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THE MANAGEMENT OF SUSTAINABLE RESEARCH AGENDAS

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SCHOOL OF INDUSTRIAL AND SYSTEMS ENGINEERING

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Table of Contents

List of Tables

List of Figures

Abstract

In the context of conducting research, planning is obligatory for work success. A research agenda is familiar to professionals working on research and funding projects in universities, research institutes, government agencies, and businesses, and successful researchers understand how to manage projects effectively through proper planning.

This dissertation aims to demonstrate how to create, develop, and manage sustainable research agendas by integrating research project management with a research agenda-building process in the form of a consistency model composed of standardized procedures. The proposed model is demonstrated in the unique form of a Markov process that uses an estimation method of transition probabilities. This dissertation also includes a performance evaluation metric for calculating a total effective management value (TEMV) to monitor research projects' progress and examples are given to demonstrate how to implement the proposed model and method. Furthermore, the results can be used in decision-making processes to modify the research agenda if circumstances change.

This dissertation's major contribution is that its proposed model can be used as a platform to direct and improve research activities as well as curriculum design in education. Likewise, grant proposal writers and researchers can use this dissertation as a guideline or "road map" to help them manage future research projects effectively, achieve their goals, satisfy funders' expectations, and position themselves favorably to compete for future funding opportunities. Because the model is based on simple-to-implement techniques applicable to any research field, professionals can adapt it to fit the unique characteristics of their research areas and their disciplines.

Chapter 1: Introduction

This chapter is an introduction to the problem of research agenda management. The main research questions are addressed in order to provide an overview of the research structure, including its objectives and methodologies.

Research Background

Professionals working on research and funding projects in universities, research institutes, government agencies, and corporations are familiar with the concept of a "research agenda." Generally speaking, a research agenda is a plan of tasks to be done or problems to be addressed in conducting a research project. To develop and manage a research agenda, researchers must determine key elements to consider in defining their research goals. However, researchers sometimes lack relevant information or neglect to plan for all of the steps necessary for their research. This hinders their ability to build a sustainable research agenda. In addition to carrying out the research work itself, researchers must identify potential funders, develop grant proposals, manage funded projects, and publish their results, and each of these tasks requires effective planning tools. If researchers do not understand the broader context of tasks and activities that are necessary in building an effective research agenda, they will not select the most suitable methods for their research projects, and they will be hindered in identifying and addressing future research challenges and opportunities.

Statement of the Problem and Objectives

The research undertaken for this dissertation addresses the question, "How do we create, develop, and manage a sustainable research agenda?" Therefore, the objectives of this research are (1) to present a systematic methodology for the management of research agendas for research institutes and academics, and (2) to present an effective evaluation methodology, including critical factors, in the form of a "total effective management value" (TEMV), which enables users to convert numeric results into qualitative outcomes. To address these objectives, this dissertation is organized as outlined below:

Phase 1: Based on the typical structure of a research agenda, the methodologies of research project management are proposed, and each main step is explained in detail to clarify the important points. An array of management technical tools are introduced and categorized into groups based on specific criteria for specific research design and planning.

Phase 2: To evaluate the working performance of research projects, this dissertation proposes dividing project evaluation into three groups of critical criteria (research, control, and human) by applying the Markov property (Markov, 1954) to the proposed TEMV model. Because research plans must be flexible enough to respond to changing constraints, unexpected results, and other factors, it is important that the research agenda be able to incorporate alternatives plans as necessary.

Phase 3: Examples of TEMV model implementation are demonstrated and researchers can use as examples or guidelines when implementing TEMV in their own projects. In addition, this section of the dissertation includes a summary and conclusion as well as recommendations for future research.

Significance of the Research

A well-defined and well-planned research agenda is vital because it emphasizes the significance of the research and identifies the most crucial factors that affect research management. In this context, this dissertation makes a research contribution in the following areas:

Area 1: Grant writers and researchers can use this dissertation as a guideline for managing their future research projects effectively in order to achieve their research objectives, satisfy the research funders' expectations, and prepare for ongoing opportunities for future research funding.

Area 2: The research contributions in the management of sustainable research agendas can be used as a platform for directing and improving research activities and curriculum design in education.

Chapter 2: Literature Review

To strengthen the theoretical research background and the framework for the proposed model, this chapter examines definitions of "research agenda" and divides the research realm into five major disciplines with different approaches to research. Moreover, research is divided into four different types that differ by purpose. This chapter also discusses the significant criteria for conducting research in terms of each criterion's importance and its influence on the kinds of decision-making that researchers must undertake before starting a new research project. The relationships between those criteria are also explored. The last section of this chapter reviews previous research related to this topic, with the purpose of demonstrating the dissertation's unique contribution to the field.

Research Agenda

It is impossible to conduct successful research without planning and management; planning and prioritizing are both obligatory for work success. At the beginning of research projects, researchers do not know what to expect during their working processes, so they must plan for any possible occurrences. Lack of planning, on the other hand, can lead to disastrous consequences.

Definitions

In academic and research institutions, professionals and experts are generally familiar with the meaning of "research" and the steps in conducting research. However, new researchers and students sometimes misinterpret the main concepts of research. For the purpose of clarification, this section addresses the definitions of the terms "research" and "research agenda."

“Research” has been defined in different ways in different contexts and disciplines. The OECD (2002) has defined “research” broadly as “creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of humanity, culture and society, and the use of this stock of knowledge to devise new applications.” Martyn Shuttleworth (2008), an academic writer and editor, also has given a broad definition of research: “In the broadest sense of the word, the definition of research includes any gathering of data, information and facts for the advancement of knowledge.” Another definition of research is given by HERDC (2012) in Australia: “Research is defined as the creation of new knowledge and/or the use of existing knowledge in a new and creative way so as to generate new concepts, methodologies and understandings. This could include synthesis and analysis of previous research to the extent that it leads to new and creative outcomes.”

For the purposes of this dissertation, “research” is defined simply as “searching for and gathering information, usually for the purpose of answering a particular question or addressing a particular problem.”

Generally speaking, OECD (2002) has also emphasized that “research is used as a tool for establishing or confirming facts, reaffirming the results of previous work, solving new or existing problems, supporting theorems, and even developing new theories.” To advance our knowledge, researchers clarify the purposes of research in general forms of documentation, discovery, interpretation, and the systems’ development. According to an explanation proposed by Wikipedia, “Research approaches depend on epistemologies that vary both within and among the humanities, the social sciences, and the sciences (en.wikipedia.org, “Research,” 2015). Statistical data itself is not the core of research; rather, the critical thinking behind the research is the most important skill researchers need to discover new innovation and technology for humanity.

For this dissertation topic, “agenda” also requires a definition. The Merriam-Webster Online Dictionary (2015) defines “agenda” as “A list or outline of things to be considered or done (meeting agendas) and an underlying often ideological plan or program (a political agenda).” In these terms, “research agenda” should sound familiar to professionals working on funded research projects in universities, research institutes, government agencies, and industry. To integrate the two terms, then, “research agenda” is a plan of research tasks to conduct or a set of problems to be addressed by research.

In conversation, University of Washington graduate students Justin Reedy and Madhavi Murty (2009) defined “research agenda” as “a plan and a focus on issues and ideas in a subset of your field. You cannot study everything in your field during your time in graduate school, so decide what to focus on now, and what to defer until another day” (Reedy & Murty, 2009). Furthermore, Reedy and Murty emphasized that research agendas typically evolve over time to encompass new topics.

To develop and maintain a research agenda, researchers must consider which key elements to focus their efforts on, such as academic interest, research topic, funded project, and so forth. Furthermore, researchers need effective tools for each step in order to carefully develop a research agenda and manage a funded project.

Disciplines of Research

1) Scientific Research: Wilson (1998) stated that “science” is a systematic enterprise that builds and organizes knowledge in the form of testable

explanations and predictions about the universe. This form of research mostly relies on the application of the scientific method, a harnessing of curiosity. “It yields scientific information and theories for the explanation of nature and the properties of the world, with the purpose of making practical applications possible. In general, scientific research is funded by public authorities, charitable organizations, and private groups. Scientific research can be subdivided into different classifications according to academic discipline or application” (en.wikipedia.org, “Research,” 2015).

2) Research in the humanities: “The humanities are mainly the study of human culture and thought. Humanities disciplines use methods that are primarily critical or speculative and have a significant historical element, as distinguished from the mainly empirical approaches of the natural sciences” (Oxford English Dictionary, 2015). “Humanities scholars usually explore issues and details rather than searching for the correct answer to a question. Context is therefore important, whether it is social, political, cultural, or ethnic” (en.wikipedia.org, “Research,” 2015). For instance, in some humanities disciplines, methods include observing different cultures and societies, interviewing people, and compiling case studies from real life experiences.

3) Artistic Research: This kind of research takes place in the fields of the fine arts and the liberal arts, including painting, film, classic literature, and music. Some researchers in the arts use empirical approaches, such as conducting surveys of public opinion; others use non-empirical approaches

to analyze literature or music. "A type of artistic research known as practice-based research occurs when creative works are considered both research and object of research. In the search for knowledge and truth, artistic research is an approach that offers an alternative to purely scientific methods" (en.wikipedia.org, "Research," 2015).

4) Research in History: Evans (2001) and Munslow (2001) explained that "history refers to the academic discipline that uses a narrative to examine and analyze a sequence of past events, with the goal of objectively identifying the patterns of cause and effect that determine them" (Evans, 2001; Munslow, 2001) Researchers in history often compile data from archives, public courthouses, and historical societies and use primary sources and other evidence to create a narrative about the past.
5) Research in Philosophy: "Philosophy is the study of general and fundamental problems connected with reality, existence, knowledge, values, reason, mind, and language" (Teichmann and Evans, 1999; Grayling, 1999). According to Quinton (1995), "philosophy is especially distinguished from other disciplines in its critical, systematic approach and its reliance on rational argument. Unfortunately, some researchers believe that the discipline of philosophy does not have much application in the practical world; however, philosophers conduct theoretical research based on analytical thinking, metaphysical interpretation, and deep readings of texts" (Quinton, 1995).

Purposes of Research

Patton (1990) clearly emphasize the importance of identifying the main purpose in a research process, identifying four types of research based on different purposes (Penn State University, 2013), as follows:

1) Basic Research: The purpose of basic research is to yield understanding and explanation. Its contribution to knowledge generally takes the form of a theory explaining the phenomenon under investigation. Thus, basic research is descriptive in nature, exploring "what" and "why," questions (Patton, 1990; Penn State University, 2013).
2) Applied Research: "The purpose of applied research is to help human beings understand the nature of human problems so that they can more effectively control their environment. In other words, this type of research pursues potential solutions to human and societal problems. This research is more prescriptive in nature, focusing on "how" questions" (Patton,1990; Penn State University, 2013).
3) Evaluative Research: Evaluation research studies the processes and outcomes aimed at attempted solutions. The purpose of evaluation research is to improve the efficacy of human interventions in activities, processes, or natural phenomena. One subset of evaluation research, known as "summative evaluation," judges the effectiveness of a program, policy, or product (Patton, 1990; Penn State University, 2013).
4) Action Research: This type of research aims at solving specific problems within a program, organization, or community. Patton (1990) noted that

design and data collection in action research tends to be less formal than in the other types of research and that the people being studied are usually directly involved in gathering information and studying themselves (Patton, 1990; Penn State University, 2013).

Criteria for Research

Choosing an interesting research topic is the first challenge among several criteria that researchers must face. At the beginning, asking “who,” “what,” “when,” “where.” and “why” questions may be helpful.

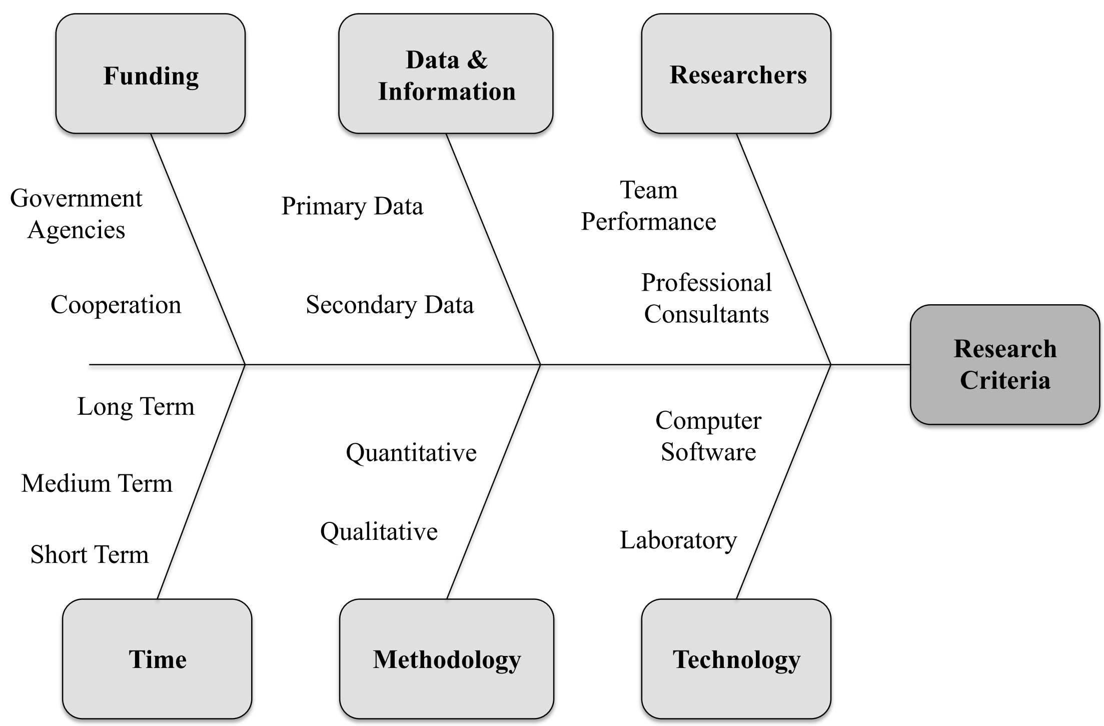

Figure 2.1. Ishikawa Diagram of Research Criteria

Prior to starting a new research project, researchers should consider many important criteria, as shown in the Ishikawa diagram shown in Figure 2.1.

1) Researchers: One of the most important elements when conducting research is the researchers who perform technical tasks and play a management role through each step of research process. A typical research group is composed of several positions: a team leader, team members, and sometimes professional consultants. Researchers are assigned to specific work depending on their expertise and experience. For the project to succeed, it is very important that highly skilled members work on every aspect of the project, including its management. Before starting work on a new project, the team leader should ensure that the team is ready to begin the first step of working process.

   As mentioned above, researchers are assigned to a specific job on the team based on their background, educational levels, skills, and work experience. Some well-qualified researchers may lack specific skills with certain tools, equipment, or computer software, but technical training may be available. When working on short-term projects, this type of training might not be good investment, especially when funding is limited. However, professional skills training is often a good investment for long-term projects because the trained researchers can apply their skills for the duration of the project, and the skills might even be useful for the next project.

   Researchers are expected to have distinct characteristics based on their position in the research group. To control the research process efficiently, the team leader should have adequate experience in the specific research area and should have a professional demeanor and work habits. The team leader is generally a researcher who provides guidance, instruction, direction and leadership to a group for the purpose of achieving the desired results. The team leader monitors the quantitative and qualitative results before reporting to the project manager or a professional consultant. Furthermore, the leader must be able to independently evaluate, select, and apply standardized scientific or engineering techniques. Similarly, the team is expected to provide support to the team leader and other members in order to achieve the research goals. To complete a research project effectively, team performance is therefore a significant success factor.

Sometimes, a professional consultant is a good choice as a team member for a long-term project that is composed of several sub-projects. The consultant is usually an expert or professional with broad knowledge in a specific field (Tordoir, 1995). Because they do not have direct authority, consultants do not directly implement any changes on research projects; rather, they solely provide services and make recommendations to those research groups on a case-by-case basis.

2) Technology: Many kinds of research cannot succeed without certain essential technology, such as laboratories, scientific instruments, and computer software. Different specialists require different instruments and technology depending on the research field. For instance, some laboratories are commonly used by computer scientists and thus require advanced computers for simulations or data analysis. Scientific instruments can include any type of equipment, apparatus, device, and even technological

support that is specifically designed and constructed through trial and error. Such instruments are part of the laboratory equipment; however, they are considered more specialized than other measuring instruments in labs. Furthermore, those instruments are increasingly improved based upon the integration of computers with purposes of controlling instrumental functions, conditions, and parameters. Likewise, data collection and analysis are integrated functions of those instruments, and they are often coupled with Internet access to databases that are suitable for comparing results and analyzing advanced data for rapid exchange of information between group members. When researchers need more sophisticated instruments, a financial investment is required for the project to continue. However, a new model of laboratory design known as the "open laboratory" allows the sharing of space, equipment, and even support staff among different research groups, with the purpose of reducing investment cost on new laboratories.

3) Data and Information: "Data are distinct pieces of information that usually are formatted in a special way. Research data are collected, observed, or created for analyzing and producing original research results" (en.wikipedia.org, "Data," 2015). In the context of this dissertation, the word "data" refers to research data that can be generated for different purposes and through different processes. Research projects often generate many different kinds of data, each of which may require a different type of data management plan. "Data can be categorized as "primary" or "secondary." Primary data is collected specifically for the research project, such as data

from interviews or questionnaires. Secondary data, by contrast, is data that already exists and can be reused for a new project. Mixed-method research, which includes both qualitative and quantitative elements, often uses both primary and secondary data" (en.wikipedia.org, "Data," 2015).

"Data" is not the same as "information." Data in themselves are rather meaningless. But when a set of data is processed, organized, structured, or presented in a given context with the purpose of making it useful and meaningful, it becomes "information." Although they are not identical, data and information are both important resources that require the researcher's focus. Without data and information, the project would not be possible and the results would be unsuccessful (en.wikipedia.org, "Information," 2015). .

4) Research Methodology: "The goal of research methodology is to produce new knowledge or to enable deeper understanding of interesting issues. This process takes three main forms: exploratory research, which helps to identify and define a problem or question; constructive research, which tests theories and proposes solutions to a problem or question; and empirical research, which tests the feasibility of a solution using empirical evidence." (en.wikipedia.org, "Research," 2015). Moreover, there are two major types of research design: qualitative and quantitative. Researchers choose either qualitative or quantitative methods depending upon the nature of the research and the specific research questions that they want to investigate (en.wikipedia.org, "Research," 2015).

Most qualitative research focuses on understanding human behavior and the reasons governing it. This type of research is designed to investigate a question without attempting to measure variables in a quantifiable way. In other words, qualitative research identifies and describes the relationships among variables. However, this research type is generally more restrictive in testing hypotheses because it is expensive and time-consuming. As a result, researchers often use qualitative research as exploratory research, which forms the basis for further quantitative research hypotheses. Quantitative research, by contrast, is a systematic empirical investigation of quantitative properties and their relationships. To analyze statistical data, researchers ask a narrow question and systematically collect relevant numerical data. Thus, the statistical method can be used to establish the existence of relationships between variables in numeric forms, which are relatively easy to summarize, compare, and generalize from (en.wikipedia.org, "Research," 2015).

In scientific fields, quantitative research methods are usually preferred because scientific experiments are well suited to numerical analysis. Researchers select specific quantitative methods to achieve the best result, and the choice of method also directly affects other research criteria, such as research budget and schedule.

5) Research Funding: Conducting research requires financial support. Research funding for both the sciences and the social sciences is available through highly competitive processes from funders that include government agencies, corporations, and foundations. "Only the most promising projects

receive funding. Most research funding come from two major sources: corporations' research and development (R&D) departments and government grants, which are given primarily to universities and specialized government agencies. Charitable foundations fund small amounts of scientific research, generally with the primary purpose of developing cures for diseases" (en.wikipedia.org, "Research Funding," 2015).

According to an OECD report (2002), approximately two-thirds of R&D in science and technology is funded by industry. The government, on the other hand, provides only 10% to 20%, but the proportion varies by research field. For example, the United States government supplies approximately 36% of the funding for medical research, and even more for certain research fields, such as the social sciences and humanities. The most research-oriented corporations and universities focus heavily on the near-term possibilities in research and development (OECD, 2002).

An advantage of government-sponsored research is that the results are shared publicly. With privately funded research, on the other hand, a single group usually controls the project idea. As a result, government-sponsored research can result in massively collaborative projects that are beyond the scope of isolated private researchers. Government grants are able to fund research projects solely for the sake of knowledge or benefit to humanity. Research funding from corporations, on the other hand, is motivated mainly by profit. The profit incentive causes researchers to spend the most energy on projects that are perceived to have the potential for generating the most profits. Martinson (2005) reported the funding influences on research projects by surveying "3,247 U.S. researchers who were all publicly funded by the National Institutes of Health. Approximately 15% of the scientists admitted to altering the design, methodology, or results of their studies due to pressure from an external funding source. Furthermore, funded research by a particular company is often expected to yield a favorable outcome for the funder. This means that biased results are highly probable; in fact, research shows the results of corporate-funded research are indeed more favorable than would be expected from a more objective view of the evidence" (Martinson, 2005). However, without research funding by either corporations or government, researchers are not able to conduct new research and technology.

6) Research Time: Generally speaking, a short-term project takes a few hours, days or weeks to complete, whereas a long-term project lasts for months or years. Funders therefore require more documentation and infrastructure for longer-term projects. According to the research topic of "Critical Success Factors in Effective Project Implementation" by Pinto and Slevin (1987), Research decisions on project governance usually depend on several factors: budget, resource requirement, business impact, and the scope of the project. One job of the project managers is to assess the project's scope to determine how much time is needed to achieve the desired outcomes.

    a. Budget: A long-term project typically requires much more money to complete than a short-term project. A short-term project, on the other hand, usually requires fewer approvals to get started and completed because it typically costs less. As a result, “short-term project leaders may be able to keep track of expenditures on a simple spreadsheet, whereas longer and more complex projects might require sophisticated accounting software packages to track and monitor costs” (Pinto and Slevin,1987).

b. Resources: “The number of resources required for a short-term project depends on the type of product or service” (Pinto and Slevin, 1987). Furthermore, a short-term project usually requires specialized expertise. Comparatively, a complicated project generally requires numerous resources over its course, from initiation and planning, to execution, control, and completion.

c. Impact: Pinto and Slevin (1987) explain that a longer-term project tends “to have a larger impact on the business, community, or employees than a short-term project. For example, a company might institute a long-term project to analyze complex problems and make sweeping changes that have a major effect on the entire company. Therefore, it is best if project team members commit to working on the project for the duration of the effort to ensure consistency and continuity” (Pinto and Slevin, 1987).

d. Scope: Due to the complexity of a long-term project, its project plan typically describes “multiple objectives, business needs, and interdependent requirements. Occasionally, a long-term project is divided into small sub-projects for more manageable and more immediate results" (Pinto and Slevin, 1987). A short-term project, by contrast, focuses on a single goal or objective. A company may require a formal scope statement for each project and establish governance to ensure that the early requirements of the project are not miscommunicated or misunderstood, which risks the possibility of cost overruns as the project progresses.

Relationships among Research Criteria

Regarding the Ishikawa diagram of research criteria used in this study, each criterion has a strong influence on the others. After prioritizing the research criteria, research funding and time constraints are found to have the greatest effect on the other four criteria in terms of research productivity. Without funding, researchers would be unable to conduct the entire research project effectively, and they would struggle with continuously hiring team members and staff to work when research funding is cut. The impact of funding cuts can cause a research project to become difficult to manage and control over time. Research funding cuts affect how researchers conduct research. In some circumstances, they may even have to consider whether they can keep their labs open at all. Even when they are successful in receiving grants, the challenge is how to manage a project with limited funding and limited time. Sometimes, researchers are forced to figure out how to eliminate some of the work without compromising entire project.

Markov Chain

Since researchers deal with normal decision-making problems within the context of systems randomness, they must attempt to quantify all possible factors to predict the effects of randomness on these systems. A mathematical theory has been developed to solve problems based on probability and stochastic processes or events. An effective conceptual model was first developed by Russian mathematician and probability theorist Andrey A. Markov in 1907 (Cinlar, 1975). However, even before Markov, Galton and Watson, a British scientist and mathematician, worked on solving similar Markov chain problems during the second half of the nineteenth century (Feldman & Valdez-Flores, 1995) and proposed the so-called “Galton-Watson process” (Galton & Watson, 1875).

The technical term “Markov chain” represents a type of “memoryless process,” which satisfies the Markov property that “the future state of the process is independent of the past given the present state” (Feldman & Valdez-Flores, 1995, p. 37). In other words, “given the current state of the process, the history contains no additional information about the future time evolution of the process” (Programmable Artificial Cell Evolution, 2008).

Definitions

In presenting the concept of Markov chains, this dissertation refers to the basic definitions given by Feldman & Valdez-Flores in their book *Applied Probability & Stochastic Processes* (Feldman & Valdez-Flores, 1995).

Definition 1: “A stochastic process is a sequence of random variables.”

“It is possible for a stochastic process to consist of a countable number of random variables … in which case it is called a *discrete parameter process.* It is also possible that a stochastic process consists of an uncountable number of random variables, in which case it is called a *continuous parameter process*” (Feldman & Valdez-Flores, 1995, p. 38).

Definition 2: “The set of real numbers containing the ranges of all the random variables in a stochastic process is called the state space for the stochastic process.”

Feldman and Valdez-Flores also mention that “the state space of a process may be either discrete or continuous.” In general, a Markov process therefore has a countable state space, and also “ a Markov chain is a discrete parameter process in which the future is independent of the past given the present” (Feldman & Valdez-Flores, 1995, p. 38).

Definition 3: “The stochastic process $X = \{X_n;\ n = 0, 1, \ldots\}$ with discrete state space E is a Markov chain if the following holds for each $j \in E$ and $n = 0, 1, \ldots$” Feldman and Valdez-Flores simplify this definition in a general formula:

“$Pr\{X_{n+1} = j | X_0 = i_0, X_1 = i_1, \cdots, X_n = i_n\} = Pr\{X_{n+1} = j | X_n = i_n\}$, for any set of states $i_0, \cdots, i_n$ in the state space. Furthermore, the Markov chain is said to have the stationary transition probabilities if $Pr\{X_1 = j | X_0 = i\} = Pr\{X_{n+1} = j | X_n = i\}$” (Feldman & Valdez-Flores, 1995, p. 39).

To explain the concept of the above equations, Feldman and Valdez-Flores state that the first equation in definition 3 is the statement of the Markov property. They also provide more detail: “Time n is the present state of process, and the left-hand side of the equation shows the probability of going to state j next, given the information of all past states in the process. Likewise, the probability of going to state j next, given only the present state of the process, is indicated in the right-hand side of the equation" (Feldman & Valdez-Flores, 1995, p. 40). The second equation demonstrates that "the probability of one-step transition does not change as time increases" (Feldman & Valdez-Flores, 1995, p. 40). Therefore, the matrix is normally used for demonstrating the transition probabilities, as follows:

$$P(i,j) = Pr\{X_1 = j | X_0 = i\}.$$

Furthermore, the transition matrix is called a Markov matrix, which contains nonnegative probabilities, and the sum of probabilities in each row is equal to one (Feldman & Valdez-Flores, 1995).

Markov Property

To briefly explain the Markov property, this dissertation refers to the general case of a stochastic process based on equations proposed by Durrett in 2010 as follows:

"Let $(\Omega, \mathcal{F}, \mathrm{P})$ be a probability space with a filtration $(\mathcal{F}_t, t \in T)$, for some index set *T*; and let (S, S) be a measure space. An *S*-valued stochastic process $X = (X_t, t \in T)$ adapted to the filtration is said to possess the Markov property with respect to the $\{\mathcal{F}_t\}$ if, for each $(A \in S)$ and each $(s, t \in T)$ with $s < t$, $\Pr(X_t \in A | \mathcal{F}_s) = \Pr(X_t \in A | X_s)$. A Markov process is a stochastic process which satisfies the Markov property with respect to its natural filtration" (Durrett, 2010, p. 274).

In addition, this dissertation applies the concept of Markov chain to the proposed model to demonstrate the process's "memorylessness" and the nonnegative probabilities of proceeding from one step to another step of the model.

Supply Chain Management

This dissertation will discuss the details in each step of the development and management of a research agenda, in general, and explore its application based on a case study of supply chain systems. Even though research agendas related to this topic have been developed, none of them addresses how to manage a research agenda. Thus, supply chain is an apt topic for a case study illustrating the implementation of consistency model proposed by this dissertation.

Overviews

Logistics and supply chain management (SCM) is a field that integrates several processes in an attempt to optimize the flow processes of materials and supplies throughout an organization and its operations, particularly during the planning process, and to optimize information collection in each supply chain activity that is a crucial success factor. In practice, companies in the supply chain system should extend the logic of logistics activities upstream to suppliers and also downstream to final customers. The companies whose supply chains are most cost-effective are, unsurprisingly, most likely to succeed in the highly competitive market place. Furthermore, supply chain decision makers in both manufacturing and business are aware that the market turbulence of the 1990s was only a starting point; in its aftermath, continuous uncertainty makes responsiveness to change a more valuable consideration than ever before.

Therefore, one of the most important current issues in SCM is the development of a more flexible and effective methodology to support decision-making across a system. Most top executives in the world's leading companies know that improved

SCM is essential to profits and even to their organizations' survival. In terms of business visions, the focus on changing customer response abilities have had a large impact on purchasing strategy, so companies need powerful tool sets to support their purchasing-related decisions. One potential solution is supply chain strategy and management.

Supply Chain Management System

Keith Oliver coined the term "supply chain management" in an interview in the *Financial Times* in 1982 (Jacoby, 2009). According to one definition, "SCM is the systematic, strategic coordination of traditional business functions and tactics across all business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole" (Mentzer et al., 2001). Hines (2004) provides a different definition of SCM: "Supply chain strategies require a total systems view of the links in the chain that work together efficiently to create customer satisfaction at the end point of delivery to the consumer" Hines (2004).

In general, SCM deals with "the management of material and information flow both in and between facilities, such as vendors, manufacturing and assembly plants, and distribution centers. The supply chain is composed of three traditional stages: procurement, production, and distribution. Each stage may be composed of several facilities in different locations around the world" Hines (2004).

Throughout the entire supply chain system, raw materials and finished goods flow downstream, and cash flows upstream. Data and information flow in both directions. In order to optimize the system in effective and economic ways, the company must focus simultaneously on the total management of both upstream flow of money and downstream flow of goods.

Research Trends for Supply Chain Management

In preparation for a case study of this dissertation, it is very important to understand the current circumstances and not to ignore any significant factors that affect the energy market and the energy industry. Recently, many marketing experts and professionals have emphasized several key trends affecting the oil and gas industry in 5.

Because information technology (IT) is ubiquitous, cyber security risk management is essential, according to an interview with the consulting firm Booz Allen Hamilton published by Energy Digital in 2013. Although oil and gas companies recognize the advantages of networked infrastructures that allow for more efficient business operations with their suppliers, cyber risk management challenges have increased dependence on this technology. Thus, companies should set up higher-level security protection systems to screen access to their business databases and to minimize the impact of any attempted attack or hack.

It is impossible not to include SCM issues among the new trends in oil and gas industry. Agrawal (2013) noted that asset management is of critical importance for the energy industry because companies can reduce the non-productive time of revenue-generating machines by constructing effective maintenance plans. Likewise, Burke (2014) stated that the industry still faces significant operational challenges to improve exploration and production (E&P) due to high demand for energy sources. Therefore, companies need new, advanced technologies for extraction methods in more complex

Previous Related Research

This section explores a sample of research articles and conference proceedings related to research agendas and published in the past 50 years (between 1960 and 2014), retrieved from the University of Oklahoma (OU) Libraries' subscription databases. A relatively small number of publications were retrieved on this topic; it is possible that consulting other commercial databases not available through the OU Libraries might yield additional articles providing more comprehensive data. Examples of research agendas based on different research areas will be discussed in this section.

A search for "research agenda" in the OU research databases found 1,726 articles representing many different research fields. As illustrated in Figure 2.4, the number of published articles about research agendas increased slowly between 1960 and 1981 and then rapidly (more than 1000%) between 1982 and 1992. The number of research articles then increased dramatically, by 582 between 1993 and 2003, and by 1,058 between 2004 and 2014.

According to Arif Jinha (2010), the first journal articles appeared in 1665, and the cumulative total was estimated to be more than 50 million in 2009. Therefore, approximately 80 million research articles are in existence in 2014 based on a rapid increasing growth rate of research publications in recent years. Even though the number of articles related to research agendas is less than 0.000002% of all published research articles, the landscape of research on this topic has changed significantly over the last 50 years, indicating that researchers have begun looking forward to new challenges as the situations in their research fields have changed over this time period.

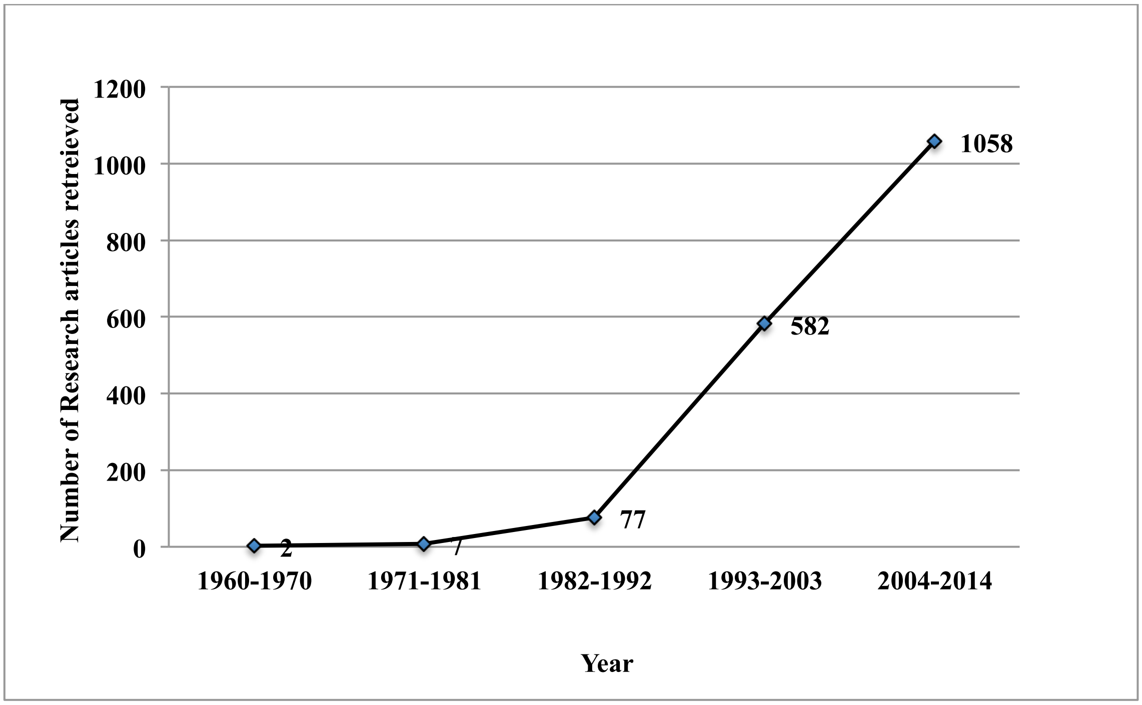

Figure 2.2. Research Trend on the topic of Research Agendas, 1960-2014

Interestingly, the data demonstrate that the majority of research related to research agendas is scientific research – especially medical research on topics such as cancer prevention and HIV/AIDS. Research agendas in other fields, including engineering and technology, the social sciences, education, culture, and environmental policy, also started developing their own milestones during the time period. This phenomenon is a good sign for the new research era, as it demonstrates that researchers and policymakers are more active about research planning in order to establish new consistency frameworks and future directions.

This five-decade research trend reveals that most research agendas implemented similar processes to establish a new agenda and research framework by the participants, who generally are professionals from the academic, business, or technology sectors as well as representatives from government. The following research examples are chosen in order to demonstrate how researchers set their research agendas in general.

Community Resources, LLC (2007) presented an Executive Summary of Proceedings from "Focus on the Future," a conference held in San Antonio, Texas. Researchers and stakeholders prioritized a set of research questions about community health workers. The purpose of this research agenda focusing mainly on clarifying what information is required about community health workers in order to fulfill its potential and meet the expectations of funders, policymakers, and even employers. Furthermore, the conference hosts expected that all interested parties would discuss the future of community health workers by using this research agenda as a starting tool kit. General findings and recommendations were also generated by gathering the conference participants' ideas. Some examples include the wide variety of methods that researchers should implement to find the roles, techniques, and community environments of the field; likewise, participants suggested that researchers should find the relevant topics to meet the interest of policymakers and funders.

It is impossible not to mention research agendas in social sciences related to medical research, because professionals in this field have been quite active in developing new research agendas. Researchers in the social sciences and related fields attended the 8th AIDS Impact Conference with the primary goal of fighting the HIV epidemic. Moatti and Spire (2008) discussed a research question about HIV prevention and also a major current concern about primary and secondary medical prevention strategies. A related concern was about behavioral interventions. Furthermore, they emphasized that social science research should be concerned about the cultural, psychological, economic and social barriers, and even motivations for prevention in order to control the HIV epidemic with a long-term agenda.

At a conference of the International Association for K-12 Online Learning, Kennedy (2013) presented results from a survey identifying research needs for developing a research agenda for blended and online earning. The primary purpose of this research agenda is "To evaluate broad needs across the field and prioritize future research needs" (Kennedy, 2013). Kennedy also stated the three main steps of developing a research agenda: 1) brainstorming with the experts in the field, 2) identifying research needs, and 3) creating the final report. The goal of this research agenda is to transform the traditional education system into a new student-centered system. This research agenda presented a set of priorities for research needs in the next five years for developing research projects in the field of education by delivering important research questions to each priority. This research agenda by clearly emphasizes the significant factors that concern researchers; however, this research still lacks precise planning for obtaining the researchers' goals.

Research agendas on energy issues have become popular due to a new era of energy alternatives. Researchers in this field have begun building research agendas on specific topics in order to set milestones for future research directions and emphasize the importance of the natural gas supply chain system to new technological development of global energy sources. In Perry's article (2013) in *Fractured Communities*, she discussed the environmental effect of the rapid development of shale gas exploration, production, and transaction on multiple locations and rural communities. To better understand the relationship between environmental and cultural change processes, she started the data collection, scheduled to last from 2013 to 2021, in the projected areas to investigate residents' opinions and reactions. She then will complete the project by proposing a research agenda on unconventional energy and culture change.

The Simon Fraser University Centre for Dialogue and the Pacific Institute for Climate Solutions arranged a dialogue session on carbon talks for building a research agenda with the goal "to advance Canadian global competitiveness by shifting to a low-carbon economy" (Simon Fraser University's Centre for Dialogue, 2013). The participants typically answered key questions and brainstormed their ideas for possible solutions to start setting a research agenda; moreover, the dialogue also identified key gaps in research and public education for developing a new research agenda and a framework in the field of natural gas development (Simon Fraser University's Centre for Dialogue, 2013).

Joe McMonigle and the Honorable Spence Abraham (2014) discussed several interesting topics regarding top energy issues at the Potomac Energy Conference. Adam Sieminski, a keynote speaker and the administrator of the U.S. Energy Information Administration (EIA), discussed the U.S. oil and natural gas outlook. He mentioned that the natural gas and oil production and U.S. primary energy consumption were not balanced because of the increasing rate of onshore natural gas productivity. To solve the problem, the EIA projected that the U.S. should export more natural gas by 2017. Washington's agenda primarily proposed the recent problems and then suggested the possible solutions for each issue.

Recently, the National Oilheat Research Alliance (NORA) hosted a meeting and gathered many professionals from the heating oil industry to develop a research and development agenda (Oil & Energy Online, 2014). To emphasize the primary mission of the Alliance on research and development, NORA President John Huber stated “This conference will provide us with a roadmap of the type of research that we should accomplish. Thus, we will reach out to the community for potential research partners who will be able to accomplish the tasks that we identified as important” (Oil & Energy Online, 2014). Participants prioritized issues for a new research agenda: biofuels, combustion and atomization, control & emerging technologies, low-cost high-effeciency equipment, fuel quality, and documentation of field performance. During the meeting, NORA gathered and evaluated participants’ feedback in order to develop a research agenda and also to set new criteria based on a research agenda for new research proposals and projects for its next annual budget.

Research agendas have been discussed in broad research fields; however, the majority of research agendas solely proposed to create lists of research rather than demonstrating how to manage and develop a research agenda itself. Generally speaking, to start setting a research agenda, researchers or participants in the meeting work through generic questions based on the objectives of research and new assumptions by prioritizing them in order to find better plans or “to do lists” for challenging new research. Undeniably, researchers must be ready for any new challenges or unexpected circumstances. In terms of continuous development, it is very important for an organization to arrange annual or semi-annual meetings to redefine the previous research agenda by including additional areas of research or even removing out-of-date topics.

What are the differences and similarities between the research agenda management and research project management? Although the two concepts share some similarities, the main difference is that research project management has a narrower scope in solely focusing on research itself. By contrast, the management of research agendas (especially as discussed in this dissertation) focuses on developing an agenda and managing research criteria (researcher, technology, methodology, data and information, funding, and time). Furthermore, previous research based on research project management focused solely on implementing managerial approaches to research projects and did not include research agendas. In addition, it is very important to clearly understand the concept of both methods in order to correctly implement them regarding the objectives of research. The proposed model of the management of research agendas and the comparison between these concepts of management will be discussed in the following chapter of this dissertation.

Chapter Summary

Research project management has been applied to some research fields, and a limited amount of research has been undertaken on the topic of research agendas. However, this dissertation will contribute to knowledge in this area by 1) proposing a consistency model with standardized processes and 2) implementing the proposed model on a case study of natural gas supply chain systems. To summarize this chapter, a list of key words and brief descriptions are given below.

1) A research agenda is a plan of tasks to be done or problems to be addressed to establish new frameworks and future directions for specific intervals of time. Brainstorming is an important process for gathering researchers' ideas about new projects.
2) Research project management is the activity of planning, organizing, and controlling resources and procedures. These activities are based on the objectives of research in order to achieve specific goals. This approach has a narrower scope than working solely on the research itself.
3) The research agendas management is the activity of creating and developing support and infrastructure for research projects by considering each criterion of research, with the primary purpose of completing research effectively.

Chapter 3: Research Methodology

This dissertation demonstrates how to create, develop, and manage a sustainable research agenda by integrating research project management with research agenda-building processes in the form of the proposed consistency model. This model has the potential to serve as a "road map" or set of guidelines that grant proposal writers, researchers, and principal investigators (PIs) can use as they create their research agendas. This chapter will discuss the principal methodology, followed by the details for implementing each step of the process of creating and managing research agendas using the proposed model.

Principal Methodology

Research agendas generally propose a list of core research tasks, generated by a brainstorming process, in order to build new platforms for future research. To adjust to new challenges and to ensure their organizations' continuous improvement, researchers typically revise their research agendas annually to add new areas of research and remove outdated topics. Although the processes of *research agenda management* and *research project management* have some similarities, they are different in one important respect: research project management focuses solely on the research work itself, whereas research agenda management also includes associated tasks, such as procuring funding (near the beginning of the process) and managing publications (near the end).

For the purposes of this dissertation, research agenda management is considered to begin with the development of a research agenda and end with management of the resulting publications. This chapter also discusses critical working criteria and demonstrates how researchers can use them as a model or rubric for managing the entire process.

The ultimate goal of this research methodology is total effective management (TEM), the core purpose of which is to manage a research agenda-building process that leads to success in completing the research, publishing its results, and fostering effective collaboration by team members on all critical working criteria. Shown in Figure 3.1, this model can be applied to any research discipline, including the sciences, the social sciences, the humanities, and the arts, as mentioned in chapter 2.

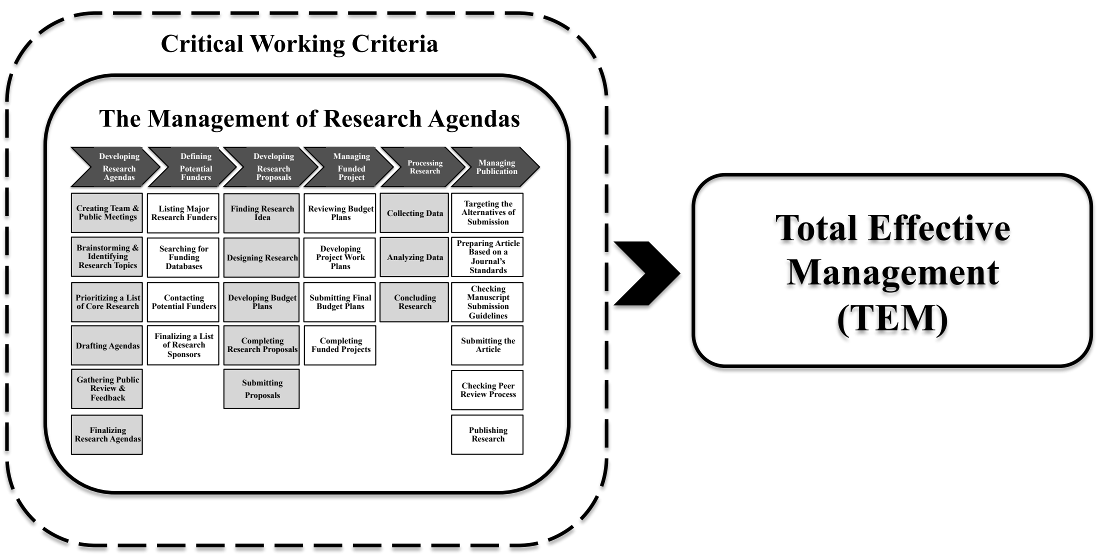

Figure 3.1. A Proposed Model for the Management of Research Agendas

To manage a research agenda, researchers should consider not only research criteria but also three important control criteria: quality, risk, and impact.

Steps in Research Methodology

The proposed consistency model for the management of research agendas is composed of six major steps based on the guidelines, which proposed by Research Center, University of Massachusetts Amherst (2013). However, the proposed model develop those guidelines by including more important detail in every major steps in order to clarify how this proposed model can be used as a "road map" for new researchers. Each of which consists of several essential tasks, as shown in Figure 3.2.

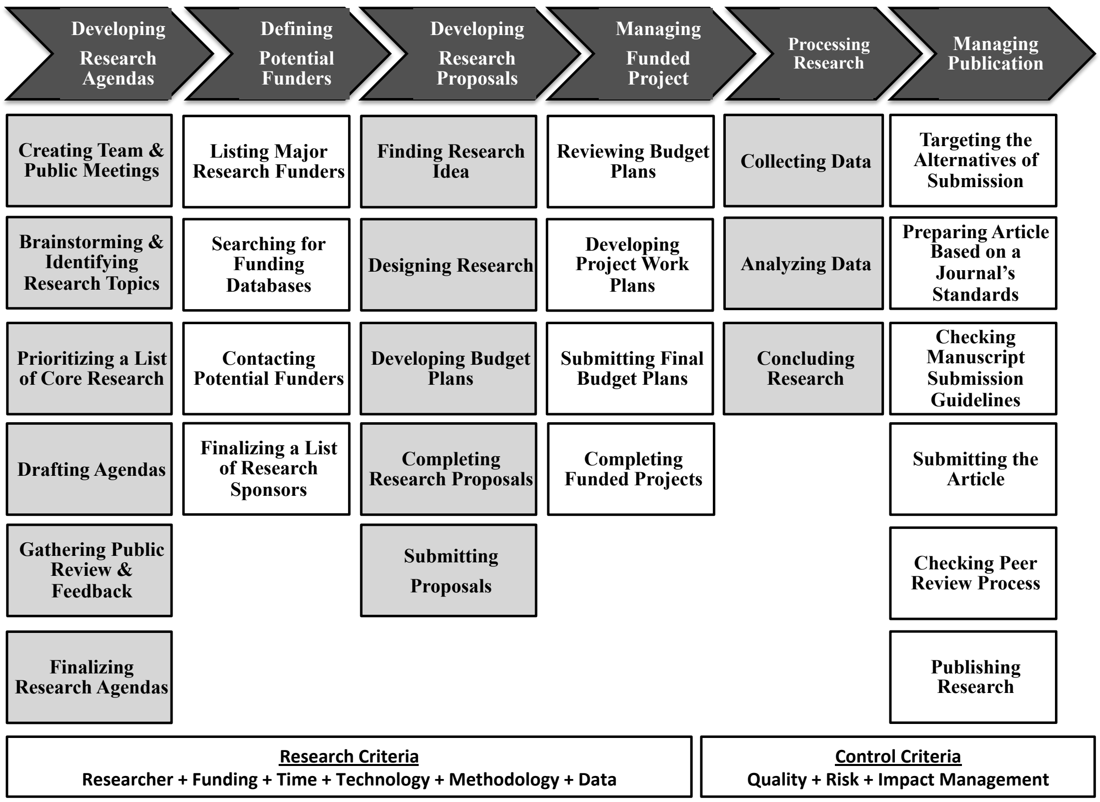

Figure 3.2. The Major Steps in Research Methodology

The research and control criteria have an important influence on both the research processes and the researcher's decisions in each major step. Thus, this chapter will also discuss in detail the importance of each criterion that researchers should consider in managing research agendas and projects. Due to the highly competitive demands of funding, researchers must be able to address not just technical considerations but also the budgetary issues involved in conducting experiments and managing support resources. Therefore, strategic planning becomes an important technique that helps researchers vie for funding. This dissertation addresses these kinds of tasks, which, although not strictly research-related, are nonetheless essential for success in the research enterprise.

Step 1: Developing Research Agendas

To develop and manage a research agenda, researchers must identify the key elements of their research goals, clarify their research interests, and plan their road maps for pursuing their professional careers into the future. Furthermore, they must be aware of the existing research in their areas of expertise and align their research interests with funding agencies' priorities. The essential tasks and their descriptions are presented in Table 3.1.

Table 3.1 Steps in Developing Research Agendas

Tasks	Descriptions
Create team & public meetings	• Researchers and professionals in specific fields • Public seminars or workshops
Brainstorm & identifying research topics	• Research reviews • Recent research trends
Prioritize a list of core research	• Most interesting topics • Possible to be developed • Funding opportunities
Draft agendas	• Semi-standard format
Gathering public review & feedback	• Public seminars or workshops • Annual reviews
Finalizing research agendas	• Research criteria (researchers, funding, time, technology, methodology, and data) • Control criteria (quality, risk, and impact)

Task 1.1: Creating Team and Public Meetings

Research agendas cannot be built without professional teams. Researchers can begin the process by setting up a small group to work on creating a sustainable research agenda. Public meetings such as workshops, seminars, and conference are a good way to exchange ideas with other professions in the same field. Research priorities can change over time as knowledge grows, so it is unrealistic to expect agendas to be immutable. However, even in the early stages, researchers can create preliminary research agendas for short-term or long-term projects

Task 1.2: Brainstorming and Identifying Research Topics

During meetings or workshops, participants should review previous research and brainstorm general interests to consider all possible topics. Furthermore, recent research trends can be discussed and used as a guideline to help researchers identify topics that are over-studied and areas where additional work is needed.

Task 1.3: Prioritizing a List of Core Research

To select topics for building research agendas, researchers can divide topics into two groups: topics in established research areas and topics in new and emerging research areas. Next, they should prioritize these topics, according to their aims, to develop a list of core research areas that interest most group members. It is important that the team explores the research areas' funding viability and determines whether their selected topics match potential granting agencies' missions.

Task 1.4: Drafting Agendas

In general, research agendas present a "to-do list" consisting of research questions, a list of prioritized topics, the goals of each research problem, proposed problem-solving methods, and possible solutions. Furthermore, budget plans and time schedules are included in agendas, so that researchers can present potential funders with an overview of realistic time frames and a reasonable budget plan for project completion.

Task 1.5: Gathering Public Reviews and Feedback

Different researchers and professionals often approach the same problems from differing perspectives. The review process is thus very important to help researchers obtain useful comments, solicit feedback on draft agendas, and complete projects more efficiently. It is useful to form an editorial group to review various agendas. As mentioned above, research ideas change over time, so agendas should be revisited and updated annually.

Task 1.6: Finalizing Research Agendas

The expected outcome of this step is to finalize the research agenda in preparation for identifying potential funders.

What criteria should researchers consider in managing the tasks associated with this step? In developing research agendas, both the research criteria and the control criteria are important, because they directly affect the quality of the research agenda's outcomes. For instance, the team and the workshop participants should have sufficient research skills and background knowledge in specific fields to brainstorm productively during the research agenda building process. Likewise, to ensure that the work will be completed successfully, researchers should also have the ability to manage time and control budget constraints.

Step 2: Identifying Potential Funders

This step consists of four essential tasks, which focus mainly on how to gather useful information for identifying potential funding sponsors. Accessing funding databases is important because the information available in them can guide research teams in managing their time effectively and in developing and submitting their grant proposals. Table 3.2 lists and describes the essential tasks.

Table 3.2 Steps in the Process of Identifying Potential Funders

Tasks	Descriptions
Listing major research funders	• Federal funding organizations • Private companies
Searching funding databases	• Funders' priorities and requirements • Grant and training programs • Application guidelines
Contacting potential funders	• Research agendas • Direct contacts
Finalizing list of research sponsors	• Criteria (data & information, time, and risk)

Task 2.1: Listing Major Research Funders

Based on their areas of research interest, researchers should search for a wide variety of funding resources appropriate to their projects. Major research funders can be categorized broadly into two groups: federal funding sponsors and private companies. As an example, the National Science Foundation (NSF) is one of the major federal research sponsors supporting research funding to academic institutions – especially research that builds fundamental knowledge for social, human behavior, and economic systems. Likewise, the National Center for Science and Engineering Statistics (NCSES), which is operated by NSF, also provides financial support to help improve the nation's science and engineering infrastructure. Another major federal research sponsor is the U.S. Department of Education's Institute of Education Science (IES). This organization primarily supports research whose purpose is to improve student academic achievement. After researchers have general information about which organizations or sponsors allocate funds for their fields, they can categorize these sponsors based on their research areas before examining the funder's requirements in more detail.

Task 2.2: Searching Funding Databases

Many academic and research support websites regularly gather and share useful information in the form of funding databases, which provide information about funding sources' research scope, funding priorities, grant or training programs, funding application guidelines, and application deadlines. Recently, funding alert services have become popular, and researchers now can register to receive updated funding information regarding their interests.

Task 2.3: Contacting Potential Funders

When their research agenda is ready, researchers should discuss their work plan with team leaders, who can contact the research funders directly in order to optimize their chances of receiving funding.

Task 2.4: Finalizing the List of Research Sponsors

Next, researchers should finalize their list of potential research sponsors and start developing funding proposals that meet the funder's priorities and requirements.

What criteria must researchers consider in managing the tasks associated with this step? At this stage, one of the most important criteria is the reliability of the information they use in identifying potential funders. Reliable information at this stage will reduce the risk of funding rejection. It is thus important to choose trustworthy websites and databases before contacting grant sponsors. To ensure that they are accessing reliable information, researchers should seek out databases created by government information centers, academic institutions, or research institutes. Another criterion is managing time constraints. Because it is essential to submit research proposals on time, researchers must know how to manage time successfully and organize work plans effectively.

Step 3: Developing Research Proposals

When researchers apply for grant, the funder expects that they will submit a precise, descriptive research proposal including information about the researchers' previous work, as well as a detailed budget plan. The purpose of the proposal is to ensure that researchers have done sufficient preliminary reading and preparatory work in the proposed research area and also provide a feasible research plan. In the budget plan, the funder expects the researcher to list and explain all of the proposed project's expenses. Research proposals exhibit greater detail than research agendas do. Descriptive details for each task are shown in Table 3.3. In writing the proposal, the challenge is to convince the sponsor that the researchers are capable of solving the research problem within a realistic time frame and at a reasonable cost, two criteria that are of great importance from a managerial perspective.

Table 3.3 Steps in the Process of Developing a Research Agenda

Tasks	Descriptions
Finding research ideas	• Refer to research agendas • Seminars, conferences, training, and course works
Designing research	• Disciplines of research • Data sources
Developing budget plans	• Reasonable expenses • Realistic time frames • Flexible plans
Completing research proposals	• Internal reviews • consultations
Submitting proposals	• Research criteria (researchers, funding, time, technology, methodology, and data) • Control criteria (quality and risk)

Task 3.1: Finding Research Ideas

The researcher's goal is to find a new idea that might make a significant contribution to their field of expertise. Potential research topics should be narrow enough to be attainable in a reasonable amount of time, yet broad enough to be recognizable as part of a particular discipline. With this in mind, the researcher usually develops a list of potential research topics based on research agendas. Choosing a topic that stems from recently developed agendas is wise, because funding proposals are typically evaluated by professionals in the same field and area of research interest. To build and maintain awareness of current trends in funded research in one's discipline community, it is useful to participate actively and frequently in seminars and conferences.

Task 3.2: Designing Research

Research design systematizes research; it provides the framework for finding answers to research questions. Most researchers are interested in obtaining reliable data or observations that can lead to better understanding of a phenomenon. Research design is often categorized into two main approaches: quantitative and qualitative. Generally speaking, "quantitative research generates numerical data or information that can be converted into numbers, whereas qualitative research generates non-numerical data" (Explorable, 2015). Each approach has advantages and disadvantages, and researchers typically choose the type of research design based on their research aims and the nature of the phenomenon to be studied. Another factor to be considered in choosing a research design is cost: Researchers should design the project in such as way as to optimize the amount of work they can achieve with limited funding.

Task 3.3: Developing Budget Plans

To maximize the odds of receiving funding, researchers should prepare a precise budget plan with a list of reasonable expenses (both direct and indirect costs) and a realistic time frame. It is very important for the budget justification to be transparent and easy to understand, because financial sponsors use this information to determine whether an expense is allowable or not. If the justification is not clear enough, the entire proposal will run the risk of being denied. At the same time, however, a budget plan should be flexible enough to adjust as necessary. For example, if the research sponsors reduce funding, researchers must be prepared to adjust the plan by either cutting out unnecessary expenses or reducing expenses in certain categories.

Task 3.4: Completing the Research Proposals

Before submitting a full proposal, researchers should check the funder's guidelines to find out what additional documents are required. Furthermore, it is likely that the researcher's institution will require internal reviews and consultations to finalize the proposal and check the construction of the budget. Academic and research institutions usually provide this service for graduate students and researchers.

Task 3.5: Submitting the Proposal

After the researchers' institution has approved the proposal, the team leader or research advisor submits it to the funding sponsor.

What criteria must researchers consider in managing the tasks associated with this step? In developing research proposals, a primary focus is on the budget plan, which must be detailed enough to present the funder with all possible costs related to the project. To reduce the risk of rejection, researchers should consider having financial experts review the plan prior to submission.

Step 4: Managing Funded Projects

When embarking on a newly funded project, the researcher must not only oversee the research processes but also manage the grant effectively. One of the most challenging tasks is keeping track of all aspects of the research budget. Regular monitoring from the very beginning is advised to enable researchers to address any unexpected changes that arise. This step consists of the essential tasks shown in Table 3.4.

Table 3.4 Steps in the Process of Managing Funded Projects

Tasks	Descriptions
Reviewing budget plan	• A list of all expenses • Changing factors
Developing project work plan	• Goal setting for sub-projects • Team project agreements
Submitting final budget report	• Internal reviews • Budget summaries
Completing funded projects	• Criteria (time, risk, and budget)

Task 4.1: Revising Budget Plans

Sometimes, research proposals receive conditional acceptance. When this occurs, the sponsor usually returns the proposal to the researcher with a list of comments and recommended revisions. The research team then has the opportunity to revise the budget plan, the project scope, and the timeline to meet the funder's requirements. After receiving a conditional acceptance, the best way to proceed is to review the plan with the advisor and project team. It is often helpful to invite consultants, research assistants, and staff to participate in the review meeting. At this meeting, researchers should clarify the roles of team member in managing the project's administrative aspects, including hiring staff, procuring office space, purchasing supplies and equipment, and planning for travel expenses. Researchers usually submit a revised proposal to the sponsor for approval and then continue to the next step.

Task 4.2: Developing Project Work Plans

To manage a funded project and establish its work plan, researchers should identify goals by dividing the work into monthly, quarterly, semi-annual, and annual sub-projects. Gantt charts and project management tools can be useful for setting deadlines and monitoring progress for each sub-project. They can also help establish common expectations among team members and control workflows effectively. This has the advantage of allowing researchers to monitor finances and identify who is responsible for each financial activity.

Task 4.3: Submitting Final Budget Reports

It is strongly recommended that researchers contact the funder whenever the financial plan is updated.

Task 4.4: Completing Funded Projects

When closing out the project, researchers should consider scheduling an internal review meeting prior to completing the research work and submitting the final financial report to the funder. The primary purpose of this kind of internal review is to summarize all expenses and analyze the remaining budget and timeframe. After this review, researchers write the final report to the sponsor and usually submit a copy to their own institution.

What criteria must researchers consider in managing the tasks associated with this step? In managing funded projects, budget and time still play an important role. To close out a research project on schedule, researchers must know how to manage time and organize working plans effectively. Continuous monitoring is a strategy that can help researchers control the research project's effectiveness, and project management tools are useful for tracking any changes that arise.

Step 5: Processing Research

The process of research starts with general questions about natural or social phenomena and proceeds to focus on an interesting specific issue. Next, researchers conduct a literature review to find out what previous work has been performed in their area of inquiry, as mentioned in Step 3, "Developing Research Proposals." Regarding the proposed model in this dissertation, the fifth step presents the tasks of data collection and data analysis. The essential tasks are outlined in Table 3.5.

Table 3.5 Steps in Processing Research

Tasks	Descriptions
Collecting data	• Quantitative data collection methods • Qualitative data collection methods
Analyzing data	• Primary and secondary data sources • Descriptive analysis • Data visualization
Concluding research	• Research criteria (researchers, funding, time, technology, methodology, and data) • Control criteria (quality, risk, and impact)

Task 5.1: Collecting Data

After a funder approves a research proposal, the researcher is ready to start collecting data based on the research design outlined in the proposal. Data collection is a very important part of the research study because inaccurate data lead to invalid results.

Data collection methods are categorized broadly into two types: quantitative and qualitative. *Quantitative data collection methods* yield numerical data, such as direct measurements, or information that can be converted into numbers, such as responses from surveys, polls, and observations, which produce results revealing attitudes, opinions, behaviors, and other defined variables. With the aim of testing hypotheses or theories, these methods generalize results from a statistically representative sample population to a larger general population. Quantitative data collection methods in practice are more structured than qualitative data collection methods. *Qualitative data collection methods* typically use unstructured or semi-structured techniques, such as group discussions (including focus groups), individual interviews, and observations of population samples too small to be statistically representative of a larger group. These methods' purpose is to provide insight into phenomena such as underlying opinions and motivations, which can help researchers develop hypotheses or supplement their quantitative research findings.

In research design, a new researcher must be careful not to use the two methods interchangeably. The wrong method can lead to distorted findings and result in wasted resources – especially budget and time.

Task 5.2: Analyzing Data

Depending on the data collection methods used, the researcher can use data from either primary or secondary sources. Primary sources are original works or newly discovered information, which is sometimes called "raw data." Primary sources include observations, interviews, questionnaires, statistical data, research reports, and documents reporting on original research. By contrast, secondary sources are studies or documents in which researchers have analyzed the data or information in primary sources to make it more accessible to a non-expert audience. For example, a newspaper article that reports about the results of a scientific study is a secondary source.

To prevent data errors, the researcher must clean the collected data. The data type determines the appropriate cleaning method. For example, outlier detection can be used to identify and remove data that were entered incorrectly.

With regard to data analysis, several techniques are available to help the researcher understand, interpret, and summarize the data. Descriptive statistics is one such technique. Its primary aim is to summarize a sample and provide either quantitative or simple visual summaries. For instance, an average can be generated to help the researcher understand the data. Another technique is known as exploratory data analysis (Tukey, 1977), which is typically used to identify a data set's main characteristics and generate a summary in visual form. However, this method sometimes requires additional data cleaning or even additional data collection. A third method is data visualization, which is used to examine the data in graphical format and to communicate the data's significance effectively to others (Friedman, 2008). Using these various data analysis techniques, the researcher interprets the data and presents all important findings in a report.

Task 5.3: Concluding Research

In the research paper's conclusion, researchers draw everything together and answer as many of the original research questions as possible. Although it is sometimes necessary to leave some questions unanswered, researchers can use their findings to suggest areas for future research and even propose recommended follow-up research questions.

What criteria must researchers consider in managing the tasks associated with this step? In processing research, they must be concerned about both research criteria and control criteria: The research criteria directly affect the actual research work, but the control criteria also have a crucial influence on the research outcomes. The quality of the research outcomes is correlated with the research criteria, such as the researchers' skills, the support tools and technologies, the methodologies employed, and the reliability of data sources. But for the best outcomes, researchers must also manage time effectively and control budget constraints, because these criteria have a strong influence on work completion. Moreover, risk and impact are considerable constraints that researchers should take seriously: If any of their conclusions are incorrect, the errors may cause flaws in future research.

Step 6: Managing Publications

Generally, the last step of the process is to contribute to the research community by publishing a research paper in an academic journal or conference proceedings. Academic journals' standards are high, so it is not always easy for researchers to have their work published in the most suitable or most prestigious journal. To achieve publishing success, it is helpful for researchers to be aware of the usual process, as shown in Table 3.6.

Table 3.6 Steps in the Process of Managing Publications

Tasks	Descriptions
Targeting publication types	• The journals • The conference proceedings
Preparing articles based on a journal's standards	• The journal's standards • The researcher's limitation
Checking manuscript submission guidelines	• The standard formats • The main components
Submitting the article	• Online submission • Paperwork submission
Checking peer review process	• Acceptance/rejection • Conditional acceptance with major/ minor revisions
Publishing research	• Criteria (time, risk, and budget)

Task 6.1: Targeting Publication Types

First, the researcher should be aware of the various publication types and the advantages and disadvantages of each. For instance, if the research work is being undertaken for a thesis or dissertation, it is often beneficial to submit a "progress paper" or interim report to a conference to gain valuable feedback from other conference participants before completing the entire project. When preparing an article after the research has been completed, on the other hand, it is generally best to choose to publish in an academic journal. To maximize the probability of acceptance, the researcher should choose a journal whose scope is appropriate to the research. It is also a good idea for the article to cite works previously published in the same journal.

Task 6.2: Preparing the Article Based on the Journal's Standards

As mentioned above, researchers must determine the primary aims and scope of the journal. In addition, they should consider both the journal's standards and the researcher's limitations. Most journals publish only specific types of submissions, such as review papers, book reviews, or empirical research papers, so researchers should choose a journal appropriate to the type of paper they have prepared. Furthermore, some journals may prefer to publish research articles that include citations to previously published articles in the journal. To increase the chances of acceptance, the researcher should therefore consider these criteria carefully before submitting. A journal's rank typically is correlated with its acceptance/rejection rate, so those who plan to submit an article to highly ranked journals must be prepared for a higher risk of rejection.

In some situations, researchers are limited in what they are legally allowed to publish under the terms of the funding contract or the terms of employment at their institution. If the funder is a private company, it might require nondisclosure of the research results. On the other hand, if the funder is a government agency, it might require the research results to be published in an "open access" journal that makes the results available to the general public without a subscription fee. Likewise, some academic institutions require or encourage employees who publish articles to retain legal copyright of their works. It is important to consult with the research team, the funder, and the university or research institute to ensure that all legal and contractual requirements are met when publishing research results.

Task 6.3: Checking the Manuscript Submission Guidelines

Most journal websites provide useful information and guidelines for authors to following when submitting articles. Such guidelines typically include information about the citation format, the word limit, the permissions required for using copyrighted information, and so forth. A typical article generally consist of the following sections: an abstract, an introduction, a literature review, a statement of research problems and hypothesis, a methodology section, analysis and discussion, and a research summary or conclusion. In addition, it is customary to include a cover letter along with the article.

Task 6.4: Submitting the Article

When the article is completed, it is submitted to the journal editors either online or in paper format. In the last decade, many journals have adopted online-only submissions procedures. Some journals accept submissions at any time of the year, whereas others have specific deadlines for specific issues of the journal. Researchers should be aware of deadlines, if any, and should also find out whether the journal requires a submission fee. This kind of information is usually available on the journal's website.

Task 6.5: Checking Peer Review Processes

If the journal uses an online submissions system, the researchers usually are assigned a reference number that allows them to track their manuscripts through the review process. Researchers should be aware that the review process sometimes takes a long time, depending upon how difficult it is for the editor to find suitable peer reviewers. When the review process is complete, the researchers will receive one of four possible outcomes: the paper will be rejected, conditionally accepted with major revisions (sometimes referred to as a "revise and resubmit"), conditionally accepted with minor revisions, or accepted with no changes required. If the paper requires revisions, the researchers must study the referees' reports and the editor's letter to identify and address specific problems and rework the article point by point. The same steps are useful if the paper is rejected, because the revised article can be submitted to a different journal.

Task 6.6: Publishing Research

After the paper has been accepted, the journal editors will contact the researchers with instructions for preparing their work for publication. If the article includes images created by someone else or published previously, the researchers will be required to seek legal permission to reprint the images, and this may take a few months. Furthermore, researchers will be asked to update their contact information, job title, and affiliation to be published along with the article.

What criteria must researchers consider in managing the tasks associated with this step? In managing publications, the first criterion is time constraint, which has a significant effect on work completion. It is advisable to select a potential journal and set the schedule for submitting the research paper at the very beginning stages of developing the research proposal, so that the working plan can be set up to accommodate the selected journal's standards and the researchers' limitations. Funding should be considered even at the earliest stages, because if a submission fee is required, researchers must include this expense in the financial plan before presenting the research proposal to the funder. Last, researchers still deal with the risk constraint in the process of article submission – especially in selecting a potential journal. To reduce the risk of article rejection, researchers should have good strategic planning skills so that they can control risk and manage unexpected circumstances. Moreover, an alternative plan (such as a second-choice journal) is quite a good idea in case the primary plan fails.

Chapter Summary

This chapter has outlined a step-by-step methodology for the management of research agendas in the form of the proposed model. Key words and their brief descriptions are summarized as follows:

1) The scope of research agenda management encompasses everything from the first step of developing an agenda until the final step of managing publications.
2) The ultimate goal of this research methodology is total effective management (TEM).
3) The core concept behind this model is the consideration of all relevant criteria and factors in managing the research agenda-building process.
4) The model is composed of six major steps: developing research agendas, identifying potential funders, developing research proposals, managing funded projects, processing research, and managing publications.
5) The research criteria (researcher, funding, time, technology, methodology, and data) and control criteria (quality, risk, and impact) have a strong impact on the effectiveness of the process and influence the researcher's decisions in each major step.

Chapter 4: Choices of Management Tools and Techniques

This chapter presents overviews of management tools and techniques to address the problems of critical working criteria: research criteria, control criteria, and human criteria. Researchers can apply these management tools to develop, manage, and control the constraints that have a significant effect on research agendas, as discussed in chapter 3. These techniques can be generalized and applied to any research discipline: the sciences, the humanities, the arts, and the social sciences. These management tools and techniques will be categorized into three groups based on the different types of criteria and the different types of challenges that they present.

Tools and Techniques for Addressing Challenges Presented by Research Criteria

Prior to starting new research, professionals should consider many important criteria, especially those directly related to both the effectiveness and the efficiency of work processes. The major challenge is how to manage and coordinate all research criteria to achieve both high-quality research outcomes and success in managing the research agenda.

The two most significant research criteria are time and budget, which have a significant impact on project completion. Researchers can manage these constraints by creating a precise budget plan, including a list of reasonable expenses, and by setting a realistic work schedule from the very beginning of proposal development. To manage any problems caused by a lack of criteria control, researchers can apply the management techniques and tools designed for specific types of problems, as outlined in this chapter.

Time Management

Because the goal is to maximize research outcomes within a limited amount of time, time management helps researchers increase effectiveness, efficiency, and productivity. Time management includes a range of skills, tools, and techniques that researchers can use for specific tasks and projects. Time management is often considered to be a subset of project management, attention management, or personal knowledge management. Within the realm of project management, for instance, time management is commonly known as project planning or project scheduling (Project Management Institute, 2004). These useful techniques and tools help researchers achieve maximum productivity and personal organization.

1) ABC Analysis. This approach, a transformation of the 80/20-principle, has been used in business management since General Electric first applied it to optimize inventory (Dickie, 1951). Using this technique, researchers categorize and rank large volumes of data into prioritized groups, designated "A," "B," and "C." This technique is frequently combined with Pareto analysis.
2) Pareto Analysis, sometimes known as "the 80-20 rule." The idea behind this technique is that, in general, 80% of tasks can be completed in 20% of the available time (Bunkley, 2008). To implement this technique, researchers sort tasks into two groups and assign a higher priority to the first task group, the relatively small number of tasks that have a relatively large effect on profits, rewards, or budgeting. If the primary aim is productivity, researchers

should prioritize significant tasks higher than others (en.wikipedia.org, “Time Management,” 2015).

3) The Eisenhower Method, also known as the Eisenhower Box or the Eisenhower Decision Matrix (McKay; Brett; Kate, 2013). With this technique, each task is designated as either important or unimportant, and either urgent or non-urgent (Fowler, 2012). This creates a two-by-two matrix for a total of four categories.
4) POSEC Method is an acronym for “prioritize by organizing, streamlining, economizing and contributing”. Researchers therefore can use this technique to create a “pyramid” of goals based on its importance and implement the associated tasks from the bottom to the top of pyramid. Based on Abraham Maslow’s hierarchy of needs (Maslow, 1943), this POSEC method was created to assist the team to be able to build their efficiency and improve the total effectiveness of team performance (MELINTE, 2013).

In addition, “Time management is critically important for any successful project. Researchers who succeed in meeting their project schedule are more likely to stay within their budget”(Project Management Institute, 2004), because lack of time management is the most common cause of project budget failure. Fortunately, many choices of techniques and tools are available to help researchers manage project schedules and timelines.

Budget Management

Generally speaking, budget management includes the managerial methods for analyzing and organizing all costs and expenditures for a business to control and monitor budget plans. Managing a budget requires adherence to strict internal expenditure protocols. Regarding Westland's statement on "the 4 ways to manage your budget", "a well-managed budget allows for smooth operations and growth. A research budget normally allocates specific amounts of money to various items that require funding. When a budget is out of balance, researchers must find ways to increase or reduce spending in certain areas. Good budget management thus helps researchers run the project in an orderly, productive manner, whereas poor budget management often leads to chaos, causing severe cash shortfalls that can jeopardize the project. A typical budget provides funds for general expenses, equipment, services, and miscellaneous expenditures, and researchers must make careful decisions about how to allocate funds among the various categories" (Westland, 2011).

To assist the project team with budget planning, several customized tools are available. The choice of tool depends upon the project's complexity and level of uncertainty. Project Management Guru (2012) mentions about two general budget management techniques are described below.

1) Project Spend Plan: "This is a spreadsheet that lists the project team's planned purchases. This technique is generally used for simple projects with a relatively narrow focus. Researchers divide the spending plan into two parts: a list of "investments" in laboratories, equipment, and other durable equipment, and a list of other expenses for things such as material, supplies, staff time, travel costs, and so forth" (Project Management Guru, 2012).
2) Project Budget: "This is a time-based spreadsheet showing the team's intent to spend the organization's resources on project activities. The spreadsheet

typically is organized by listing the project activities in the spreadsheet rows and designating each column as a time period. This data can be transferred to the organization's financial planning and management system. After the project budget is created, the intended costs for each time period are summed in each column. This technique enables researchers to present the data in graphs and charts, for clearer communication of cost information" (Project Management Guru, 2012).

These budget management techniques can help researchers *organize* and *manage* the project budget; however, techniques that can help *control* the budget plan are also necessary to avoid any unexpected expenses. Some examples of budget control techniques are break-even analysis, return-on-investment, management by objectives, and the critical path method. Researchers should choose the technique best suited to specific problems that arise during the research processes (Project Management Guru, 2012).

Tools and Techniques for Addressing Challenges Presented by Control Criteria

In managing research agendas, researchers deal with challenges associated with control criteria. The most critical criterion is risk constraint, which is directly caused by poor planning and a lack of effective management of research criteria. Risk management is therefore necessary, starting with the first steps in research agenda development.

Another significant criterion is quality, which is a key indicator of research outcomes. Limited resources (research criteria) do not necessarily cause quality problems in research processes, but management failure in research planning and processes can lead to poor-quality outcomes. Researchers are generally familiar with the concept of quality management that focuses on product and service quality. But quality management also should be applied to the processes that lead to outcome quality. Overviews of such techniques will be discussed below in the form of brief descriptions and examples of tools.

Risk Management

"Risk management" is defined as "the identification, assessment, and prioritization of risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability or impact of unfortunate events" (Hubbard, 2009) or to maximize the realization of opportunities. However, definitions, methods, and goals vary widely in different contexts, such as project management, public health, engineering, and industrial processes. Clarizen Team (2013) outline useful tools and techniques for risk management and researchers can use these tools and methodologies during various phases of managing risk, as described below.

1) Risk Identification. "*Information gathering techniques* are used to achieve a consensus of experts and to generate unbiased data. Interviewing and brainstorming are two methods that can be used for gathering ideas about possible risks. Another technique is *root cause analysis*, which researchers can use for identifying a problem, discovering its causes, and developing preventive action. *Assumption analysis* can reveal inconsistent or problematic assumptions. *Diagramming techniques* include cause and effect diagrams, process flow charts, and influence diagrams. These kinds of diagrams are graphical representations of the causal influences or

relationships among variables and outcomes. *SWOT analysis* is a structured planning method frequently used to evaluate the strengths, weaknesses, opportunities, and threats involved in research projects" (Clarizen Team, 2013).

2) Risk Analysis. Risk analysis consists of tools and techniques for two types of risks.

   a. For Qualitative Risk Analysis: "*Risk probability and impact assessment* is used for investigating the probability of each specific risk and its potential effect on project objectives, such as schedule, cost, quality, and performance. Researchers define risk levels by interviewing or meeting with relevant stakeholders and documenting the results. *Probability and impact matrix* allows researchers to rate risks for further quantitative analysis by using a probability and impact matrix. *Risk categorization* is a risk-grouping method for determining the areas of the project most exposed to the effects of uncertainty" Clarizen Team (2013).

   b. For Quantitative Risk Analysis: "*Probability distributions* are used for data gathering and representation. Researchers use this method in modeling and simulations to represent uncertainty about task duration or project cost. *Sensitivity analysis* can determine which factors are likely to have the greatest impact on the project by examining the effect of varying the inputs of a mathematical model on the output of the model itself. *Expected monetary value (EMV)* *analysis* allows researchers to calculate the average outcome of future expenses using a decision tree analysis. *Cost risk analysis* uses cost estimates as input values, which are chosen randomly to calculate total cost. With *schedule risk analysis,* researchers use duration estimates and network diagrams as input values by random selection to calculate completion date" Clarizen Team (2013).

3) Risk Response Planning. "*Risk reassessment* is used to reassess current risks and closing risks. *Risk audits* can examine the effectiveness of risk responses in dealing with identified risks and their root causes, as well as the effectiveness of the risk management process. The format for the audit and its objectives should be clearly defined before team leaders conduct the audit. *Variance and trend analysis* uses performance information to compare planned results with actual results to control and monitor risk events and to identify trends. Outcomes from this analysis may forecast potential deviation from cost and schedule targets. *Technical performance measurement* is implemented to compare technical accomplishments during project execution to the project management plan's schedule. In order to compare actual results against targets, researchers define objectives through quantifiable measures of technical performance. *Reserve analysis* compares the amount of remaining time and cost to the amount of remaining risk to determine whether the remaining reserves are enough to complete the research tasks. *Status meetings* are frequent discussions during which

researchers identify and address risks and opportunities" Clarizen Team (2013).

Researchers should use risk management strategies to address any uncertainties with potentially negative consequences, so that they can take action to transfer, avoid, and reduce the effects of the threat.

Quality Management

In developing effective and efficient research agendas and managing research projects, quality is a significant criterion that researchers must not overlook. In the proposed model, therefore, quality is prioritized as a control criterion that researchers must monitor and control at every step.

Quality management is defined as "the management of activities and functions involved in determining quality policy and its implementation through four approaches: quality planning, quality control, quality assurance, and quality improvement" (Rose, 2005). The implementation of these approaches is referred to as total quality management (TQM). The Project Management for Development Organization states that "project quality management is not a separate, independent process that occurs at the end of an activity to measure the level of quality of the output" (PM4DEV, 2008). Rather, researchers should consider quality management to be part of every process in project management. Furthermore, researchers should implement the four main components of quality management to ensure a consistent outcome.

1) Quality Planning: "This is a systematic process that translates quality policy into measurable objectives and requirements and establishes a sequence of working steps within a specified timeframe" (Business Dictionary, 2015).

This technique is implemented before the first task of the project begins. Several quality-planning techniques are used in different application areas. *Cost-benefit analysis* considers the trade-offs between the costs of implementing quality assurances and the benefits to be reaped by doing so. *Benchmarking* involves studying actual or planned project practices within or outside the organization, in the same application area or a different one, which are used for quality planning and performance measurement. *Design of experiments* (DOE) is a statistical method that identifies the factors influencing specific variables of products or processes under development or in production. This provides a useful input for optimizing products and processes, and it also provides a framework for systematically changing important factors simultaneously rather than one at a time. This analysis therefore provides information on optimal combinations of conditions, which can be used in project implementations. *Cost of quality* (COQ) helps calculate the total costs involved in preventing nonconformance to requirements, as well as the costs of failure (also called the "cost of poor quality").

2) Quality Control: This requires the project manager and team to inspect the accomplished work to ensure its alignment with the project scope (Phillips, 2008). This technique is used to improve the quality of products or methods by focusing on such outputs as rework decisions, acceptance decisions, and process adjustment. It is also done during the implementation phase of the

project life cycle. Several notable approaches to quality control are described below.

a. *Statistical quality control* (SQC) is the application of statistical methods used by quality professionals. Specifically, SQC tools are control charts and acceptance sampling for quality control (Juran, 1995). Kaoru Ishikawa, a professor of engineering at the University of Tokyo, developed these powerful quality tools and demonstrated how to apply each one to specific problems (Nancy, 2004). A *cause-and-effect diagram* is known as an Ishikawa chart or “fishbone chart.” This technique can be used to identify the probable root causes of potential problems and to sort ideas into useful categories. A *check sheet* is a structured form for collecting and analyzing data. Researchers can adapt this generic tool for a wide variety of purposes. *Control charts* are used to demonstrate the stability of monitoring processes. This tool also indicates how a process changes over time. The upper and lower limits are also set for the process and are usually at 3σ. A *histogram* is also known as a column graph; it is the most commonly used graph for showing frequency distributions. A *Pareto chart* is a bar chart presenting the probability density and the distribution function. Researchers use it to detect the most significant factors. A *scatter diagram* illustrates the correlation between two variables and also the relationship between two parameters. A *stratification chart* or *run chart* is a technique that separates data gathered from a variety of sources to show trends that help researchers understand problems.

b. *Total quality control* (TQC) is an application used for optimizing production, based on ideas developed by Japanese industries beginning in the 1950s. Armand V. Feigenbaum proposed this technique in a 1956 *Harvard Business Review* article.

c. *Statistical process control* (SPC) is the use of control charts to monitor and control an individual industrial process to ensure that it operates at its full potential. An operator is responsible for checking feedback performance.

d. *Total quality management* (TQM) originated with the United States Department of Defense. In TQM, the techniques of statistical quality control are used to drive continuous organizational improvement (Evans & Lindsay, 1999).

3) Quality Assurance: This must be performed *during* the actual tasks to ensure that the standards identified in the quality planning stage are met. Several quality assurance tools are available. *Quality audits* are structured reviews of quality aimed at improving performance. *Benchmarking* is used to compare the project's products or methods with others within or outside of the organization. In some cases, benchmarks are standardized throughout an industry or discipline.

   The difference between quality assurance and quality control is that quality assurance attempts to improve and stabilize production to minimize any issues leading to the defects in the first place, whereas quality control mainly emphasizes testing of products to uncover defects and report to the managers who decide whether the product should be released.

4) Quality Improvement: This refers to a systematic approach to the analysis of performance and systematic efforts to improve performance by reducing or eliminating waste, rework, and losses. *Six Sigma* (6σ) is a set of techniques for process improvement, originally developed by Motorola in 1986 (Motorola University, 2006; Process Quality Associates Inc., 2012). Six Sigma can improve the quality of a process by identifying and removing the causes of defects and minimizing variability in manufacturing and business processes. The Six Sigma methodology, which is inspired by Deming's Cycle (Shewhart, 1939; Deming, 1950), comprises five phases, sometimes referred to as "DMIAC": define, measure, analyze, improve, and control. Within each phase of a DMAIC project, Six Sigma utilizes many established quality-management tools such as statistical tools, cause & effect diagrams, and design of experiments.

Lack of proper quality management in a project can increase uncertainty and the risk of project failure. Researchers should implement a process to manage the changes, problems, and issues that emerge during the production of the outputs. However, it is appropriate for researchers to change the management techniques from project to project based on the types of problems, processes, and criteria that they encounter.

Tools and Techniques for Addressing Challenges Presented by Human Criteria

This section addresses knowledge management and decision management and describes the advantages of each in developing research agendas and planning for research funding. In this dissertation, “human criteria” refers to researchers’ knowledge and skills, especially as they pertain to managing projects, conducting experiments, and solving problems.

Knowledge Management

From the industrial revolution to the computer era, the development of technology has had a significant impact on human life. The key technology of the twentieth century, information technology (IT), has given way over the last couple of decades to knowledge management (KM). Many companies and organizations have realized that, although IT is still important, KM is now the most influential tool for an organization’s success and even for developing new forms of organization.

Davenport (1994) proposed the original definition of knowledge management as “the process of capturing, distributing, and effectively using knowledge.” As this technique became popular, many professionals proposed other definitions of KM specific to their own industry or discipline. Karlen & Gottschalk’s definition is cited frequently: “Knowledge management is a method to simplify and improve the process of creating, sharing, distributing, capturing, and understanding knowledge in a company” (2004). Both definitions share a very organizational, very corporate orientation. Ronald Young (2010) collected essential KM methods and tools based on IT in a form of a manual. Outlines of these tools are presented below.

1) Non-IT Methods and Tools: *Knowledge mapping ("K-mapping")* became one of the support techniques to empower organizations by organizing and structuring knowledge and by establishing new concepts or ideas to fulfill the knowledge organization system. The developed concept map is known as a Novakian concept map (Novak & Gowin, 1984), and the concept mapping method (Palmer, 1995; 1998) has been used as a technical tool to increase meaningful learning in science as well as to illustrate expert knowledge in education, government organization, and business fields. Experienced experts often have a great deal of "tacit knowledge," achieved over many years of work experience, but frequently they cannot communicate their knowledge or know-how to other colleagues. As a result, the concept map has great potential to enable the sharing of knowledge within an organization, to help identify gaps or missing ideas within the organization's knowledge structure, and to enhance an understanding of the relationship among ideas and concepts. *Brainstorming* is a simple way of helping a group of people generate new and unusual ideas. The process of brainstorming can be divided into two phases: divergence and convergence. Researchers can use this method when they need to generate a range of options or alternatives. *Learning and idea capture* is a KM method that helps researchers systematically acquire better knowledge by using both personal capture tools and collective capture tools, such as paper-based organizers, cameras, websites, and social networks. *Peer assist* is a method dubbed "learning before doing" by British Petroleum (BP). The project team uses

this technique to solicit assistance from peers and subject matter experts regarding a significant issue the team is facing. *Learning review* is conducted during work processes to adapt and improve the project by encouraging continuous learning among team members. This technique is also sometimes called "learning while doing." *After action review (AAR)* is used both to evaluate projects and to capture the lessons learned when a project is completed, in order to sustain the team's strengths and improve its weaknesses. *Storytelling* is a quite simple technique, but it has been used as a powerful way to share and transfer knowledge, especially experiential and tacit knowledge. In the method known as *collaborative physical workspace,* researchers share or create knowledge and interact with others in a well-designed physical workspace, which facilitates knowledge creation and sharing activities. The *APO Knowledge Management Assessment Tool* is a questionnaire that provides a rapid assessment of a team's readiness for KM by identifying its strengths and opportunities for improvement and assessing the following key elements: KM leadership, process, people/members, technology, knowledge processes, learning and innovation, and KM outcomes. *Knowledge Café*, pioneered by David Gurteen, is a group discussion method that facilitates development and sharing of thoughts and insights. *Community of practice* (COP) was originated by social scientist Etienne Wenger and his team. In the context of KM, COPs are formed with the purpose of intentionally or spontaneously sharing and creating common skills, knowledge, and expertise among team members. This technique has played an especially important role for sharing common knowledge beyond formal departments and breaking down the barriers to knowledge flow across organizations. *Taxonomy* is a technique used for organizing information, documents, and libraries in a more consistent way to help users navigate, store, and retrieve data and information efficiently. Recently, many organizations have begun to realize the importance of the link between taxonomy and corporate culture, especially with regard to creating a common language for communicating about mission-critical information across the organization.

2) IT Methods and Tools: *Document libraries,* leading to a document management system, help users access better information and manage documents in efficient and effective ways. *Knowledge bases* comprise two types of knowledge: tacit knowledge and explicit knowledge. Unlike a database, a knowledge base typically creates new knowledge for a topic; expands knowledge by discussions, feedback, new learning, and new ideas; edits and enhances the expanded knowledge; and maintains a history of revisions. *Blogs* are websites that take the form of a journal containing short articles or stories related to current events. Researchers can use blogs to capture and publish information about specific topics and make this information available to the public. *Social network services* can be very powerful as knowledge-sharing tools that allow researchers to access highly relevant knowledge, connections, and advice . *Building knowledge cluster* is a technique that helps researchers set up a group to create, innovate, and

disseminate new knowledge. *Expert locator* is an IT tool that connects people who need particular knowledge with people who possess the knowledge, thereby enabling effective and efficient use and sharing of existing knowledge. *Collaborative virtual workspaces* enable people to work together, regardless of where they are physically located, using technologies that combine document sharing, collaborative editing, and audio/video conferencing.

Researchers can use KM to develop and improve their tacit knowledge and experiences related to their projects' research processes and even managerial processes. The word "knowledge" is sometimes used interchangeably with the word "information," but part of the difficulty in defining "knowledge" arises from its relationship to the concepts of "data" and "information." KM helps professionals learn from mistakes and successes, leading to better planning for future projects. Moreover, KM enhances researchers' ability to modify knowledge from previous projects to create new solutions or plans. In addition, KM is a powerful technique that researchers can implement to deploy their knowledge assets to the task at hand: managing research agendas. It is especially effective when brainstorming to gather new idea for research topics.

Decision Management

Researchers need systematic managerial techniques to support decision-making activities that result in any management-related project outcomes. "Every decision-making process produces a final choice that may prompt action. Generally speaking, decision-making is the process of identifying and choosing alternatives based on the values and preferences of the decision maker; moreover, this process is one of the central activities of management. Decision-making is a major part of the implementation of any process or activity" Huber (1980). To make a good decision, researchers must weigh the positive and negative aspects of each alternative and then consider all alternatives to decide or discover which one is the best for the particular situation.

Decision management is the systematic process or set of processes for correcting illogical actions to make the whole system more efficient. Its ultimate goal is to use all available information to increase the consistency and agility of decisions by considering known risks and time constraints. Increasingly, decision management systems are referred to as "decision support systems," a term that has become popular as financial services and insurance companies have adopted decision-making software to support high-volume decision-making. Huber (1980) categorized decision-making into two approaches: normative analysis and descriptive analysis.

1) Normative Analysis: Derived from the fields of economics and statistics, normative analysis is concerned with the development and application of normative decision rules based on formal logic. In 1947, von Neumann and Morgenstern wrote in *Theory of Games and Economic Behavior* that "a variety of techniques have been derived for making optimal decisions. A distinction is often drawn between riskless choices and risky choices" (p. x). Outlines are given here of two examples of each approach. *Multi-attribute utility* (MAU) applies to decisions made with more-or-less certain outcomes. Gardiner and Edwards (1975) explained that users could adopt this approach

to calculate utility values, which are derived from the weighted sum of separate parts of utilities for various attributes, for the various alternatives. The alternative with the highest utility value is then selected. *Linear models* also are used to describe judgments under conditions of certainty. The user assigns weights to the attribute values based on multiple-regression analyses. *Decision-tree analysis* is a graphical model that displays the sequence of decisions and events comprising a risky or sequential decision situation (Huber, 1980). This approach for uncertain outcomes displays alternatives, uncertain events, and outcome utilities in the form of tree branches. The optimal choice is the alternative with the highest expected value. *Bayesian networks* also are designed for conditions of uncertainty. This integrated approach combines the techniques of Bayesian probability theory, artificial intelligence, and graphical analysis into a decision-analytic tool (Breese & Heckerman, 1999). All possible cause-and-effect linkages between nodes are built in a connected network, and researchers use computer algorithms to process "pruning" to reduce problem complexity.

2) Descriptive Analysis: This method is applied for making judgments, decisions, and choices. *Social judgment theory* (SJT) was developed by Hammond (1955) as a comprehensive perspective on judgment and decision-making based on the "lens model" proposed by Brunswik (1952). By adapting procedures from multiple regressions, this approach combines elements of both normative and descriptive analyses into a single framework. *Information integration theory (IIT)* is implemented by

psychologists to analyze the combination of psychological rules people use when making decisions based on the judgments. *Image theory* views the decision maker as possessing three distinct but related images: value image, trajectory image, and strategic image. Each one comprises a particular part of decision-related knowledge (Beach, 1990). *Heuristics and biases* is a method proposed by Tversky and Kahneman (1974) in light of the fact that decisions are often made using psychological shortcuts or "heuristics," which often lead to "biases" in the outcome of the decision-making process. *Fast and frugal heuristics,* proposed by Simon (1957), is based on "bounded rationality," the idea that decision makers are necessarily limited in their knowledge. Gigerenzer and Todd (1999) developed and extended Simon's ideas to take advantage of environmental constraints by applying various simple "fast and frugal" heuristics. *Naturalistic decision making* (NDM) was developed by Klein (1993) to account for online decision-making by experts in time-sensitive environments. When time is limited, it can be difficult to apply normative choice rules, which frequently prompts decision makers to follow "recognition primed decision making" by using their experiences in dealing with similar situations in the past. *Expert decision making* is a technique that psychologists implement to help professionals make better decisions with less bias.

Researchers can apply both normative and descriptive decision-making techniques to any research field and even to daily decision-making activities. The choice of technique is generally based on the complexity of the problem to be solved.

Franklin (1956) described how to implement the concept of "problem decomposition," the notion that decision-making can usually be improved by breaking a problem into parts, working on the parts separately, and then combining them to make a final decision. This method can be applied to the management of research agendas: Researchers can break a project into sub-projects, which can be more easily monitored and controlled by assigning tasks to staff members.

Chapter Summary

As outlined in Table 4.1, the management tools and techniques discussed in this chapter are categorized into three groups to reflect the different types of critical working criteria that they address and to emphasize the different purpose of implementations.

1) Time management is a necessity in developing any project, as it affects both the time frame for project completion and the scope of work that can be accomplished within a limited amount of time. Time management helps researchers control processes and increase the project's effectiveness, efficiency, and productivity (Westland, 2011; Project Management Institute, 2004).
2) Budget management is the analysis, organization, and oversight of an organization's costs and expenditures. Managing a budget requires adherence to strict expenditure protocols. A well-managed budget allows for continued smooth operations and growth (Project Management Guru, 2012).
3) Risk management is "the identification, assessment, and prioritization of risks followed by coordinated and economical application of resources to

minimize, monitor, and control the probability or impact of unfortunate events" (Hubbard, 2009) or to maximize the realization of opportunities.

4) Quality management refers to the management of activities and functions involved in determining quality policy and its implementation through four approaches: quality planning, quality control, quality assurance, and quality improvement (Rose, 2005). The implementation of these approaches is referred to as total quality management (TQM).
5) Knowledge management is a method to simplify and improve the process of creating, sharing, distributing, capturing, and understanding knowledge in a business or organization (Karlen & Gottschalk, 2004).
6) Decision management is a systematic process or set of processes for correcting illogical actions to make the whole system more efficient. Its ultimate goal is to use all available information to increase the consistency and agility of decisions by considering known risks and time constraints Huber (1980).

Table 4.1 Examples of Tools and Techniques for Critical Criteria

Criteria		Tools and Techniques
Research	Time management	• ABC analysis • Pareto analysis • The Eisenhower method • Prioritize by organizing streamlining, economizing, and contributing method
	Budget management	• Project spend plan • Project budget
Control	Risk management	For risk identification • Information gathering techniques • Assumption analysis • Diagramming techniques • SWOT analysis For risk analysis • Risk probability and impact assessment • Probability and impact matrix • Risk categorization • Probability distribution • Sensitivity analysis • Expected monetary value analysis • Cost and schedule risk analysis For risk response planning • Risk reassessment • Risk audits • Variance and trend analysis • Reserve analysis
	Quality management	For quality planning • Cost-benefit analysis • Benchmarking • Design of experiment • Cost of quality For quality control • Statistical quality control • Total quality control • Statistical process control • Total quality management For quality improvement • Six Sigma

Human	Knowledge management	Non-IT methods • Knowledge mapping • Brainstorming • Learning and idea capture • Peer assist • Learning review • After action review (AAR) • Storytelling • Collaborative physical workspace • Community of practice (COP) • Taxonomy IT methods • Document libraries • Knowledge bases • Social network services • Blogs • Building knowledge cluster • Expert locator
	Decision management	For normative analysis • Multi-attribute utility • Linear models • Decision tree analysis • Bayesian network For descriptive analysis • Social judgment theory • Information integration theory • Image theory • Heuristic and biases • Fast and frugal heuristics • Naturalistic decision making • Expert decision making

Chapter 5: Project Evaluation Metrics

The first section of this chapter focuses mainly on demonstrating project evaluation methodologies by applying Markov property (Markov, 1954) to the proposed model and by using an evaluation metric to calculate project performances based on the three main critical criteria: research, control, and human. In the next section, with the aim of measuring project performance, the numeric outcomes resulting from the evaluation metric will be calculated and converted to descriptive terms to demonstrate performance outcomes both quantitatively and qualitatively. This will help project managers and researchers gain a better understanding of their research projects' progress and use these outcomes for making decisions. The last section of this chapter presents ways to adapt the Markov decision process to create alternative plans if constraints and circumstances change.

Project Evaluation Metrics for Critical Criteria

What outcomes do most project managers expect from research projects? Some researchers may be satisfied simply by successful research results that meet the objectives or achieve research goals. But from a managerial perspective, project managers are concerned not only with the results, but also with overall effective performance, indicating that researchers are meeting their goals at each step and managing limited resources efficiently.

Before proceeding to the next step in the proposed model, researchers should be able to answer typical questions about their projects. Often, project managers have no specific measurement in mind; they simply want an update or overview of ongoing progress. However, if they ask more specific questions, they will be able to monitor progress more accurately. Project managers generally expect, and want, an assessment that provides numeric results along with a descriptive explanation. The challenge, therefore, is determining which constraints or variables should be monitored and measured, and how to convert these outcomes into descriptive evaluative language by referring to a practical scale converter. After conducting this kind of evaluation, researchers will be able to proceed to the next steps.

Building upon a performance metric proposed in Turbit's "Measuring Project Health" (2008), this dissertation categorizes six constraints from Turbit's metrics into three groups of critical criteria. These criteria are discussed in detail below.

Research Criteria

In general, project managers and researchers place high priority on time and cost constraints because both are highly sensitive when other constraints are changed over time. To monitor projects' progress, project managers may ask, "Are we on schedule? Are we on budget?" Researchers therefore must determine which methodologies to use to measure projects' progress or performance. The most common technique for managing projects is maintaining a time schedule, enabling researchers to monitor each task at each phase in the project. The number of tasks on time or behind schedule can be noted and reported to project managers. Another technique is to calculate the average amount of times that researchers are able to proceed to the project's next step by using the transition matrix from the Markov process of the proposed model. This technique requires an estimation of the transition probabilities for each step; details about this will be discussed in the next section. With regard to monitoring techniques for cost constraint, researchers can apply the principles of Earned Value Management (EVM) to projects. Budget Spend Plan is a simple technique for monitoring projects' costs. Researchers can plot actual costs against the budget plan to see differences between these two variables. Another technique is cash flow, which can be used to illustrate the movement of expenditures against the operating activities of projects. Project managers can monitor budget balances reflecting the actual expenditure during any specific time period of ongoing projects.

Control Criteria

To avoid negative project outcomes, researchers must manage time and cost constraints as carefully as they control scope and quality constraints. If they do not control the growth in project scope, researchers may find it difficult to maintain their projects' timelines and budgets. However, it is natural for a project's scope to change over time (Turbit, 2008). Researchers therefore should anticipate scope growth but limit it to an acceptable rate, building a budget that accounts for some unexpected expenditures. It is also important to keep a record of scope changes to help project managers monitor progress. In this dissertation, quality constraint refers to the quality of outputs such as documents, lab reports, and research papers. If these documents are correct, researchers do not need to rework any tasks, which helps them stay on schedule and on budget. Project managers also should identify which tasks are quality-related and pay attention to controlling quality outcomes.

Human Criteria

This dissertation identifies human criteria as human resources and human activities (Turbit, 2008). Before starting projects, project managers should estimate how much personnel time is used for each task. Researchers, technicians, staff, and anyone else involved in the project are counted in the human resources category. An effective monitoring technique is to use a time sheet for estimating the number of personnel hours spent in a given period of time and to compare actual time spent with estimated time spent. The human resources constraint directly affects the time and cost constraints, especially due to variations in personnel skill levels. If project managers hire highly skilled technicians, tasks are likely to take less time and require less rework. However, highly skilled workers generally receive higher pay, which increases the project's budget. Similarly, the human activity constraint refers to the number of outstanding tasks that personnel are unable to complete on time. When this happens, project managers must choose the most effective way to revise the project plan.

Based on this conception of project management, this dissertation proposes a model for performance evaluation for research agendas and projects. The six constraints identified above are categorized into three groups of critical criteria (Turbit, 2008). Table 5.1 shows some examples of quantitative methods or techniques for monitoring projects, measuring working performances, and setting goals.

Table 5.1 Examples of Quantitative Methods Categorized into Three Groups of Critical Criteria

Criteria		Quantitative Methods	Goals
Research	Time	Average amount of time (using transition matrix) Number of on-time tasks	On-time schedule
	Cost	Project cash flow Budget spend plan	Budget in control
Control	Scope	Number of scope change requests	Acceptable growth rate
	Quality	Inspection of qualified documents	No document rework
Human	Resource	Human resource time sheet Personnel hours per time period	Schedule & budget in control
	Activity	Number of overdue tasks	No overdue tasks

Project managers and researchers agree on goals together during the planning process. However, they can determine whether to add more quantitative methods to the evaluation metrics to measure each criterion for any of the project's tasks or processes, based on the research field's unique characteristics. Regarding the proposed model, the quantitative techniques are included in the equations to calculate total effective management value (TEMV) in the next section.

Markov Process of Proposed Model

Based on the proposed model in Chapter 3, this dissertation proposes the transformation of the model by applying Markov property, which was proposed by Markov in *Theory of Algorithms*, as illustrated in Figure 5.1. The expected outcome of the proposed model is total effective management (TEM), which is presented in the form of qualitative outcomes. The transformed model, by contrast, will present numeric outcomes as total effective management value (TEMV).

Furthermore, this dissertation proposes a standard scale for converting the TEMV outcomes to TEM format in case researchers prefer to measure and report the outcomes qualitatively to project managers. A TEMV scale converter and additional details will be discussed in the following section.

To simplify the proposed model, the simple state diagram for the Markov process is presented in Figure 5.2. In this diagram, the arrows represent transition probabilities in the form of transition rates from step 1 to step 6. For instance, p_{12} is the probability that step 1 is followed by step 2, and p_{21} is the probability that step 2 is followed by step 1. The bold arrows represent forward transitions, whereas the dashed arrows represent backward transitions.

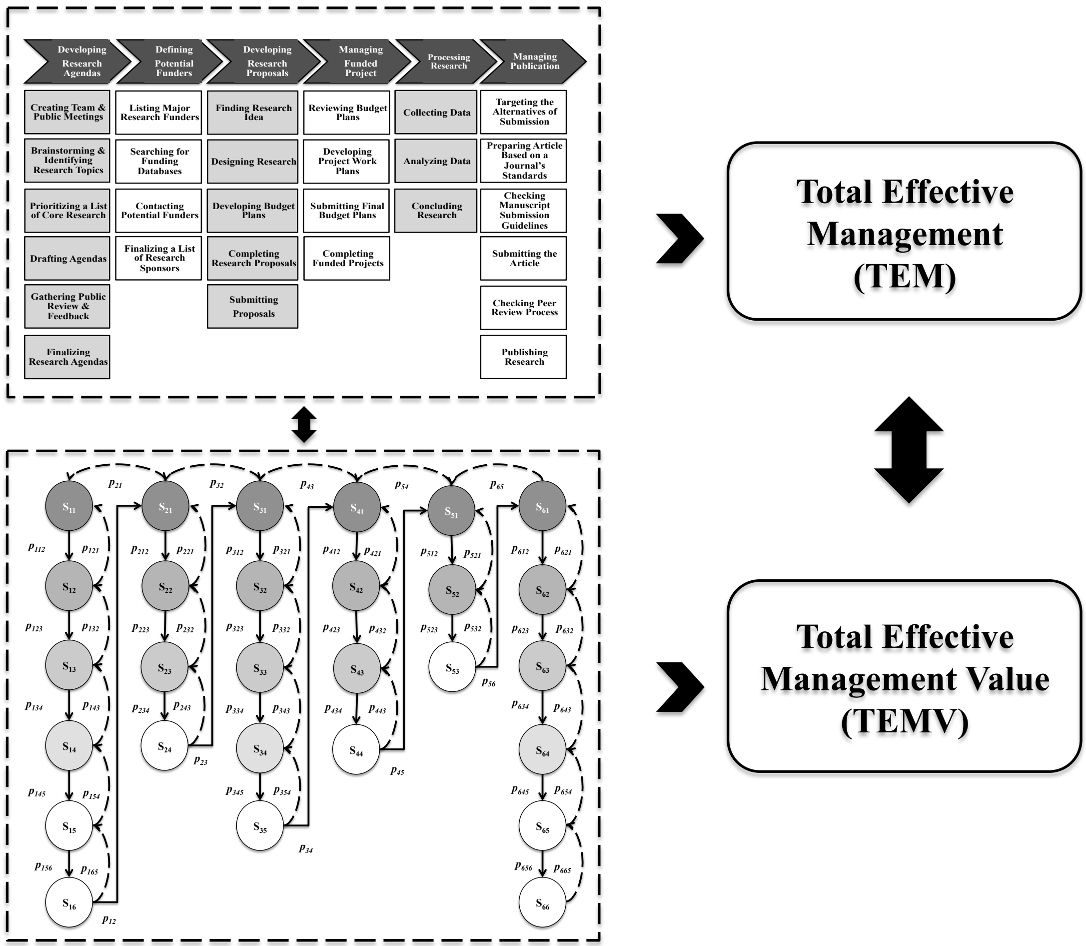

Figure 5.1 Transformation of the Proposed Model

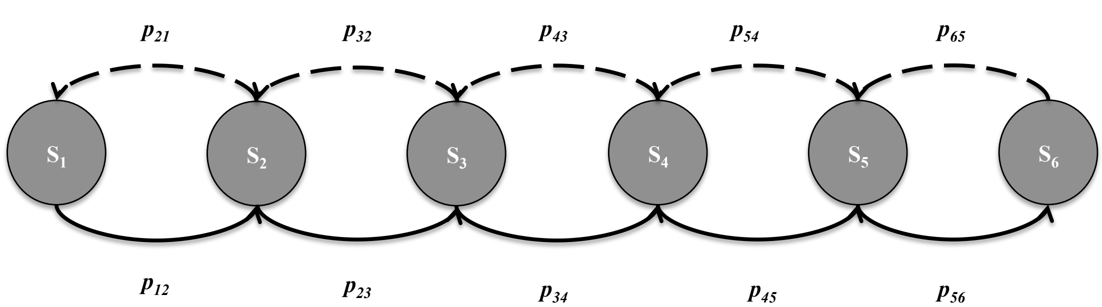

Figure 5.2 A Simple State Diagram of the Markov Process

Let

S be a step in the proposed model

i be a step number in the proposed model

$P_{i,\ i+1}$ *be the probability that step i is followed by step i+1 (forward)*

$P_{i,\ i-1}$ *be the probability that step i is followed by step i-1 (backward)*

From Figure 5.1, the proposed model is transformed into a more complex state diagram that represents all tasks in the model, as shown in Figure 5.3.

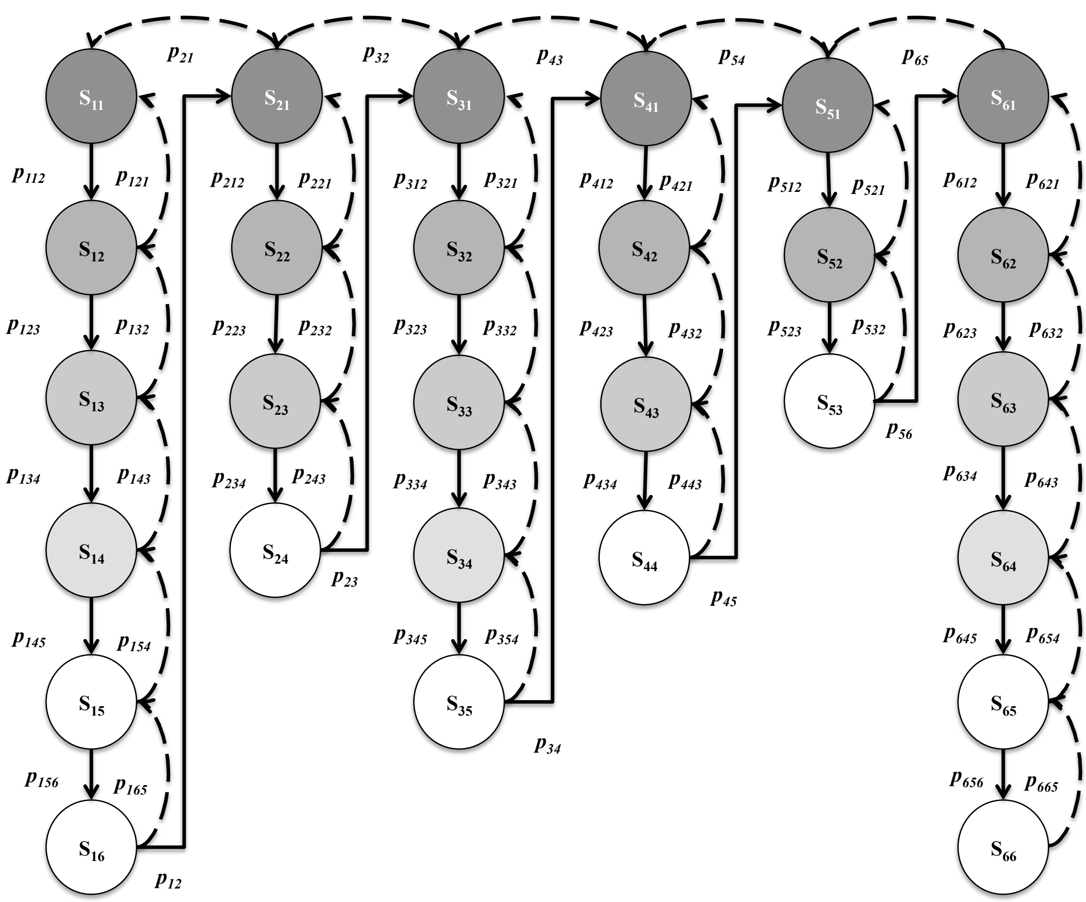

Figure 5.3 A Complex State Diagram of the Markov Process

Let

S be a step in the proposed model

i be a step number in the proposed model

j be a task number in step i

$P_{i,\,i+1}$ *be the probability that step i is followed by step i+1 (forward)*

$P_{i,\,i-1}$ *be the probability that step i is followed by step i-1 (backward)*

$P_{i,\,j,\,j+1}$ *be the probability that task j of step i is followed by task j+1*

$P_{i,\,j,\,j-1}$ *be the probability that task j of step i is followed by task j-1*

Using the transition probabilities to calculate the value of the time constraint and the steady-state probabilities to indicate the percentage of time that will be spent in a specific state or using the transition matrix, it is possible to calculate the average amount of time it takes for step (i) or task (i, j) to be followed by the next step (i+1) or the next task (i, j+1). Examples of the transition matrixes for the proposed model are following.

$$Step\ (i) \qquad S_1 \quad S_2 \quad S_3 \qquad S_4 \quad S_5 \quad S_6 \qquad \sum_{i=1}^{n} p_{i,i\pm1}$$

$$P = \begin{matrix} S_1 \\ S_2 \\ S_3 \\ S_4 \\ S_5 \\ S_6 \end{matrix} \begin{bmatrix} 0 & p_{12} & 0 & 0 & 0 & 0 \\ p_{21} & 0 & p_{23} & 0 & 0 & 0 \\ 0 & p_{32} & 0 & p_{34} & 0 & 0 \\ 0 & 0 & p_{43} & 0 & p_{45} & 0 \\ 0 & 0 & 0 & p_{54} & 0 & p_{56} \\ 0 & 0 & 0 & 0 & p_{65} & 0 \end{bmatrix} \begin{matrix} p_{12} = 1 \\ p_{21} + p_{23} = 1 \\ p_{32} + p_{34} = 1 \\ p_{43} + p_{45} = 1 \\ p_{54} + p_{56} = 1 \\ p_{65} = 1 \end{matrix}$$

Based on Markov property (Markov, 1954), the probability does not depend on any states or steps that the process was in before the current state or step. This dissertation proposes the consistency model in a unique form of the transition probabilities. If researchers work on step 1, they are just as likely to go forward to step 2 after they finish working in step 1. However, researchers have an even chance of going back to previous step if they find problems while they are working. A probability vector is a row vector whose probabilities are non-negative and sum to one, $\sum_{i=1}^{n} p_{i,i\pm1} = 1$, as illustrated in the transition matrix.

$$
\begin{array}{cccccccc}
Task\ (1j) & S_{11} & S_{12} & S_{13} & S_{14} & S_{15} & S_{16} & \sum_{i=1,j=1}^{n} p_{i,j,j\pm1}
\end{array}
$$

$$
P = \begin{array}{c} S_{11} \\ S_{12} \\ S_{13} \\ S_{14} \\ S_{15} \\ S_{16} \end{array}
\begin{bmatrix}
0 & p_{112} & 0 & 0 & 0 & 0 \\
p_{121} & 0 & p_{123} & 0 & 0 & 0 \\
0 & p_{132} & 0 & p_{134} & 0 & 0 \\
0 & 0 & p_{143} & 0 & p_{145} & 0 \\
0 & 0 & 0 & p_{154} & 0 & p_{156} \\
0 & 0 & 0 & 0 & p_{165} & 0
\end{bmatrix}
\begin{array}{c}
p_{112} = 1 \\
p_{121} + p_{123} = 1 \\
p_{132} + p_{134} = 1 \\
p_{143} + p_{145} = 1 \\
p_{154} + p_{156} = 1 \\
p_{165} = 1
\end{array}
$$

$$
\begin{array}{cccccc}
Task\ (2j\ ) & S_{21} & S_{22} & S_{23} & S_{24} & \sum_{i=1,j=1}^{n} p_{i,j,j\pm1}
\end{array}
$$

$$
P = \begin{array}{c} S_{21} \\ S_{22} \\ S_{23} \\ S_{24} \end{array}
\begin{bmatrix}
0 & p_{212} & 0 & 0 \\
p_{221} & 0 & p_{223} & 0 \\
0 & p_{232} & 0 & p_{234} \\
0 & 0 & p_{243} & 0
\end{bmatrix}
\begin{array}{c}
p_{212} = 1 \\
p_{221} + p_{223} = 1 \\
p_{232} + p_{234} = 1 \\
p_{243} = 1
\end{array}
$$

$$
\begin{array}{ccccccc}
Task\ (3j) & S_{31} & S_{32} & S_{33} & S_{34} & S_{35} & \sum_{i=1,j=1}^{n} p_{i,j,j\pm1}
\end{array}
$$

$$
P = \begin{array}{c} S_{31} \\ S_{32} \\ S_{33} \\ S_{34} \\ S_{35} \end{array}
\begin{bmatrix}
0 & p_{312} & 0 & 0 & 0 \\
p_{321} & 0 & p_{323} & 0 & 0 \\
0 & p_{332} & 0 & p_{334} & 0 \\
0 & 0 & p_{343} & 0 & p_{345} \\
0 & 0 & 0 & p_{354} & 0
\end{bmatrix}
\begin{array}{c}
p_{312} = 1 \\
p_{321} + p_{323} = 1 \\
p_{332} + p_{334} = 1 \\
p_{343} + p_{345} = 1 \\
p_{354} = 1
\end{array}
$$

$$Task\ (4j)\quad S_{41}\quad S_{42}\quad S_{43}\quad S_{44}\quad \sum_{i=1,j=1}^{n} p_{i,j,j\pm1}$$

$$P = \begin{matrix} S_{41} \\ S_{42} \\ S_{43} \\ S_{44} \end{matrix} \begin{bmatrix} 0 & p_{412} & 0 & 0 \\ p_{421} & 0 & p_{423} & 0 \\ 0 & p_{432} & 0 & p_{434} \\ 0 & 0 & p_{443} & 0 \end{bmatrix} \begin{matrix} p_{412} = 1 \\ p_{421} + p_{423} = 1 \\ p_{432} + p_{434} = 1 \\ p_{443} = 1 \end{matrix}$$

$$Task\ (5j)\quad S_{51}\quad S_{52}\quad S_{53}\quad \sum_{i=1,j=1}^{n} p_{i,j,j\pm1}$$

$$P = \begin{matrix} S_{51} \\ S_{52} \\ S_{53} \end{matrix} \begin{bmatrix} 0 & p_{512} & 0 \\ p_{521} & 0 & p_{523} \\ 0 & p_{532} & 0 \end{bmatrix} \begin{matrix} p_{512} = 1 \\ p_{521} + p_{523} = 1 \\ p_{532} = 1 \end{matrix}$$

$$Task\ (6j)\quad S_{61}\quad S_{62}\quad S_{63}\quad S_{64}\quad S_{65}\quad S_{66}\quad \sum_{i=1,j=1}^{n} p_{i,j,j\pm1}$$

$$P = \begin{matrix} S_{61} \\ S_{62} \\ S_{63} \\ S_{64} \\ S_{65} \\ S_{66} \end{matrix} \begin{bmatrix} 0 & p_{612} & 0 & 0 & 0 & 0 \\ p_{621} & 0 & p_{623} & 0 & 0 & 0 \\ 0 & p_{632} & 0 & p_{634} & 0 & 0 \\ 0 & 0 & p_{643} & 0 & p_{645} & 0 \\ 0 & 0 & 0 & p_{654} & 0 & p_{656} \\ 0 & 0 & 0 & 0 & p_{665} & 0 \end{bmatrix} \begin{matrix} p_{612} = 1 \\ p_{621} + p_{623} = 1 \\ p_{632} + p_{634} = 1 \\ p_{643} + p_{645} = 1 \\ p_{654} + p_{656} = 1 \\ p_{665} = 1 \end{matrix}$$

The above transition matrixes of each task in the proposed model also apply the concept of Markov property (Markov, 1954). If researchers finish the final tasks of each step or state, they would continue to the first task of the next step or state. Similarly, the probabilities that task j of step i is followed by task j+1 or task j of step i is followed by task j-1 are non-negative, and the total value is equal to one, $\sum_{i=1,j=1}^{n} p_{i,j,j\pm1} = 1$.

The Estimation of Transition Probabilities

The project evaluation metrics include quantitative methods that researchers can use to find the values of constraints in the proposed model in order to calculate the total effective management value (TEMV). Because the time constraint is one of the most significant, researchers might choose to add methods to measure the time constraint in different ways. For example, researchers can simply count the number of on-time tasks in each working step. If the first step of the project has five tasks, researchers can check how many tasks are on schedule or behind schedule against a predefined goal. This dissertation develops a transformation of the proposed model into a state diagram by implementing Markov property (Markov, 1954), enabling researchers to calculate the average amount of time from a transition matrix of the model. At the beginning, of course, no figures will be available, so researchers will have to estimate the transition probabilities to calculate the average amount of time it will take to get from one step to the next step or task.

This dissertation defines the proposed model as a discrete-time Markov chain process (DTMC), which represents "a stochastic process in discrete time in a form of a sequence of random variables in especially in a discrete space" as previously mentioned in chapter 2 (Markov, 1954; Feldman & Valdez-Flores, 1995, pp. 38-40; Durrett, 2010, p. 274; Sigman, 2009, p.1). Due to "unavailable data and the restriction related to problems, Lee, Judge, and Zellner proposed the estimation methodology of the transition probabilities for the Markov model based on aggregate time series data" (Lee, Judge & Zellner, 1970, p. 20). Furthermore, Anderson and Goodman (1957) state that project managers and researchers sometimes must deal with situations in which "only aggregated or total occurrence sample data are available. Under these conditions, to define the behavior of the micro units or projects, researchers must address this question: "Is it possible to use the aggregate outcome data as a basis for estimating the transition probability matrix?" (Anderson & Goodman, 1957) In addition, "assuming that a sample of micro data exists and repeated observations of the Markov chain have been made" (Lee, Judge & Zellner, 1970, p. 23), researchers can develop maximum likelihood and Bayesian estimators of the transition probabilities as follows:

Method 1: The Micro Maximum Likelihood (ML) Estimator

Based on the definitions and notations of the Markov probability model, researchers have "a sample of repeated observations on an Ergodic Markov chain. Assume that researchers are given $n_i(0)$ individuals in state i at time $t = 0$, and the elements of an observation demonstrate the sequence of states the individuals are in at $t = 0, 1, \dots, T$"(Lee, Judge & Zellner, 1970, p. 23). Anderson and Goodman (1957, p. 91) have noted that "the n_{ij} in equation (1) form a set of sufficient statistics. The distribution of the $n_{ij}(t)$ can be obtained by considering the $n_t(t-1) = \sum_j n_{ij}(t)$ observations on a multinomial distribution with probabilities p_{ij}."

$$n_{ij} = \sum_t n_{ij}(t) \tag{1}$$

Let $n_{ij}(t)$ be the number of individuals for $x_{t-1} = s_t$ and $x_t = s_t$

Because "the n_{ij} are non-negative, the ML estimator therefore fulfills the non-negative constraint" as presented in equation (2) (Lee, Judge & Zellner, 1970, p. 25).

$$\dot{p}_{ij} = \frac{n_{ij}}{\sum_j n_{ij}} \geq 0 \qquad (2)$$

Let $\dot{p}_{ij}$ *be the transition probabilities by the ML estimator*

The ML estimator is derived from the sample information and the transition probabilities, with the parameters that "(1) it cannot be negative, (2) it cannot be larger than one or unity, and (3) the row sum of the probabilities of the exhaustive and mutually exclusive events must be one or unity" (Lee, Judge & Zellner, 1970, p. 26).

Method 2: The Bayesian Estimator

In many cases, researchers have "prior information about the structure of the individual elements of the transition matrix" (Lee, Judge & Zellner, 1970, p. 26). If information is available, researchers can use it to make inferences about transition probabilities. Lee, Judge and Zellner therefore emphasize that "the Bayesian method is a convenient approach for combining sample information and prior information" (Lee, Judge & Zellner, 1970, p. 26). In addition, "the complete posterior probability density function (PDF), which incorporates sample and prior information, can be implemented to make inferences about transition probabilities. Regarding the point estimation, the mean of the posterior PDF is the Bayesian estimator, whereas the median of the posterior PDF is optimal for any absolute error loss function. Furthermore, the mode of the posterior PDF is associated with the value for transition probabilities" in equation (3) (Lee, Judge & Zellner, 1970, p. 30).

$$\ddot{p}_{ij} = \frac{n_{ij} + a_{ij} - 1}{\sum_j n_{ij} + \sum_j a_{ij} - r}\ , for\ i = 1, 2, \ldots, r\ and\ j = 1, 2, \ldots, r - 1 \qquad (3)$$

Let

$\ddot{p}_{ij}$ *be the transition probabilities generated by the Bayesian estimator*

n_{ij} *be the sample information*

a_{ij} *be the positive parameters representing prior information*

In addition, researchers will be able to estimate the transition probabilities by using equation (2) or (3), depending on their available information. Researchers then can measure the time constraint and use it to find the TEMV. Details of this approach will be discussed in the following section.

Total Effective Management Value

With the primary purpose of evaluating project performances, this dissertation includes a performance evaluation metric that quantitatively measures three critical criteria (research, control, and human) consisting of six constraints (time, cost, scope, quality, resource, and activity). Equation (4) represents *effective management value* (EMV_i) for step i of the proposed model. It is important to decide the weight of each criterion's value before calculating the outcome's value. Project managers and researchers will rate the level of importance differently for each step i based on which step has the most significant effect on project completion. Moreover, equation (4) includes an error factor, ε, which indicates any error in reporting measured quantities at each step i. The total value of the weighting factor, τ_i for step i, is equal to 1 or 100% in equation (5).

$$EMV_i = \alpha_i T_{Ti} + \beta_i C_{Ti} + \gamma_i S_{Ti} + \delta_i Q_{Ti} + \zeta_i R_{Ti} + \eta_i A_{Ti} + \cdots + \varepsilon_i \quad (4)$$

$$\tau_i = \alpha_i + \beta_i + \gamma_i + \delta_i + \zeta_i + \eta_i + \cdots + \varepsilon_i = 1 \quad (5)$$

Where

EMV_i *is the effective management value for step i*

T_{Ti} *is the total value of time constraint for step i*

C_{Ti} *is the total value of cost constraint for step i*

S_{Ti} *is the total value of scope constraint for step i*

Q_{Ti} *is the total value of quality constraint for step i*

R_{Ti} *is the total value of resource constraint for step i*

A_{Ti} *is the total value of activity constraint for step i*

Let

i be a step in the proposed model

k be the quantitative method for constraints in step i

τ *be the total value of weighting factors*

α *be the weighting factor for time constraint*

β *be the weighting factor for cost constraint*

γ *be the weighting factor for scope constraint*

δ *be the weighting factor for quality constraint*

ζ *be the weighting factor for resource constraint*

η *be the weighting factor for activity constraint*

ε *be an error factor for all constraints*

To calculate the total value of each constraint in each step, the percentage change formula is applied in this dissertation as presented in equations (6) – (17) when researchers want to evaluate their projects by comparing their goals to the actual results of each step in the proposed model. Therefore, the total value of each constraint is the average of the percentage changes of the quantitative methods that the researchers use for measuring the constraints in each step.

$$T_{Ti} = \frac{1}{n} \sum_{i=1,k=1}^{n} T_{ik} = \frac{(T_{11} + T_{12} + \cdots + T_{1n-1} + T_{1n})}{n} \tag{6}$$

$$T_{ik} = \left[\frac{(T_{Aik} - T_{Gik})}{T_{Gik}}\right] \times 100 \tag{7}$$

$$C_{Ti} = \frac{1}{n} \sum_{i=1,k=1}^{n} C_{ik} = \frac{(C_{11} + C_{12} + \cdots + C_{1n-1} + C_{1n})}{n} \tag{8}$$

$$C_{ik} = \left[\frac{(C_{Aik} - C_{Gik})}{C_{Gik}}\right] \times 100 \tag{9}$$

$$S_{Ti} = \frac{1}{n} \sum_{i=1,k=1}^{n} S_{ik} = \frac{(S_{11} + S_{12} + \cdots + S_{1n-1} + S_{1n})}{n} \tag{10}$$

$$S_{ik} = \left[\frac{(S_{Aik} - S_{Gik})}{S_{Gik}}\right] \times 100 \tag{11}$$

$$Q_{Ti} = \frac{1}{n} \sum_{i=1,k=1}^{n} Q_{ik} = \frac{(Q_{11} + Q_{12} + \cdots + Q_{1n-1} + Q_{1n})}{n} \tag{12}$$

$$Q_{ik} = \left[\frac{(Q_{Aik} - Q_{Gik})}{Q_{Gik}}\right] \times 100 \tag{13}$$

$$R_{Ti} = \frac{1}{n} \sum_{i=1,k=1}^{n} R_{ik} = \frac{(R_{11} + R_{12} + \cdots + R_{1n-1} + R_{1n})}{n} \tag{14}$$

$$R_{ik} = \left[\frac{(R_{Aik} - R_{Gik})}{R_{Gik}}\right] \times 100 \tag{15}$$

$$A_{Ti} = \frac{1}{n} \sum_{i=1,k=1}^{n} A_{ik} = \frac{(A_{11} + A_{12} + \cdots + A_{1n-1} + A_{1n})}{n} \tag{16}$$

$$A_{ik} = \left[\frac{(A_{Aik} - A_{Gik})}{A_{Gik}}\right] \times 100 \tag{17}$$

Where

T_{ik} *is the percentage change in the time constraint for method k in step i*

C_{ik} *is the percentage change in the cost constraint for method k in step i*

S_{ik} *is the percentage change in the scope constraint for method k in step i*

Q_{ik} *is the percentage change in the quality constraint for method k in step i*

R_{ik} *is the percentage change in the resource constraint for method k in step i*

A_{ik} *is the percentage change in the activity constraint for method k in step i*

T_{Gik} *is the goal value of the time constraint for method k in step i*

C_{Gik} *is the goal value of the cost constraint for method k in step i*

S_{Gik} *is the goal value of the scope constraint for method k in step i*

Q_{Gik} *is the goal value of the quality constraint for method k in step i*

R_{Gik} *is the goal value of the resource constraint for method k in step i*

A_{Gik} *is the goal value of the activity constraint for method k in step i*

T_{Aik} *is the actual value of the time constraint for method k in step i*

C_{Aik} *is the actual value of the cost constraint for method k in step i*

S_{Aik} *is the actual value of the scope constraint for method k in step i*

Q_{Aik} *is the actual value of the quality constraint for method k in step i*

R_{Aik} *is the actual value of the resource constraint for method k in step i*

A_{Aik} *is the actual value of the activity constraint for method k in step i*

Researchers should also give the weighting factors, ρ_i, for each main step i before they calculate TEMV, as demonstrated in equations (18) and (19). The total value of weighting factor, ω, which includes an error factor, θ, is equal to 1 or 100% in equation (20).

$$TEMV = \sum_{i=1}^{n} \rho_i EMV_i \quad (18)$$

$$TEMV = \rho_1 EMV_1 + \rho_2 EMV_2 + \cdots + \rho_{n-1} EMV_{n-1} + \rho_n EMV_n \quad (19)$$

$$\omega = \sum_{i=1}^{n} \rho_i + \theta = 1 \quad (20)$$

Where

$TEMV$ *is the total effective management value*

EMV_i *is the effective management value for step i*

Let

i be a step of the proposed model

n be the total number of steps in the proposed model

ω be the total value of weighting factors for steps in the model

ρ_i *be the weighting factor for each step i*

θ *be an error factor for all steps*

However, researchers can include other criteria and quantitative methods for measuring each constraint and then apply the proposed formulas to calculate the TEMV. The concept of performance metrics, from the realm of project management, is applied in each step of the model to find a project's effectiveness and efficiency. The numeric results are used in the decision-making process to change the working steps or plan as needed. The qualitative methods are not included in this proposed model. The TEMV (%) will be converted to qualitative terms or descriptions by using the proposed scale converter shown in table 5.2.

Table 5.2 A Scale Converter for Total Effective Management Value (TEMV)

<table>
<tr><th>TEMV (%)</th><th colspan="2">Qualitative Description</th><th>Decision</th></tr>
<tr><td>(+) 75.00 to (+) 100.00</td><td>Absolutely</td><td rowspan="4">Acceptable</td><td rowspan="4">Continue to the next step of the proposed model</td></tr>
<tr><td>(+) 50.00 to (+) 74.99</td><td>Strongly</td></tr>
<tr><td>(+) 25.00 to (+) 49.99</td><td>Moderately</td></tr>
<tr><td>(+) 0.01 to (+) 24.99</td><td>Minimally</td></tr>
<tr><td>0.00</td><td colspan="2">Inconclusive</td><td>Review working steps</td></tr>
<tr><td>(-) 0.01 to (-) 24.99</td><td>Minimally</td><td rowspan="4">Unacceptable</td><td rowspan="4">Place the project on hold</td></tr>
<tr><td>(-) 25.00 to (-) 49.99</td><td>Moderately</td></tr>
<tr><td>(-) 50.00 to (-) 74.99</td><td>Strongly</td></tr>
<tr><td>(-) 75.00 to (-) 100.00</td><td>Absolutely</td></tr>
</table>

Using the proposed scale converter, researchers are able to report projects' performance in both quantitative and qualitative terms to project managers. TEMV can be either a positive or negative number resulting from the products (EMV_i) of measuring results and setting goals. For example, if researchers calculate a TEMV of -0.25 or -25%, project's overall performance is *minimally unacceptable,* indicating that the project might have missed goals or be behind schedule or over budget. Furthermore, project managers and researchers can use this table for converting the EMV after each working step is finished. For instance, if the EMV is negative, researchers might place the project on hold to review processes and alter the plan before they proceed to the next step.

Examples of Implementing Project Evaluation Metric

In this section, examples are given to demonstrate how to implement the proposed model and project evaluation metric. Researchers begin by following the major steps of the proposed model and considering all critical criteria that affect the team's performance. To measure the project's performance, researchers choose more than one quantitative method and apply the evaluation metrics to calculate the effective management value (EMV) for each step, as demonstrated in equations (4) – (20). This dissertation uses the percentage change to quantify the difference between the goal and the actual results, and expresses the changes as an increase or decrease in percentage.

Table 5.3 An Example of EMV Calculation for a Step of Processing Research in the Proposed Model

Constraint	Quantitative Method (k)	Goal	Actual Result	Percentage Change (%)	Total Value (%)
Time (T)	Average time (hours)	5.5	6	-9.09	-21.21
	Number of on-time tasks	6	4	-33.33	
Cost (C)	Actual expenses ($)	175	200	-14.29	17.86
	Allowances ($)	50	25	50.00	
Scope (S)	Number of additional tasks	2	2	0	0
Quality (Q)	Number of quality action items	10	9	-10.00	-10.00
Resource (R)	Man-day/period/task	5	5	0	25.00
	Number of skilled staff	2	1	50.00	
Activity (A)	Number of overdue tasks	1	2	-100.00	-100.00

However, researchers keep in mind that the results can be either positive or negative. In this case, for example, the researchers planned to spend an average of 5.5 hours processing research, but they actually spent 6 hours. Thus, the percentage change will be a negative number, because they spent more time than planned. The project is therefore behind schedule and over budget. Conversely, the project manager initially planned to hire two skilled researchers to process research, but instead, the team recruited just one highly skilled researcher who is able to complete the work effectively. Thus, the project manager is able to save money. The percentage change of resource constraint in this step will therefore be a positive number. Table 5.3 presents an example of EMV calculation for step 6 of the proposed model by using equations (6) - (17). Because the researchers find the percentage change of each constraint for each method in the research process, they are able to calculate the total value of the percentage changes for each constraint.

Table 5.4 An Example of EMV calculation for Step of Processing Research in the Proposed Model

Constraint	Weighting Factor	Value (%)	EMV (%)
Time (T)	α	0.25	-5.30
Cost (C)	β	0.30	5.36
Scope (S)	γ	0.15	0
Quality (Q)	δ	0.20	-2.00
Resource (R)	ζ	0.045	1.13
Activity (A)	η	0.045	-4.50
Error	ε	0.01	0.01
Total	$\boldsymbol{\tau}$	**1.00**	**-5.30**

Prior to calculating the effective management value (EMV) for any step of the proposed model, researchers can use equations (4) and (5) by giving the value of weighting factors in percentage as demonstrated in Table 5.4. This yields the EMV of each constraint, which is either positive or negative as well.

Table 5.5 An Example of TEMV Calculation for Each Major Step of the Proposed Model

Major Step	Value of Weighting Factor $\boldsymbol{\rho}$	EMV (%)	$\boldsymbol{\rho}$EMV (%)
Developing research agendas	0.175	10.85	1.89
Identifying potential funders	0.15	5.27	0.79
Developing research proposals	0.20	-8.34	-1.67
Managing funded projects	0.25	-19.75	-4.94
Processing research	0.20	-22.69	-4.54
Managing publication	0.175	3.58	0.63
Error (θ)	0.025	0.025	0.025
Total	**1.00**	**-**	**-7.82**

As shown in Table 5.5, total effective management value (TEMV) is calculated by using equations (18) - (20). Researchers can weight each step in the proposed model to reflect and communicate the relative importance of the steps to be monitored and to guide the team's performance on the project. Also, researchers should consider the value of weighting factors for each major step in order to make any decision on the projects.

Table 5.6 An Example of Summary Results from Project Evaluation Metrics

Major Step	EMV/ TEMV (%)	Qualitative Description	Conclusion
Developing research agendas	10.85	Slightly Acceptable	Continue to the next step
Identifying potential funders	5.27		
Developing research proposals	-8.34	Slightly Unacceptable	Hold or Review the step
Managing funded projects	-19.75		
Processing research	-22.69		
Managing publication	3.58	Slightly Acceptable	Finish the project
Overall project	**-7.82**	**Slightly Unacceptable**	**Review the project's steps**

The summary results of the project evaluation metric are presented in Table 5.6. In addition, project managers are able to make decisions about their projects based on the EMV and TEMV results for each major step and for the overall project, respectively. As previously mentioned, project managers can monitor the ongoing project in every step of the proposed model by considering the EMV result. Furthermore, project managers can alter their project's plan as needed when constraints affect performance and cause projects to become over budget or behind schedule. With the primary purpose of total effective management, this dissertation proposes the consistency model with project evaluation metrics that are flexible enough to allow project managers and team members to alter their plans, adjust their goals, control their time, and modify their budget in ways that do not affect other critical criteria.

Chapter Summary

The methodologies of project evaluation apply Markov property (Markov, 1954) to the proposed model and also use an evaluation metric to calculate project performance based on the three main critical criteria: research, control, and human. With an aim toward measuring project performance, the numeric outcomes resulting from the evaluation metric are calculated and converted to descriptive terms to demonstrate performance outcomes both quantitatively and qualitatively.

1) Time and cost constraints are the two most significant constraints because both are highly sensitive when other constraints are changed over time.
2) If researchers do not control growth in the project's scope, they may experience difficulties in keeping the project on schedule and on budget (Turbit, 2008). In addition, to control quality outcomes, project managers also must identify and pay particular attention to tasks that are quality-related.
3) Researchers, technicians, and anyone else involved in the project are counted as human resources, and the human activity constraint is the number of outstanding tasks that human resources are unable to complete on time.
4) The project evaluation metric includes six constraints that are categorized into three groups of critical criteria. Quantitative methods or techniques are used for monitoring projects and measuring working performances against project goals.

5) Markov property (Markov, 1954) is applied to transform the proposed model. If researchers prefer to measure outcomes qualitatively, the standard scale can be used to convert the TEMV outcomes to TEM outcomes.
6) Based on the proposed methods by Lee, Judge & Zellner in 1970, this dissertation assumes that "a sample of micro data exists, that repeated observations of the Markov chain can be made, and that researchers can develop maximum likelihood and Bayesian estimators of the transition probabilities to calculate the average length of time" (Lee, Judge & Zellner, 1970, pp. 23-30).
7) Researchers can include other criteria and quantitative methods for measuring each constraint and then apply the proposed formulas to calculate the TEMV. The concept of performance metrics from the realm of project management is applied in each step of the model to find the project's effectiveness and efficiency. Furthermore, researchers are able to report the projects' performance in both quantitative and qualitative terms by using the proposed scale converter.

Chapter 6: Summary, Contributions, and Recommendations

This chapter includes a summary of this dissertation and its research contributions, which demonstrate the superiority of the proposed model to previously proposed approaches to research agenda management. The primary purpose is to enable professionals and researchers to manage research agendas and projects effectively and efficiently under specific conditions and limitations.

Summary

The primary objective of this dissertation is to present a systematic methodology for the management of research agendas. Based on this, a model is proposed to create, develop, and manage sustainable research agendas by integrating research project management with a research agenda-building process. The proposed model is demonstrated as a Markov process with the estimation of transition probabilities. To monitor projects, a performance evaluation metric is included and used for calculating the total effective management value (TEMV). Furthermore, the evaluation results allow for a great deal of flexibility: When circumstances change, the results can be used in decision-making processes to alter research agendas to enable the researcher to achieve at least the minimum goals of the project.

A research agenda is a plan of tasks to be completed or problems to be addressed in conducting a research project. Its purpose is to establish new research frameworks and future research directions for specific intervals of time. Brainstorming is an important process for gathering researchers' ideas about new projects. Likewise, research project management is the activity of planning, organizing, and controlling resources and procedures. These activities are based on the research objectives, are focused on achieving specific goals, and are narrower in scope than the research work itself. Thus, as described in this dissertation, research agenda management is the activity of creating and developing support and infrastructure for research projects by considering each criterion of research, for the primary purpose of completing research effectively. Total effective management (TEM) of research agendas encompasses everything from the first step of agenda development to the final step of managing publications. This approach distinguishes itself in its focus on both research criteria (researcher, funding, time, technology, methodology, and data) and control criteria (quality, risk, and impact). These criteria have a significant impact on the effectiveness of processes and influence the researcher's decisions at every step. The model comprises six major steps: developing research agendas, identifying potential funders, developing research proposals, managing funded projects, conducting research, and managing publications.

This dissertation also covers management tools and techniques, which are categorized into three groups. First, *time management* is necessary for every project, as it determines project completion forecasts and helps researchers maximize their productivity and their projects' outcomes within a limited amount of time. Second, *budget management* consists of the analysis, organization, and oversight of costs and expenditures. Managing a budget requires adherence to strict internal expenditure protocols, and a well-managed budget allows for continued smooth operations and growth. Third, *risk management* is "the identification, assessment, and prioritization of risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability or impact of unfortunate events" (Hubbard, 2009) or to maximize the realization of opportunities. Fourth, *quality management* consists of quality-related activities and functions comprising four approaches: quality planning, quality control, quality assurance and quality improvement (Rose, 2005). The implementation of these approaches is referred to as total quality management (TQM). Fifth, *knowledge management* is undertaken to simplify and improve the process of creating, sharing, distributing, capturing, and understanding knowledge within an organization (Karlen & Gottschalk, 2004). Last, *decision management* is a systematic procedure or set of procedures for improving processes and correcting illogical actions to make the whole system more efficient. Its ultimate goal is to use all available information to increase the consistency and agility of decisions by considering known risks and time constraints.

The proposed methodologies of project evaluation apply Markov property (Markov, 1954) to the proposed model and also use an evaluation metric to calculate project performance based on three main critical criteria: research, control, and human. With the goal of measuring project performance, the numeric outcomes resulting from the evaluation metric are calculated and converted to descriptive terms to demonstrate performance outcomes both quantitatively and qualitatively. These results have the potential to help project managers and researchers gain a better understanding of their research projects' status and improve decision-making when changing circumstances and constraints make it necessary to alter the project plan.

Each of the three main critical criteria is associated with two constraints, for a total of six constraints that must be accounted for. Time and cost constraints, which are associated with the research criterion, are most significant because both are highly sensitive when other constraints are changed over time. Scope and quality are the two constraints associated with the control criterion. If researchers do not control a project's scope for growth, they may find it difficult to work within time and cost constraints. Project managers also must identify which activities are related to quality so that they can pay adequate attention to controlling overall quality outcomes. Within the human criterion, the two constraints are human resources and human activities. Researchers, technicians, and everyone else involved in a project is part of its human resources, and the human action constraint refers to the number of outstanding tasks that human resources are unable to complete on time.

The project evaluation metric is based on these six constraints, each of which corresponds to specific qualitative methods or techniques for monitoring progress and measuring performance. Markov property (Markov, 1954) is applied to transform the proposed model so that it yields quantitative results, expressed as the total effective management value (TEMV). If researchers prefer to measure the outcomes qualitatively, they can implement the standard scale developed in Chapter 5 of this dissertation (and shown in Figure 5.2) to convert the outcomes of TEMV into TEM format. This dissertation assumes that a sample of micro data exists and that repeated observations of the Markov chain can be made, which maximizes the outcomes' precision. Researchers can include other criteria and qualitative methods for measuring each constraint and then apply the proposed formulas to calculate the TEMV. The concept of performance metrics, from project management, is applied in each step of the model to calculate the project's effectiveness and efficiency. Furthermore, researchers are able to present the projects' performance in both quantitative and qualitative terms by using the proposed scale converter.

State-of-Art Research Contributions

Researchers might cope with similar problems, which they may miss or forget some steps or tasks while they are working on research agendas and projects. Using trial and error is not a practical approach; so new researchers usually need project managers or supervisors to guide them through the steps of planning and help them divide projects into tasks and subtasks to be completed in a specific sequence. Therefore, the question that must be answered is "What is the overall need for research agenda management?" Project managers and researchers alike are aware of the need for a systematic approach to project management, one that considers all possible criteria that might influence the project's progress. In addition to a systematic approach, project managers also want the ability to monitor their work's ongoing status. Thus, researchers need appropriate techniques for evaluating project performance so that they can report progress to project managers for decision-making in the next step.

However, project managers and researchers often must overcome barriers that obstruct projects' progress. Lack of planning skills and research experience often cause incomplete planning and faulty decision-making, which can lead to misdirection. Furthermore, significant constraints (both uncontrollable and controllable, and both external and internal) sometimes are not considered in analysis. Researchers are generally familiar with performance evaluation of project management, which presents results solely qualitatively rather than quantitatively. Because overall needs and barriers are deliberated, researchers in some fields have attempted to propose general guidelines and apply the concept of project management to specific problems. For example, Megali et al. (2006) applied the Hidden Markov models to evaluate surgical performance, and Sun and Li (2007) proposed a Markov process to calculate project risk, rather than using Monte Carlo simulation. In 2010, Jung and Seo explored the analytic network process approach for the evaluation of research and development projects by including benefit and cost constraints in their model.

To satisfy the overall need for research agenda management and overcome most barriers that obstruct projects' progress, this dissertation develops a more systematic model, consisting of detailed working-steps in the form of a Markov process that integrates research project management with the research agenda-building processes. To enable the calculation of numerical results (TEMV), this dissertation proposes a more effective evaluation methodology that includes all possible critical criteria that might affect the research agenda. Moreover, the proposed model enables researchers to convert the numeric outcomes to qualitative terms in order to explain and describe the project's performance, and researchers can use the results to alter project plans based on changing circumstances, such as modification of time constraints or cost constraints.

This dissertation's most significant contribution is that its proposed models can be used as a platform for directing and improving research activities and curriculum design in education. Similarly, grant writers and researchers can use the proposed models as guidelines for effective management of their future research projects, enhancing their ability to achieve their research goals, satisfy funders' expectations, and position themselves to compete successfully for additional research funding opportunities in the future.

Recommendations for Future Research

Innovations and advanced technologies historically have improved the lives of human beings, and great potential exists for similar progress in the future. But in the era of "big data" and distributed research projects, the research programs that enable such advances are increasing in size, scope, and complexity, and they therefore require more professional management. It is a challenge to enable researchers to handle complex systems' problems with a problem-solving method that is simple, yet flexible enough to account for and respond to changing circumstances and constraints. This dissertation proposes a consistency model for research agenda management, which features a simple-to-implement technique applicable to any research field.

To build upon this work, professionals and researchers might adapt the proposed model to fit the unique characteristics of their research areas and their disciplines by including other potential factors and criteria. Moreover, advanced techniques might be added to the proposed model to enhance its performance, especially for the solution of more complex problems or systems.

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