4	M	-.056[e]	-1.193	.234	-.062	1.000
	CI	-.016[e]	-.341	.733	-.018	1.000
	OT	-.069[e]	-1.476	.141	-.077	1.000
	EE	.113[e]	2.430	.016	.125	1.000
	E	-.037[e]	-.794	.428	-.041	1.000
5	M	-.056[f]	-1.201	.231	-.062	1.000
	CI	-.016[f]	-.344	.731	-.018	1.000
	OT	-.069[f]	-1.486	.138	-.077	1.000
	E	-.037[f]	-.799	.425	-.042	1.000

a. Dependent Variable: Current Position
b. Predictors: (Constant), TS
c. Predictors: (Constant), TS, PM
d. Predictors: (Constant), TS, PM, SyAp
e. Predictors: (Constant), TS, PM, SyAp, SC
f. Predictors: (Constant), TS, PM, SyAp, SC, EE

At step 1 in Table 13, the variable, Time Study (TS), entered into regression model 1 as a significant predictor to transition success F (1,374) = 25.496, p<.05. At step 2 in Table 13, the variable, Project Management (PM), entered into regression model 2 along with Time Study as significant predictors to transition success F (2,373) = 27.173, $p<.05$. At step 3 in Table 13, the variable Systems Approach (SyAp) entered into regression model 3 along with Time Study and Project Management as significant predictors to transition success F (3,372) = 23.398, $p<.05$. At step 4 in Table 13, the variable, Supply Chain (SC), entered into regression model 4 as significant predictors to transition success F (4,371) = 20.781, $p<.05$.

Ending at step 5 in Table 13, the variable, Engineering Economics (EE), entered into regression model 5 as significant predictors to transition success F (5,370) = 18.025, $p<.05$. The systems approach factor included dynamic thinking (DT), system-as-cause thinking (SCT), forest thinking (FT), closed-loop thinking (CLT), and quantitative thinking (QT) while the supply chain factor included production planning and control (PPC) and logistics (L). Four factors, modeling ($t = -1.201$, $p > .05$), continuous improvement ($t = -.344$, $p > .05$), operational thinking ($t = -1.486$, $p > .05$), and ergonomics ($t = -.799$, $p > .05$), did not enter regression models 1 - 5 as shown in Table 13.

Using regression model 5 and the coefficients table shown in Table 14, the regression equation for predicting transition success in this study is defined as Y = 2.194 - .289 (Time Study) + .288 (Project Management) + .203 (Systems Approach) + .178 (Supply Chain) + .130 (Engineering Economics).

Table 14

Model coefficients of the factors of the systems thinking and industrial engineering skills

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.194	.057		38.384	.000
	TS	-.289	.057	-.253	-5.049	.000
2	(Constant)	2.194	.055		39.700	.000
	TS	-.289	.055	-.253	-5.222	.000
	PM	.288	.055	.252	5.203	.000
3	(Constant)	2.194	.054		40.383	.000
	TS	-.289	.054	-.253	-5.312	.000
	PM	.288	.054	.252	5.293	.000
	SyAp	.203	.054	.178	3.736	.000
4	(Constant)	2.194	.054		40.924	.000
	TS	-.289	.054	-.253	-5.384	.000
	PM	.288	.054	.252	5.364	.000
	SyAp	.203	.054	.178	3.786	.000
	SC	.178	.054	.156	3.322	.001
5	(Constant)	2.194	.053		41.194	.000
	TS	-.289	.053	-.253	-5.419	.000
	PM	.288	.053	.252	5.399	.000
	SyAp	.203	.053	.178	3.811	.000
	SC	.178	.053	.156	3.344	.001
	EE	.130	.053	.113	2.430	.016

Table 15 shows that the multiple regression coefficient (R) for Regression Model 5 is .443, accounting for 19.6% ($R^2 = .196$) of the variance explained for the combined variables and transition success. This suggests a modest fit to the data with low practical significance in the relationship between time study, project management, systems approach, supply chain, and engineering economics to managerial transition success among industrial engineers in this study. Thus, Hypothesis 3 is rejected.

Table 15

Model summary of the factors of the systems thinking and industrial engineering skills

Model[f]	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.253[a]	.064	.061	1.1084	
2	.357[b]	.127	.122	1.0717	
3	.398[c]	.159	.152	1.0536	
4	.428[d]	.183	.174	1.0396	
5	.443[e]	.196	.185	1.0328	1.990
a. Predictors: (Constant), TS					
b. Predictors: (Constant), TS, PM					
c. Predictors: (Constant), TS, PM, SyAp					
d. Predictors: (Constant), TS, PM, SyAp, SC					
e. Predictors: (Constant), TS, PM, SyAp, SC, EE					
f. Dependent Variable: Current Position					

ANOVA[a]		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	31.325	1	31.325	25.496	.000[b]
	Residual	459.502	374	1.229		
	Total	490.827	375			
2	Regression	62.418	2	31.209	27.173	.000[c]
	Residual	428.409	373	1.149		
	Total	490.827	375			
3	Regression	77.913	3	25.971	23.398	.000[d]
	Residual	412.914	372	1.110		
	Total	490.827	375			
4	Regression	89.841	4	22.460	20.781	.000[e]
	Residual	400.986	371	1.081		
	Total	490.827	375			
5	Regression	96.139	5	19.228	18.025	.000[f]
	Residual	394.688	370	1.067		
	Total	490.827	375			
a. Dependent Variable: Current Position						
b. Predictors: (Constant), TS						
c. Predictors: (Constant), TS, PM						
d. Predictors: (Constant), TS, PM, SyAp						
e. Predictors: (Constant), TS, PM, SyAp, SC						
f. Predictors: (Constant), TS, PM, SyAp, SC, EE						

Research Question 4

Research Question 4 asked whether a predictive relationship between systems thinking skills and transition success among industrial engineers. As a result, Hypothesis 4 stated there is a predictive relationship between systems thinking skills and managerial transition success among industrial engineers. After factor analysis, this study's 21 observable variables originally designed to measure seven systems thinking constructs were found clustered into three component factors: component 1, systems approach; component 2, modeling; and component 7, operational thinking. In Table 14, five factors were deemed significant predictors to transition success F (5,370) = 18.025, $p < .05$. Only component 1, systems approach, entered into the regression models with component 2, modeling, and component 7, operational thinking, excluded.

This indicates confidence that there will be a relationship between time study, project management, systems approach, supply chain, and engineering economics and transition success in the population. However, with modest fit ($R = .443$) and only 19.6% ($R^2 = .196$) of the variance explained for the combined variables and transition success, Hypothesis 4 is rejected.

Summary of Results

The researcher conducted a survey to collect data and performed factor analysis and multiple regression analysis on the data to discover whether there is a relationship between systems thinking and technical industrial engineering skills usage and transition success. The following hypotheses are relevant to determining the existence of this relationship:

1. There is no significant relationship between systems thinking skills and managerial transition success among industrial engineers.
2. There is no significant relationship between technical industrial engineering skills and managerial transition success among industrial engineers.

Although evidenced by weak to low strength in their relationship, five of seven systems thinking skills and five of the ten technical industrial engineering skills included in this study reflected statistically significant correlations to transition success. Based on the results of the Spearman rho correlation analyses, both null hypotheses were rejected.

Due to their statistically significant correlations, as the skills of dynamic thinking, system-as-cause thinking, forest thinking, closed-loop thinking and quantitative thinking increase in the workplace among industrial engineers, the industrial engineer's transition success into management increases. In addition, as time study skills decrease complemented with increases in project management, production planning and control, engineering economics and logistics skills in the workplace among industrial engineers their transition success into management increases.

On the contrary, are industrial engineers who rely heavily on their systems thinking skills and technical industrial engineering skills less likely to transition successfully into managerial and executive leadership positions? The following hypothesis was tested:

3. There is a significant contribution made by systems thinking skills and technical industrial engineering skills to managerial transition success among industrial engineers.

Given a low practical significance in the relationship between time study, project management, systems approach, supply chain, and engineering economics to managerial transition success among industrial engineers in this study, hypothesis 3 was rejected.

To determine how certain are we in making predictions that systems thinking skills predict managerial transition success, the following hypothesis was tested:

4. There is a predictive relationship between systems thinking skills and managerial transition success among industrial engineers.

Five factors were deemed significant predictors to transition success F (5,370) = 18.025, $p < .05$. However, with modest fit ($R = .443$) and only 19.6% ($R^2 = .196$) of the variance explained for the combined variables and transition success, hypothesis 4 is rejected.

Although this study found low practical significance (R^2), it did find five statistically significant independent predictors to transition success among industrial engineers. This means the researcher is confident that there is a relationship between time study, project management, systems approach, supply chain, and engineering economics and transition success in the population of industrial engineers. With significant coefficients representing the mean change in transition success for one unit of change in, for example, systems approach, while holding other predictors in the model constant, this researcher can make important conclusions about how changes, in the systems approach (predictor) value are associated with changes in transition success (response value) and offer value-added recommendations for further research.

CHAPTER 5: IMPLICATIONS AND CONCLUSIONS

Introduction and Overview of Findings

The implications and conclusions discussed in this chapter are derived from the findings generated by the analyses of the data collected in the previous chapter. The study found that the systems thinking skills of dynamic thinking, forest thinking, quantitative thinking, system-as-cause thinking, and closed-loop thinking have statistically significant positive correlations with transition success. The technical industrial engineering skills with significant correlation include time study, project management, engineering economics, production planning and control, and logistics. The study shows that mastery of these systems thinking and technical industrial engineering skills by industrial engineers will aid in a successful transition to management.

Systems thinking skills and technical industrial engineering skills were combined into factors for additional analysis. Ultimately, five factors were used to create a regression equation to determine if there was a significant contribution made to managerial transition success by these five factors. The five factors generated by the model were deemed significant predictors to transition success accounting for 19.5% of the variance. The study shows that the five factors identified in the model are statistically significant independent predictors to transition success among industrial engineers. All findings in the study imply that the study of systems thinking skills and industrial engineering skills is significant to the transitional success of industrial engineers to management.

Implications of Findings

There are individuals who view a school as a system, a galaxy as a system, or an organization as a system; and, most likely, they can describe the elements that make up that system and the broad purpose or goal. For example, an organization is a system that has engineers, supervisors, managers, directors, vice-presidents and a president. The goal of the organization is to be successful. However, the challenge is that every part of the system has interconnections, or simply stated relationships that hold the elements together. It can be frustrating at any level if the members of the organization have conflicting purposes resulting in an overall behavior of failure. Knowledge age organization are comprised of many elements working toward the common goal of a successful enterprise. This is why it is important to begin the process of understanding systems over time.

Barry Richmond (2000) claimed that systems thinking "requires mastering a whole package of thinking skills that requires intensive practice and patience" (pp. 3-4). Working to build the capacity of people to understand systems thinking, Richmond (2000) developed a series of "seven different cognitive processes that seasoned systems thinkers need to employ as they address problems or concerns from a systems thinking perspective" (p. 3).

The seven skills that serve as independent variables in this study are:

- dynamic thinking,
- system-as-cause thinking,
- forest thinking,
- operational thinking,

- closed-loop thinking,
- quantitative thinking, and
- scientific thinking.

Systems thinking skills correlate to managerial transition success with five out of seven skills deemed statistically significant. Dynamic thinking, forest thinking, quantitative thinking, system-as-cause thinking, and closed-loop thinking reflected statistically significant positive correlations with transition success. Despite weak to low strength, these correlations suggest that as these systems skills increase, so does managerial transition success. Moreover, all of the above systems thinking skills were positively correlated to transition success; therefore, it would be important to investigate further the specific causes for the positive correlations between all seven systems thinking skills and managerial transition success. Systems thinking skills should be a core competency for industrial engineers. The significance of the factors implies that systems thinking skills should be included in the industrial engineering curriculum.

As the technical industrial engineer transitions upwards toward management, one would assume less dependence on the technical industrial engineering skills and more dependence on the skills of systems thinking would be required. In essence, one would expect to see an inverse correlation between technical industrial engineering skills and transition success. Despite some inverse relationships, the study found technical industrial engineering skills are critical to transition success. Interestingly, this study found that of the ten technical industrial engineering skills included in this study:

1. Five skills including engineering economics, production planning and control, logistics, project management, and performance metrics reflected a positive correlation.
2. Five skills including time study, statistical analysis, simulation modeling and analysis, ergonomics, and process improvement reflected a negative correlation.
3. Five skills correlated significantly with transition success including time study, engineering economics, production planning and control, and logistics at the .01 level; and project management at the .05 level; all with weak to low strength in relationship to transition success.

Lastly, this study found that the regression model used to test hypotheses 3 and 4 contained five of the nine prediction variables (renamed factors) and was reached in five steps with four variables removed. These five factors were:

- time study;
- project management;
- systems approach comprised of dynamic thinking, system-as-cause thinking, forest thinking, closed-looped thinking, and quantitative thinking;
- supply chain, which includes production planning and control as well as logistics; and
- engineering economics.

Even though there is statistical significance in this regression model, F (5,370) = 18.025, $p<.05$, there is low practical significance ($R^2 = .196$) accounting for 19.6% of the variance explained in the relationship of the predictors to managerial transition success.

Therefore, both hypotheses were rejected. It is worth noting that both project management and time study involve the element of time. A time study is an activity that takes place in the very short-term, while project management can be short- medium- and long-term in duration. Scientific study on the job, whether time study or project management helps to provide “a vastly closer approximation as to time than we ever had before” (Wren & Bedeian, 2009, p. 125).

The five significant factors of time study, project management, systems approach, supply chain, and engineering economics should be a primary focus for an industrial engineer seeking to successfully transition to management. Time studies, which were developed by Taylor in a search for efficiency, characterize the work of an industrial engineer. Effective use and analysis of time studies and the resulting data provide industrial engineers who transition to management the ability to focus on systematization and bring standardization to their managerial role. Industrial engineers are also able to successfully transition to management because of their skill in project management. The work of Henry Gantt and his Gantt chart has propelled engineers to a project-driven mindset that allows them to contribute important information about the business.

Supply chain consists of production planning and control and logistics. These skills also allow the industrial engineer to view the organization through Henry Ford’s eyes. Fordism describes an unprecedented method of production from which industrial engineers take an active management role at the production level. Engineering economics helps industrial engineers to develop the financial mindset required at the management level introduced by Adam Smith through his work in the *Wealth of Nations.*

Finally, systems approach, including dynamic thinking, system-as-cause thinking, forest thinking, closed-loop thinking, and quantitative thinking are systems thinking skills that are integral to successful management transition. These skills all build upon each other and, according to Richmond (2000), draw importance to systems and to the value of developing an understanding of the intricacies of any given system. The study showed that there is a link between systems thinking and technical industrial engineering skills and transition success.

The inclusion and application of systems thinking skills by industrial engineers helps to explain the 20% increase of industrial engineers as managers from 2008-2018 as shown earlier in the U.S. Bureau of Labor Statistics management employment data. By incorporating systems thinking skills into their work activities, industrial engineering practitioners are able to successfully transition into management and organizational leadership.

Ethical Considerations

As with any research involving human subjects, there were ethical considerations in this study and the study was subject to Institutional Review Board approval. The researcher followed Institutional Review Board procedures established by Walsh College and was Collaborative Institutional Training Initiative certified. The study sought responses from human subjects. Participants were given the opportunity to indicate consent prior to completing the study. Any data collected from surveys that were not finished were not included in the study and answers were not reported. No identifying information was collected including IP addresses or email addresses. The researcher maintained the integrity of the data by limiting access to the data to only the researcher and the dissertation committee. All data were reported in aggregate to protect personal anonymity and confidentiality was protected.

As an industrial engineer, the researcher, by nature, introduced some personal bias into the study. Personal bias was limited by completing reviews of the survey questions by other industrial engineers. These reviews provided valuable information to the researcher and allowed for questions to be revised without bias prior to inclusion in the survey. The pilot study also protected against bias and enabled the researcher to test the reliability of the questions prior to putting the question in the final survey. The researcher also protected against bias by using Qualtrics to conduct the survey and SPSS to analyze the data. Qualtrics allowed for an internet based survey instead of face to face interview which introduces bias. Additionally, no adverse incidents occurred during the collection of survey responses or in the data analysis of the study.

Limitations and Weaknesses of Study

The study was quantitative in nature; this limited the study by not allowing the researcher to interact with the respondents. Interviews conducted by the researcher may have allowed more detailed explanations of the skills and resulted in higher correlations. While the technical industrial engineering skills and the systems thinking skills were selected based on a detailed literature review, it is possible that not all industrial engineers understand the skills or have used the skills under the name given to them in the study. For example, an IE may regularly perform the tasks associated with forest thinking. However, the engineer may not realize the tasks are associated with forest thinking. A future qualitative study would be able to discuss the tasks in greater detail and ask follow-up questions to clarify tasks and processes. The study was limited by the instrument in so far as the questions strived to capture a clear distinction among the skills and management levels.

The research was conducted using an online survey which has inherent limitations including variable cooperation and potentially high respondent misunderstanding. The challenges of using this method included the inability to guarantee respondent participation and uneven population distribution. Additionally, the sample was a judgment sample which is subject to the researcher's bias. The population was the Institute of Industrial Engineers membership who self-selects their job type in the directory. So, the researcher's preconceptions about the sample were based on the respondent's selections thus limiting bias.

The researcher used the Institute of Industrial Engineers membership email directory as of June 2013; however, the total number of respondents was limited to those who actually received the email requesting participation in this study, excluding those whose email address was no longer current, or the request to participate was sent directly to the member's email spam folder. The researcher had no way to determine whether the survey was taken by the person to whom the invitation was addressed, although Qualtrics prevents the survey from being shared. Additional responses might also be gathered if the time period for respondents to complete the survey instrument was longer.

Directions for Future Research

This study explored the relationship between systems thinking skills and technical industrial engineering skills in the transition to management. Ultimately, the researcher was able to prove a statistical link between the skills and transition success, the researcher was also able to identify several skills that are meaningful to transition success. The study found there were statistically significant positive correlations between transition success and the technical industrial engineering skills of engineering economics, production planning and control, logistics, and project management.

The statistical analysis performed in this study was useful in proving a correlation between systems thinking skills and technical industrial engineering skills to transition success. Further statistical analysis could be performed to strengthen the study. Additional statistical analysis could be completed to test the mean scores between the transition levels for statistical significance. Completing a post hoc pairwise analysis using the Tukey test within SPSS would extend the scope and study length.

Additional technical industrial engineering skills could be considered for future research because for this study, the researcher used the skills deemed as fundamental by the Institute of Industrial Engineers. However, IE practitioners may choose other skills as fundamental to the IE profession. While the study was able to explain 19.6% of variance, future research could be conducted to further explain the variance gap. Further variance could be explained by the inclusion of additional demographics such as years of experience, education level, industry, gender, and age. If a statistically significant number of responses could be obtained, then the responses could be analyzed by demographic. The STTSU questionnaire could be refined with the additional technical industrial engineering skills and demographic questions to be reused for future research. While this study focused on the frequency of the technical industrial engineering skills usage, additional studies could focus on the importance of the skills to managerial transition success.

The systems thinking skills used in the study were those identified by Richmond (2000) as the core systems thinking skills. Additional research could be done to include different or additional systems thinking skills. Richmond's (2000) skills, while useful, are not necessarily the definitive skills. Using other systems thinking skills would enrich the survey and provide a greater wealth of information to study.

Future research may also investigate the predictive capabilities of time and system thinking on managerial transition success. Systems thinkers recognize that one needs to be watching both the short- and long-term—in other words, the whole system. A recommendation for future research would be to further develop and refine the instrument used in this study to capture a clearer distinction among the various levels of systems thinking skills developed by Barry Richmond (2000). A significant revision could even make the questionnaire relevant for a variety of professions, and it could be used for many empirical studies on the current use and efficacy of systems thinking skills in the management of organizations in several types of industries.

An important research consideration would be to conduct a qualitative study on the effect of systems thinking skills and technical industrial engineering skills on management transition success. A qualitative study allows for open dialogue between the researcher and respondents which would allow greater explanation of the skills and may result in higher correlations. By asking industrial engineers directly, conducting a case analysis or through participant observation, the researcher can gain valuable insight into how systems thinking and technical industrial engineering skills are obtained and also how they are used. A qualitative study of industrial engineers to assess how well they understand the terminology of the systems thinking skills would be another point for future research. The study could then test how well the participants understand the terminology and systems thinking skills because they are not explicitly taught the skills. A study could be conducted to discover the language industrial engineers would use to describe the same phenomena as Richmond’s (2000) skills.

Transition success can be studied in greater depth by asking industrial engineers directly and obtaining data on the timing of success as well as skill usage throughout career phases as opposed to the point in time used in this study. This study could be revised after evaluating its usefulness. Information can be corrected and the role of systems thinking skills can be further studied and revised.

Another area for future research surrounds the engineers who transition to management and whether there are significant differences in the types of engineering disciplines that advance to management. Additional investigation using secondary data analysis or public records or Institute of Industrial Engineers provided data of the numbers of industrial engineers who transition to management versus other disciplines could be completed to determine whether this is because industrial engineers developed modern management skills and are closer to management than electrical or mechanical engineers. Future research may also reveal attributes of the industrial engineers transition to management outside of systems thinking.

Systems thinking is a theory of leadership skills introduced in the 1990s. Industrial engineers are taught technical skills directly through course work and practical on the job application. This becomes the focus of their industrial engineers body of work. The industrial engineers are perhaps indirectly taught systems thinking skills in their academic studies and practical work experience. The respondents of this study may have been unable to consciously attribute their transition success to systems thinking skills. Further study including the acquisition of both the systems thinking skills as well as the technical industrial engineering skills may provide significant insight into the relationship of both skills to management transition success.

Summary

This study endeavored to understand the relationship between systems thinking skills and technical industrial engineering skills and transition success to management among industrial engineers. This study is significant in several ways. First, it proved a link between systems thinking skills and transition success among industrial engineers. It also proved a link between technical industrial engineering skills and transition success. Second, the study showed that there is a link between combining systems thinking skills and industrial engineering skills and transition success. Finally, the study developed a regression model that industrial engineers can utilize for successful transition to management.

The study contributes to the field of industrial engineering in several ways. The literature review of the study illustrates that industrial engineers have transitioned from the factory floor to the boardroom in the knowledge age organization. This study also serves as the first quantitative study to examine this transition. The study shows which technical industrial engineering skills are critical to transition success and highlights the skills that an industrial engineer should master to pursue a career in organizational management.

Beyond industrial engineering, the study also makes a significant contribution to the systems thinking field. First, through research and testing, the study showed which systems thinking skills (Richmond, 2000) correlate to managerial transition success among industrial engineers. The study illuminates the field of systems thinking for industrial engineers and shows systems thinking skills as core competencies for the industrial engineering field.

Systems thinking is a predictor of managerial transition success among industrial engineers as industrial engineers make the transition to management positions throughout their careers. This study successfully provided a starting point to determining the link between industrial engineers and their use of systems thinking skills while transitioning to management. The study shows, with confidence, that there is a relationship between time study, project management, systems approach, supply chain, and engineering economics to transition success. The systems approach factor is composed of systems thinking skills including quantitative thinking, forest thinking, dynamic thinking, system-as-cause thinking, and closed-loop thinking. While the study had some limitations and ethical considerations, it provides important groundwork for future research. Industrial engineers who seek to make a successful transition to management will benefit from the valuable insights and conclusions derived in this research study.

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APPENDIX A

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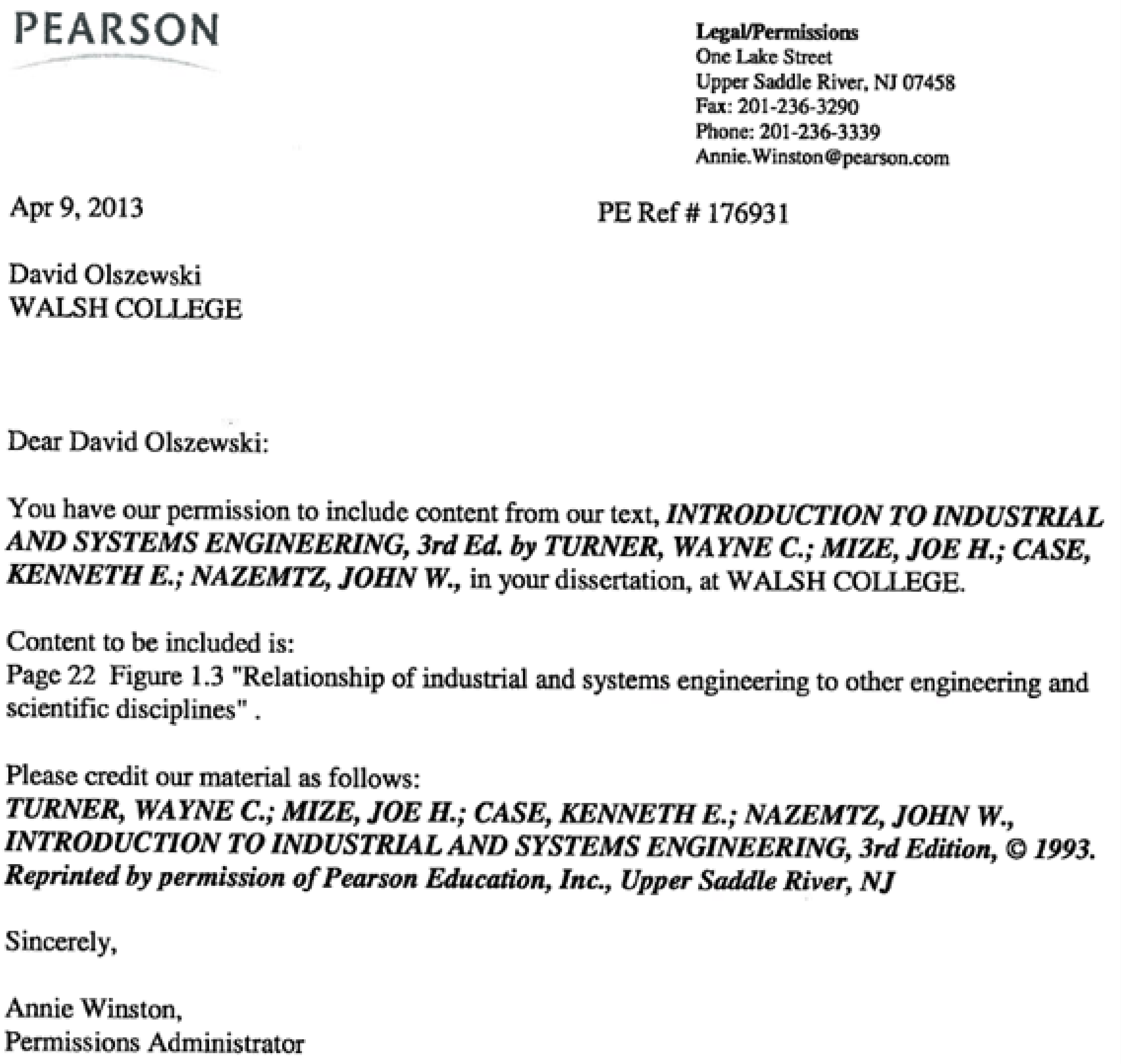

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Apr 9, 2013

PE Ref # 176931

David Olszewski
WALSH COLLEGE

Dear David Olszewski:

You have our permission to include content from our text, ***INTRODUCTION TO INDUSTRIAL AND SYSTEMS ENGINEERING, 3rd Ed. by TURNER, WAYNE C.; MIZE, JOE H.; CASE, KENNETH E.; NAZEMTZ, JOHN W.,*** in your dissertation, at WALSH COLLEGE.

Content to be included is:
Page 22 Figure 1.3 "Relationship of industrial and systems engineering to other engineering and scientific disciplines" .

Please credit our material as follows:
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Sincerely,

Annie Winston,
Permissions Administrator

APPENDIX B

Permission to Solicit Participation of Institute of Industrial Engineers Members

Received: Monday, January 7, 2013

David,
Thank you for your inquiry. We highly recommend that Ph.D. students use the IIE LinkedIn group for this purpose (http://www.linkedin.com/groups?mostPopular=&gid=75670) as we've learned that it's a better way to get a cross-section of responses.

You can also use the IIE member directory as you have requested, however based on our experience and feedback from members, we recommend that you be very selective about who you send your survey to and focus on individuals who are likely to be very interested in what you are doing.

Please let us know if you need any further assistance and good luck with your dissertation!

Heather Bradley
Director of Membership, IIE

Sent: Sunday, January 6, 2013

Hello,
My name is David Olszewski and I am currently an IIE member. I am also a student at Walsh College, Troy, MI in the Doctor of Management program working on my dissertation titled "The Use of Systems Thinking by the Industrial Engineer as Organizational Leader."

I am writing to formally request permission to use the IIE Membership Directory to obtain email addresses of current IIE members that I can send my dissertation survey to. I am aware that you no longer provide the service of sending out a survey request on my behalf but through several phone conversations, I learned that I can compile the email addresses and send the survey request myself.

Please respond to this email with your consent to allow me to utilize the membership directory for my study. If you have any questions or would like to discuss the request in further detail, feel free to contact me.

Regards,
David Olszewski

APPENDIX C

Participant Solicitation Emails

Initial email sent to the Institute of Industrial Engineers membership directory:

Subject: Industrial Engineers – Please Participate in a Survey

As a member of the Institute of Industrial Engineers, you are being invited to participate in a research study being conducted by a fellow member of the organization. The survey should take 15-20 minutes of your time to complete. The results will be used by the researcher to complete his Doctor of Management in Executive Leadership degree from Walsh College in Troy, Michigan.

The purpose of the study is to explore the theory of systems that relates systems thinking to organizational management among industrial engineers. The survey statements ask your opinions about technical industrial engineering and systems thinking skills. All responses will be anonymous and all data will be reported in the aggregate. You will not be identified by name.

The survey can be accessed at:

http://walshcollege.qualtrics.com/SE/?SID=SV_25hRqp1i6ItNz0N

If your e-mail system does not support links or you have problems starting the survey, please copy the URL to your browser to begin the survey. The survey link is valid from 07/12/13 until 07/26/13. It can be accessed more than once, but after clicking "submit", the link will no longer be valid.

If you have questions about this research study or survey, please contact the researcher, David Olszewski, at XXXX@alumni.walshcollege.edu or the faculty advisor, James McHann, PhD., at XXXX@walshcollege.edu.

Thank you for your participation,

David Olszewski

Second email sent one week after the initial email to the entire population:

Subject: Reminder: Industrial Engineers – Please Participate in a Survey

Thank you to all who have already taken the survey. If you have not already completed it, please consider taking this survey aimed at exploring the industrial engineering field. The original email request can be found below, along with a link.

As a member of the Institute of Industrial Engineers, you are being invited to participate in a research study being conducted by a fellow member of the organization. The survey should take 15-20 minutes of your time to complete. The results will be used by the researcher to complete his Doctor of Management in Executive Leadership degree from Walsh College in Troy, Michigan.

The purpose of the study is to explore the theory of systems that relates systems thinking to organizational management among industrial engineers. The survey statements ask your opinions about technical industrial engineering and systems thinking skills. All responses will be anonymous and all data will be reported in the aggregate. You will not be identified by name.

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If your e-mail system does not support links or you have problems starting the survey, please copy the URL to your browser to begin the survey. The survey link is valid from 07/12/13 until 07/26/13. It can be accessed more than once, but after clicking “submit,” the link will no longer be valid. It can be accessed more than once, but after clicking “submit”, the link will no longer be valid.

If you have questions about this research study or survey, please contact the researcher, David Olszewski, at XXXX @alumni.walshcollege.edu or the faculty advisor, James McHann, PhD., at XXXX @walshcollege.edu.

Thank you for your participation,

David Olszewski

Final email sent three days prior to the close of the survey period:

Subject: Reminder: Industrial Engineers – Please Participate in a Survey

Thank you to all who have already taken the survey. If you have not already completed it, please consider taking this survey aimed at exploring the industrial engineering field. The original email request can be found below, along with a link.

As a member of the Institute of Industrial Engineers, you are being invited to participate in a research study being conducted by a fellow member of the organization. The survey should take 15-20 minutes of your time to complete. The results will be used by the researcher to complete his Doctor of Management in Executive Leadership degree from Walsh College in Troy, Michigan.

The purpose of the study is to explore the theory of systems that relates systems thinking to organizational management among industrial engineers. The survey statements ask your opinions about technical industrial engineering and systems thinking skills. All responses will be anonymous and all data will be reported in the aggregate. You will not be identified by name.

The survey can be accessed at:

http://walshcollege.qualtrics.com/SE/?SID=SV_25hRqp1i6ItNz0N

If your e-mail system does not support links or you have problems starting the survey, please copy the URL to your browser to begin the survey. The survey link is valid from 07/12/13 until 07/26/13. It can be accessed more than once, but after clicking “submit,” the link will no longer be valid. It can be accessed more than once, but after clicking “submit”, the link will no longer be valid.

If you have questions about this research study or survey, please contact the researcher, David Olszewski, at XXXX @alumni.walshcollege.edu or the faculty advisor, James McHann, PhD., at XXXX @walshcollege.edu.

Thank you for your participation,

David Olszewski

APPENDIX D

Letter of Informed Consent

Title of Study:
The Use of Systems Thinking by the Industrial Engineer as Organizational Leader

Principle Researcher:
Name: David H. Olszewski
Department: Walsh College Doctorate of Management
E-mail: XXXX @alumni.walshcollege.edu

Background:
You are being invited to take part in a research study. Before you decide to participate in this study, it is important that you understand why the research is being done and what it will involve. Please take the time to read the following information carefully.

The purpose of this study is to explore the theory of systems that relates systems thinking to organizational management among industrial engineers. Members of the Institute of Industrial Engineers who have been or are currently employed in any industry are invited to participate.

Study Procedure:
The process of completing the survey should take 15-20 minutes to complete. The online questionnaire is presented through Qualtrics, a web-based third party host. No personal identifying information including email address of the participants will be collected by the researcher or Qualtrics.

Confidentiality:
You will not be asked to provide any personally identifying information. Information from this research will be used solely for the purpose of this study and any publications that may result from this study. All participants involved in this study will not be identified and their confidentiality will be maintained.

Risks:
There are minimal discomforts or risks associated with your participation in this study. No participant names will be collected during the survey; therefore, in the event of an inadvertent release of data, no personally identifiable information would be released.

Benefits:
The research is not designed to help you personally, but it will offer the investigator insight into learning more about the industrial engineering profession. As a participant, you may find that by completing the study you are contributing to greater direction for both the educational and work-related needs of industrial engineers.

Costs and Compensation:
There are no costs to you for your participation in this study. There is no monetary compensation to you for your participation in this study.

Questions:
Any questions concerning this research project should be directed to David Olszewski, principal investigator for this project, at XXX.XXX.XXXX or XXXX@alumni.walshcollege.edu. The faculty advisor for this project, James McHann, PhD., can also be contacted at XXXX @walshcollege.edu.

Questions regarding rights as a subject in this research project or regarding this consent form should be directed to Louise August, Ph.D., Walsh College Institutional Review Board Chair, at XXXX@walshcollege.edu or XXX.XXX.XXXX.

It is recommended that you print a copy of this informed consent for your records.

PRINT HERE
Alternatively, you can use your browser's print option: File -> Print

Agreement:
This agreement states that you have received a copy of this informed consent, read and comprehend the terms of it and agree to the terms of it. Your consent below indicated that you agree to participate in this study.

I understand that my participation is voluntary and that I am free to withdraw at any time prior to submitting results, without giving a reason and without cost.

☐ Yes, I agree to participate in this study.
☐ No, I do not wish to participate in this study.

APPENDIX E

Survey Statement Matrix

No.	**Skill Area**	**Ind. Var.**	**Question**
9	Dynamic Thinking	ST	In my current position, I frame such things as issues, challenges, and opportunities in terms of a set of patterns that unfold over time.
10	Dynamic Thinking	ST	In my current position, I investigate how variables of interest have changed in the past, how they're doing now, and how I expect them to change in the future.
11	Dynamic Thinking	ST	In my current position, I look closely at the underlying relationships between the variables of interest to shape and time a desirable path forward.
12	System-as-Cause Thinking	ST	In my current position, I focus upon identifying the set of forces that lie inside the control of decision-makers as the primary drivers of behavior and performance.
13	System-as-Cause Thinking	ST	In my current position, I seek to identify actions that produce desirable behavior patterns rather than trying to predict which behavior patterns are likely to "happen to us."
14	System-as-Cause Thinking	ST	In my current position, I try to identify how the relevant decision-makers are responsible for behavior and performance in a given situation.
15	Forest Thinking	ST	In my current position, I investigate the connections between distinct parts and knit them together into a larger whole in order to see new connections.
16	Forest Thinking	ST	In my current position, I find boundaries and seek to transcend them in my thinking in order to gain an elevated perspective.
17	Forest Thinking	ST	In my current position, I look for similarities rather than differences in people, situations, problems, and organizations so that I can identify what is essential, simple, and important.
18	Operational Thinking	ST	In my current position, I seek out and identify the causes of a given behavior or performance, rather than merely its correlation.
19	Operational Thinking	ST	In my current position, I think in terms of stock-generated and flow-generated production functions in order to understand the activities I am examining.
20	Operational Thinking	ST	In my current position, when I am seeking to understand a particular event, trend, or process, I ask, "How does this actually work?"

21	Closed-Loop Thinking	ST	In my current position, I see causal relationships in circular terms, as two-way streets rather than one-way streets.
22	Closed-Loop Thinking	ST	In my current position, I study the feedback processes set in motion by actions in order to identify unintended consequences.
23	Closed-Loop Thinking	ST	In my current position, I use feedback processes to help me identify high-leverage initiatives capable of creating and sustaining the outcomes I seek.
24	Quantitative Thinking	ST	In my current position, I outfit my measureable and non-measurable assumptions about how something works with numbers in order to increase clarity and boost the rigor of my thinking about it.
25	Quantitative Thinking	ST	In my current position, I sharpen my thinking about how something works by providing numerical values for constants, choose initial magnitudes for stocks, and specify numerical values for graphical function relationships.
26	Quantitative Thinking	ST	In my current position, I quantify my understanding of the dynamics in a situation in order to discover effective leverage points for change.
27	Scientific Thinking	ST	In my current position, I seek simulation results that test for model robustness, face validity, and "goodness-of-fit."
28	Scientific Thinking	ST	In my current position, I simulate model results under a range of possible conditions in order to discover ways to improve real-world behavior and performance.
29	Scientific Thinking	ST	In my current position, I examine model-generated behavior patterns so that I can identify levers for creating the future, rather than predicting it.
30	Time Study	IE	In my current position, I collect time study data to determine reliable time standards for all work.
31	Time Study	IE	In my current position, I analyze time study data to determine operator productivity for the efficient and effective management of operations.
32	Time Study	IE	In my current position, I make recommendations to optimize workflows at a defined level of performance based on time study data.
33	Statistical Analysis	IE	In my current position, I analyze data collected through surveys or interviews to determine specific task characteristics such as frequency.
34	Statistical Analysis	IE	In my current position, I graphically display sampled process data using charts or graphs to determine trends in the data.

35	Statistical Analysis	IE	In my current position, I select an appropriate probability model for collected data to predict the probability of future outcomes.
36	Simulation Modeling & Analysis	IE	In my current position, I create models to predict the performance of a new system.
37	Simulation Modeling & Analysis	IE	In my current position, I run simulations to generate and analyze sample model behavior.
38	Simulation Modeling & Analysis	IE	In my current position, I interpret simulation results to predict performance of model parameters.
39	Ergonomics	IE	In my current position, I design solutions with safety as a goal to minimize operator injuries.
40	Ergonomics	IE	In my current position, I design solutions with quality as a goal to reduce production errors and variation.
41	Ergonomics	IE	In my current position, I design solutions with high operator productivity as a goal.
42	Project Management	IE	In my current position, I utilize critical path modeling to accommodate unexpected changes and ensure there are no delays in the project.
43	Project Management	IE	In my current position, I develop project timelines using Gantt charts to ensure projects are completed on schedule.
44	Project Management	IE	In my current position, I assign resources to projects when needed to ensure project deliverables and milestones are achieved.
45	Process Improvement	IE	In my current position, I use CQI (Continuous Quality Improvement) tools or techniques to reduce non-value added activities while improving operator productivity.
46	Process Improvement	IE	In my current position, I benchmark industry standards or use best practices to improve workplace processes or operator productivity.
47	Process Improvement	IE	In my current position, I use six sigma related tools or techniques to promote continuous process improvement for lean operations in the workplace.
48	Engineering Economics	IE	In my current position, I adopt forecasting techniques that make the best use of historical data, accuracy desired, time period, and value to the organization.
49	Engineering Economics	IE	In my current position, I supply inputs and forecasts for the planning and budgeting process to ensure accurate planning information is available for the organization.

50	Engineering Economics	IE	In my current position, I perform labor analysis to record, measure, and control costs in an effort to manage labor resources.
51	Production Planning & Control	IE	In my current position, I use material requirements planning to ensure that products are produced at the right time and in the right quantities.
52	Production Planning & Control	IE	In my current position, I design facility and work cell layouts to promote just-in-time inventory operations.
53	Production Planning & Control	IE	In my current position, I conduct audits to promote consistency, accountability, and integrity for standard operating procedures.
54	Performance Metrics	IE	In my current position, I utilize SMART (specific, measurable, attainable, relevant, time bound) goals to help establish organizational operating objectives.
55	Performance Metrics	IE	In my current position, I develop metrics to measure outcomes or results achieved against predetermined standards to help organizations manage performance.
56	Performance Metrics	IE	In my current position, I provide feedback or variance analysis on metrics to assist organizations in improving its desired outcome.
57	Logistics	IE	In my current position, I order and schedule materials to arrive according to production requirements to avoid bottlenecks and idle production times.
58	Logistics	IE	In my current position, I conduct material handling or storage analysis to ensure that the movements of materials or supplies within a facility are practical and cost effective.
59	Logistics	IE	In my current position, I communicate with suppliers and vendors to understand their processes and material handling capabilities for an efficient supply chain management system.

APPENDIX F

STTSU Survey Instrument

1. Letter of Informed Consent

Title of Study:
The Use of Systems Thinking by the Industrial Engineer as Organizational Leader

Principle Researcher:
Name: David H. Olszewski
Department: Walsh College Doctorate of Management
E-mail: XXXX@alumni.walshcollege.edu

Background:
You are being invited to take part in a research study. Before you decide to participate in this study, it is important that you understand why the research is being done and what it will involve. Please take the time to read the following information carefully.

The purpose of this study is to explore the theory of systems that relates systems thinking to organizational management among industrial engineers. Members of the Institute of Industrial Engineers who have been or are currently employed in any industry are invited to participate.

Study Procedure:
The process of completing the survey should take 15-20 minutes to complete. The online questionnaire is presented through Qualtrics, a web-based third party host. No personal identifying information including email address of the participants will be collected by the researcher or Qualtrics.

Confidentiality:
You will not be asked to provide any personally identifying information. Information from this research will be used solely for the purpose of this study and any publications that may result from this study. All participants involved in this study will not be identified and their confidentiality will be maintained.

Risks:
There are minimal discomforts or risks associated with your participation in this study. No participant names will be collected during the survey; therefore, in the event of an inadvertent release of data, no personally identifiable information would be released.

Benefits:
The research is not designed to help you personally, but it will offer the investigator insight into learning more about the industrial engineering profession. As a participant,

you may find that by completing the study you are contributing to greater direction for both the educational and work-related needs of industrial engineers.

Costs and Compensation:
There are no costs to you for your participation in this study. There is no monetary compensation to you for your participation in this study.

Questions:
Any questions concerning this research project should be directed to David Olszewski, principal investigator for this project, at XXX.XXX.XXXX or XXXX@alumni.walshcollege.edu. The faculty advisor for this project, James McHann, PhD., can also be contacted at XXXX@walshcollege.edu.

Questions regarding rights as a subject in this research project or regarding this consent form should be directed to Louise August, Ph.D., Walsh College Institutional Review Board Chair, at XXXX@walshcollege.edu or XXX.XXX.XXXX.

It is recommended that you print a copy of this informed consent for your records.

PRINT HERE
Alternatively, you can use your browser's print option: File -> Print

Agreement:
This agreement states that you have received a copy of this informed consent, read and comprehend the terms of it and agree to the terms of it. Your consent below indicated that you agree to participate in this study.

I understand that my participation is voluntary and that I am free to withdraw at any time prior to submitting results, without giving a reason and without cost.

☐ Yes, I agree to participate in this study.
☐ No, I do not wish to participate in this study.

If No is Selected, Then Skip to End of Survey

2. What is your gender?
   - ☐ Male
   - ☐ Female

3. What is your age?
   - ☐ 21-30 years of age
   - ☐ 31-40 years of age
   - ☐ 41-50 years of age
   - ☐ 51-60 years of age
   - ☐ 61-70 years of age
   - ☐ Over 70 years of age

4. In what category would you best place your current role?
   - ☐ Industrial engineer, jr. industrial engineer, sr. industrial engineer, or principal industrial engineer
   - ☐ Supervisor, or manager
   - ☐ Section manager, unit manager, or director
   - ☐ Vice-president or president

5. In what category would you place your previous role?
   - ☐ Industrial engineer, jr. industrial engineer, sr. industrial engineer, or principal industrial engineer
   - ☐ Supervisor, or manager
   - ☐ Section manager, unit manager, or director
   - ☐ Vice-president or president

6. In your current industry, how many years have you been employed?
   - ☐ 1-10 years
   - ☐ 11-20 years
   - ☐ 21-30 years
   - ☐ 31-40 years
   - ☐ 41-50 years
   - ☐ Over 50 years

7. What is your highest attained education level?
   - ☐ High school diploma
   - ☐ Associate degree
   - ☐ Bachelor degree
   - ☐ Master degree
   - ☐ Doctorate/PhD

8. For your highest degree, what was your discipline?
   - ☐ Engineering, except industrial
   - ☐ Industrial Engineering
   - ☐ Business Administration
   - ☐ Arts and Sciences
   - ☐ Other

9. In my current position, I frame such things as issues, challenges, and opportunities in terms of a set of patterns that unfold over time.
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

10. In my current position, I investigate how variables of interest have changed in the past, how they're doing now, and how I expect them to change in the future.
    - ☐ Never
    - ☐ Rarely
    - ☐ Sometimes
    - ☐ Often
    - ☐ Always

11. In my current position, I look closely at the underlying relationships between the variables of interest to shape and time a desirable path forward.
    - ☐ Never
    - ☐ Rarely
    - ☐ Sometimes
    - ☐ Often
    - ☐ Always

12. In my current position, I focus upon identifying the set of forces that lie inside the control of decision-makers as the primary drivers of behavior and performance.
    - ☐ Never
    - ☐ Rarely
    - ☐ Sometimes
    - ☐ Often
    - ☐ Always

13. In my current position, I seek to identify actions that produce desirable behavior patterns rather than trying to predict which behavior patterns are likely to "happen to us."
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always
14. In my current position, I try to identify how the relevant decision-makers are responsible for behavior and performance in a given situation.
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

15. In my current position, I investigate the connections between distinct parts and knit them together into a larger whole in order to see new connections.
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

16. In my current position, I find boundaries and seek to transcend them in my thinking in order to gain an elevated perspective.
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

17. In my current position, I look for similarities rather than differences in people, situations, problems, and organizations so that I can identify what is essential, simple, and important.
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

18. In my current position, I seek out and identify the causes of a given behavior or performance, rather than merely its correlation.
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

19. In my current position, I think in terms of stock-generated and flow-generated production functions in order to understand the activities I am examining.
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

20. In my current position, when I am seeking to understand a particular event, trend, or process, I ask, “How does this actually work?”
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

21. In my current position, I see causal relationships in circular terms, as two-way streets rather than one-way streets.
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

22. In my current position, I study the feedback processes set in motion by actions in order to identify unintended consequences.
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

23. In my current position, I use feedback processes to help me identify high-leverage initiatives capable of creating and sustaining the outcomes I seek.
    - ☐ Never
    - ☐ Rarely
    - ☐ Sometimes
    - ☐ Often
    - ☐ Always

24. In my current position, I outfit my measureable and non-measurable assumptions about how something works with numbers in order to increase clarity and boost the rigor of my thinking about it.
    - ☐ Never
    - ☐ Rarely
    - ☐ Sometimes
    - ☐ Often
    - ☐ Always

25. In my current position, I sharpen my thinking about how something works by providing numerical values for constants, choose initial magnitudes for stocks, and specify numerical values for graphical function relationships.
    - ☐ Never
    - ☐ Rarely
    - ☐ Sometimes
    - ☐ Often
    - ☐ Always

26. In my current position, I quantify my understanding of the dynamics in a situation in order to discover effective leverage points for change.
    - ☐ Never
    - ☐ Rarely
    - ☐ Sometimes
    - ☐ Often
    - ☐ Always

27. In my current position, I seek simulation results that test for model robustness, face validity, and "goodness-of-fit."
    - ☐ Never
    - ☐ Rarely
    - ☐ Sometimes
    - ☐ Often
    - ☐ Always

28. In my current position, I simulate model results under a range of possible conditions in order to discover ways to improve real-world behavior and performance.
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

29. In my current position, I examine model-generated behavior patterns so that I can identify levers for creating the future, rather than predicting it.
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

30. In my current position, I collect time study data to determine reliable time standards for all work.
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

31. In my current position, I analyze time study data to determine operator productivity for the efficient and effective management of operations.
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

32. In my current position, I make recommendations to optimize workflows at a defined level of performance based on time study data.
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

33. In my current position, I analyze data collected through surveys or interviews to determine specific task characteristics such as frequency.
- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often
- ☐ Always

34. In my current position, I graphically display sampled process data using charts or graphs to determine trends in the data.
- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often
- ☐ Always

35. In my current position, I select an appropriate probability model for collected data to predict the probability of future outcomes.
- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often
- ☐ Always

36. In my current position, I create models to predict the performance of a new system.
- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often
- ☐ Always

37. In my current position, I run simulations to generate and analyze sample model behavior.
- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often
- ☐ Always

38. In my current position, I interpret simulation results to predict performance of model parameters.
- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often

☐ Always

39. In my current position, I design solutions with safety as a goal to minimize operator injuries.
    ☐ Never
    ☐ Rarely
    ☐ Sometimes
    ☐ Often
    ☐ Always

40. In my current position, I design solutions with quality as a goal to reduce production errors and variation.
    ☐ Never
    ☐ Rarely
    ☐ Sometimes
    ☐ Often
    ☐ Always

41. In my current position, I design solutions with high operator productivity as a goal.
    ☐ Never
    ☐ Rarely
    ☐ Sometimes
    ☐ Often
    ☐ Always

42. In my current position, I utilize critical path modeling to accommodate unexpected changes and ensure there are no delays in the project.
    ☐ Never
    ☐ Rarely
    ☐ Sometimes
    ☐ Often
    ☐ Always

43. In my current position, I develop project timelines using Gantt charts to ensure projects are completed on schedule.
    ☐ Never
    ☐ Rarely
    ☐ Sometimes
    ☐ Often
    ☐ Always

44. In my current position, I assign resources to projects when needed to ensure project deliverables and milestones are achieved.
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

45. In my current position, I use CQI (Continuous Quality Improvement) tools or techniques to reduce non-value added activities while improving operator productivity.
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

46. In my current position, I benchmark industry standards or use best practices to improve workplace processes or operator productivity.
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

47. In my current position, I use six sigma related tools or techniques to promote continuous process improvement for lean operations in the workplace.
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

48. In my current position, I adopt forecasting techniques that make the best use of historical data, accuracy desired, time period, and value to the organization.
   - ☐ Never
   - ☐ Rarely
   - ☐ Sometimes
   - ☐ Often
   - ☐ Always

49. In my current position, I supply inputs and forecasts for the planning and budgeting process to ensure accurate planning information is available for the organization.
- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often
- ☐ Always

50. In my current position, I perform labor analysis to record, measure, and control costs in an effort to manage labor resources.
- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often
- ☐ Always

51. In my current position, I use material requirements planning to ensure that products are produced at the right time and in the right quantities.
- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often
- ☐ Always

52. In my current position, I design facility and work cell layouts to promote just-in-time inventory operations.
- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often
- ☐ Always

53. In my current position, I conduct audits to promote consistency, accountability, and integrity for standard operating procedures.
- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often
- ☐ Always

54. In my current position, I utilize SMART (specific, measurable, attainable, relevant, time bound) goals to help establish organizational operating objectives.
    - ☐ Never
    - ☐ Rarely
    - ☐ Sometimes
    - ☐ Often
    - ☐ Always

55. In my current position, I develop metrics to measure outcomes or results achieved against predetermined standards to help organizations manage performance.
    - ☐ Never
    - ☐ Rarely
    - ☐ Sometimes
    - ☐ Often
    - ☐ Always

56. In my current position, I provide feedback or variance analysis on metrics to assist organizations in improving its desired outcome.
    - ☐ Never
    - ☐ Rarely
    - ☐ Sometimes
    - ☐ Often
    - ☐ Always

57. In my current position, I order and schedule materials to arrive according to production requirements to avoid bottlenecks and idle production times.
    - ☐ Never
    - ☐ Rarely
    - ☐ Sometimes
    - ☐ Often
    - ☐ Always

58. In my current position, I conduct material handling or storage analysis to ensure that the movements of materials or supplies within a facility are practical and cost effective.
    - ☐ Never
    - ☐ Rarely
    - ☐ Sometimes
    - ☐ Often
    - ☐ Always

59. In my current position, I communicate with suppliers and vendors to understand their processes and material handling capabilities for an efficient supply chain management system.

☐ Never
☐ Rarely
☐ Sometimes
☐ Often
☐ Always