ORGANIZATIONAL IMPACTS OF PARTICIPATION IN INDUSTRY-LEVEL COLLECTIVE ACTION (TECHNOLOGY ROADMAPS)

By

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DEDICATION

To Jesus Christ, my Lord and Savior - thank You for guiding me through this journey, and may all the glory be Yours,

To my amazing wife, Leigh - you believed in me when I doubted myself,

and

To my wonderful children: Nicholas, Matthew, Jaclyn, David, and Lucas - may you achieve all you desire in life, while honoring God.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

1.1: Background

My research evaluates the organizational impacts of participation in developing an industry technology roadmap (ITR), and tests the influence of motivation, ITR development, roadmap attributes, and industry characteristics on the usefulness of the roadmap by participating organizations. The study addresses several questions: What are the organizational impacts of participation in the development of an ITR? What factors contribute to the organizational impacts of development of an ITR? And how does industry clockspeed affect ITR development and its impacts?

Governments in the United States, Canada, and Australia have taken the lead in stimulating the creation of roadmaps in a variety of industries, investing significant resources in the efforts and asking industry executives to do the same (Industry Canada, 2005; Commonwealth of Australia, 2001; US Department of Energy, 2005). The drawback to this investment is in not knowing whether it pays dividends - little theoretical or empirical work has been conducted to investigate the effectiveness of these roadmapping efforts, nor is there quantitative evidence of characteristics that relate to roadmaps' use by organizations in their respective industries (de Laat, 2004). Three theories are used as the main foundation for this study: 1) collective action (Astley and Fombrun, 1983), 2) stakeholder view of the corporation (Freeman, 1984), and 3) industry clockspeed (Fine, 1998).

Technology roadmapping at the industry level is a specific example of a broader concept sometimes referred to as an *industry collective* (Astley, 1984; Barnett, 2004): firms within an industry working together to establish standards, conduct pre-competitive research, pursue joint promotion initiatives, or set political action agendas at an industry level. ITRs researched in this study were developed by establishing industry goals to be reached within 10-30 years, depending on the industry. Establishment of goals was followed by conducting a technology gap analysis, and setting research priorities and timelines to reach the goals in the desired timeframe. Some of the most common benefits touted by advocates of industry technology roadmapping are that it: 1) creates a shared vision for the industry; 2) provides information to make better-informed technology investment decisions by government, research organizations/consortia, and industry, by identifying areas of research need and reducing or eliminating redundant research projects; 3) leads to accelerated technology development; 4) increases collaborative research among organizations (de Laat, 2004; Schaller, 2004; Yasunaga, Watanabe, and Korenaga, 2009); and 5) provides a benchmark against which to monitor progress (Saritas and Aylen, 2010). An organizational impact construct is developed from this information, and impact on participating organizations is evaluated.

The International Technology Roadmap for Semiconductors (ITRS), pioneered by Sematech, and researched extensively, is an example that has been held up by both researchers and practitioners as a model of the effectiveness of industry-level collective efforts (Carayannis and Alexander, 2004; Schaller, 2004; Browning and Shetler, 2000), specifically technology roadmapping. The ITRS has a unique grassroots history (Schaller, 2004; Browning, Beyer, and Shelter, 1995) when compared with the vast number of roadmaps produced since the late 1990's. Many of these roadmaps are initiated and co-sponsored by government agencies (de

Laat, 2004), rather than being primarily industry-driven. Are government and industry goals, presumably different, both achieved during roadmap development and subsequent execution in these cases? In addition, the semiconductor industry has characteristics not shared by other industries, the primary one being that the industry has for over four decades followed Moore's Law, first identified by and named after Intel co-founder Gordon E. Moore (Moore, 1965), which states that the number of components per chip doubles every 18-24 months (**Figure 1**).

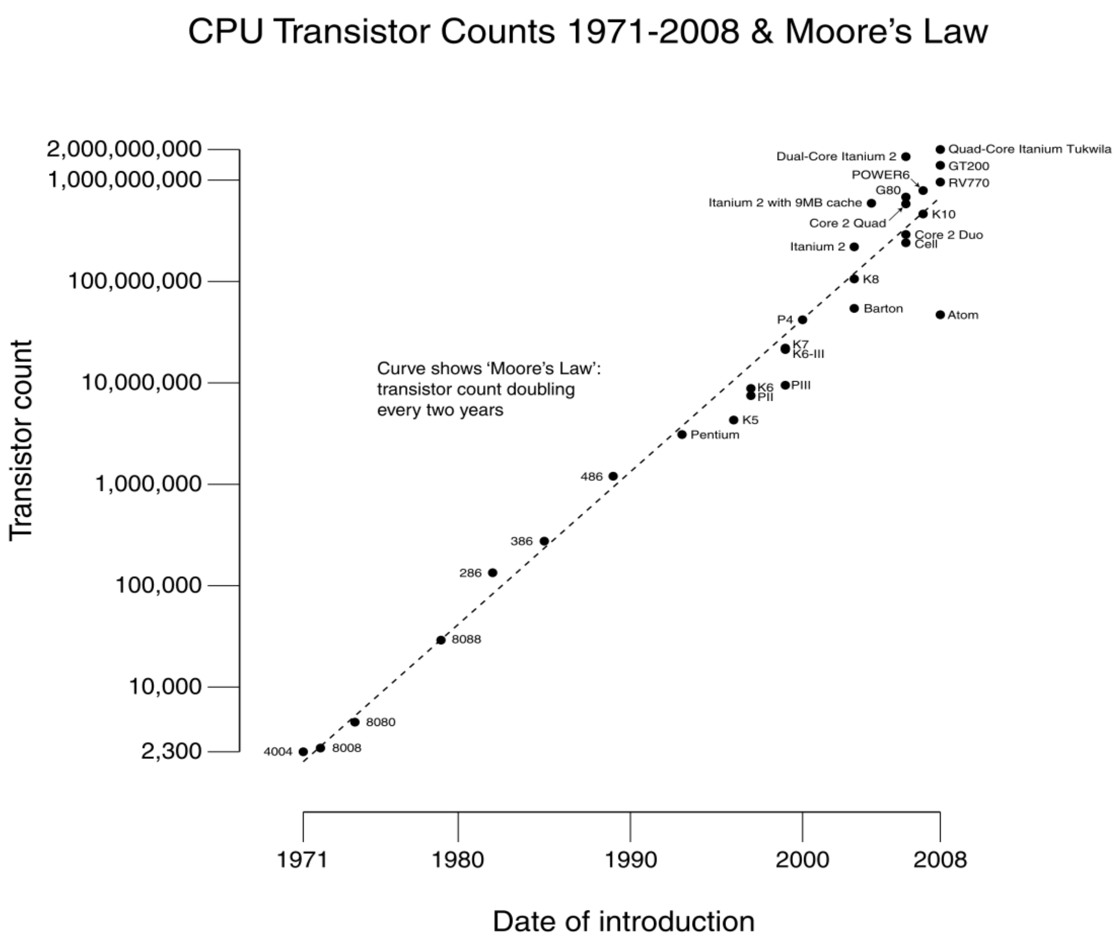

Figure 1: Illustration of Moore's Law (Free Software Foundation, 2008)

While not actually a "law" in a formal sense, this historical trend allows for an overriding, numerically-driven, shared goal for the ITRS - stay on pace with Moore's Law. Second, the industry is research intensive when compared with many of the other industries for which roadmaps have been developed. Underscoring this fact is the existence of several research consortia in the semiconductor industry, such as SEMATECH, which conducts a significant amount of research and development activity. Because an ITR is a strategic management approach for technology development, which relies heavily on research activities, research intensity would presumably play a role in usability of a roadmap. Third, the semiconductor industry changes at a fairly rapid rate when compared with many other industries. Does the pace of change, or clockspeed (Fine, 1998), in an industry, impact usability of a technology roadmap? For instance, the concrete industry deals with a material used since the Roman Empire existed, and advances to the product are modest, particularly before the advancements in chemical and mineral admixtures over the past few decades. Comparatively, high-tech electronics began being produced about 50 years ago, and product advancements occur annually. If clockspeed is slow, and the goals and activities identified in the ITR too far in the future (i.e. a decade or more), organizations that developed the roadmap may be more likely to place the roadmap on a shelf, as the information contained in the document is less pressing. In contrast, if a particular new technology identified in a roadmap must be in place in a relatively short timeframe (i.e. months or several years) in order for an industry to move forward, organizations may be more likely to pursue activities to create and implement that technology. Finally, several of the organizations that participated in the inception of what led to eventual development of the ITRS had direct experience with technology roadmapping at the company level. In fact, Motorola, one of the founding ITRS organizations, pioneered the roadmapping approach to technology planning and development in the early 1990's (Galvin, 1998). While differences exist between company and industry-level roadmapping, direct experience and comfort level by participating organizations with the technology roadmapping method may impact roadmapping efforts at the industry level.

Impacts and characteristics necessary for an industry technology roadmapping effort that have a positive effect on the industry were previously defined using only qualitative studies, determined either by exploring one industry roadmapping collective in-depth through interviews with participants (Schaller, 2004), or primarily interviewing initiators or facilitators from multiple roadmaps (de Laat, 2004). Feedback from participants in ITRs other than the ITRS, are extremely rare in the literature, leaving one to question how roadmapping has affected participating organizations in other industries. Do the published results cited by Schaller (2004) hold true for ITRs in other industries, or do the unique set of characteristics for the semiconductor industry and the ITRS make it more impactful on participating organizations? Potential effects of industry technology roadmap development and roadmapping group characteristics were identified from previous research (Kostoff and Schaller, 2001; de Laat, 2004, Schaller, 2004; Kappel, 2001; Phaal, Farrukh, and Probert, 2004; Peteraf and Shanley, 1997) and through a pilot study conducted on two roadmapping collectives (semiconductor and concrete industries). Factors that potentially contribute to use of an ITR by organizations that participated in its development have been drawn from these roadmapping specific studies, organizational partnership literature, research on collective action, and the stakeholder perspective.

A quantitative analysis of these roadmapping collectives is necessary for a more complete understanding, and is accomplished through this study primarily via application of a survey instrument of roadmapping participants from multiple ITR collectives. The survey instrument provides an approach to obtain a more representative answer to the aggregate impacts of roadmap development, as well as the overall characteristics of each roadmapping collective effort (Fowler, 2003). These aggregated measures from multiple roadmaps are statistically analyzed as a group, giving an empirical result that relates motivation, ITR development, roadmap attributes, and industry characteristics to the impact on organizations that participated in ITR development. Open-ended questions were asked, and phone interviews were conducted with select respondents, to provide additional insight into the quantitative results.

1.2 Dissertation Outline

Chapter 2 of this dissertation explores, in depth, the previous literature on collectives, stakeholder theory, and industry clockspeed, and intertwines these approaches with the technology roadmapping research. Constructs for organizational impact (dependent construct), organizational motivation to participate in ITR development, industry motivation to create an ITR, ITR collective structure and processes, and ITR characteristics, are developed, based on this literature. Hypotheses are then proposed, from which a model is created, predicting relationships between each independent construct and the impact on organizations that participated in development of an ITR.

Chapter 3 describes the methodological approach to collecting and analyzing data. The process used to develop the survey instrument is explained in detail, including survey questions and support from previous literature for their inclusion. The overall approach to data collection is described, along with methods of overcoming difficulties in acquiring lists of roadmapping participants and improving response rates. Some demographics of respondents are provided, and general characteristics of each roadmap included in the study are provided.

Chapter 4 supplies analysis from the results of data collection described in the previous chapter. Principal components analysis is conducted to identify common factors for grouping survey questions, and ensure survey items load on the appropriate construct. Linear regression of the constructs and control variables is performed to identify the effect of various characteristics on how the ITR impacts individual organizations. Because literature stresses the importance that ITRs be "living documents," analysis of variance (MANOVA) is then used to analyze differences between roadmaps that are being or have been updated as compared with those that were conducted as one-time efforts. For the final quantitative analysis, MANOVA is utilized to explore differences between high clockspeed industries and slow clockspeed industries. An analysis of responses to open-ended questions in the survey instrument is then conducted, to examine convergence of using qualitative methods with the quantitative research results. Based on these findings, a revised model is developed, and theoretical underpinnings are explained. Finally, challenges to validity of the study are identified and scrutinized.

Chapter 5 summarizes results of the study into theoretical and practical implications of these results. Limitations of the study are explained, and potential next steps in this research stream are shared.

1.3 Contributions of this Study

Drawing on collective action, stakeholder theory, the concept of industry clockspeed, inter-organizational partnerships, and technology roadmapping literature, this research takes a first step in tackling the problem of quantitatively analyzing the organizational effects of participating in ITR development. This study begins to establish a clearer link between the practice of ITR development and expected results. For researchers, this work identifies how organizations make use of the ITR and the roadmapping process in which they participated, and provides additional evidence as to which characteristics and approaches to operating an industry collective relate more strongly to its impact on participating organizations. Organizations involved in industry technology roadmapping and those active in other collective efforts, benefit from this research by gaining insight into ways of better organizing and operating an industry collective to improve the likelihood of a positive impact on organizations, and further, whether creation of an ITR is of value to a particular industry, given its characteristics.

Additional significance of this research is that it is the first study to combine quantitative and qualitative analysis of ITRs, and it extends stakeholder theory of the firm to the inter-organizational domain. This research also identifies implications of industry clockspeed on technology planning and implementation for an industry.

CHAPTER II

LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.1 Collectives

The term *collective* typically refers to a group of individual people or organizations with similar interests who work toward common goals (Fombrun and Astley, 1983). Collective action deviates from the traditional strategic paradigm of emphasizing individual interests, to explore how concerns important to survival of a group of related people or organizations might motivate them to form a cohesive effort to affect change (Astley, 1984; Astley and Fombrun, 1983).

As a cursory discussion will reveal, collectives are pervasive. Most universities have a faculty senate composed of faculty representing various colleges, schools, or departments, which is intended to represent the common interests of all faculty members on that campus. Similarly, trade unions represent the collective concerns of their members, union workers. Collectives serve to pool resources, providing benefits to participants that would otherwise not exist, and it is thought that they are usually formed as the result of some perceived or real threat (Carney, 1987). Through collective efforts, individuals have become empowered, countless resources have been expended, and history has been changed. Referring back to the trade union reference, if a single worker were to individually complain about hazardous working conditions for his particular job, management within a large company may very well ignore this single asperity. However, if this same worker were to invoke the power of the union, representing numerous workers for that company, management would be more inclined to seriously consider the complaint, due to the potential repercussions of alienating a significant number of union workers. Military efforts may also be viewed from a collective perspective, as during the Second World

War, where one collective (the Allies) pooled resources to battle a perceived threat (the Axis Powers, another collective), likely impacting the results of World War II.

While perhaps not quite as dramatic as the World War II example, industry performance has been shown to correlate, at various levels, with the success of organizations in that industry (Schmalensee, 1985; Rumelt, 1991; Powell, 1996; McGahan and Porter, 1997; Mauri and Michaels, 1998). Results conflict regarding the importance of industry success to performance of individual firms within that industry. In a more recent study, organizations that are the middle performers, rather than the leading or lagging outlier organizations within an industry, were shown to be most affected by the industry in which they participate (Hawawini, Subramanian, and Verdin, 2003), which may explain some of the contradictory results from these previous authors. According to Hawawini et al, (2003), these middle performers represent the majority of organizations within an industry. If industry performance has a direct relationship to the performance of the majority of stakeholders in an industry, as suggested by these authors, there may be more motivation for that majority to initiate and sustain industry-wide collective action, and for the outlier organizations not to participate. A multi-level study incorporating firm, strategic group, and industry effects, indicates that industry effects explain the variance of firm-level return on assets by 14.68%, longer-term market measures (Tobin's Q) by 3.67%, and bankruptcy risk (Altman's Z) by 0.98%. (Short, et. al., 2007), when the strategic groups are inductively defined (i.e. no pre-defined strategic group characteristics), and even greater effects when deductively defined. Thus, the fate of a firm is tied to the fate of the industry in which it operates, stressing the importance of collective efforts to enhance competitiveness with other industries.

2.2 Industry Collectives

Formally, an industry collective is any grouping of organizations based around a specific industry sector, and is intended to protect or improve the situation of that industry and its members (Barnett, 2004). Industry collective examples include national trade associations, professional sports leagues or associations, and any of a multitude of others representing business and industry segments from law to higher education. The collective's purpose may be broad and ongoing, as with the trade association, or narrow and for a defined timeline, as could be the case for a committee within that association, whose purpose might be to tackle a specific industry problem or concern. Several forms of industry collectives deserve special attention, for their prevalence and/or importance to this study; these include trade associations, research consortia, and technology roadmapping efforts.

Trade associations are one of the most common forms of industry collective, representing a vast array of organizations. Trade associations set standards for an industry, develop educational offerings for employees of their member companies, and lobby government officials on behalf of industry legislative concerns (Barringer and Harrison, 2000; Wilts and Meyer, 2005). According to the American Society of Association Executives (ASAE), the annual budgets of all associations exceeded $21 billion in 2003 (American Society of Association Executives, 2005). In addition to annual association budgets, are the many resources of time, people, and capital expended by their organizational members to remain active and support the association's collective efforts. Thousands of industries in the United States have at least one trade association geared toward the similar interests of their member organizations (Downs, 2006).

Research consortia are a technically driven form of industry collective, and are sometimes, although not usually, an offshoot of the trade association. These groups often involve a mix of industry, university, and government research and development personnel. Research consortia are intended to take advantage of the collective knowledge and resources of their participants by reducing unnecessary repetitive studies and focusing R&D efforts on the issues deemed most important by the group (Hagedoorn, Link, and Vonortas, 2000). Research project collaboration is usually the primary goal among participants in a research consortium, unlike an emerging form of technology-driven industry collective, the technology roadmapping committee (Barringer and Harrison, 2000).

Technology roadmapping efforts are seeing growing use in industry and increased attention from researchers (Kostoff and Schaller, 2001; de Laat, 2004; Foden and Berends, 2010; Blismas, Wakefield, and Hauser, 2010; Masum, Ranck, and Singer, 2010; Hou et. al., 2010). Roadmapping has features that have led to interest from technology management researchers, who view the roadmapping approach as a unique phenomenon in industry (Kostoff and Schaller, 2001; McMillan, 2003; Talonen and Hakkarainen, 2008), that combines strategic, research and development (R&D), and marketing/business perspectives, to improve communication among these entities and other stakeholders about technology development plans and directions, whether developed at the organizational or industry level.

First, technology roadmappers take a strategic perspective of technology, in an attempt to better manage pre-competitive R&D activities. Industry roadmaps are intended to marshal resources and focus participants within an industry in a common direction, rather than choosing a limited number of specific scientific projects on which to collaborate, as might be the case with pure research consortia (Kostoff and Schaller, 2001). Specific R&D partnerships are not outlined in the roadmap document, but roadmap literature points to coordinated R&D initiatives as a result of developing an ITR (Kostoff and Schaller, 2001; Schaller, 2004). So, while technology roadmapping committees can be thought of as industry strategic planning groups, they are focused specifically on how technology may be leveraged, strategically, to better an industry.

A second unique feature is that roadmapping incorporates a marketing perspective and is often preceded by a vision document (U.S. Department of Energy, 2005; Industry Canada, 2005; Commonwealth of Australia, 2001), taking into account the industry's current and projected market environment. Inclusion of market considerations again emphasizes the fact that roadmapping is indeed a strategic management approach, rather than focusing on completion of specific projects, as with research consortia. A related distinguishing factor of roadmapping efforts is their attempt to include the full breadth of an industry in the roadmapping process, so that all stakeholders may take part in forming the roadmap. Research consortia may only involve select segments, organizations, or even specific participants, such as only research experts, within an industry or a segment of an industry. While involving the full breadth of stakeholders distinguishes industry roadmaps from research consortia, it provides a common ground with the trade association, which attempts to gain strength through unity for an entire industry. The combination of a business and technology perspective, with a timeline to accomplish proposed tasks, developed by relevant stakeholders, and written in a way that communicates a strategic technology plan in language understandable by the business community, are what distinguish roadmapping from prior technology planning methods (Groenveld, 2007). The following section provides additional detail on technology roadmapping by reviewing the history and evolution of the method and existing literature on the subject.

2.3 Roadmapping as a Form of Industry Collective

Motivated by the rapid advancement of technologies and increasingly turbulent business environments, companies began creating product/technology roadmaps during the early 1980's (Galvin, 1998). The intent of roadmapping was to get all employees "on the same page," by incorporating a broad array of managers, marketing professionals, and researchers in the process of technology planning (Kappel, 1998) in an effort to better manage the development and integration of future technologies into products (Kappel, 2001; Kostoff and Schaller, 2001; Probert and Shehabuddeen, 1999). Introduced by Robert Galvin of Motorola (Kappel, 1998), roadmap development has become commonplace within larger technology-driven companies (McMillan, 2003; Kajikawa, et. al., 2008; Foden and Berends, 2010; Lee, Kim and Phaal, 2011). Roadmaps are a unique planning tool, encompassing: traditional technology forecasting techniques; alignment/integration of technology planning with overall business strategy; and development and communication of technology/research ideas, plans, and timelines throughout an organization (Kappel, 1998; Lee, Phaal, and Lee, 2011). Literature on roadmaps, as is the case in many business disciplines, lagged behind their use in practice, and it wasn't until the mid-90's that the first journal articles began to appear (Barker and Smith, 1995; Galvin, 1998). Many scholars argue that much of the value is not contained simply in the roadmap, but in the roadmap development process, or "roadmapping" (Kostoff and Schaller, 2001; Kappel, 1998; Probert and Shehabuddeen, 1999; Radnor and Probert, 2004; Lee, Kim, and Phaal, 2011).

Roadmapping transitioned from the company level to the supra-company level around 1990, when Sematech gathered companies in the U.S. semiconductor industry and its suppliers in an effort to regain the market share lost to international competition (Schaller, 2004). The roadmap for semiconductors was viewed by the industry as so important, that participation spread from a national effort to the international level, in an attempt to keep the pace of development in the entire semiconductor industry from slowing. Researchers and practitioners alike have held up the International Technology Roadmap for Semiconductors (ITRS) not only as a model for success, but as justification for government sponsorship of other industry-level roadmaps. Another roadmapping effort gives a different impression of the value of roadmapping collectives. Well over a hundred professionals representing various position levels and a broad cross-section of organizational stakeholders within the concrete industry, initially developed a vision document (Strategic Development Council, 2001) and then a roadmap (Strategic Development Council, 2002). After consulting with leaders involved in this roadmap's construction, there seem to be no specific plans to pursue the efforts outlined in the roadmap or to revisit the roadmap for revision and updating. Eisenhardt (1989) suggests a potential cross-case tactic of describing similarities and differences in select pairs of cases, so these two contrasting industry roadmap examples (ITRS and Roadmap 2030) were incorporated into a preliminary study, described in section 3.3.1. This pilot study provided the basis for a more valid and complete survey to use with a broader group of ITRs. Are other ITRs being utilized by and providing ongoing value to their creating organizations? If that is the case, one would expect to see pursuit of joint research projects, changes in the technology direction and evolution within participating organizations, and revisions to the roadmap over time. Are these additional industry roadmaps headed down the highway of success, or are governments and other organizations spending precious resources and manpower on a “one-time” exercise, one that creates a document to collect dust on a shelf? While product roadmapping within a single organization and its effects have been examined for several cases, how the industry technology roadmapping experience translates to specific actions by participating organizations has been investigated for only the ITRS. A comprehensive evaluation of the use of ITRs by organizations that participated in their development will provide some answers to these questions.

Taking an additional step, several blueprints for improved organizational benefits from industry roadmapping suggest “best practices” to be used in the process of organizing and managing a roadmapping collective (de Laat, 2004; Kostoff and Schaller, 1998; Industry Canada, 2005; Commonwealth of Australia, 2001; US Department of Energy, 2005), but outcomes are not well-defined in these studies and a theoretical model tying practices to impacts on participating organizations has yet to be attempted. Measuring organizational impacts and the potential contributors to those impacts requires taking a step back to incorporate a broader theoretical perspective of the process. Where in the literature might one look to find theoretical underpinnings for studying a collective effort? Collective strategy literature provides one obvious answer, but focuses more on motivations for organizations to form a collective effort, rather than substantive approaches to predict outcomes from participation. However, as motivation is deemed important for a collective to even form, it seems that motivation may be a key element to determine outcomes of that collective. Additional details regarding motivation’s influence on organizational impacts of participating in collective efforts are discussed in section 2.6.2. A collective effort could also be viewed as forming a partnership to take action, so literature on partnerships and consortia are another reasonable source for relevant information to the study of industry-level collectives. Several models have been developed for successful partnerships (Mohr and Spekman, 1997; Butterfield, Reed, and Lemak, 2004; Mothe and Quelin, 2001; Williams, 2005; Yarbrough and Powers, 2006).

These models, and many other quantitative studies of partnerships, examine one or more partnerships between only two organizations, rather than examining collaboration among multiple organizations with a vested interest in a common outcome. So, an overarching theoretical backing or foundation for a model of successful collaboration, involving multiple organizations representing an entire industry, is yet to be identified. The stakeholder perspective provides that foundation for studying ITRs, keeping in mind that industry roadmapping is a collective effort of industry stakeholders. Thus, stakeholder theory as applied to collective efforts is examined next.

2.4 Stakeholder Views and Collective Efforts

Stakeholder theory has traditionally concerned itself with the study of how individual organizations interact with various stakeholders (**Figure 2**). According to Freeman (1984), a stakeholder is any group or individual that "can affect or is affected by an organization's objectives."

Three core approaches of studying stakeholder theory have been used (Donaldson and Preston, 1995): (1) describing or explaining organizational behaviors based on managers' prioritization of stakeholder needs/desires (Jawahar and McLaughlin, 2001); (2) an instrumental approach, investigating potential links between effective stakeholder management and organizational performance (Jones, 1995); and (3) normative approaches, applying the theory to

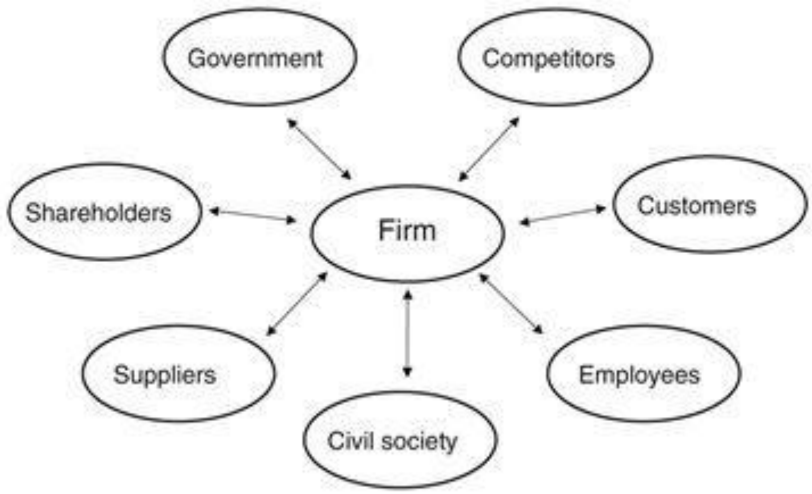

Figure 2: Original Stakeholder Model (Freeman, 1984)

prescribe organizational behavior and decision-making processes from an ethical/moral perspective, in consideration of all stakeholder groups - a sort of social responsibility viewpoint (Donaldson and Preston, 1995). Instrumental stakeholder theory, while originally developed for the individual organization, is specifically geared toward managing multiple individuals or groups with a stake in the performance of an organization, and is suggested by many authors to provide a unique approach to achieving improved performance (Laplume, Sonpar, and Litz, 2008). It seems logical that stakeholder theory can be extended to an environment where stakeholder management is critical, when collaboration among multiple stakeholders is absolutely necessary for an effort to have an impact on those stakeholders - an industry-level collective effort. For this reason, stakeholder theory was selected as a theoretical foundation for this research; however, conventional stakeholder theory has been applied narrowly, primarily only to individual organizations.

Emphasis in the instrumental stakeholder literature is placed on identification and management of relevant stakeholders (Jones, 1995; Harrison, Bosse, and Phillips, 2010; Benson and Davidson, 2010), which at the industry level would be various industry segments (producers, customers, suppliers, etc.), as well as non-profit organizations (government bodies, universities, trade associations, etc.) in order to improve performance, particularly long-term impact (Garcia-Caston, et. al., 2011). A study by Surroca, Tribo, and Waddock (2010), showed that intangible resources play a significant role in whether stakeholder management principles affect firm performance. Using this premise, structure, defined as breadth and depth of the collective participants, should have an influence over outcomes of the collective effort. Since the way in which stakeholders are managed by the organization is emphasized by the stakeholder concept (Garcia-Castro, et. al., 2011), applying stakeholder theory, the process of managing a collective effort (i.e. roadmap development) would be expected to impact outcomes as well. Motivation of the stakeholders to play an active role in the organization (or collective) is also pertinent to stakeholder theory, helping to identify those stakeholders that matter most (Mitchell, Agle, and Wood, 1997). Identification of relevant stakeholders, those with the highest stake in roadmap development, seems critical. In ITR development, those would be people with the highest motivation to participate, those most dependent on technology advancement in the industry.

2.5 Hypotheses and Model Development

For this research, a potential stakeholder model for industry-level collective action, specifically technology roadmapping, was developed, whereby participating organizations are considered the stakeholders, and factors posited to correlate with the impact of the collective effort on participating organizations is modeled. Motivations for development of the ITR collective (Astley, 1984; Astley and Fombrun, 1983), stakeholder-based practices for organizing and managing the ITR collective (Kostoff and Schaller, 2001; de Laat, 2004; Saxton, 1997; Mohr and Spekman, 1994; Butterfield, Reed, and Lemak, 2004; Mothe and Quelin, 2001; Laplume, Sonpar, and Litz, 2008), ITR collective characteristics (Kostoff and Schaller, 2001), and industry clockspeed (Fine, 1998), are predicted to correlate with impact on organizations that developed the ITR. The purpose of developing and testing this model are to improve industry technology roadmapping efforts, by identifying the factors that matter most to those organizational and collective impacts.

In addition, multiple exogenous industry and organizational characteristics are incorporated as control variables, including industry fragmentation (Powell, 1996; Rumelt, 1991; Dollinger, 1990; Ho, Tjahjapranata, and Yap, 2006), organizational size (Carter, 1990; Wilts and Meyer, 2005), prior or concurrent collaborative experiences of participating organizations (Gray, 1985; Sakakibara, 2002), technological emphasis of an industry (Kostoff & Schaller, 2001), and public/private organizational differences (Abzug and Webb, 1999; Casile and Davis-Blake, 2002), among others. A proposed stakeholder model of industry-level roadmapping is shown in **Figure 3**. The constructs of this model are described in greater detail in sections 2.6.1 through 2.6.6.

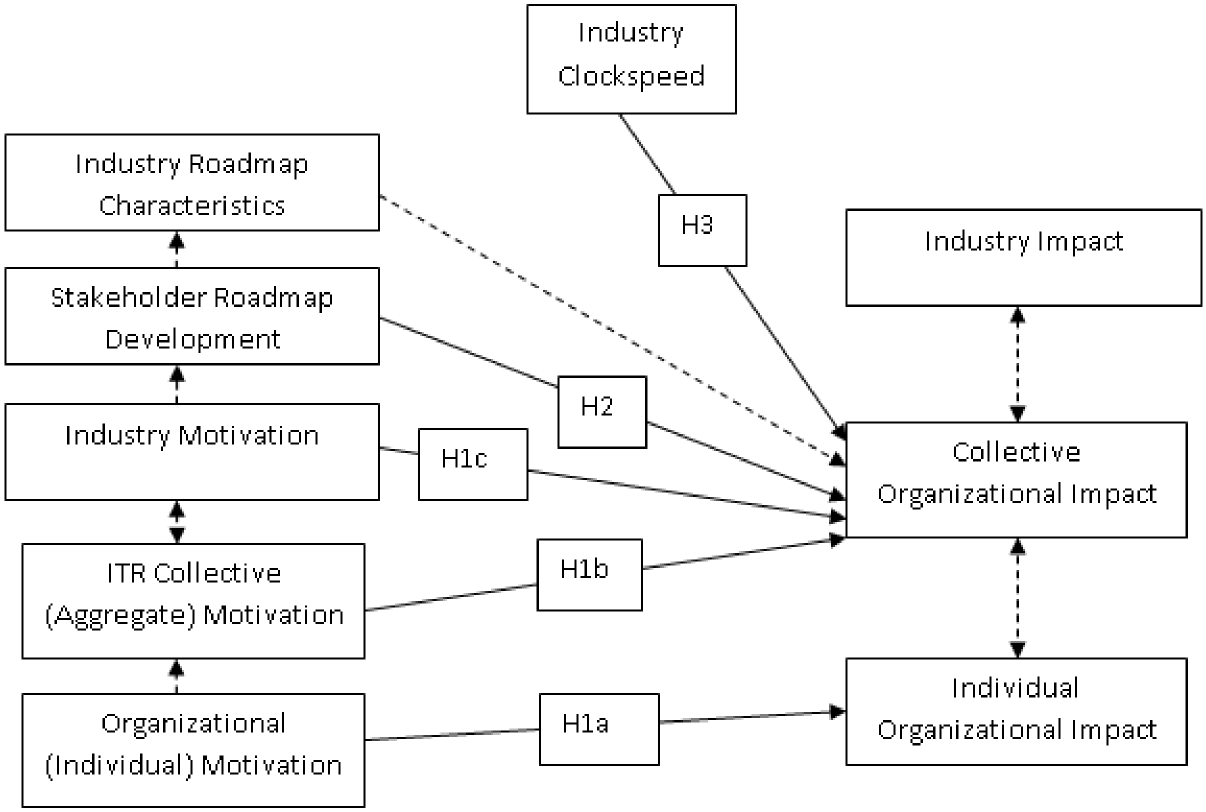

Figure 3: Proposed Stakeholder-Based Model for Industry-Level Roadmapping

(Control variables proposed for individual organizational impact analysis include organizational size, public/private status, organizational participant position, organizational type, executive support, industry fragmentation, industry R&D emphasis, industry vs. government lead, and ITR)

2.5.1 Organizational Impacts

Any time one attempts to empirically show results from a given initiative, the question comes to mind of how to define the expected impact. Literature over the past two decades has placed increasing emphasis on methods that incorporate a non-financial approach (Neely, Gregory, and Platts, 1995; Neely, 2005), such as Management by Objectives (Antoni, 2005; Invancevich, 1972; McConkey, 1965), Benchmarking (Engle, 2004), Malcolm Baldridge (Shetty, 1993), or the Balanced Scorecard (Kaplan and Norton, 1992, 1993; Ahn, 2001). For inter-organizational collectives, even less emphasis is placed on direct financial gain by individual firms. Financial performance measurement seems less applicable for most industry collectives, and specifically technology roadmapping, where the direct objectives are typically not expressed in financial terms (U.S. Department of Energy, 2005; Industry Canada, 2005; Commonwealth of Australia, 2001), so the focus of measuring organizational impact for participation in collectives for this study will remain on non-financial measures. Two potential reasons the literature has not included financial performance measures for industry collectives are 1) anti-trust legislation that prohibits discussion among companies regarding many financial issues and 2) the motivations for collective behavior are often considered to be survival-based (Astley, 1984; Astley and Fombrun, 1983) rather than directly financially-based. Research on partnerships seems to be a natural place to begin the search for a more specific perspective on expected organizational impacts for this study, as the collective is a form of partnership among multiple organizations. Previous models describing collaborative activities, and how they tie into studying technology roadmapping, are discussed next.

Some authors focus on designing (structuring) collaborative activities to ensure high impact on participating organizations (Mothe and Quelin, 2001; Williams, 2005), but those measurements are typically targeted specifically toward partnerships involving few participating organizations - these are of modest value to the domain of collaboration of an entire industry due to the low number of participants in the collaborative arrangement being modeled. One expected favorable outcome in collaborative efforts is participant satisfaction in the initiative (Anderson and Narus, 1990) or a “feeling of success” by the participants (Schaller, 2004; Butterfield, Reed, and Lemak, 2004). However, this is only one outcome measurement, and is anecdotal at best. Satisfaction in these studies has not been shown to correlate with any substantive action by the participants, but it is an important ingredient to continued participation in an effort. However, “good feeling” alone is necessary but not sufficient, and does not justify the hours and dollars spent in creating an ITR. Thus, more specific measures of an ITR’s impact on organizations participating in the collective are needed.

One specific measurement avenue to consider is whether the effort achieved some or all of its stated objectives, such as continuation, partnership activities, innovation, etc. (Todeva and Knoke, 2005; Industry Canada, 2001; Commonwealth of Australia, 2001; U.S. Department of Energy, 2005). This coincides with the Management by Objectives approach to measuring individual performance (Ivancevich, 1972; French and Hollman, 1975). However, it is important to obtain relevant measures for objectives that are general enough to apply to various different industry roadmapping initiatives, but specific enough to be meaningful. A pilot study of the semiconductor and concrete industry roadmaps, conducted as part of this research, served to improve the measurement approach for the more comprehensive study of ITRs. Preliminary impact measures are described in the following two paragraphs.

Membership retention/addition from various industry segments over time is an indication of the industry collective’s performance, as empirically verified for R&D consortia (Olk and Young, 1997), and should be included as a component of performance measurement. If an increasing number of organizations are willing to participate in a collective effort and organizations continue participating long-term, there is at minimum a perception of value-added in being a part of the collective. Finally, the industry roadmapping process should impact participating organizations. If none of the participants’ behaviors change as a result of the roadmapping process, then the effects must be minimal, but impact throughout participating organizations is an indication that the collective is performing.

Functional and technological impacts of ITR development on participating organizations, industry, and government have been advocated in the literature. These include items related specifically to the roadmapping process, such as development of networks and partnerships, impacts on technology planning, identification of technology gaps, increasing the pace of innovation, and others. A set of survey items were developed, based on the literature, and proposed in the model as a single organizational impact construct, by combining items related to participant satisfaction, objective achievement, membership participation, and direct organizational impact measures. Broad measures of roadmapping collective impact were developed for use in this study, so they would be applicable to ITRs in multiple industries. Organizational impact is the dependent construct in the proposed model, and the initial step in operationalizing the study - the dependent constructs of organizational and industry motivation are examined next.

2.5.2 Motivation of Participating Organizations

Astley (1984), Astley and Fombrum (1983), and Schaller (2004) agree that participants' having a sense of urgency motivates collective activities to be more impactful. Organizations that view their collective effort as necessary for their individual survival will be more likely to participate in, collaborate, and draw perceived benefits from a collective activity. Does that same sense of urgency exist in industries other than the semiconductor industry? At what level of motivation do participation, collaborative activities, and perceived benefit of the collective technology roadmapping effort tend to wane? How important is support from executives in participating organizations in order for the industry roadmapping effort to have impact?

Motivation has been posited to affect outcomes for decades, from the weekly fall debate regarding which college football team is more motivated to win a particular game, to the empirical evidence provided in the academic literature. Studies have focused on how motivation affects performance of individuals (Knippenberg, 2000; Katzell and Thompson, 2000; Chung, 1968) as well as the impacts of organizational efforts (Huarng, Horng, and Chen, 1999). The particular context of this study is concerned with how motivation to form and/or participate in an ITR collective may relate to impact on organizations that participated in developing an industry roadmap. Collective action is considered a survival mechanism, with roots in human/social ecological theory, where true cooperation is essential (Astley, 1984; Astley and Fombrun, 1983). Thus, common/group interests and a sense of urgency or "survival instinct" could be considered as essential components to the impact on organizations participating in an industry roadmapping collective - what might be termed a "shared fate" (Barnett, 2004) perspective. The literature on partnerships and stakeholder motivation backs up this perspective, from theoretical viewpoints (Rowley and Moldeavu, 2003; Peteraf and Shanley, 1997; Mitchell, Angle, and Wood, 1997), to qualitative (de Laat, 2004; Schaller, 2004) and quantitative studies supporting the effects of motivation on outcomes. What are the specific motivations that may be important to collective efforts in general, and specifically to industry technology roadmapping?

There are many reasons why an organization may choose to engage in a collective effort (Barringer and Harrison, 2000). Some of these may be individually driven, such as a desire for organizational learning or a tendency not to join to avoid risks of dependency, while others are shared, like collective lobbying and antitrust implications (Barringer and Harrison, 2000). From a stakeholder viewpoint, shared or common interests of participants in an effort should lead to improved performance (Freeman, 1984). If stakeholder participants enter into an industry collective with a focus on the shared interests of the organizations and have a strong sense of group identity, the collective (which is intended to serve the interests of all stakeholders) should have increased participation, more overall satisfaction of participants, greater longevity, and enhanced organizational impact from the ITR collective (i.e. collaborative activities and attempts to acquire/apply knowledge gained) (Peteraf and Shanley, 1997). However, Tropp (2004), performed two empirical studies comparing the effects of individual enhancement motivations compared with motivations for group enhancement, and concluded that motivations for individual enhancement strongly correlate with interest and involvement in collective action.

The motivation level of individuals has also been shown to correlate with positive impacts on those individuals. This effect has been recently studied in both academic and athletic settings. Abdelfattah (2010) conducted a study of 797 ninth-graders, and concluded that high levels of motivation to take examinations in mathematics or science correlated significantly with increased mean performance in the exams. Two separate analyses, one investigating 170 French junior national tennis players and the other 250 French junior national fencers, each showed those that scored lowest on the Sport Motivation Scale (Pelletier, et. al., 1995), administered prior to the sports season, performed at lower levels, controlling for past performance (Gillet, Vallerand, and Rosnet, 2009). Another study showed a positive correlation between organizational motivation and the performance of R&D alliances in the Taiwanese manufacturing industry (Lai and Chang, 2010), from both transaction-cost economics and resource-based theory views. Participant motivation or “urgency” is also a vital key to collective action (Astley and Fombrun, 1983), and, thus, to industry technology roadmapping (Schaller, 2004).

While the studies involving motivation and its ties to collective action examined individuals specifically, and those tying motivation to its impacts studied individuals and R&D alliances, an extension of these findings to organizational collectives has face validity. The level of individual organizational motivation, defined as "reasons for an organization's participation in the roadmapping effort," is therefore predicted to positively correlate with the impact on that organization (**H1a**).

Hypothesis 1a: Organizations with higher levels of organizational motivation to participate in the ITR collective will experience higher individual organizational impact from participation in the collective.

In addition, the aggregate motivation of organizations participating in collective activities is predicted to positively correlate with the collective (aggregate) impact on organizations. Thus, organizations that participate in collective efforts, with higher average motivation of the participating organizations, should experience higher impacts (**H1b**).

Hypothesis 1b: Higher levels of overall (collective) organizational motivation correlate with higher levels of overall (collective) organizational impact.

While the sum of individual organizational motivations to participate in the collective effort is a partial description of industry motivations, there are some overarching industry motivations for developing a roadmap. As opposed to aggregate organizational motivations, industry motivations involve collective motivation, such as driving research and development activities for the entire industry, and governmental investment, research directions, and policies (Winbrake, 2004; Yasunaga, et. al., 2009). For instance, creating a shared vision for technology pursuits, to eliminate duplicate research efforts, is one such motivation. This includes both directing industry-funded research through consortia, as well as influencing the path of government-funded research related to the industry. Such industry motivations, defined as "reasons underlying and industry's ITR development," are predicted to positively correlate with overall (collective) organizational impacts as well (**H1c**).

<u>Hypothesis 1c</u>: Higher levels of industry motivation correlate with higher levels of overall (collective) organizational impact.

The independent constructs related to motivation to conduct a collective effort are predicted to correlate with the impacts on participating organizations, but are an incomplete explanation. The make-up of the collective body, or the background of participants, as well as the processes used to construct the roadmap, are indicated to be key ingredients to an impactful roadmapping effort as well (Kostoff & Schaller, 2001, de Laat, 2004). Stakeholder principles provide a theoretically grounded approach to prescribing effective identification and use of stakeholders in an industry collective effort.

2.5.3 Stakeholder Management Principles

The stakeholder roadmap development construct has dimensions of both structure and process, and is defined as "incorporation of stakeholder principles in the structure and operation of the collective." The relationship of organizational structure to performance has been investigated extensively in the literature (Dalton, et al., 1980; Ingham, 1992; Defee and Stank, 2005). Stakeholder theory suggests that inclusion of all relevant parties in decision processes is positively related to success. (Friedman and Miles, 2002; Donaldson and Preston, 1995; Jones, 1995) To have inclusion, there must be participation from the appropriate stakeholders. As the ITR involves creation of a strategic plan for technology development and advancement, the experience of participating organizational representatives with both short and long-term research and development, is also considered an important structural dimension of the collective (Kostoff and Schaller, 2001). In addition, it may be important to have the right mix of various levels and areas of individual participation (Carayannis and Alexander, 2004), such as chief executive officers of companies, technical experts/executives, and marketing professionals and executives.

From an industry collective perspective, these parties will include suppliers (materials, equipment, and services), producers, and customers, as well as government representatives and other interested parties, such as consultants to the industry. If the collective effort involves research or education, academic participation is logical. Organizers and managers of the collective activity should be able to explain and justify exclusion of any relevant industry/government segments. In the case of industry collective efforts, top management involvement/support from participating organizations has been shown to be an important link to positive results (Kappel, 2000, 2001; Kostoff and Schaller, 2001; de Laat, 2004; Wilson, 2005). So the breadth and experience of individuals and the companies they represent in the collective effort are included in the proposed stakeholder roadmap development construct. Stakeholder models at the organizational level have been developed.

Through a qualitative study, Butterfield, Reed, and Lemak (2004) developed a theoretical model showing combined effects of stakeholder motivation and process on outcomes at the organizational level. Mohr and Spekman (1994) developed a similar model and performed a quantitative test, to conclude that partner attributes and management processes contribute to partnership success. Mohr and Spekman (1994) also considered the communication processes and conflict resolution involved in the partnership. Butterfield, Reed and Lemak (2004) were more comprehensive, and included management processes such as communication, cooperation, planning, and relationships. Both studies showed that inclusive processes correlated with positive outcomes. Thus, from a stakeholder perspective and the case of an industry collective effort, consideration of input from all relevant stakeholders, defined previously as motivated individuals from all industry segments with a stake in technology advancement for roadmapping collectives, in the decision-making processes (i.e., stakeholder-oriented management processes) should correlate with higher impact on participating organizations.

Stakeholder-oriented processes include those that encourage and incorporate the diverse opinions of all stakeholder groups in the management of the roadmapping collective. The manager of a collective and the participants in the collective, have a responsibility to ensure that all participants are allowed to offer ideas and have those ideas openly discussed. Measurement of stakeholder oriented processes will be accomplished using: 1) self-reported satisfaction of participants with regard to their opinions being encouraged by the collective leader/manager; 2) self-reported level of satisfaction by participants that their voice has been heard by other participants in the collective; 3) participant feedback that communication was shared among all participants during roadmapping; and 4) self-reported participant involvement in the planning process (Freeman, 1984; Kostoff and Schaller, 1998; de Laat, 2004; Industry Canada, 2005; Commonwealth of Australia, 2001; US Department of Energy, 2005). This discussion results in **hypothesis 2**:

<u>Hypothesis 2</u>: An ITR collective that applies stakeholder principles in roadmap development (processes and structure) will result in a greater overall (collective) impact on organizations that participated in its creation.

2.5.4 Industry Clockspeed

Industry clockspeed, a term first introduced by Fine (1998), examines the effects of the pace of change in an industry with how organizations in that industry can best compete. Following his description of the concept, industry clockspeed is defined as the "pace of an industry's change from organizational, process, and product perspectives." The pace of the industry's technology development should have a direct impact on an ITR's update cycle. Industries with faster technological change should be inclined to more frequent updates of the ITR, whereas industries with slower technological change may require less frequent visitation of an ITR's pathways.

Examples of high clockspeed industries would include those such as personal computers, personal electronics, and semiconductors, where new products are introduced on a nearly continuous basis. Slow clockspeed industries would include those where new product or process generations may be introduced only once every decade or more, such as the aerospace industry, or raw materials (e.g. metals, aggregates, soils) industries. The existence of Moore's law, and its impact on the roadmapping process, and the subsequent pace of change perceived by organizations in the semiconductor industry, is well chronicled. In his case study of the ITRS, Schaller (2004) cites numerous instances where participants in the semiconductor roadmap reference a "beat the roadmap" mentality that organizational members believed increased the pace of innovation and new product development in their organizations, essentially bumping up the clockspeed of the industry. The ITRS timeline was influenced significantly by the expectation that the industry should continue to increase product capability according to Moore's Law. In a fast clockspeed industry, where roadmap goals and timelines lead to short-term impacts, benefits of the roadmap should be more easily realized, keeping organizations' attention more focused on accomplishments related to the roadmap. A significant number of participants in Schaller's (2004) study (29%) indicated that the fast and somewhat predictable pace of change in the industry was the major reason they felt that roadmapping had been adopted so enthusiastically in the semiconductor industry.

In addition, the primary intention of industry technology roadmaps is to improve technology development in an industry, increasing its pace and productivity, by marshaling resources to focus on technological issues identified by an industry collective. In the waste-water treatment industry, a slow clockspeed example, analysis found that incremental innovations over time had caused the technology to nearly reach its limit, meaning that further industry planning would have minimal affect (Parker, 2011). If a significant focus of ITRs is to increase the rate of new product development in an industry, essentially encouraging organizations to move toward a higher clockspeed, then organizations in a slow-clockspeed industry may not be well served by participating in the industry roadmapping process, which leads to **hypothesis 3**:

Hypothesis 3: Organizations from high clockspeed industries will be more likely to experience a greater impact from developing an ITR than those from slow clockspeed industries.

2.5.5 Technology Roadmap Characteristics

Characteristics of the final roadmap document, while certainly an outcome of the roadmapping process, also may play a critical role in how the roadmap is used by organizations in an industry for which the ITR was developed. Important overarching traits include: breadth and depth of the topics covered; a goal-orientation, including prioritization and timeline for technological developments deemed important; and an appropriate overall timeline for the roadmap (i.e. 10 years, 15 years, 20 years, or longer).

First, the roadmap should have sufficient breadth and depth of coverage (Lee, Phaal, and Lee, 2011). ITRs are intended to "map out" technological developments most critical to an industry's success. If the ITRs breadth is insufficient, the situation would be akin to travelling by way of a roadmap that had boundaries beyond which there was no data. If one desired to travel to that destination, the roadmap would not include that destination as a possibility, leaving the traveler without direction. Similarly, if an ITR lacked depth, a parallel can be drawn to geographic travel. Roadways would be missing from a map lacking detail/depth. If a traveler encountered construction, traffic, or some other situation that impeded progress on a particular roadway, additional depth in the roadmap would identify alternate pathways to a particular destination, allowing the traveler to choose another route. It follows that in order for an organization to choose to use a roadmap's information, the roadmap must be viewed as having sufficient breadth and depth to reach the desired destination.

Second, an ITR should be goal-oriented, with an emphasis on targets for the industry and pathways to reach each target (Kostoff & Schaller, 2001; Lee, Phaal, and Lee, 2011). The overarching goal of continuing to develop technology according to Moore's Law guided roadmap development in the semiconductor industry and was identified by participants in the ITRS as critically important to its ongoing evolution and use by organizations in the industry (Schaller, 2004).

Finally, an ITR must have a timeline appropriate to the industry (Shengbin, Bo, and Weiwei, 2008). If the roadmap is viewed, by a roadmap participant, as too short-sighted in its perspective, it may not be considered as a strategic document. In contrast, an ITR with what organizations consider an inappropriately long overall viewpoint could be considered too "futuristic" and not practical enough for the organization's application. While a hypothesis correlating roadmap characteristics to impacts of ITR development is not proposed, a roadmap characteristics construct, defined as "overarching qualities of the ITR document" is developed and included in this research as an independent variable.

2.5.6 Control Variables

Characteristics of a particular industrial sector likely influence the use of an ITR by organizations in that industry. Several variables common to inter-organizational studies are included, such as: organizational size, industry consolidation, public/private status, the participant's organizational position, and executive support for the effort (Astley and Fombrun, 1983; Abzug and Webb, 1999; Casile and Davis-Blake, 2002; Wilts and Meyer, 2005; Todeva and Knoke, 2005; Mora-Valentin, Montoro-Sanchez, and Guerras-Martin, 2004). Others, more specific to technology planning and roadmapping, have also been identified: position of an industry's technology development on the technology S-curve; the industry's emphasis on research and development; level of industry versus governmental lead in the initiative; and the ITR which the organization helped to develop.

Organizational size may tie in with organizational impacts from a roadmapping effort. Larger organizations would have increased resources to implement R&D initiatives outlined in the roadmap, and would be more inclined to have an organizational technology roadmap that could be informed and modified by the industry discussions during ITR development and the contents of the subsequent industry roadmap. However, smaller organizations are often more nimble, and able to adapt to changing environments. Therefore, organizational size is an important control variable.

Industry consolidation/fragmentation involves the size and number of companies in an industry. When a small number of larger organizations make up a considerable market share of an industry, it is said to be more consolidated, whereas when many smaller companies make up the majority of an industry it is described as fragmented. Smaller organizations may not have the resources to individually pursue a potentially new technology, and so may be more inclined to form joint ventures and make use of research consortia to accelerate research and development activities. Therefore, fragmented industries may be more likely to benefit from a collective activity such as industry technology roadmapping. However, because of availability of resources, more consolidated industries tend to be more capable of initiating and sustaining a comprehensive activity such as roadmapping, and can be led to initiate activities based on the positive responses from a few large companies in leadership positions within the industry. From this perspective, consolidated industries may be more inclined to initiate technology roadmapping activities.

The S-curve (**Figure 4**) is used to explain the evolution of technologies in a particular field. According to the S-curve, a technology tends to experience periods of slow growth during the earlier and later stages of its lifecycle, and steady-state growth during the middle stage.

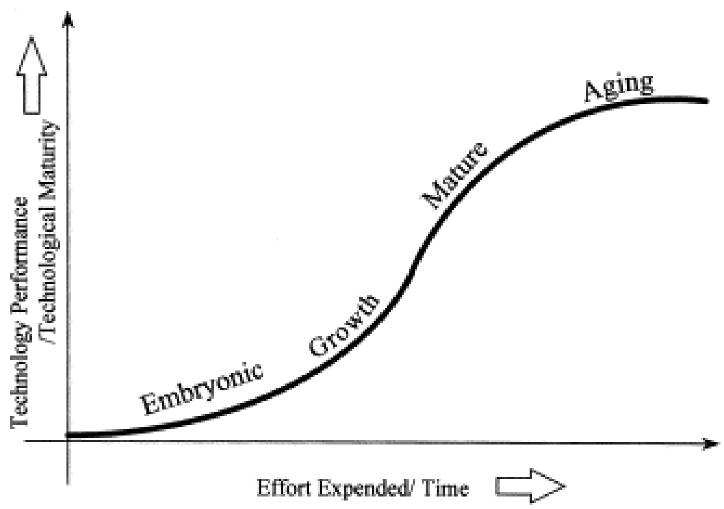

Figure 4: Technology S-Curve (Nieto, Lopéz, and Cruz, 1998)

Technology development begins at a slow pace as a new technology is explored and breakthroughs obtained. When all major obstacles to adoption are overcome, and a dominant design has emerged, growth in the technology is ongoing as incremental innovations are uncovered. Toward the end of a technology's lifecycle, physical limits of the approach begin to be reached, and development slows. Schaller (2004) posits that industries where technology is experiencing steady-state growth may be the best candidates to take advantage of an ITR. Industries where the technology is at an inflection point on the S-curve, changing from early adoption to steady progress or slowing toward the end of its lifecycle, may not be ideal candidates for ITR development. Increased uncertainty in technological forecasting and planning is an obvious reason for this conclusion. In addition, there may be less opportunity for collaborative research, an anticipated outcome of ITR development, as investors and researchers pursue more proprietary investigations.

The technological nature of an industry should tie closely with ITR development (Kostoff & Schaller, 2001). Industries that rely heavily on technological progress may be more inclined to develop, apply, and regularly update a technology roadmap. Industry R&D concentration is a reasonable indicator of industry emphasis on technology development, and is included as a control variable when analyzing organizational impacts. The methodology of the study, including the research context, operationalization of the constructs, and development, validation, and administration of the survey instrument, follows.

CHAPTER III

METHODOLOGY

3.1 Research Context

Technology roadmapping efforts in the United States have been selected as the context in which to examine the organizational effects of industry collective action. Reasons for selecting industry technology roadmaps primarily include: 1) technology roadmapping is a current form of industry collective activity; 2) participants are generally identifiable and reachable; 3) because technology roadmaps have specific and measurable goals, organizational impacts tend to be more measurable; and 4) it allows for analysis across multiple industries.

Technology management as a field of study has grown in prominence, as technology is beginning to be seen as a potential strategic and tactical advantage. Technology roadmapping, as a strategic planning tool for technology driven companies and industries, is widely used in industry (Phaal, Farrukh, and Probert, 2004a, 2004b) and is receiving increased attention in the literature, as witnessed by the growing presence of articles on the subject appearing in peer-reviewed journals. This research was limited to the United States in order to focus the study and eliminate the additional variable brought about by performing a multi-national examination. In addition, the majority of industry roadmaps have been developed in the U.S. While collective efforts have been in existence throughout history, industry level collectives are a relatively new form by historical standards, and technology roadmapping at the industry level is an operationalization developed and used in increasing levels in recent years (Kostoff and Schaller, 2001; Winebrake, 2004; Saritas and Aylen, 2010).

Participants in industry roadmapping are relatively accessible through either published documents, (i.e. roadmaps), or through sponsors of the roadmapping efforts, such as trade associations. Roadmapping efforts also have a defined timeline and specific goals (Kostoff and Schaller, 2001; Phaal, Farrukh, and Probert, 2004a, 2004b; Petrick and Echols, 2004), allowing for the organizational impacts to be operationalized and measured with less difficulty than the broader activities of some industry collectives. For instance, an organizational representative can be asked what specific goals outlined in the roadmap document were pursued/accomplished by their organization.

For this research, roadmapping participants are serving as a window into the effects on their organization of participation in the industry collective. Generally, roadmap participants are senior level scientists or executives in their respective organizations, and, as such, should have a fairly accurate perspective as to changes in their organization prompted by both the roadmap itself and/or their participation in the roadmapping effort. A significant number of roadmapping participants may have retired or changed companies or industries, as many of these roadmaps were developed a decade or more ago, and the US has experienced a significant economic downturn since that time. The survey was distributed to those participants who are still employed with the organization for which they worked when developing the roadmap.

Outcomes of research in the industry roadmapping arena can see immediate application to benefit these efforts - a value to government agencies that are often sponsors of industry roadmaps as well as industry participants who typically lead the process. Industry roadmapping now reaches across the world through efforts in multiple countries. Thus, the impact from the results of this study can have far-reaching and relatively immediate implications.

3.2 Methodology

Previous research involving industry technology roadmapping has analyzed factors affecting performance of such efforts using a case approach, either looking in depth at a single industry (Schaller, 2004), or interviewing a small number (1-3) of select participants from multiple roadmapping efforts (de Laat, 2004). This research will combine an analytical survey with open-ended questions and telephone follow-up, to obtain a different perspective on industry roadmapping. Primary data for this study is collected using a survey instrument, following the approach described by Fowler (2002) and Dillman (2007), which is detailed in section 3.3. The survey method was chosen for several reasons. First, a survey approach provides an efficient means of collecting data from the numerous sources necessary for an empirical analysis of roadmapping collectives. Second, roadmapping participants are reasonably identifiable for administration of the survey instrument. Third, obtaining responses is aided by representatives from industry roadmap sponsoring agencies, such as government offices and industry associations, who are interested in empirical findings that might improve organizational impacts of roadmapping. Finally, surveys have not been used to study industry roadmapping collectives in the past, because the field is relatively new (Kostoff and Schaller, 2001; Schaller; 2004; de Laat, 2004), and a case approach is often the preliminary method used to generate knowledge in new areas of study (Yin, 2002). As the use and study of technology roadmaps at the industry level has progressed, more information has been published and more collectives are available for analysis (de Laat, 2004). Based on these observations, now seems to be the ideal time to utilize surveys for an empirical examination of industry roadmapping. Industry roadmapping collectives were selected for study with the intent of providing a breadth of roadmap collective and industry types (Eisenhardt, 1989).

However, as has been discussed at length in the literature, qualitative research provides a richness that cannot be obtained from purely quantitative work. Case methods and qualitative measures are particularly valuable when developing a new theory (Eisenhardt, 1989) or when knowledge of why a certain phenomenon is taking place is of interest. In addition, triangulation using more than one research method to collect data for analysis, and showing that multiple methods converge on a similar outcome, strengthens validity of a study (Jick, 1979). Thus, qualitative measures, in the form of open-ended questions, telephone discussions with roadmapping facilitators, and a review of the roadmap documents, are used as a secondary data collection method to supplement the quantitative study. Pattern matching methods were employed, such as described by Trochim (2001). A pilot study, described in 3.3.1, using the two contrasting examples of ITR performance mentioned previously - the Concrete Industry and Semiconductor Industry technology roadmapping efforts - solidified the future approach for a broader study of multiple industries (Yin, 2003).

3.3 Survey Development

3.3.1 Pilot Study

Using the total survey design methodology described by Fowler (2002) and the tailored design method described by Dillman (2007), a pilot survey instrument was developed based on a review of the academic literature, industry roadmap documents, and roadmapping publications by various agencies, stating the ideal inputs and expected outcomes of roadmap development. The purpose of the pilot study was to get initial insights into the dynamics of these two roadmapping collectives and further evaluate the survey for enhancements, such as: improved clarity of questions; where practical, conversion of open-ended questions to Likert scale (1-5 ranking) format; addition of questions that might have been missed; and removal of redundant questions (Fowler, 2002).

This preliminary survey instrument was administered to the roadmap organizer/manager and key development team leaders from the ITRS and Roadmap 2030: The U.S. Concrete Industry Technology Roadmap. The ITRS was selected for preliminary analysis because it is well recognized as the pioneering industry technology roadmap and considered highly successful in the academic literature (Schaller, 2004). The Concrete Industry Roadmap was selected due to its seemingly much lower use by participants and because the concrete industry moves at a much slower clockspeed technologically, providing a contrasting perspective. The response rate was 100% from the ITRS leadership and 60% from Roadmap 2030. The organizers and leaders of these two efforts illuminated areas where questions were absent from the pilot survey instrument. In addition, some preliminary insight was gained into the issues that may influence the impacts of industry roadmapping efforts.

The sample size of the pilot study was extremely small. Ten participants from the ITRS leadership team and six from Roadmap 2030 completed surveys, which limits conclusion from the pilot study. But its primary intent was to review questions for clarity and inform the survey instrument. Aside from modifications to the final survey instrument, however, one outcome is worth noting. Participants in the ITRS, the seminal ITR collective and seemingly high performing based on positive reviews by researchers (Schaller, 2004), are almost exclusively high level researchers who stress the critical importance of R&D advancement to the industry's future success. In contrast, participants in the Roadmap 2030 collective, a seemingly one-time roadmapping exercise, are a mix of technical executives, marketing professionals, and chief executives, and do not place as high regard on the importance of R&D to the concrete industry's future. The difference in ranking the importance of R&D could also be an industry effect, due to the semiconductor industry's higher clockspeed and emphasis on more rapid technology development. Additional research investigating more numerous ITR collective efforts may indicate if this is a coincidence or a correlation.

3.3.2 Survey Review and Revision

A final draft survey instrument was developed using results from the pilot study. This final draft was validated by three experts in the roadmapping field, which included: 1) Lisa Devon Streit, a government official with significant experience in roadmapping several different industries; 2) Linda Wilson, who spent over a decade growing and managing the renowned ITRS roadmap; as well as 3) Dr. Ronald Kostoff, a leading technology roadmap researcher and primary author of the most cited journal article on technology roadmaps (Kostoff and Schaller, 2001). The expert review resulted in rewording of several questions to improve clarity and usability of responses, and the addition of an "unknown" response to some questions. A copy of the final survey is included in Appendix A. Survey items representing each construct tested in this study, and previous literature supporting their inclusion in this research, are listed in **Tables 1-4**. The tables list each proposed construct, its operational definition, measures (survey instrument items), and supporting sources found in the literature on technology roadmaps, consortia, collectives, stakeholders, and other inter-organizational activities. **Table 1** includes the Organizational Impact (dependent) and the Organizational Motivation (independent) constructs. **Table 2** describes the Industry Motivation (independent) and Roadmap Characteristics (independent) constructs. Stakeholder Roadmap Development (independent) and Industry Clockspeed (independent) constructs are shown in **Table 3,** and **Table 4** lists the Control Variables used in this study.

3.4. Survey Administration

The survey instrument was administered to 846 organizational participants, representing 17 roadmapping collectives. Response rates for the majority of ITRs were too low to include in analysis, even after repeated reminders to ITR collective participants. There were a number of reasons for the low response rates. First, as stated earlier, most of the roadmaps were developed around a decade ago. As such, many of the participants in those efforts have retired or left the companies for which they worked when participating in development of the roadmap. Only responses from individuals currently employed by the organization for which the person worked when serving on the ITR collective would be considered, as the survey responses were centered around the impacts on participating organizations. This reduced the number of potential respondents significantly for some ITRs, often more than 50%. Since the average roadmapping collective had about 40 members (30 – 100+), that left less than 30 potential respondents, sometimes less than ten, for specific roadmapping collectives. Because the number of responses was low, the number of ITRs usable in the study was limited. Multi-level analysis (O'Brien, 1990) where the organization is one level and the collective is another, would have been ideal, but required data from a minimum of 30 roadmaps (collectives) with 30 responses each to complete with statistical validity. Alternate approaches, described in chapter 4, were chosen.

Table 1: Organizational Impact and Motivation Constructs and Operationalization

Construct	Definition	Survey Items	Sources
Organizational Impact (dependent variable)	Changes in an organization due to participation in ITR development	Improved your organization's technology planning	Schaller (2004); Phaal et. al. (2004); Masum et. al. (2010)
		Increased the pace (speed of change) of your organization's technology development	Schaller (2004)
		Increased the number of collaborative technology-based activities	Hagedoorn et. al. (2000); Yasunaga et. al. (2009)
		Improved the quality of collaborative technology-based activities	Yasunaga et. al. (2009)
		Fostered the development of new products/processes	Schaller (2004); Yasunaga et. al. (2009)
		Stimulated the creation of new solutions to technical problems	Schaller (2004); Yasunaga et. al. (2009)
		Learned what technology solutions will NOT work	Schaller (2004)
		Helped identify technology gaps that will inhibit your organization's future development	Schaller (2004); Yasunaga et. al. (2009)
Organizational Motivation	Reasons for an organization's participation in the roadmapping effort	Contributing to the industry	Astley & Fombrun (1983); Schaller (2004); Butterfield et. al. (2004)
		Reprioritizing research/development projects in my organization	Schaller (2004)
		Identifying technology gaps in my organization	Schaller (2004); Butterfield et. al. (2004)
		Increasing the pace of technology development/innovation in my organization	Schaller (2004)
		Ensuring my organization's survival	Astley & Fombrun (1983); Kappel (2001); Schaller (2004)
		Enhancing technological learning for my organization	Schaller (2004)
		Increasing the number of collaborative technology-based activities in my organization	Astley & Fombrun (1983); Schaller (2004); Phaal et. al. (2004)
		Increasing the quality of collaborative technology-based activities in my organization	Astley & Fombrun (1983); Schaller (2004); Yasunaga et. al. (2009)

Table 2: Industry Motivation and Roadmap Characteristics Constructs and Operationalization

Construct	Definition	Survey Items	Sources
Industry Motivation	Reasons underlying an industry's ITR development	Increasing government funding for research related to the industry	Pilot Study
		Reprioritizing industry-funded research/development	Yasunaga et. al. (2009); Masum et. al. (2010)
		Reprioritizing government-funded research/development related to the industry	Winbrake (2004); U.S. Department of Energy (2005)
		Identifying technology gaps in the industry	Schaller (2004); Masum et. al. (2010)
		Increasing the pace of technology development/innovation in the industry	Schaller (2004); Yasunaga et. al. (2009); Masum et. al. (2010)
		Creating a shared technology vision for the industry	Kostoff & Schaller (2001); Yasunaga et. al., (2009)
		Ensuring the industry's survival	Astley & Fombrun (1983); Schaller (2004); Butterfield et. al. (2004)
		Enhancing technological learning for the industry	Schaller (2004); Butterfield et. al. (2004); Yasunaga et. al. (2009)
		Increasing the number of collaborative technology-based activities in the industry	Astley & Fombrun (1983); Schaller (2004); Phaal et. al. (2004)
		Increasing the quality of collaborative technology-based activities in the industry	Astley & Fombrun (1983); Schaller (2004); Yasunaga et. al. (2009)
Roadmap Characteristics	Overarching qualities of the ITR document	The roadmap document has specific/measurable goals	Donaldson & Preston (1995); Schaller (2004)
		The roadmap document includes dissenting opinions of participating organizations	Butterfield et. al. (2004)
		The roadmap document is revisited/updated adequately (i.e. time between revisions)	Kostoff & Schaller (2001); De Laat (2004); Butterfield et. al. (2004)
		The roadmap document covered the complete range of industry segments where technology development is important	Gerdsri et. al. (2009); Surroca et. al. (2010)
		The roadmap document provided details for each technical area addressed	Kostoff & Schaller (2001); Benson & Davidson (2010)
		The timeline of the roadmap document was appropriate (i.e. number of years in the future addressed	Kappel (2001); Schaller (2004)

Table 3: Stakeholder Roadmap Development and Industry Clockspeed Constructs and Operationalization

Construct	Definition	Survey Items	Sources
Stakeholder Roadmap Development	Incorporation of stakeholder principles in the structure and operation of the collective	Did the technology roadmap leadership (core group) develop a skeletal framework (i.e. identify major technical areas to be addressed) of the technology roadmap prior to the entire group's efforts	de Laat (2004); Butterfield et. al. (2004)
		Was there a sense of urgency within the industry for developing the industry technology roadmap	Astley & Fombrun (1983); Mitchell et. al. (1997); Schaller (2004); de Laat (2004) Butterfield et. al. (2004)
		How open were the group's discussions when developing/revising the industry technology roadmap	Jones (1995); Butterfield et. al. (2004)
		Was a consensus decision-making process used when developing/revising the industry technology roadmap	Jones (1995); Kostoff & Schaller (2001); Butterfield et. al. (2004)
		Were dissenting opinions from organizational participants welcomed when developing/revising the industry technology roadmap	Mohr & Spekman (1994); Jones (1995); Butterfield et. al. (2004)
		Did your organization have experience in developing/using organizational technology roadmaps prior to participation in the industry's technology roadmapping efforts	Kostoff & Schaller (2001)
		Do you have experience working directly in short-range technology development and application	Probert & Shehabudden (1999); Wells et. al. (2004); Gerdsri et. al. (2009)
		Do you have experience working directly in long-range technology development and research	Mitchell et. al. (1997); Probert & Shehabudden (1999); Benson & Davidson (2010)
Industry Clockspeed	Pace of an industry's change from organizational, process, and product perspectives	No survey items for this construct	Fine (1998); Mendelson & Pillai (1999); Schaller (2004); Nadkarni & Narayannan (2007); Yasunaga et. al. (2009); Dedehayir & Makinin (2011)

Table 4: Control Variables

Variable	Definition	Survey Items	Sources
Organizational Size	Number of employees in an organization	Number of employees in your organization: 1) 1-10, 2) 11-50, 3) 51-100, 4) 101-500, 5) 501-1000, 6) >1000	McKendrick & Wade (2010); Gallo & Christensen (2011)
Organizational Public/Private Status	Privately-held organizations vs. publicly-held (government, public corporations)	Your organization is: 1) public 2) private	Gerpacio (2003); Danner (2008)
Organizational Participant Position	Respondents’ position in their organization	Your position within your organization can best be described as: 1) executive (CEO/VP), 2) technical, 3) marketing, 4) project manager, 5) other	Dilts & Pence (2006)
Organizational Type	Industry segment to which organization belongs	Your organization can best be described as a: 1) supplier, 2) producer, 3) customer, 4) consultant, 5) specifier, 6) government agency, 7) non-profit/academic institution	Freeman (1983); Kostoff & Schaller (2004)
Executive Support	CEO/VP support	Top executives (CEO/VP) in my organization supported development of the industry technology roadmap.	Kostoff & Schaller (2004)
Industry Fragmentation	Few larger organizations or many smaller ones	N/A - the Herfindahl-Hirschman Index (HHI), utilized by the U.S. Census Bureau to measure industry consolidation, was used for this study	Sakakibara (2002)
Industry R&D Emphasis	Industry R&D expenditures	N/A - U.S. Census data on industry R&D expenditures as a % of sales was collected	Kappel (2001); Schaller (2004)
Industry Lead	Industry vs. government lead	Which group led development of the industry technology roadmap?	de Laat (2004)
ITR	Which ITR/industry?	N/a - Surveys administered by ITR collective	de Laat (2004)

3.5 Open-Ended Questions

The survey instrument included six open-ended questions to get a clearer sense of what respondents meant when they responded that the roadmapping effort impacted their respective organizations at a particular level. These open-ended questions are correlated with the statistical results to examine agreement/disagreement between the two and to bring greater insight into the specific impacts on organizations due to the ITR collective effort.

3.6 Survey Analysis

Exploratory factor analysis was conducted to determine which survey questions loaded on various constructs (Long, 1983). Responses from individual participants served as a proxy for those from organizations participating in the roadmapping process. This presents three issues which must be acknowledged and managed. First, it is important to recognize the position of each individual participant within his respective organization. For instance, is the individual an executive, technical expert, or marketing professional? The answer to this question of position may impact the response (Allison and Zelikow, 1999). Second, is consideration of each participant's organization within the scope of the industry that is being roadmapped. As an example, is the organization a user, producer, supplier, government agency, educational institution, or other? Control variables of organization size and public/private status were collected. Third, if there is a committee structure within the roadmapping collective, perhaps one committee performs admirably, but the others fail, resulting in poor overall performance. Individuals representing organizations are nested in committees within the ITR collective. Data was gathered regarding position of individuals within their respective organizations, participating organizational characteristics, and participant level of involvement within the roadmapping collective.

The survey instrument was distributed to 17 industries. Responses from the majority of industries were too low to be included in the analysis. ITRs with more than 10 responses, resulting in data from six different roadmaps, were used for analysis. All six roadmapping initiatives were at least ten years old. Four of the roadmaps were one-time activities, meaning the roadmap in that industry has not been updated. Those four include the concrete industry, magnesium industry, metal casting industry, and powder metallurgy industry. The other two roadmaps, the electronics manufacturing industry (iNEMI) and the forest products industry, have been updated within the last year, meaning they can be considered ongoing activities. Response rates for the six roadmaps are displayed in **Table 5**. The overall response rate for the roadmaps used in this study for all surveys sent is 20%.

Table 5: Survey Response Rate

Roadmap	**Members**	**Surveyed**	**Responses**	**Response Rate**
Concrete	95	77	15	19%
Electronics (iNEMI)	575	302	28	9%
Forest Products	109	109	35	32%
Magnesium	40	27	12	44%
Metal Casting	107	98	25	26%
Powder Metallurgy	32	32	13	41%

Each of the six roadmapping efforts used in the study is profiled in **Table 6**. The earliest iNEMI roadmap was developed in December, 1994, and the roadmap is updated on a bi-annual basis. The only other ITR to be updated is the Forest Products roadmap (2011). The other four industries have not revisited their ITR. As can be expected, the high clockspeed iNEMI industry roadmap has a shorter timeline than the other ITRs, because it is too difficult to predict what technological changes may occur in a rapidly changing industry beyond 10 years.

Table 6: Roadmapping Characteristics by Industry

Roadmap	**Earliest Roadmap**	**Most Recent Roadmap**	**Timeline (years)**	**HHI**	**R&D % of Net Sales**	**Clockspeed**
Concrete	2002	N/A	30	216	1.8	Slow
Electronics (iNEMI)	1994	2010	10	475	12.0	Fast
Forest Products	2006	2011	15	159	1.0	Slow
Magnesium	2005	N/A	15	119	0.6	Slow
Metal Casting	1998	N/A	15	112	0.6	Slow
Powder Metallurgy	2001	N/A	20	489	1.6	Slow

The remaining roadmaps range from 15 years for the majority, 20 years for the Powder Metallurgy industry, and a high value of 30 years for the Concrete ITR. The Herfindahl-Hirschman Index (HHI), a common measure used to approximate industry consolidation, was obtained using the US Economic Census (2007). The North American Industry Classification System (NAICS) codes for the Concrete (NAICS=3273), iNEMI (NAICS=3344), Metal Casting

(3315), and Powder Metallurgy (NAICS=332117) industries were fairly straightforward, allowing the HHI measurement to be taken directly from the census data. The NAICS value for non-ferrous metals was used for the Magnesium industry, because a category specific to magnesium was not available. The Forest Products HHI was calculated using weighted averages of the two NAICS segments making up the industry, based on % value of shipments. For example, the industry was made up of wood product manufacturing (NAICS=321), which had $101,711,917,000 in shipments, and paper manufacturing (NAICS=322), which shipped $176,687,641,000 in products. Using each as a fraction of the total dollars in shipments (36.5% and 63.5%, respectively) and multiplying by the HHI from each segment (38.3 and 227.8, respectively), yields:

$$0.365*38.3 + 0.635*228 = 159 \text{ (weighted Forest Products HHI estimate)}$$

All six industries are considered to have low consolidation, since HHI values for all industries fall below 1000. R&D % of Net Sales was only available for a limited number of NAICS segments. For instance, only the more general nonmetallic mineral products industry category (NAICS=327) information was available, and was substituted for the more specific concrete industry category (NAICS=3273).

3.7 Validity Threats

Threats to validity in this study come from several sources. One primary threat is hindsight bias. Motive levels of various organizations when first considering forming/joining the industry collective is likely to be influenced by participants' current view of the roadmapping effort. While this bias cannot be entirely eliminated, questions were specifically framed to ask about motivations for participating in the ITR development process.

Non-response bias is another major concern with regard to validity of this research. Where possible, follow-up e-mails and phone calls were used to increase response rates and ensure responses do not come from similar groups of participants with a single perspective (Fowler, 2002). Using open-ended questions and interviews of select participants, as a second method of data collection, should also help to alleviate this threat (Trochim, 2001). Representativeness of respondents was verified by comparing the group of those in the population who did not respond with those who did respond, to help ensure there were not significant differences between the two (Fowler, 2002).

An additional validity threat to validity is caused the small sample size. The low number of respondents limits the conclusions of this study. Due to the reduced power of the resulting statistical analyses, the independent variables that do not show significant correlation with the dependent variable (Organizational Impact), in fact, may be significant.

CHAPTER IV

ANALYSIS & DISCUSSION

4.1 Descriptive Statistics and Initial Observations

A total of 128 responses were received, representing the six industries. Descriptive statistics were computed for all survey responses. The highest number of respondents to a single question was N=127 (19.7%) and the lowest was 101 (15.7%). Key variables, consisting primarily of demographics and a few overall ITR measures, were also reviewed using histograms. As shown in **Figure 4**, 42% of the organizational representatives responding were from privately owned organizations, and 58% were from public entities (government, public universities, and publicly-held firms).

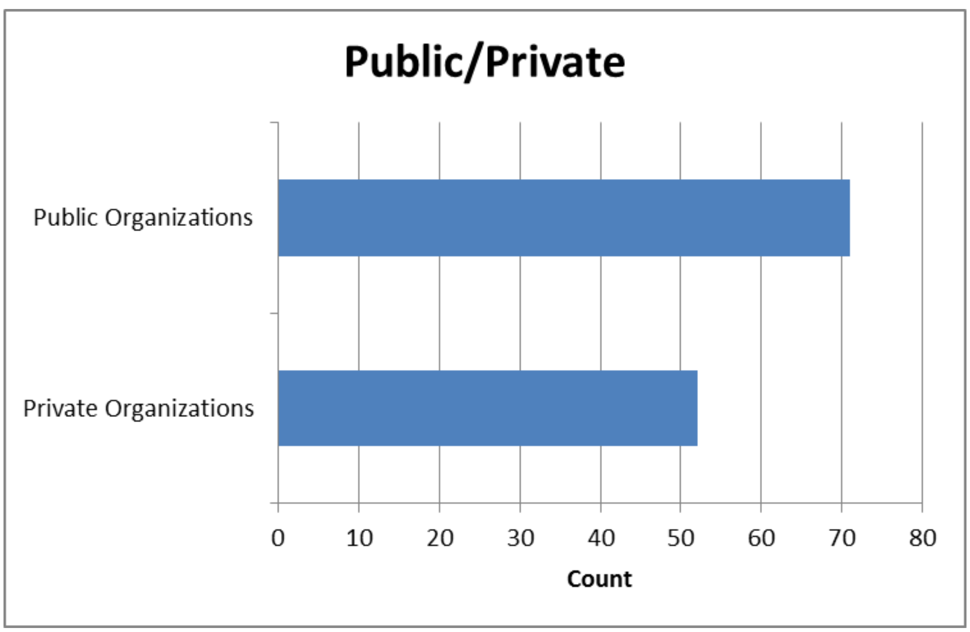

Figure 4: Number of Respondents from Public and Private Organizations

About two thirds of respondents were industry representatives, and one third was from government agencies, non-profits, or academic institutions (**Figure 5**). This profile distribution is comparable to comprehensive lists of participants in ITR collectives, as listed in numerous individual ITR documents for various industries.

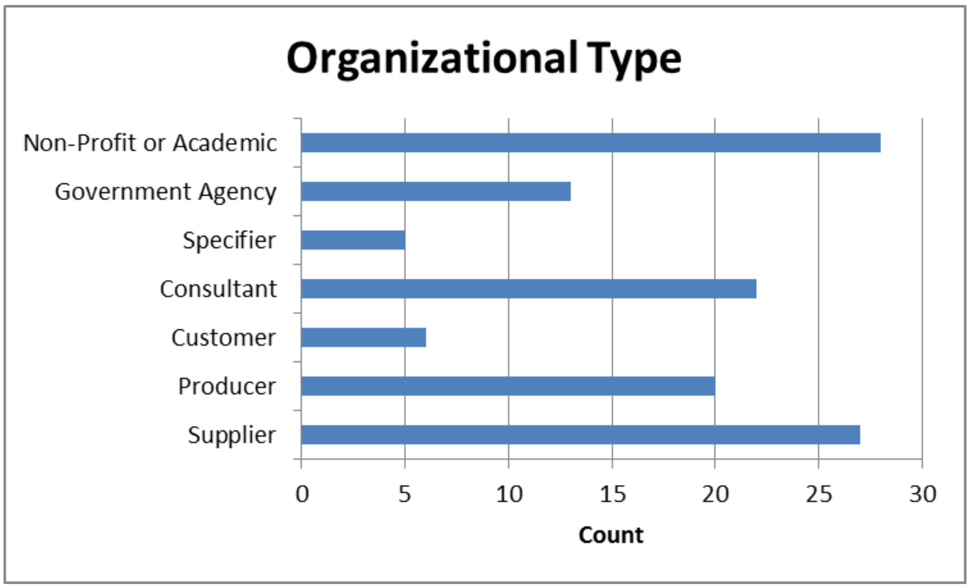

Figure 5: Number of Respondents by Type of Organization

Nearly half of the 127 respondents represented organizations with over 1,000 employees, followed by over 17% from very small organizations, with ten or less employees (**Figure 6**). Most participants were either executives (43%) or from technical positions (42%) in their organizations (**Figure 7**). The remaining respondents were primarily project managers (12%), with a few from marketing positions. This provides a good cross-section of organizational sizes, and is representative of the population from each roadmapping collective.

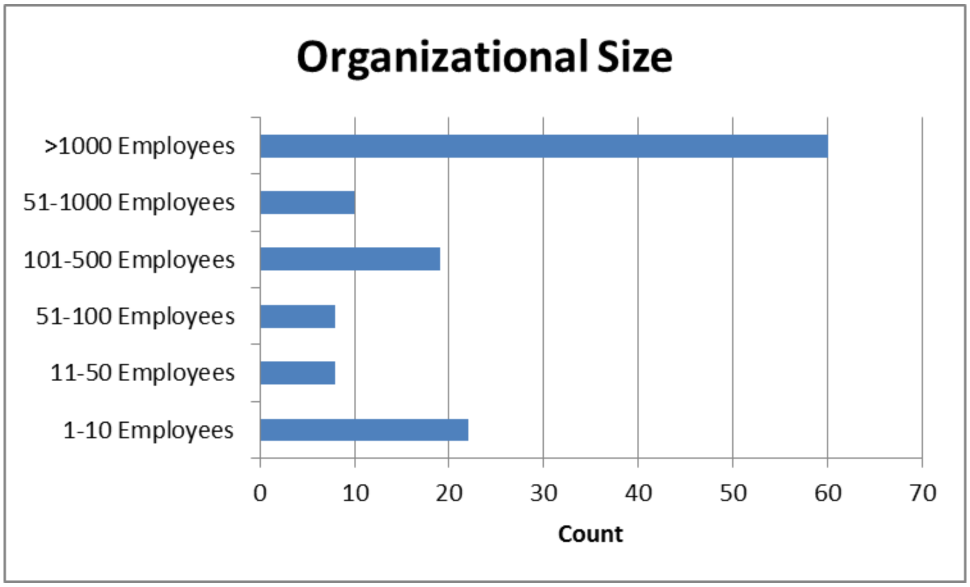

Figure 6: Number of Respondents by Size of Organization

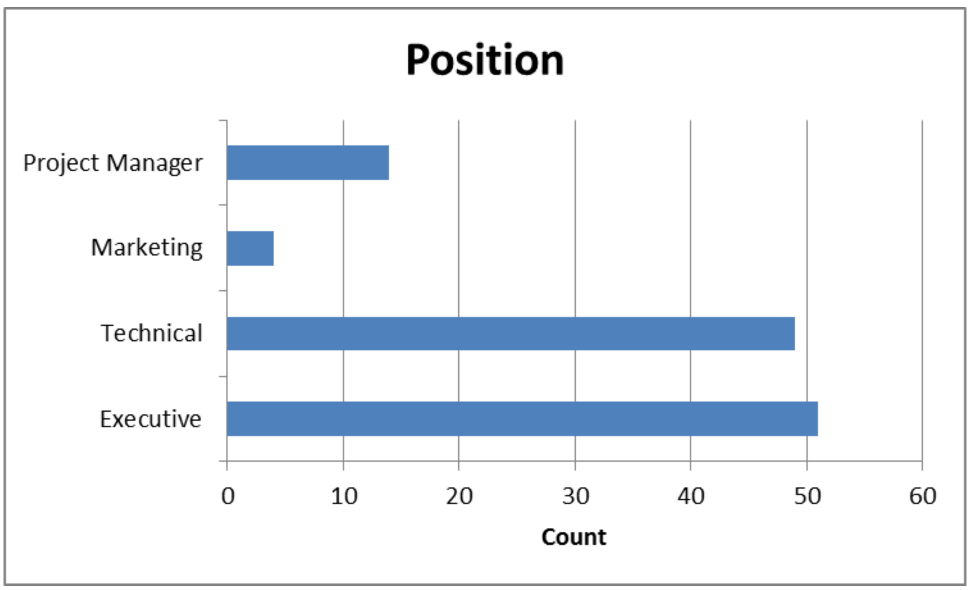

Figure 7: Number of Respondents by Position in Organization

Figure 8 show that 20% of respondents indicated their participation in the ITR collective had a significant or extensive effect on their organizations, while 16% responded that it had no effect, and the majority (64%) responded that it had a somewhat or moderate effect. When asked about the level of effect on the industry (**Figure 9**), the number of respondents who indicated the ITR collective had a significant or extensive effect on the industry was 19%, somewhat or moderate effect 75%, and no effect was only 6%. As shown in **Figure 10**, only 7% of respondents indicated their organizations would not participate in future industry roadmapping efforts, while over 61% were significantly convinced their organizations would participate in future ITR collectives. Overall, these results indicate that industry roadmapping efforts are viewed positively by participating organizations.

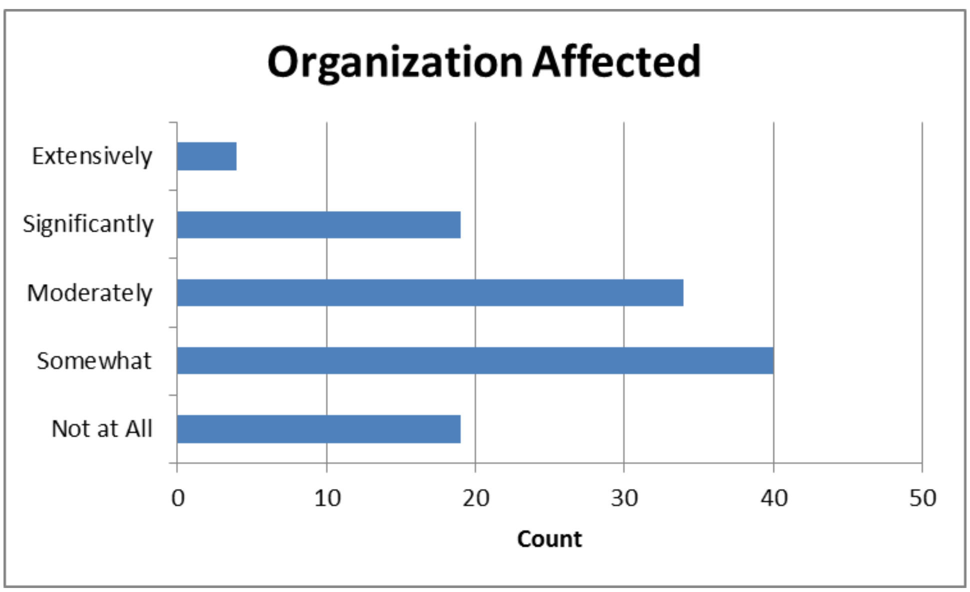

Figure 8: Number of Respondents by Effect on Organization

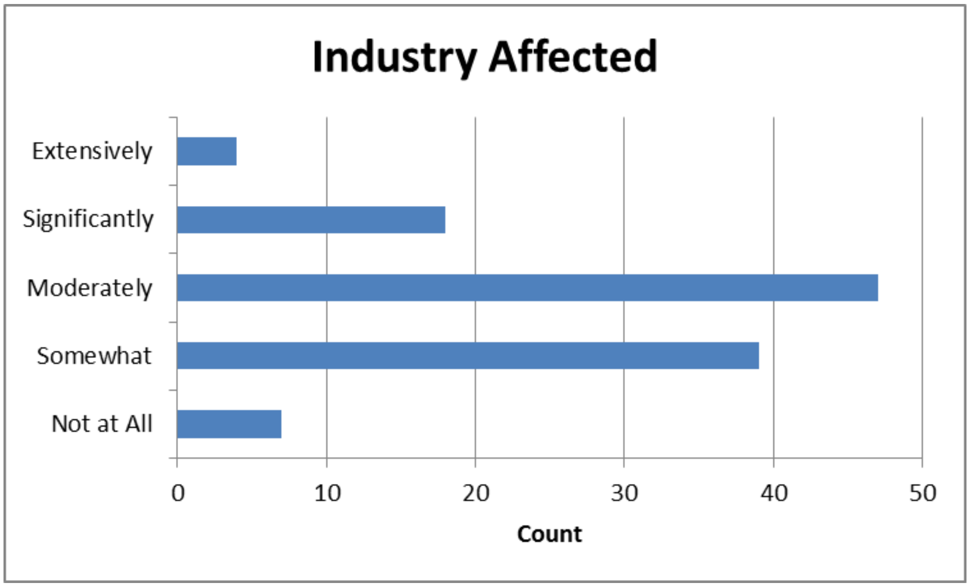

Figure 9: Number of Respondents by Effect on Industry

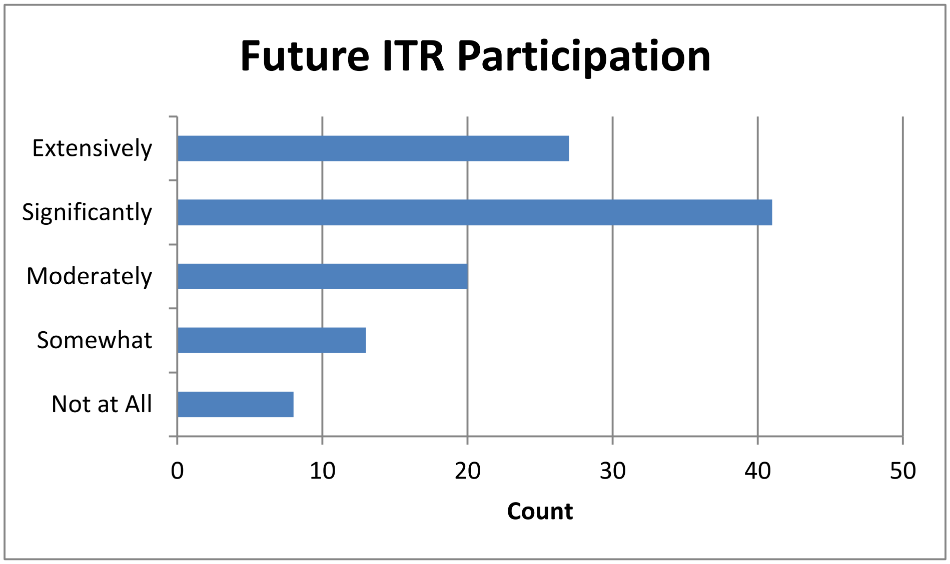

Figure 10: Number of Respondents by Organizational Likelihood of Participation in Future ITRs

4.2 Exploratory Factor Analysis

Responses from the six roadmaps were next analyzed by conducting a principle component analysis (exploratory factor analysis), to ensure items were aggregated into appropriate constructs (Agresti and Finlay, 1997). Initially, results were confusing, because control variables and questions representing the independent variable (Organizational Impact) were included. When responses relating to these questions were parsed out, and the results were rotated using Varimax with Kaizer Normalization to improve interpretability, six clearly identifiable factors appeared, explaining in total 64.4% of the variance in the data. The rotated factor matrix is shown in **Table 7**. Items that loaded at 0.600 or above on a factor and 0.400 or less on any other factor were retained. In addition, a few items loaded between 0.500 and 0.600 on a factor. In those cases, the item was retained if its next highest factor loading was at least 0.300 below.

Factor one included questions relating to roadmap development, so was titled the Stakeholder Roadmap Development Processes construct. Questions, and their loadings for factor one, are shown in **Table 8**. Five questions loaded on factor one at 0.600 or above. The question regarding openness of discussions during roadmap development also loaded on factor three at 0.400, but better related to the processes construct and loaded on factor one at 0.693. Questions asking about breadth and depth of the group conducting the roadmapping effort, loaded on factor four at 0.384 and 0.300 respectively, but were also retained on factor one, because they loaded on the roadmap development construct at above 0.700. A sixth question, relating to development of a skeletal framework for the roadmap prior to the entire group working on the effort, loaded on factor one at 0.580, and was also retained, as its second highest loading was only 0.229.

Table 7: Factor Loadings

Rotated Component Matrix[a]

	Component					
	1	2	3	4	5	6
Dev. Process - Skeletal Framework Created	.580	.039	-.163	.229	.154	.177
Dev. Process - Sense of Urgency	.501	.098	.191	.218	.376	.017
Dev. Process - Open Discussions	.693	.036	.400	.014	-.020	.210
Dev. Process - Consensus Decisions	.737	-.067	.271	-.152	.122	.085
Dev. Process - Dissenting Opinions	.756	.045	.159	.049	-.008	-.167
Dev. Process - Prior Experience with Roadmapping	-.152	.198	.055	.467	.091	.611
Structure (Participant R&D Experience - Application)	.072	.152	.042	.132	-.139	.730
Structure (Participant R&D Experience - Research)	.108	.143	.000	.161	.022	.766
Dev. Process - Breadth of Industry Participation	.753	.078	.144	.384	.199	-.006
Dev. Process - Depth of Industry Participation	.743	.135	.106	.300	.193	.064
Industry Motivation - Increase Government Funding	.209	.041	.069	-.081	.866	-.152
Industry Motivation - Guide Industry Research	.224	.041	.300	.121	.699	.184
Industry Motivation - Guide Government Research	.123	.178	.236	.026	.859	.017
Industry Motivation - I.D. Technology Gaps	.504	.165	.178	.124	.179	.444
Industry Motivation - Technology Pace	.401	.009	.579	-.039	.251	.339
Industry Motivation - Create a Shared Vision	.424	.267	.429	.155	.174	.347
Industry Motivation - Industry Survival	.279	.171	.614	.095	.260	.138
Industry Motivation - Technological Learning	.212	.177	.775	.217	.066	-.024
Industry Motivation - Collaboration Quantity	.236	.294	.722	.082	.255	-.020
Industry Motivation - Collaboration Quality	.096	.364	.702	.062	.226	-.035
Organizational Motivation - Contribute to Industry	.358	.185	.185	-.040	.085	.411
Organizational Motivation - Reprioritize Research	.153	.759	.063	.137	.258	.125
Organizational Motivation - I.D. Technology Gaps	.051	.834	.056	-.101	-.068	.227
Organizational Motivation - Technology Pace	.008	.804	.125	-.049	-.049	.224
Organizational Motivation - Organization Survival	.109	.617	.064	.121	.109	-.042
Organizational Motivation - Technological Learning	-.044	.611	.477	-.005	-.241	.109
Organizational Motivation - Collaboration Quantity	.110	.790	.266	.161	.117	.068
Organizational Motivation - Collaboration Quality	-.013	.853	.165	.118	.118	.109
Roadmap - Measurable Goals	.161	.005	.207	.659	.172	.136
Roadmap - Dissenting Opinions	.048	-.065	.225	.542	-.058	-.251
Roadmap - Adequate Frequency of Updates	-.069	.048	.333	.620	-.154	.305
Roadmap - Breadth of Coverage	.449	.231	-.060	.678	.090	.099
Roadmap - Depth of Coverage	.320	.041	-.024	.738	.043	.336
Roadmap - Appropriate Timeline	.084	.206	-.189	.441	-.025	.220

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. a. Rotation converged in 11 rotations.

Table 8: Principle Components Analysis Factor 1 (Stakeholder Development Process) Loadings

Stakeholder Roadmap Development Process Questions	**Rotated Loading**
Did the technology roadmap leadership (core group) develop a skeletal framework (i.e. identify major technical areas to be addressed) of the technology roadmap prior to the entire group's efforts?	0.580
How open were the group's discussions when developing/revising the industry technology roadmap?	0.693
Was a consensus decision-making process used when developing/revising the industry technology roadmap?	0.737
Were dissenting opinions from organizational participants welcomed when developing/revising the industry technology roadmap?	0.756
Did the roadmap development group include a breadth of participation from various industry segments (i.e. suppliers, producers, customers, government agencies, academics/non-profits, etc.)?	0.753
Did the roadmap development group include technical experts from multiple industry segments (i.e. suppliers, producers, customers, government agencies, academics/non-profits, etc.)?	0.743

The second factor included questions asking about organizational motivations for participating in the roadmapping effort, and was titled the Organizational Motivation construct. The questions and their loadings on factor two are in **Table 9**. The second highest value for each question was below 0.300, except for the question related to technological learning, which loaded on factor three at a value of 0.477, and was removed from factor two.

Factor three included several of the questions about industry motivations for collaborating to develop a technology roadmap, but only those emphasizing how the industry works together. Loadings are shown in **Table 10**. Only one question, increasing the quality of

Table 9: Principle Components Analysis Factor 2 (Organizational Motivation) Loadings

Organizational Motivation Questions – Please rate your organization's motivations for participating in development of the industry technology roadmap:	Rotated Loading
Reprioritizing research/development projects in my organization	0.759
Identifying technology gaps in my organization	0.834
Increasing the pace of technology development/innovation in my organization	0.804
Ensuring my organization's survival	0.617
Enhancing technological learning for my organization	0.611 (eliminated)
Increasing the number of collaborative technology-based activities for my organization	0.790
Increasing the quality of collaborative technology-based activities for my organization	0.853

Table 10: Principle Components Analysis Factor 3 (Functional Industry Motivation) Loadings

Functional Industry Motivation Questions – Please rate the industry's motivations for developing the industry technology roadmap:	Rotated Loading
Ensuring the industry's survival	0.614
Enhancing technological learning for the industry	0.775
Increasing the number of collaborative technology-based activities in the industry	0.722
Increasing the quality of collaborative technology-based activities in the industry	0.702

collaborative activities, loaded at above 0.300 on any other factor. The question loaded at 0.364 on factor two, but was retained in factor three, because of the significant difference in loading on the two factors and the fact that the question specifically asked about industry motivation, not organizational. Factor three was titled the Functional Industry Motivation construct, because the questions that loaded on it focused on how the industry works together to help ensure success.

Five questions relating to characteristics of the roadmap document, as shown in **Table 11**, loaded on factor four. The question about dissenting opinions loaded second highest on factor three at 0.225, and was retained on factor four. The question regarding the adequacy of updates to the roadmap loaded at 0.333 on factor three, and was retained on factor four. The question relating to technical details in the roadmap loaded on factor one at 0.320, and was also retained on factor four. The question about the range of industry segments covered in the roadmap document, loaded on factor one at 0.449, and was removed from factor four. Factor four was titled the Roadmap Characteristics construct.

Table 11: Principle Factor Analysis Factor 4 (Roadmap Characteristics) Loadings

Roadmap Characteristics Questions – Please rate the following characteristics of the industry technology roadmap:	**Rotated Loading**
The roadmap has specific/measurable goals.	0.659
The roadmap document includes dissenting opinions of participating organizations.	0.542
The roadmap document is revisited/updated adequately (i.e. time between revisions).	0.620
The roadmap document covered the complete range of industry segments where technology development is important.	0.678 (eliminated)
The roadmap document provided details for each technical area addressed.	0.738

Industry motivations for prioritizing industry and government research efforts and for prioritizing government funding related to the industry, loaded on factor five. Reprioritizing industry funding also loaded at 0.300 on factor three, but was retained on factor five. No other loadings above 0.300 were present for these three questions. The factor was titled R&D Industry Motivation, with loadings as shown in **Table 12**.

Table 12: Principle Components Analysis Factor 5 (R&D Industry Motivation) Loadings

R&D Industry Motivation Questions – Please rate the industry's motivations for developing the industry technology roadmap:	**Rotated Loading**
Increasing government funding for research related to the industry.	0.866
Reprioritizing industry-funded research/development.	0.699 (retained)
Reprioritizing government-funded research/development related to the industry.	0.859

Table 13 shows the questions that loaded highest on factor six. Each of the three questions related to the experience of participants and the organizations they represented. The question regarding prior organizational experience with technology roadmapping loaded at 0.467 on factor four as well, so it was removed from factor six, titled the Stakeholder Roadmap Development Structure construct, leaving two questions.

After separating the dependent variables into constructs using exploratory factor analysis, the dependent construct of Organizational Impact was analyzed using an identical approach. A

Table 13: Principle Components Analysis Factor 6 (Stakeholder Development Structure) Loadings

Stakeholder Roadmap Development Structure (experience) Questions	**Rotated Loading**
Did your organization have experience in developing/using organizational technology roadmaps prior to participation in the industry's technology roadmapping efforts?	0.611 (eliminated)
Do you have experience working directly in short-range technology development and application?	0.730
Do you have experience working directly in long-range technology development and research?	0.766

Table 14: Principle Components Analysis Organizational Impact Construct Loadings

Organizational Impact Questions – Did developing an industry technology roadmap affect your organization?	**Loading**
Improved your organization's technology planning.	0.854
Increased the pace (speed of change) of your organization's technology development.	0.855
Increased the number of collaborative technology-based activities (i.e. joint ventures, partnerships, etc.).	0.843
Improved the quality of collaborative technology-based activities (i.e. joint ventures, partnerships, etc.).	0.873
Fostered the development of new products/processes.	0.861
Stimulated the creation of new solutions to technical problems.	0.861
Learned what technology solutions will NOT work.	0.697
Helped identify technology gaps that will inhibit your organization's future development.	0.725

single factor, explaining 67.8% of the variance, emerged, with all questions loading at 0.600 or above. The eight questions relating to various organizational impacts and their loadings are shown in **Table 14**.

4.3 Reliability Analysis

After selection of items that loaded appropriately on each construct, a reliability analysis was conducted. Scales for constructs were developed by averaging the responses to the questions that loaded on each. The results are shown below in **Table 15**. Internal consistency was acceptable for all seven new constructs at above 0.700 (Churchill, 1979), very good for four of the seven at above 0.800, and excellent for the Organizational Impact construct at above 0.900. A description of the analyses conducted on these scales follows.

Table 15: Scale Reliability Analysis

Construct	**Number of Items**	**Cronbach's Alpha**
Stakeholder Dev. Processes	6	0.845
Organizational Motivation	6	0.888
Functional Industry Motivation	4	0.852
R&D Industry Motivation	3	0.836
Roadmap Characteristics	4	0.720
Stakeholder Dev. Structure	2	0.786
Organizational Impact	8	0.930

4.4 Linear Regression

Although the sample size was relatively small, the value to individual organizations in evaluating characteristics that correlate to a more impactful experience from participation in a roadmapping collective could be gleaned from a linear regression. A step-wise linear regression was conducted using Organizational Impact as the independent construct, the remaining six constructs as dependent variables, and a number of control variables, including: organizational size, public/private status, participant position, executive support, industry fragmentation, industry R&D expenditures as a percent of sales, industry/government lead of roadmapping, and industry coded as a dummy variable (ITR). Again, the main objective of conducting the linear regression was to determine if any variables impacted the level of benefit expressed by individual organizations from the roadmapping experience. **Table 16** displays data for the three models that resulted (N=53). A histogram of the standardized Organizational Impact showed the data to be normally distributed (SD=0.887). In addition, a plot of the standardized residuals versus the standardized predicted values for Organizational Impact showed the data to have good linearity, indicating that a linear approximation is appropriate. Autocorrelation was not indicated (Durban-Watson = 1.872).

Each Model was extremely significant overall ($p<0.001$). Model 3 explained over 59% of the variance in the Organizational Impact construct (Adjusted R^2=0.593), and included: Organizational Motivation ($p<0.001$); Executive Support ($p<0.001$); and Stakeholder Roadmap Development Structure (participant experience) at $p=0.026$. Organizational Size was the only excluded variable other than these three that showed significance when the first model was run ($p=0.037$) and had a negative beta value, that showed smaller organizations indicated greater impact from participation in the ITR. However, it became insignificant when the second model, which included Executive Support, was created.

Table 16: Organizational Impact Step-Wise Linear Regression Models

	B	**Std. β**	**t**	**Significance**	**F**	**R^2**	**Adjusted R^2**
Model 1				**0.000**	**37.833**	**0.426**	**0.415**
Constant	0.654		1.976	0.052			
ORGMOT	0.610	0.653	6.151	0.000			
Model 2				**0.000**	**33.895**	**0.576**	**0.559**
Constant	0.112		0.354	0.725			
ORGMOT	0.447	0.478	4.730	0.000			
EXECSUP	0.303	0.424	4.198	0.000			
Model 3				**0.000**	**26.292**	**0.617**	**0.593**
Constant	-0.516		-1.265	0.212			
ORGMOT	0.407	0.436	4.419	0.000			
EXECSUP	0.281	0.393	4.014	0.000			
PARTEXP	0.221	0.212	2.298	0.026			

This result shows an inverse correlation between Organizational Size and Executive Support. Functional Industry Motivation and R&D Industry Motivation showed the highest positive correlation (0.542) among the independent variables, indicating a positive relationship between the two constructs. These results are not surprising, given that these two constructs were originally proposed as a single Industry Motivation construct.

The linear regression was conducted again, using only the Organizational Motivation, Executive Support, and Stakeholder Roadmap Development Structure (experience) variables, creating the most parsimonious model possible to describe individual Organizational Impact, and minimizing missing data (N=75). Results of the model are shown below in **Table 17**. A histogram of the standardized Organizational Impact showed the data again to be normally distributed (SD=0.980). The plot of the standardized residuals versus the standardized predicted values for Organizational Impact again showed good linearity, as did the partial plots. Autocorrelation was not indicated (Durban-Watson=1.869).

Table 17: Linear Regression Model with Only Significant Variables

	B	**Std. β**	**t**	**Significance**	**F**	**R^2**	**Adjusted R^2**
Model 3				**0.000**	**46.883**	**0.665**	**0.660**
Constant	-0.518		-1.792	0.077			
ORGMOT	0.409	0.445	5.791	0.000			
EXECSUP	0.282	0.403	5.311	0.000			
DEVSTRUCT	0.217	0.231	3.167	0.002			

4.5 Linear Regression Discussion

The reduced linear regression model, which includes the independent constructs Organizational Motivation and Stakeholder Roadmap Development Structure (experience), and the control variable Executive Support, explains 66% of the variance in the Organizational Impact construct (Adjusted R^2=0.660). The equation for the reduced model is:

Organizational Impact = -0.518 + 0.409*(OM) + 0.282*(ES) + 0.217*(SS)

Where:
OM = Organizational Motivation
ES = Executive Support
SS = Stakeholder Structure (participant experience)

Since the beta values are positive, increased Organizational Motivation, Executive Support, and Stakeholder Roadmap Development Structure (participant experience) are positively correlated with Organizational Impact. This result provides support for **hypothesis 1a**:

H1a - Organizations with higher levels of Organizational Motivation to participate in the ITR collective will experience higher Organizational Impact from participation in the collective – Supported (*p*<0.001)

The results also show that both small and large organizations can benefit from participation in ITR development. Technology roadmapping at the organizational level for small and medium sized businesses (SMEs) has been reviewed positively by organizations in a study conducted by Ferril and Holmes (2005). Thirty-six SMEs in Singapore developed technology roadmaps, with over 80% of those stating that they had achieved their objectives from the exercise and 40% stating they would integrate technology roadmapping into their planning routine. The remaining 60% would use technology roadmapping on an ad-hoc basis as needs arose. 100% of the SMEs indicated they were more likely to use a structured technology planning approach after the roadmapping exercise. Results from my study indicate that this perceived benefit of organizational technology roadmapping can be extended to the collective industry roadmapping level. It makes sense in some respects that smaller organizations stand to benefit the most from an industry roadmapping effort.

A smaller organization likely has less abundance of resources to expend on technology research and development, and a guide (ITR) provided by their industry's technical experts should prove extremely helpful in focusing their expenditures and directions in technology and product development. The Hawthorne effect may apply here as well, as simply observing the current technology position of an organization through the roadmapping process, could bring about improvements. This result also provides support for the empirical study of the benefits for small organizations to participate in trade associations (Wilts and Meyer, 2005), another form of collective, and actually provides additional evidence to suggest that smaller organizations may actually benefit more than large organizations by participation in an industry collective, as top executives in smaller organizations are more likely to be aware of and directly support activities in which their employees are engaged. My study indicates that, with executive support, both large and small organizations experience similar impacts from industry roadmapping. A proposed model based on the reduced linear regression results is shown in **Figure 11**.

4.6 MANOVA – Updated Roadmaps vs. One-Time Roadmaps

Previous authors have indicated that industry roadmaps should be "living" documents to remain effective (Amer and Daim, 2009; Schaller, 2004). Thus, continuing roadmapping exercises should have greater impact at the collective level. Due to the relatively small data set, which included responses from only six ITRs, multiple analysis of variance (MANOVA) was next selected as an approach to analyze the data (Dilts and Pence, 2005) to evaluate what factors influence collective (aggregate) organizational impact. The six roadmaps were separated into two groups: 1) industries whose roadmap has been or is being updated (iNEMI and Forest Products), which should have greater impact on the collective, and 2) industries that developed a

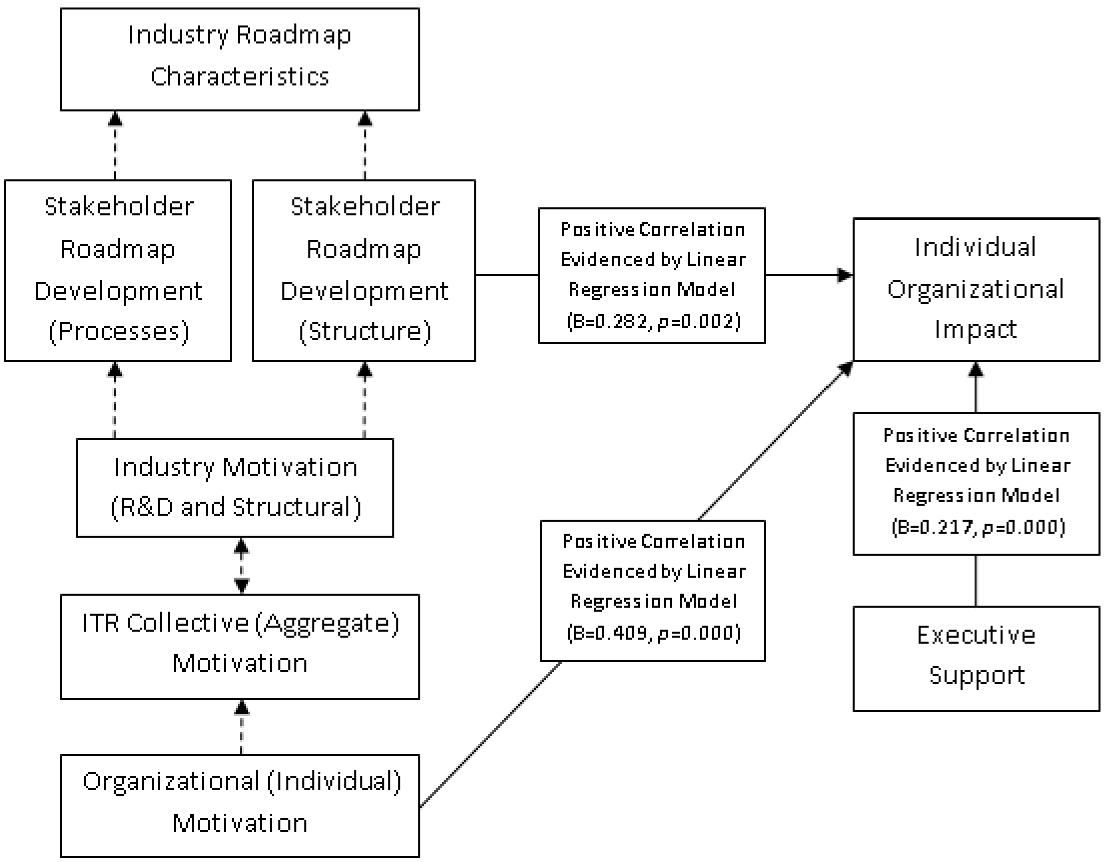

Figure 11: Proposed Linear Regression Model for Industry-Level Roadmapping

roadmap a single time (Concrete, Magnesium, Metal Casting, and Powder Metallurgy) – more than a decade ago in all four cases. Again, continuation of the roadmapping effort in this analysis served as a proxy for a higher level of collective organizational impact; therefore, the Organizational Impact construct was not utilized in this analysis. Another justification for separating the ITRs in this manner lies in the fact that the aggregated Organizational Impact values for the six roadmaps showed mean values below 2.5 for each of the four one-time roadmaps, and mean values above 2.5 for each of the two continuing efforts. The MANOVA test was conducted on these two groups using the six identified independent constructs and executive support, which was found through the multivariate regression analysis to be significant at the individual organization level.

Table 18 shows results from the MANOVA analysis on the seven items. The sample sizes were very similar, N=40 for the continued roadmaps and N=37 for the discontinued roadmaps, so homogeneity of variances is not a major concern. A second assumption when using MANOVA is similar standard deviations. The highest difference in standard deviation is for the R&D Industry Motivation construct, at only 31% difference. The lowest is the Roadmap Characteristics construct, at 3%. The final assumption when using MANOVA analysis is approximate normality of data. A Shapiro-Wilk normality test was conducted on the data set, with the results in **Table 19**.

A number of the independent constructs failed tests for normality. While this is a caution, MANOVA has been found to be robust to significant deviations from normality (O'Brien and Kaiser, 1985) without adversely affecting p-values or power of the statistical tests. In addition, with the relatively small sample size, the normality test proved highly sensitive to slight deviations from normality. Wilks' Lambda and Hotelling's Trace for the overall model were both significant at p=0.007. The significant constructs (p<0.05) and their associated observed power are Roadmap Characteristics (P=0.792) and Participant Experience (P=0.613).

Aggregate organizational motivation was found to be significant ($p<0.10$), with an observed power of P=0.423.

Table 18: Manova Results - Continued vs. One-Time Roadmaps

	Mean	Standard Deviation	Significance
Roadmap Development Processes Construct			**0.355**
Continued Roadmaps	3.55	0.843	
Discontinued Roadmaps	3.71	0.612	
Organizational Motivation Construct			**0.078***
Continued Roadmaps	3.31	0.981	
Discontinued Roadmaps	2.93	0.898	
Functional Industry Motivation Construct			**0.633**
Continued Roadmaps	3.26	1.017	
Discontinued Roadmaps	3.36	0.841	
R&D Industry Motivation Construct			**0.477**
Continued Roadmaps	2.98	1.165	
Discontinued Roadmaps	3.15	1.008	
Roadmap Characteristics Construct			**0.006*****
Continued Roadmaps	3.21	0.714	
Discontinued Roadmaps	2.76	0.688	
Roadmap Development Structure Construct			**0.026****
Continued Roadmaps	3.88	1.059	
Discontinued Roadmaps	3.36	0.948	
Executive Support			**0.963**
Continued Roadmaps	3.50	1.340	
Discontinued Roadmaps	3.51	1.193	

*$p<0.1$.
**$p<0.05$.
***$p<0.01$

Table 19: Normality Test Results

	Shapiro-Wilk Significance
Organizational Impact Construct	
Continued Roadmaps	0.478
Discontinued Roadmaps	0.153
Roadmap Development Processes Construct	
Continued Roadmaps	0.015**
Discontinued Roadmaps	0.063*
Organizational Motivation Construct	
Continued Roadmaps	0.407
Discontinued Roadmaps	0.007***
Functional Industry Motivation Construct	
Continued Roadmaps	0.244
Discontinued Roadmaps	0.022**
R&D Industry Motivation Construct	
Continued Roadmaps	0.015**
Discontinued Roadmaps	0.208
Roadmap Characteristics Construct	
Continued Roadmaps	0.430
Discontinued Roadmaps	0.069*
Roadmap Development Structure Construct	
Continued Roadmaps	0.007***
Discontinued Roadmaps	0.012**
Executive Support	
Continued Roadmaps	0.007***
Discontinued Roadmaps	0.012**

*$p<0.1$.
**$p<0.05$.
***$p<0.01$.

4.7 MANOVA Discussion – Updated Roadmaps vs. One-time Roadmaps

A proposed model based on the MANOVA results is shown in **Figure 12**. Roadmap Characteristics (p=0.006) and Stakeholder Roadmap Development Structure (p=0.026), which consisted of two items, both research and application experience of the participants, proved to be the most significant differences between roadmaps that have continued to be updated and those that have been completed as one-time exercises. The mean value was higher for the continued roadmaps in each case. These results have face validity. A more thorough and clearly defined ITR correlates with continuation of the roadmapping effort, and regular updates of the roadmap document. If an ITR is intended to develop technology plans for an industry, participants who are more experienced with researching and developing new products would be expected to create a more usable technology planning document. This conclusion is also supported from a theoretical standpoint put forward by the ITR literature (Schaller, 2004; deLaat, 2004; Kostoff and Schaller, 2001) and stakeholder theory, as those with the most to gain by participating in the collective, thus the most critical stakeholders (Jones, 1995), are those most involved in technology advancement in an industry.

Organizational Motivation was also significant (p=0.078). Higher levels of collective Organizational Motivation were exhibited by continued ITRs (mean=3.31) compared with one-time efforts (mean=2.93). The results for the Organizational Motivation construct provide support for **hypothesis 1b**:

H1b - Higher levels of overall (collective) Organizational Motivation correlate with higher levels of overall (collective) Organizational Impact – Supported (*p*=0.078).

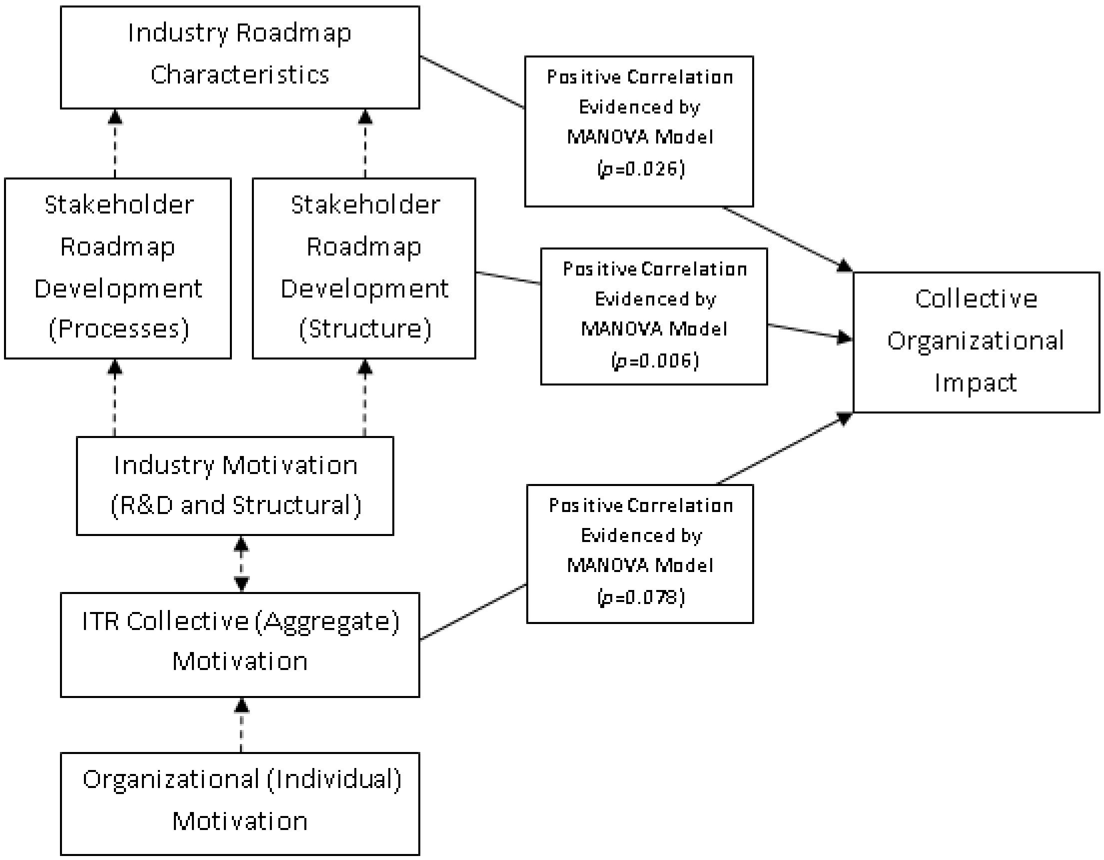

Figure 12: Proposed MANOVA Model for Industry-Level Roadmapping

Neither the R&D Industry Motivation nor the Functional Industry Motivation construct was found to be significant. The small sample size may contribute to a lack of sensitivity to a real difference, but the mean level of both constructs in this study was lower for continued roadmaps than for one-time roadmaps. While these results should be viewed tentatively because of the small number of roadmaps studied, they may indicate that perceived benefits to the industry as a whole do not drive continuation of roadmapping efforts, but rather the potential advantage that may be gained at the organizational level, as indicated by support for hypothesis 1a. Participation could also be driven partially by fear, as suggested in the collective action literature (Astley and Fombrun, 1983). If an organization is concerned about missing opportunities by a lack of participation in collective efforts that increase knowledge, and drive partnerships and technology development at higher clockspeeds (Schaller, 2004), they may be inclined to be involved to not get "left behind". Because industry motivation was not significant in this analysis or the multivariate regression, **hypothesis 1c** is not supported by the results of the study:

H1c - Higher levels of Industry Motivation correlate with higher levels of overall (collective) Organizational Impact – Not Supported.

The Stakeholder Roadmap Development Processes construct was not significant in any of the MANOVA analyses. Items making up the Roadmap Development construct focused on stakeholder-based processes for developing the roadmap. Again, the mean value for one-time roadmaps was higher than for continued. However, the Stakeholder Roadmap Development Structure, based on the responses of participants experience level, was significant (p=0.026), providing partial support for **hypothesis 2**:

H2 - An ITR collective that applies stakeholder principles in roadmap development will result in a greater overall (collective) Organizational Impact on organizations that participated in its creation – Partially Supported (Stakeholder Roadmap Development Structure p<0.05, Stakeholder Roadmap Development Structure not significant).

4.8 MANOVA – Clockspeed Differences

Next, a MANOVA was conducted by separating the six roadmapping collectives into groups by clockspeed. Unfortunately, only one roadmap, iNEMI, could be considered a fast clockspeed industry, while the other five are relatively slow clockspeed industries. This resulted in large sample size differences between the two, N=12 for high clockspeed and N=47 for low clockspeed, meaning that homogeneity of variances and correlations becomes paramount in order to ensure robustness of the method. The initial analysis was conducted on all constructs and the control variables. Results were significant ($p<0.100$) for only the variables shown in **Table 20**. Wilks' Lambda and Hotelling's Trace for the overall analysis were also significant ($p<0.001$).

A MANOVA was next run using only those variables found significant in the initial test. This test resulted in sample sizes of N=57 for slow clockspeed industries and N=17 for the iNEMI roadmapping collective. Only two of the constructs, shown in **Table 21**, remained significant in this reduced model, R&D Industry Motivation ($p<0.001$) and Participant Experience ($p<0.05$). Results using Box's Test of Equality of Covariance Matrices was insignificant at $p=0.443$, meaning the null hypothesis that they were equal across groups could not be disproven. Using Levene's Test of Equality of Variances, R&D Industry Motivation had a significance of $p=0.625$ and Stakeholder Roadmap Development Structure (experience) had a significance of $p=0.804$, meaning neither construct refuted the null hypothesis that error variance is equal across groups. Therefore, differences in sample sizes should not significantly impact robustness of the MANOVA test results. Wilks' Lambda and Hotelling's Trace for the overall analysis remained extremely significant (p<0.001).

Table 20: MANOVA Results - Fast vs. Slow Clockspeed Industries

	Mean	**Standard Deviation**	**Significance**
Organizational Impact Construct			**0.076***
iNEMI Roadmap	2.96	1.035	
Low Clockspeed Roadmaps	2.44	0.851	
Organizational Motivation Construct			**0.066***
iNEMI Roadmap	3.58	0.691	
Low Clockspeed Roadmaps	3.00	1.024	
R&D Industry Motivation Construct			**0.000******
iNEMI Roadmap	2.00	0.828	
Low Clockspeed Roadmaps	3.56	0.843	
Participant Experience Construct			**0.003*****
iNEMI Roadmap	4.38	0.678	
Low Clockspeed Roadmaps	3.56	0.832	
Organizational Type Control Variable			**0.055***
iNEMI Roadmap	2.67	1.614	
Low Clockspeed Roadmaps	4.06	2.326	

*p<0.1.
**p<0.05.
***p<0.01.
****p<0.001.

Table 21: MANOVA Results - Fast vs. Slow Clockspeed Industries Significant Variables (p<0.05)

	Mean	**Standard Deviation**	**Significance**
R&D Industry Motivation			**0.000********
iNEMI Roadmap	2.23	0.919	
Low Clockspeed Roadmaps	3.49	0.875	
Roadmap Development Structure			**0.014****
iNEMI Roadmap	4.21	0.902	
Low Clockspeed Roadmaps	3.60	0.863	

*p<0.1.
**p<0.05.
***p<0.01.
****p<0.001.

Since each of these two constructs was made up of such a small number of items - R&D Industry Motivation contained three and Stakeholder Roadmap Development Structure (experience) contained two - an analysis was conducted on the five individual items, to see if additional insight could be gained into differences between high and low clockspeed industries. The number of items was N=83 for slow clockspeed industries and N=23 for iNEMI. Abbreviations for each item were developed so more information could be included in the results table. Abbreviations are shown in **Table 22**. Results are shown below in **Table 23**.

Wilks' Lambda and Hotelling's Trace for the overall analysis remained significant (p<0.001). Box's Test was significant at p<0.001, meaning that covariance matrices were significantly different, so results of the item analysis should be considered with reservation. Levene's test for each item was insignificant. Both GOVFUND and GOVRES were extremely significant (p<0.001), with iNEMI ranking those items much lower in importance than the other ITRs. This was followed by a highly significant APPEXP at p=0.010, which the iNEMI participants rated higher, and moderately significant INDRES ($p<0.05$), which the iNEMI participants rated lower. RESEXP was not proven to be significantly different between the iNEMI ITR collective and the slow clockspeed ITRs.

Table 22: Fast vs. Slow Clockspeed Industries Individual Item Abbreviations

R&D Industry Motivation Questions – Please rate the industry's motivations for developing the industry technology roadmap:	**Abbreviated Title**
Increasing government funding for research related to the industry.	GOVFUND
Reprioritizing industry-funded research/development.	INDRES
Reprioritizing government-funded research/development related to the industry.	GOVRES
Stakeholder Roadmap Development Structure Questions	
Do you have experience working directly in short-range technology development and application?	APPEXP
Do you have experience working directly in long-range technology development and research?	RESEXP

Table 23: MANOVA Results - Fast vs. Slow Clockspeed Industries Individual Items

Item	Mean	Standard Deviation	Significance	Levene's Significance	Observed Power
GOVFUND			**0.000********	**0.744**	**1.000**
iNEMI	1.87	1.014			
Others	3.55	1.039			
INDRES			**0.020****	**0.424**	**0.646**
iNEMI	2.70	1.020			
Others	3.31	1.136			
GOVRES			**0.000********	**0.847**	**0.998**
iNEMI	2.04	1.065			
Others	3.28	1.086			
APPEXP			**0.010******	**0.307**	**0.745**
iNEMI	4.17	1.072			
Others	3.49	1.097			
RESEXP			**0.163**	**0.611**	**0.285**
iNEMI	3.91	1.125			
Others	3.55	1.074			

*p<0.1.
**p<0.05.
***p<0.01.
****p<0.001.

4.9 MANOVA Discussion – Clockspeed Differences

Based on the initial MANOVA analysis including all constructs and control variables, a difference in Organizational Impact was indicated (p=0.076), providing support for **hypotheses 3**:

Hypothesis 3: Organizations from high clockspeed industries will be more likely to experience a greater impact from developing an ITR than those from slow clockspeed industries – Supported (p<0.10).

A model combining the MANOVA results from section 4.7 with those from the clockspeed analysis is shown in **Figure 13**.

The MANOVA analysis of individual items showed extremely significant (p<0.001) differences in the industry motivations of obtaining government funding and prioritizing government research. The iNEMI participants rated each as less of a motivation for pursuing the roadmapping initiative. In addition, prioritizing industry research was also rated as less of a motivator to develop the ITR at a moderately significant level (p=0.020).

When the individual items were extracted for Stakeholder Roadmap Development Structure, long-term research experience became insignificant. However, short-term product development experience proved to be significant at p=0.010. Because the high clockspeed iNEMI industry's roadmap is updated annually, and significant roadmap objectives are achieved on a more short-term basis, the inclusion of participants possessing more extensive experience with short-term product development has face validity.

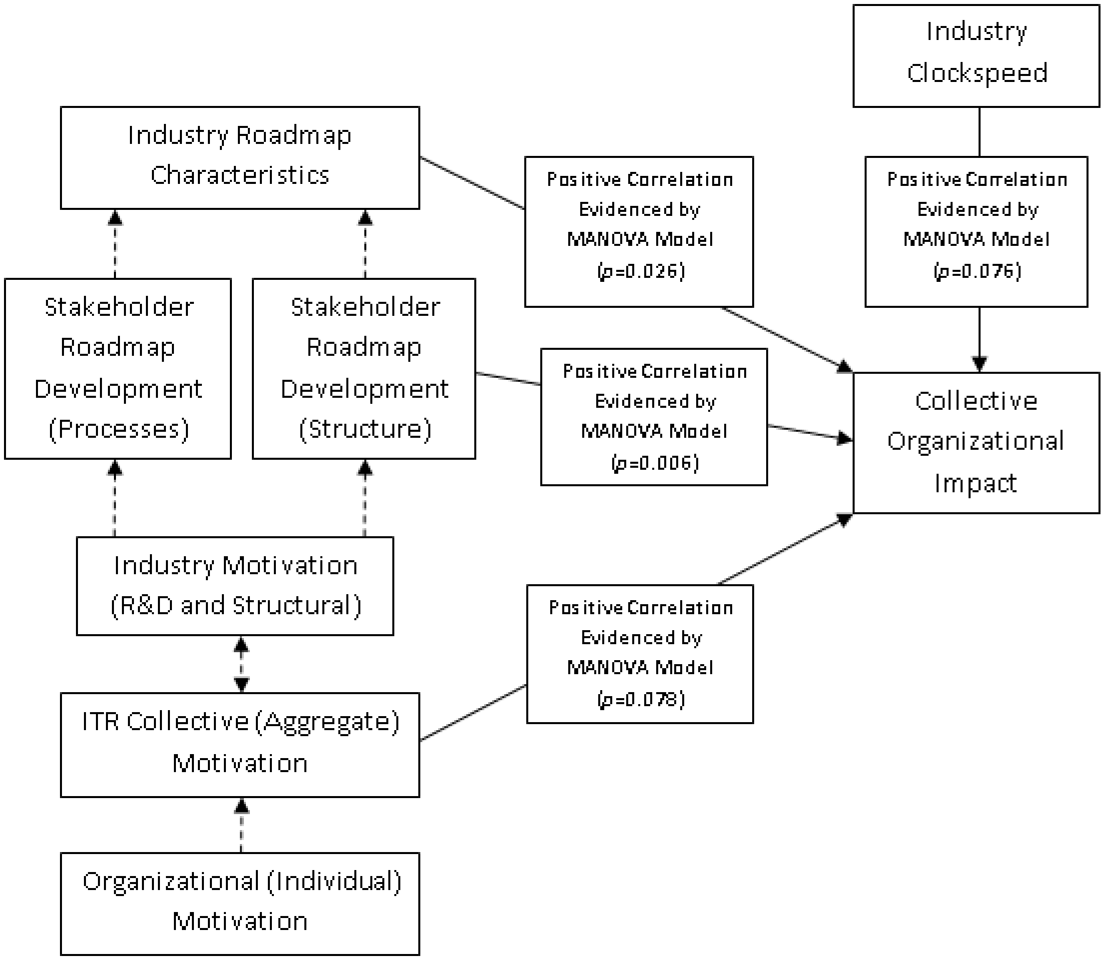

Figure 13: Proposed Combined MANOVA Model of Industry-Level Roadmapping

4.10 Short Answer Survey Responses

Six open-ended questions were asked of roadmapping participants. The six questions and the corresponding construct(s) potentially represented by each are listed below. Responses to each question were reviewed to find commonalities and differences between continued and one-time roadmapping efforts, and then categorized by applying pattern matching (Trochim, 2001). Answers that did not match any items within the construct were also grouped.

Open-Ended Questions:

1. Please provide the strongest, single example of how participation in developing the industry technology roadmap (positively or negatively) affected your organization's technology planning/implementation. – **Organizational Impact Construct**

2. Please provide the strongest, single example of how developing the industry technology roadmap (positively or negatively) affected your industry's technology planning/implementation. – **Industry Impact Constructs (Functional and R&D)**

3. Please provide the strongest, single example of how developing the industry technology roadmap (positively or negatively) affected the government's technology planning/implementation. – **R&D Industry Impact Construct**

4. Please describe the most positive attribute of the group that developed the roadmap. – **Collective Characteristics Construct**

5. Please describe the least positive attribute of the group that developed the roadmap. – **Collective Characteristics Construct**

6. Please give the strongest, single example of how the contents of the industry technology roadmap document (i.e. the roadmap itself) influenced your organization's technology planning/implementation. – **Roadmap Characteristics Construct**

Responses to each question were categorized, and counts by category tabulated for each ITR. Data was then analyzed using cross-case synthesis as describe by Yin (2003), separating the information into two groups – responses from continued roadmaps and responses from one-time roadmaps. As can be seen from the tables below when compared with overall survey response data in **Table 23**, open-ended questions responses rates ranged from a low of 47.7% for question six, to a high of 75.8% for question two.

Results for the ITR development's influence on organizations, was analyzed, and statements were arranged thematically (**Table 24**). Eight categories emerged, with the vast majority of responses falling into one of the top two, namely Technology Planning and

Partnering. Statements that fell into the organizational technology planning category include those such as, "The roadmapping helped us narrow the choices available in the production of new products and to assess the state of current technology and where we were relative to the competition." Another response was actually counted in the technology planning, partnerships, and networking categories, "Networking allowed business partnerships to form; roadmapping and gap analysis allowed projects to be identified." 53.1% of the responses from the continued roadmapping efforts fell in the technology planning category, while about half that (28.7%) of the responses from organizations representing one-time ITR development could be described as technology planning.

Partnering results between the two roadmapping categories followed a similar relationship. 14.3% of the continued efforts cited partnering, with statements such as, "helped define opportunities for my federal agency to work collaboratively with the forest products industry," while only 8.6% of responses from one-time roadmap representatives could be described as partnering. Interestingly, implementation of ITR ideas was cited more by one-time roadmap representatives (22.9%) when compared with continued ITRs (14.3%). For example, "I would have to say the single most important development would have to be the ability to increase the density of PM parts." The fact that continued roadmapping participant responses were more highly focused on technology planning and partnering as the most influential benefits from the ITR collective effort, while one-time ITR representatives cited specific implementations at almost the same level as technology planning benefits may provide some insight into what organizations in the collective expected or wanted to gain from their participation. Not surprisingly, one-time ITR participants also responded that their participation had no impact on their organization at a much higher rate (14.3%) than the continued ITRs (4.1%). Functional statements include things like, "president became aware that the roadmap exists."

Table 24: Open-Ended Question Summary - Organizational Impact of ITR Development

Response Category	Concrete	Magnesium	Metal Casting	Powder Metallurgy	Forest Products	iNEMI
Total Count	10	7	10	8	27	22
Technology Planning	3	2	5	0	14	12
Partnering	0	1	0	2	4	3
Neutral Response	1	1	1	2	3	1
Implementation	3	2	1	2	0	1
No Impact	2	0	1	2	2	0
Networking	0	0	1	0	1	3
Functional	1	1	1	0	0	2
Funding/Grants	0	0	0	0	3	0

The second question involved the impact of developing an ITR on the entire industry (**Table 25**). Again, technology planning responses dominated, particularly with continued efforts (42%) as contrasted with one-time ITRs (23.4%). Statements included, "the concept of technology and business roadblocks hadn't been previously addressed," and a statement that also fell into the urgency category, "created a sense of urgency – reinforced the need for change." Implementation comments were again more predominant from the one one-time ITR respondents (23.4%) as opposed to those from continued efforts (14%), "moving into casting chassis and suspension components in HPDC (HyperCast)." Examples of other categories of statements include: (partnering) "fostered teamwork with several other roadmap participants;" (government funding) "the roadmap helped to develop programs for subsequent government funding;" and (gov/ind alignment and lobbying) "brought about alignment with government agencies and industry initiatives."

Table 25: Open-Ended Question Summary - Industry Impact of ITR Development

Response Category	Concrete	Magnesium	Metal Casting	Powder Metallurgy	Forest Products	iNEMI
Total Count	11	8	17	11	33	17
Technology Planning	2	1	5	3	15	6
Implementation	2	2	5	2	5	2
Neutral Response	3	0	2	3	3	7
No Impact	2	3	3	2	3	1
Partnering	0	1	1	1	2	0
Networking	1	0	0	0	2	1
Created Urgency	1	0	1	0	0	0
Government Funding	0	1	0	0	1	0
Gov/Ind Alignment and Lobbying	0	0	0	0	2	0

The most common response when asked what influence development of the roadmap had on the government's technology planning/implementation, representatives from both continued (23.1%) and one-time (36.6%) ITRs responded that it had no impact (**Table 26**). This was followed by technology planning, "it affected and still affects our research planning" and "helps government agencies understand and adjust programs to meet needs of industry." Neutral responses included statements like, “too early.” Funding was cited by a few respondents, “the roadmap helped to develop programs for subsequent government funding” and “DOE partially funded our roadmapping exercise.”

Table 26: Open-Ended Question Summary - Government Impact of ITR Development

Response Category	Concrete	Magnesium	Metal Casting	Powder Metallurgy	Forest Products	iNEMI
Total Count	12	5	14	10	24	15
No Impact	2	1	5	7	4	5
Technology Planning	5	1	3	1	9	1
Neutral Response	2	0	5	2	5	8
Funding	0	1	0	0	2	1
Implementation	1	2	0	0	0	0
Partnering	1	0	1	0	1	0
Lobbying	0	0	0	0	2	0
Networking	0	0	0	0	1	0
Urgency	1	0	0	0	0	0

Breadth of expertise in the ITR collective was cited as the most positive attribute of the collective (**Table 27**) by over half (53.5% and 52.9%) of the respondents for each of the two continued roadmapping initiatives, while the highest response rate citing breadth of expertise in one-time ITR collectives was for the Powder Metallurgy industry (30%). The average across all four ITRs was 18.4%. Typical statements include “broad spectrum of contributors” and “extensively cross-functional team of open-minded “comrads” who enjoy working together”.

This higher emphasis on technical expertise matches the quantitative results, indicating the importance of the level of participant experience in a successful roadmapping effort. Openness/Cooperation was cited at slightly higher levels by the one-time efforts (40.5% versus 32.6%). "Very open discussions" and ""'willingness to be inclusive" are examples from this category. Innovativeness/Boldness was much more frequently mentioned as strengths of the collective in one-time efforts (27.0% versus 7.0%), with statements such as "willing to listen and consider new ideas and approaches". Again, results of the qualitative analysis from this question seem to align with the quantitative findings that participant experience was a significant factor when comparing continued with one-time roadmapping initiatives.

Table 27: Open-Ended Question Summary - Positive Characteristics of ITR Collective

Response Category	Concrete	Magnesium	Metal Casting	Powder Metallurgy	Forest Products	iNEMI
Total Count	11	6	11	10	26	17
Breadth	2	1	1	3	14	9
Openness/ Cooperation	5	3	4	3	8	6
Innovativeness/ Boldness	4	2	2	2	3	0
No Positives	0	0	2	0	1	0
Depth	0	0	1	0	0	1
Networking	0	0	1	0	0	1
Industry Based	0	0	0	1	0	0
Learning	0	0	0	1	0	0

Issues related to participation were most often indicated, when asked about the least positive attribute of the ITR collective (**Table 28**), such as: "lack of participation from other technical/industrial sectors not directly related to the prime industry" and "all groups struggle to gain representative membership." This result was more prevalent with continued ITRs (33.3%) than of one-time collectives (15.6%). The second most frequent response category was "none," followed by innovativeness/boldness, with statements like "thinking was not sufficiently bold and ambitious in identifying R&D opportunities" and "parochial."

Interestingly, the iNEMI ITR respondents didn't make any statements related to the innovativeness/boldness category. Perhaps the high clockspeed and regular development cycle related to Moore's Law plays into that result by requiring innovativeness to be competitive in such a fast-changing industry. Personal agendas were cited, "some were clearly interested in advocating for their opinion and seemed narrowly focused." Contributions/dominance was cited most frequently after personal agendas, "lack of quality and quantitative contributions," followed by commitment/follow-up, "zero commitment for after roadmap participation from any technical representative's sponsor for follow-up on any of the gaps shown in the roadmap in a collaborative manner."

Links to R&D entities outside the industry was cited next most often (industry driven), "not sufficiently linked to the potential research community that can contribute," and "not enough active government participation." Lack of structure was mentioned by a few respondents, "loose affiliation" and "more thought could have gone into the process – there seemed to be a little too much "winging it" in the meetings." Lack of participation from influencers was cited by three forest products ITR respondents, "few decision makers involved."

Lack of knowledge of overseas markets was mentioned by one powder metallurgy respondent, and one respondent had this to say about the powder metallurgy collective, "everyone seemed to regret the wasted time and effort and doubtful the process can be repeated after this spent effort."

Table 28: Open-Ended Question Summary - Negative Characteristics of ITR Collective

Response Category	Concrete	Magnesium	Metal Casting	Powder Metallurgy	Forest Products	iNEMI
Total Count	12	4	10	6	20	16
Participation	2	0	3	0	5	7
None	2	1	2	3	1	2
Innovativeness/ Boldness	2	0	1	1	7	0
Personal Agendas	3	0	0	0	3	1
Contributions/ Dominance	1	0	1	0	0	3
Commitment/ Follow-Up	1	2	1	1	0	0
Industry Driven	0	1	2	0	1	0
Structure	1	0	0	0	0	2
Lack of Influencers	0	0	0	0	3	0
International Knowledge	0	0	0	0	0	1
Wasted Time	0	0	0	1	0	0

In summary, breadth of participants was described by respondents as the most positive attribute of the ITR collective, and the ability of those organizational representatives to all participate on a regular basis was cited as the least positive attribute of the collective. Again, the breadth of technical knowledge (participant experience) exhibited by those developing the roadmap seems to correlate quantitatively and qualitatively with organizational impact and roadmap performance.

When asked about the influence on the ITR document on their organizations (**Table 29**), the majority, particularly in continued roadmaps (50.0%) as opposed to one-time efforts (24.1%), cited its impact on their technology planning. "Identified an important development opportunity," "targets for the industry for our kind of product have been directly used in our internal roadmaps," and "increased focus on "new to the world" product development" are examples. Since a technology roadmap's primary function is to focus strategic planning for an industry, it is not surprising that twice as many respondents from continued roadmaps cited technology planning when compared to respondents from one-time technology roadmapping exercises. Respondents (25.0% for continued and 34.5% for one-time ITRs) said the ITR document itself had no impact on their organization, providing support for theoretical conclusions by Kostoff and Schaller (2001) and a case study of the ITRS by Schaller (2004), that perhaps the greater value is in "roadmapping" as opposed to the roadmap.

Similar to the results from previous open-ended questions, Implementation of new technologies was cited more frequently as an organization impact by one-time roadmap representatives (17.2%) than continued ITR respondents (3.1%), with statements such as, "permanent magnet research program started with powder emphasis." Neutral comments like "simply confirmed what was already known" were made by a few respondents, followed by

Government Grants resulting from the ITR document contents. Partnering was mentioned by a few respondents in the powder metallurgy industry, for example, “collaboration with other parties for development of new technologies.” Knowledge creation and proliferation was also mentioned by respondents, stating “it simply broadened our knowledge” and “we took a more visionary position – wrote articles to provide education on vision.” In summary, the ITR itself seemed to have less impact on organizations than the roadmap’s development, with impact on technology planning more prevalent in organizations from ITR collectives that continued their roadmapping efforts beyond development of a first generation roadmap.

Table 29: Open-Ended Question Summary - Organizational Impact of ITR Document

Response Category	Concrete	Magnesium	Metal Casting	Powder Metallurgy	Forest Products	iNEMI
Total Count	9	5	8	7	19	13
Technology Planning	3	2	2	0	6	10
No Impact	2	2	4	2	5	3
Implementation	3	0	1	1	1	0
Neutral	1	0	1	1	1	0
Government Grants	0	0	0	0	3	0
Partnering	0	0	0	3	0	0
Knowledge	0	0	0	0	2	0
Increased Personal Influence	0	1	0	0	0	0
Knowledge	0	0	0	0	1	0

4.11 Summary Discussion of Results

Quantitative analyses and qualitative analysis seem to converge on similar organizational and collective impacts from roadmapping efforts. Organizational motivation, both individual and aggregate, correlates with the impacts of ITR collective efforts on organizations and the collective. At the individual organizational level, executive support for participating in the roadmapping effort correlates with higher organizational impact. Executive support was reported as a nearly identical mean for continued and on-time roadmaps, so no significant difference was shown. In addition, Roadmap Development Structure (participant experience) is correlated with organizational impact from participation in the ITR collective, based on the linear regression. Roadmap Development Structure (aggregate experience) is also correlated with a roadmap's continuation. These results support stakeholder theory by indicating that "identifying the stakeholders who matter most" can be best accomplished by locating organizational participants who have the greatest experience with both research and development activities, which in turn leads to a more impactful roadmapping effort. Finally, organizational representatives from the two continued roadmapping efforts rated the roadmap itself as a significantly higher level than those from one-time efforts. Based on the combined results of the quantitative and qualitative analyses, a revised model is proposed (**Figure 14**).

With regard to the differences between fast and slow clockspeed industries, although the sample was small, with only one fast clockspeed industry, results indicate that while individual organizations from slow clockspeed industries can benefit at similar levels from development of an ITR, collective impacts may be greater for fast clockspeed industries. Participants from the fast clockspeed industry (iNEMI) had more experience with short-term product development and rely less on the ITR having influence on government R&D funding, possibly due to the rapid pace of change and innovation in the industry.

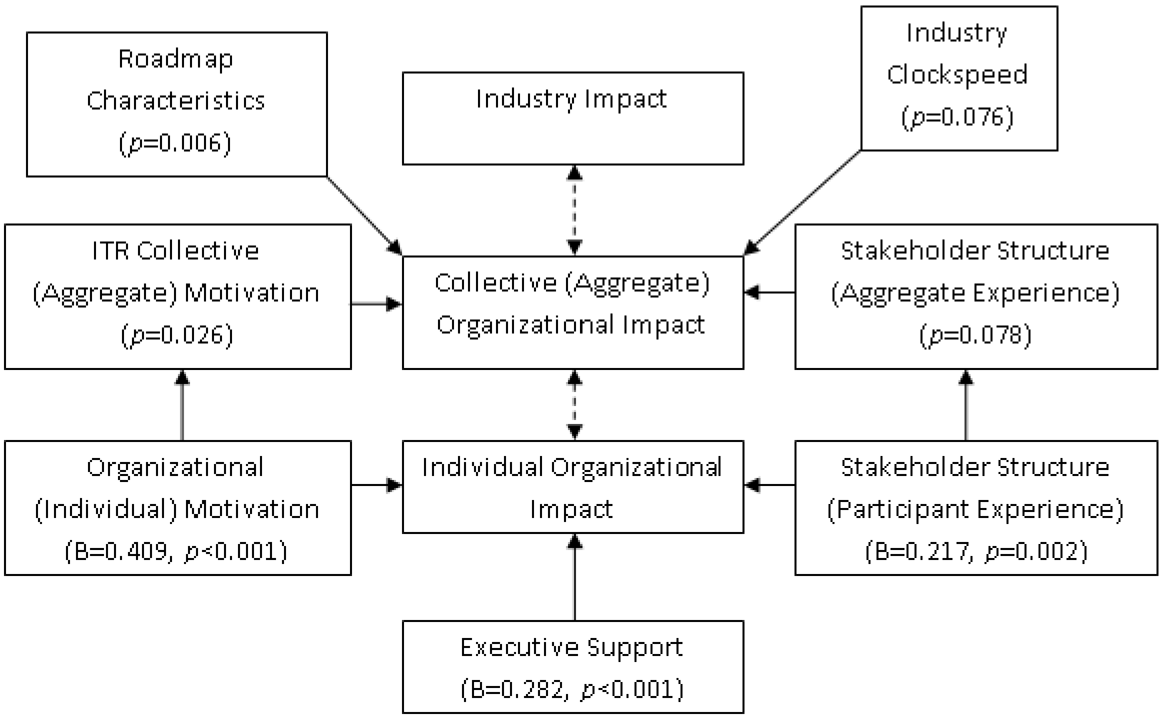

Figure 14: Revised Model of Industry-Level Roadmapping

CHAPTER V

CONCLUSIONS

5.1 Theoretical Implications

Theoretical contributions of this research may have a significant impact on future collective roadmapping efforts. On a broad front, this is the first quantitative research to apply a stakeholder perspective to study the industry collective. Stakeholder Roadmap Development Processes had nearly identical means between continued and one-time roadmaps, but a significant difference (p=0.78) did exist between the two groups for the Stakeholder Roadmap Development Structure (participant experience) construct. Involvement of a breadth of stakeholders with the appropriate experience did seem to correlate with the impact of ITR development efforts, so, from a structural prospective, stakeholder theory is supported within limits. This is the first time collective and stakeholder perspectives have been explicitly merged. In addition, it is the first quantitative test of a model of the stakeholder theory in an industry sector setting. It is expected that this work will lead to further studies and refinement of the stakeholder approach in the inter-organizational domain.

Second, a number of reliable constructs for evaluating industry technology roadmapping efforts were developed. Formally defining these constructs for the industry collective is a step in leading to more detailed studies of ITR collective efforts and possibly for industry collectives in general. It provides a clearer understanding of the connections among these constructs in the inter-organizational environment.

Third, this research indicated that the fast clockspeed industry (iNEMI) impacted participating organizations at a higher level than slow clockspeed industries. In addition, the iNEMI roadmap participants had higher short-term product development expertise than their counterparts in slow clockspeed industries, and they were less concerned about their roadmapping effort impacting government research and development activities.

Finally, an empirically validated theoretical model was developed describing important aspects in the performance of ITR collectives. This model serves as a foundational building block for future empirical studies involving industry roadmap development. Through additional work by researchers, the model can be refined, and a deeper understanding of stakeholder theory applied to the inter-organizational domain should result. The model is also a first step in the examination of contributors to an industry collective, specifically ITR collectives, impacting participating organizations. Characteristics of motivation, stakeholder management principles, and industry roadmap characteristics, were evaluated for correlations with individual and collective organizational impacts. An example of how the model may be further investigated in the future is in looking at specific methods to *achieve* the characteristics of each of the constructs that relate to high performance. This refinement will be important to researchers as they attempt to obtain a more in-depth instantiation of the contributors to high performance in inter-organizational activities, and will also become critical to practitioners, as the knowledge passes from academia to society in general.

5.2 Practical Implications

From a practitioner's perspective, the benefits of results from this research have several implications. First, a method for consistently measuring the organizational impacts of all technology roadmapping efforts provides leaders and participants in ITR collectives with a way to evaluate their effectiveness. In addition, it will also allow them to benchmark the impacts their roadmapping efforts against those of other industries or from the same industry in a "competing" country.

Second, having reliable results for measures impacting the performance of an industry collective should allow practitioners to modify their practices to improve performance. Identifying and recruiting organizational participants with the highest amount of R&D experience, and ensuring participating organizations are highly motivated to create an industry roadmap, are critical steps to produce a roadmap with appropriate detail, to achieve the greatest impact on organizations that develop the roadmap, and improve its likelihood of continued updates of the roadmap. Using this information, governments can make better decisions about the use of taxpayer money in stimulating the formation of roadmapping committees and other collectives to improve their countries. Improved effectiveness of industry roadmapping collectives should result.

From the organizational perspective, results from this study provide companies with insight into how and whether to participate in a collective. Before joining a collective effort, companies can review the collective's attributes and their own organizational situation using the model as guidance, and determine if it is a collective destined to be a continuing effort or doomed to one-time status. Results show that the motivation level of an organization for participating in an ITR collective has the greatest influence on the impact an organization feels from participation. So, if it is not a high priority for both the individual organization and the others involved, an organization should probably consider staying on the sidelines and not participating. While this may seem obvious in theory, it is not the common practice, based on this research. Organizations may be participating because it is "the thing to do" rather than expecting ITR development to actually impact their organization.

Executive support is also significantly correlated with organizational impact. If top management in an organization does not view an industry technology roadmapping effort as a priority, then the impact on that organization from participating may be minimized. The person who represents an organization in an ITR collective should be among the most knowledgeable employees.

This research shows significant correlation between the extent of the representative's experience with technology R&D, and the impact on that organization from participating. The study suggests that organizations send the most broadly and deeply experienced technology professional(s) possible to represent their organization on the ITR collective.

5.3 Limitations and Suggestions for Future Research

The small sample size is the most significant limitation on this research. With only six ITR collectives and 128 total respondents, some of the constructs that were not shown to have statistically significant correlation with organizational impact may, in fact, be significant. In addition, only one fast clockspeed industry (iNEMI) was studied.

A larger study of industry roadmapping participants is necessary to detect whether these constructs are indeed relevant to a successful ITR collective effort. A multi-level analysis (Courgeau, 1999), would be ideal for this setting, with organizational factors representing one level and collective characteristics the second. Future research opportunities include analyses of specific relationships in the initially proposed model, and further evaluation and refinement of the constructs.

Another limitation caused by the small sample size is that although there may be interactions among level and type of motivation and among breadth of organization type and participant position within their organization, the interactions cannot be reliably tested. There may only be one respondent in some categories (i.e. marketing professional working for an industry supplier). Future studies may explore this interactive relationship by studying a small number of larger collectives using a case-based approach, where the sample sizes may be large enough to perform valid analyses of the interactions.

Several connections in the revised model (**Figure 14**) were not explicitly tested, such as proposed relationships between Motivation and Stakeholder Roadmap Development (processes and structure) or that between Stakeholder Roadmap Development and Industry Roadmap Characteristics. Confirming these relationship will be necessary in order for the model to be fleshed out in greater detail, and is an opportunity for future research.

An additional area for future research is studying the relationship between individual organizational clockspeed and impacts on each organization from participation in the roadmapping process. Does the connection between clockspeed and impacts shown at the industry level in this study also hold true at the individual organization level?

Another question is whether these results hold true for ITRs in other nations. This would require an international sampling of roadmapping initiatives, but would provide further evaluation of the model.

Finally, another offshoot of this research, would be to compare the performance of organizations that incorporate long-term planning, like an industry technology roadmap, to those that primarily focus on short-term results, like stock price or quarterly profits.

APPENDIX A - SURVEY INSTRUMENT

1. Overall Effects of Industry Technology Roadmap Development and General Information

1. Participation in the development of an industry technology roadmap affected my organization.

unknown not at all somewhat moderately significantly extensively

2. Development of an industry technology roadmap affected my industry.

unknown not at all somewhat moderately significantly extensively

3. Your organization can best be described as a (examples provided for semiconductor industry roadmap):

4. Your organization is:

public (government run, traded on stock market) private

5. Number of employees in your organization:

1-10 11-50 51-100 101-500 501-1000 >1000

6. Your position within your organization can best be described as:

executive (CEO/VP) technical marketing project manager Other (please specify)

7. Your organization financially supported your participation in the technology roadmapping initiative (i.e. travel costs, etc.).

not at all somewhat moderately significantly extensively

8. Your organization supported your participation in the technology roadmapping initiative on company time.

not at all somewhat moderately significantly extensively

9. Your organization will participate in future industry technology roadmap development efforts.

not at all somewhat moderately significantly extensively

10. Indicate your participation in the industry technology roadmap development (please check all that apply).

- participated in only one meeting
- participated in less than half of all meetings
- participated in nearly all meetings
- participated in all meetings
- led a technology working group or subcommittee
- served on the overall leadership team

11. Top executives (CEO/VP) in my organization supported development of the industry technology roadmap.

unknown not at all somewhat moderately
significantly extensively

12. Top executives (CEO/VP) in my organization participated directly in development of the industry technology roadmap.

unknown not at all somewhat moderately
significantly extensively

13. Indicate your organization's participation in developing the industry technology roadmap (please check all that apply).

- participated in only one meeting
- participated in less than half of all meetings
- participated in nearly all meetings
- participated in all meetings
- led a technology working group(s) or subcommittee(s)
- served on the overall leadership team

14. Are you willing to be contacted to elaborate on your survey responses?

- yes
- no

2. Contact Information

1. Please enter your preferred contact information:

Name:
Title:
Phone/e-mail:

2. If contacted by phone, please check preferred times to be called (choose all that apply):

	Early Morning	Late Morning	Early Afternoon	Later Afternoon	Evening
Monday					
Tuesday					
Wednesday					
Thursday					
Friday					

3. If contacted by phone, please check timezone:

Pacific
Mountain
Central
Eastern

3. Organizational Effects of Developing an Industry Technology Roadmap: Did developing an industry technology roadmap affect your organization?

1. Improved your organization's technology planning:

unknown ◯ no effect ◯ slight effect ◯ moderate effect ◯
significant effect ◯ great effect ◯

2. Increased the pace (speed of change) of your organization's technology development:

unknown ◯ no effect ◯ slight effect ◯ moderate effect ◯
significant effect ◯ great effect ◯

3. Increased the number of collaborative technology-based activities (i.e. joint ventures, partnerships, etc.):

unknown ◯ no effect ◯ slight effect ◯ moderate effect ◯
significant effect ◯ great effect ◯

4. Improved the quality of collaborative technology-based activities (i.e. joint ventures, consortia, industry/academic partnerships, etc.):

unknown ◯ no effect ◯ slight effect ◯ moderate effect ◯
significant effect ◯ great effect ◯

5. Fostered the development of new products/processes:

unknown ◯ no effect ◯ slight effect ◯ moderate effect ◯
significant effect ◯ great effect ◯

6. Stimulated the creation of new solutions to technical problems:

unknown ◯ no effect ◯ slight effect ◯ moderate effect ◯
significant effect ◯ great effect ◯

7. Learned what technology solutions will NOT work:

unknown ◯ no effect ◯ slight effect ◯ moderate effect ◯
significant effect ◯ great effect ◯

8. Helped identify technology gaps that will inhibit your organization's future development:

unknown ◯ no effect ◯ slight effect ◯ moderate effect ◯
significant effect ◯ great effect ◯

9. Please provide the strongest, single example of how participation in developing the industry technology roadmap (positively or negatively) affected your organization's technology planning/implementation.

4. Industry/Government Effects of Developing an Industry Technology Roadmap: Did developing an industry technology roadmap affect your entire industry?

1. Please provide the strongest, single example of how developing the industry technology roadmap (positively or negatively) affected your industry's technology planning/implementation.

2. Please provide the strongest, single example of how developing the industry technology roadmap (positively or negatively) affected the government's technology planning/implementation.

5. Roadmapping Group Characteristics: Please rate the characteristics of the group that developed the industry technology roadmap.

1. Which group funded development of the industry technology roadmap?

unknown not at all somewhat moderately significantly extensively

2. Which group led development of the industry technology roadmap?

3. Did the technology roadmap leadership (core group) develop a skeletal framework (i.e. identify major technical areas to be addressed) of the technology roadmap prior to the entire group's efforts?

not at all somewhat moderate significant extensive

4. Was there a sense of urgency within the industry for developing the industry technology roadmap?

not at all somewhat moderate significant extensive

5. How open were the group's discussions when developing/revising the industry technology roadmap?

not at all somewhat moderately significantly extensively

6. Was a consensus decision-making process used when developing/revising the industry technology roadmap?

not at all somewhat moderately significantly extensively

7. Were dissenting opinions from organizational participants welcomed when developing/revising the industry technology roadmap?

not at all somewhat moderately significantly extensively

8. Did your organization have experience in developing/using organizational technology roadmaps prior to participation in the industry's technology roadmapping efforts?

not at all somewhat moderate significant extensive

9. Do you have experience working directly in short-range technology development and application?

not at all somewhat moderate significant extensive

10. Do you have experience working directly in long-range technology development and research?
not at all somewhat moderate significant
extensive

11. Did the roadmap development group include a breadth of participation from various industry segments (i.e. suppliers, producers, customers, government agencies, academics/non-profits, etc.)?
not at all somewhat moderate significant
extensive

12. Did the roadmap development group include technical experts from multiple industry segments (i.e. suppliers, producers, customers, government agencies, academics/non-profits, etc.)?
not at all somewhat moderate significant
extensive

13. Please rate the industry's motivations for developing the industry technology roadmap:
Increasing government funding for research related the industry
not at all somewhat moderate significant
extensive

Reprioritizing industry funded research/development
not at all somewhat moderate significant
extensive

Reprioritizing government-funded research/development related to the industry
not at all somewhat moderate significant
extensive

Identifying technology gaps in the industry
not at all somewhat moderate significant
extensive

Increasing the pace of technology development/innovation in the industry
not at all somewhat moderate significant
extensive

Creating a shared technology vision for the industry
not at all somewhat moderate significant
extensive

Ensuring the industry's survival
not at all somewhat moderate significant
extensive

Enhancing technological learning for the industry
not at all somewhat moderate significant
extensive

Increasing the number of collaborative technology-based activities in the industry
not at all somewhat moderate significant
extensive

Increasing the quality of collaborative technology-based activities in the industry
not at all somewhat moderate significant
extensive

14. Please rate your organization's motivations for participating in development of the industry technology roadmap:

Contributing to the industry
not at all somewhat moderate significant
extensive

Reprioritizing research/development projects in my organization
not at all somewhat moderate significant
extensive

Identifying technology gaps in my organization
not at all somewhat moderate significant
extensive

Increasing the pace of technology development/innovation in my organization
not at all somewhat moderate significant
extensive

Ensuring the organization's survival
not at all somewhat moderate significant
extensive

Enhancing technological learning for my organization
not at all somewhat moderate significant
extensive

Increasing the number of collaborative technology-based activities for my organization
not at all somewhat moderate significant
extensive

Increasing the quality of collaborative technology-based activities for my organization
not at all somewhat moderate significant
extensive

15. Technology development in your industry is:
not important somewhat important important
very important extremely important critical

16. Technology development in your organization is:
not important somewhat important important
very important extremely important critical

17. Please describe the most positive attribute of the group that developed the roadmap.

18. Please describe the least positive attribute of the group that developed the roadmap.

6. Technology Roadmap Characteristics: Please rate the following characteristics of the industry technology roadmap.

1. The roadmap document has specific/measurable goals.

not at all somewhat moderate significant
extensive

2. The roadmap document includes dissenting opinions of participating organizations.

not at all somewhat moderate significant
extensive

3. The roadmap document is revisited/updated adequately (i.e. time between revisions).

not at all somewhat moderate significant
extensive

4. The roadmap document covered the complete range of industry segments where technology development is important.

not at all somewhat moderate significant
extensive

5. The roadmap document provided details for each technical area addressed.

not at all somewhat moderate significant
extensive

6. The timeline of the roadmap document was appropriate (i.e. number of years in the future addressed).

extremely short short about right long
extremely long

7. Please give the strongest, single example of how the contents of the industry technology roadmap document (i.e. the roadmap itself) influenced your organization's technology planning/implementation.

7. Thank you for participating in the survey.

Results of this research will be provided in aggregate form to all survey participants who provide an email address. If you provide contact information on this page only, you will not be contacted for any other reasons.

1. e-mail address:

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