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ROADMAPPING: A DECISION-AID FOR EFFECTIVE DoD STRATEGY DEVELOPMENT, STRATEGIC COMMUNICATIONS, AND PRODUCT DEVELOPMENT IMPROVEMENTS, OR JUST ANOTHER TIME-CONSUMING PROCESS FOR DoD PROFESSIONALS?

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Roadmapping is a popular business process offering many benefits. Roadmapping has proven to increase organizational efficiencies, produce greater returns on investment, and sharpen strategic foci. It does so by connecting organizations, strategies, processes, and deliverables with a singular timeline to ensure accountability and stakeholder awareness. This process gives leaders the opportunity to set their organization's course toward a successful future, while effectively sharing that journey with both the organization and stakeholders. However, poorly planned and improperly executed roadmaps abound. Their pitfalls slow business progress. In fact, failures have caused some organizations to refrain from using them. In short, this project explores whether roadmapping is a decision aid for effective Department of Defense (DoD) strategy development and a catalyst for product development improvements or whether it is another time-consuming process for DoD acquisition professionals. This project provides recommendations on how to successfully conduct roadmapping and examines why some organizations excel at roadmapping when others fail.

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ABSTRACT

Roadmapping is a popular business process offering many benefits. Roadmapping has proven to increase organizational efficiencies, produce greater returns on investment, and sharpen strategic foci. It does so by connecting organizations, strategies, processes, and deliverables with a singular timeline to ensure accountability and stakeholder awareness.This process gives leaders the opportunity to set their organization's course toward a successful future, while effectively sharing that journey with both the organization and stakeholders. However, poorly planned and improperly executed roadmaps abound. Their pitfalls slow business progress. In fact, failures have caused some organizations to refrain from using them. In short, this project explores whether roadmapping is a decision aid for effective Department of Defense (DoD) strategy development and a catalyst for product development improvements or whether it is another time-consuming process for DoD acquisition professionals. This project provides recommendations on how to successfully conduct roadmapping and examines why some organizations excel at roadmapping when others fail.

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TABLE OF CONTENTS

LIST OF FIGURES

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LIST OF TABLES

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LIST OF ACRONYMS AND ABBREVIATIONS

5G	5th Generation Mobile Network
5G-PPP	5th Generation Mobile Network – Private-Public Partnership
CEO	Chief Executive Officer
CMOS	Complementary Metal Oxide Semiconductor
COA	Course of Action
COP	Common Operating Picture
DAU	Defense Acquisition University
DOE	Department of Energy
DoD	Department of Defense
EIRMA	European Industrial Research Management Association
EU	European Union
FIFA	Federation Internationale de Football Association
GAO	Government Accountability Office
GE	General Electric
IC	Integrated Circuit
IEEE	Institute of Electrical and Electronics Engineers
IMT-2020	International Mobile Telecommunications Standard - 2020
IPT	Integrated Product Team
ITU	International Telecommunications Union
ITRS	International Technology Roadmap for Semiconductors
kHz	kiloHertz; 1000 Hertz
LAN	Local Area Network
LED	Light-Emitting Diode
MBA	Master of Business Administration
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NFV	Network Function Virtualization
ONF	Open Network Foundation
ONR	Office of Naval Research
PM	Program Manager or Program Management

R&D	Research & Development
RACI	Responsible, Authorized, Consulted, & Informed
ROI	Return on Investment
S&T	Science & Technology
SAW	Surface Acoustic Wave
SDN	Software Defined Network
SSL	Space Science Laboratory
SWOT	Strength, Weaknesses, Opportunities, & Threats
TRM	Technology Roadmap
TTP	Tactics, Techniques, & Procedures
UK	United Kingdom
UN	United Nations
UNIDO	United Nations Industrial Development Organization

I. INTRODUCTION

Chapter I provides the definition of roadmapping, its history, and describes the growth of roadmaps since their inception. This chapter also describes project objectives, project methodology, and research questions central to this project.

A. WHAT IS ROADMAPPING?

Roadmapping is the strategic process of transforming an organizational vision into reality; it is the process of designing, applying, monitoring, and modifying a roadmap (International Energy Association [IEA], 2014). Therefore, the words "road" and "mapping" denote the active creation of roadmaps (WP2 Partners, 2002). The process links business and technology. It outlines an organization's business plans serves as a common interface for products, services, markets, and/or technologies over time (Phaal, 2006). Roadmapping is a process that helps spark innovation and forecasts demands and requirements in the out-years (IEA, 2014). Conversely, roadmapping is a decision aid for strategies as they help visualize strategic paths or courses of action in response to current or emerging threats or requirements (Seyfarth, 2016). Simply put, roadmapping links the future to the present (Phaal, 2006).

B. ROADMAP: THE PRODUCT OF ROADMAPPING

Before a deeper examination of roadmapping concepts and putting it into practice, an understanding of the term roadmap is essential. The two words, "road" and "map" represent paths or directions marked by distances from one point to another (WP2 Partners, 2002). From a business perspective, roadmaps are specialized plans that define the major steps an organization should take to bring strategic goals and objectives to fruition (Cosner et al., 2007). Furthermore, roadmaps are highly effective planning tools that help articulate an organization's strategic plan over a defined time sequence. The revelation of time differentiates the roadmap from other corporate planning documents (Albright & Kappel, 2003). Defined time intervals enable the prioritization of goal-oriented tasks. Mission scope, product type, and aggregation level help define the time interval. Since the first

roadmap, conveying capabilities in relation to time has been the key goal for most roadmaps (Groenveld, 2007).

C. BACKGROUND

Congress and the Department of Defense's exploration for improved weapon systems acquisitions span decades. Yet bad program results outnumber the good. Poor programs have developed a resistance to change similar to drug-resistant bacteria in the human body. Poor results force Congress and DoD into an improvement do-loop (Sullivan, 2010). The accelerated pace of change in the Tactics, Techniques, and Procedures (TTPs) used by adversaries of the United States has significantly impacted today's defense acquisition climate. Fast-changing technologies, complex system requirements, and increasingly shorter product life cycles have led to system development processes based on short-term thinking and the need for reactionary quick wins (Bray & Garcia, 1997; Kostoff & Schaller, 2001; Groenveld, 2003). Strategies are often tied to budget cycle reporting requirements, navigating the ever-increasing contracting challenges, and the need to provide the next deliverable as quickly as possible (Albright & Kappel, 2003). Many governments and industry executives, managers, and other decision-makers recognize the strategic importance of providing value to end-users and establishing or maintaining competitive advantages for their companies, organizations or industrial networks (Phaal, Farrukh, & Probert, 2003).

Phaal et al. (2003) contend that effective processes and systems are critical for the management of technologies; they enable current and future organizational resources to be aligned with requirements in a dynamic business environment. The rapid pace of technology growth, globalization, and external threats serve as the catalyst for various industries, organizations, and governments to have a heightened awareness and amplified interest in decision aids says Kostoff & Schaller (2001). They also state that decision aids such as metrics, data mining, information retrieval, information-based technologies, and roadmaps have become vital for success in a dynamic marketplace or industry. No matter the industry, the goal is to provide enduring value to customers and generate long-lasting competitive advantages.

When implemented properly, a powerful process known as roadmapping can sharpen the strategic foci of companies and government organizations by providing a structured mechanism that categorizes and evaluates prospective threats and opportunities in business or military/acquisition environments. Roadmaps can help assess disruptive technologies and markets. They can bolster business plans and systems alike (Phaal et al., 2003). Oftentimes, these disruptive forces generate seismic paradigm shifts in business environments, industries, and military combat power.

The concept of roadmapping and its by-product, the roadmap, is not new. The idea of the "roadmap" for business purposes dates back to the 1940s (Phaal, 2015). Motorola popularized the idea of the roadmap by implementing "technology roadmapping" into their business practices (Willyard, 1987). History from Willyard (1987) states that in the 1970s and 1980s, Motorola pioneered concepts such as integrated product-technology through the use of roadmaps. Since its inception, research (Phaal, 2015) suggests that roadmapping processes have been included and modified by various governments, businesses, and industries at multiple levels. Phaal states that initially, roadmapping techniques spread from the consumer electronics sector to other technology-driven sectors such as aerospace and the defense industry.

The acceptance of roadmapping by the semiconductor industry was a key milestone for the roadmapping movement (Schaller, 2004). Semiconductors have enabled the miniaturization of electronics, which provides consumers with cell phones, laptops, drones and other popular modern electronic devices. According to Phaal (2015), the first industry-wide semiconductor roadmap was published in 1992. He suggests this action proved influential for the growth of roadmapping acceptance and sparked the evolution of the semiconductor business because the industry-wide roadmap provided synergy; standards for development and production were derived from a more focused and cohesive sector. Therefore, Phaal believes that roadmaps helped serve as a catalyst for rapid innovation in the semiconductor business. Despite this success, it seems that many roadmaps are not released to the public. However, as shown in Figure 1, the International Technology Roadmap for Semiconductors (ITRS) has been made public. Public maps, when appropriate, help create a greater awareness and understanding of roadmapping (Phaal, 2015).

According to Phaal (2015), the U.S. Department of Energy (DOE) widely promotes and applies roadmaps. He acknowledges that the DOE has promoted roadmaps for years and attributes their support to a bevy of roadmaps developed for a number of industries. This project suggests that the DoD take a similar position and increase its exposure on roadmaps. Rick Borchelt from the DOE stated in a Science Communication article that a special panel was assembled in 1998 by NASA's George C. Marshall Space Flight Center's (MSFC) Space Science Laboratory (SSL) in Huntsville, Alabama, to help improve communications with the public on NASA's scientific research (Borchelt, 2001). One of the panel's key findings was that "the panel firmly believes that public communication of research results is, and should be, integrated into the scientific process itself" (Borchelt, 2001, p. 200). The same applies to the roadmapping process, public communication on procedures, best practices, and lessons learned will create an even wider adoption.

Roadmaps have been used in a variety of industries. According to Phaal (2011), industries such as energy, defense, and a number of others have publicly available maps. Phaal & Miles (2008), present survey data (Figure 1) of over 2,000 roadmaps. The maps from that survey encompass a variety of industries such as energy, defense, manufacturing, and others. Figure 1 also illustrates the growth of roadmaps from the 1950s to the early 2000s.

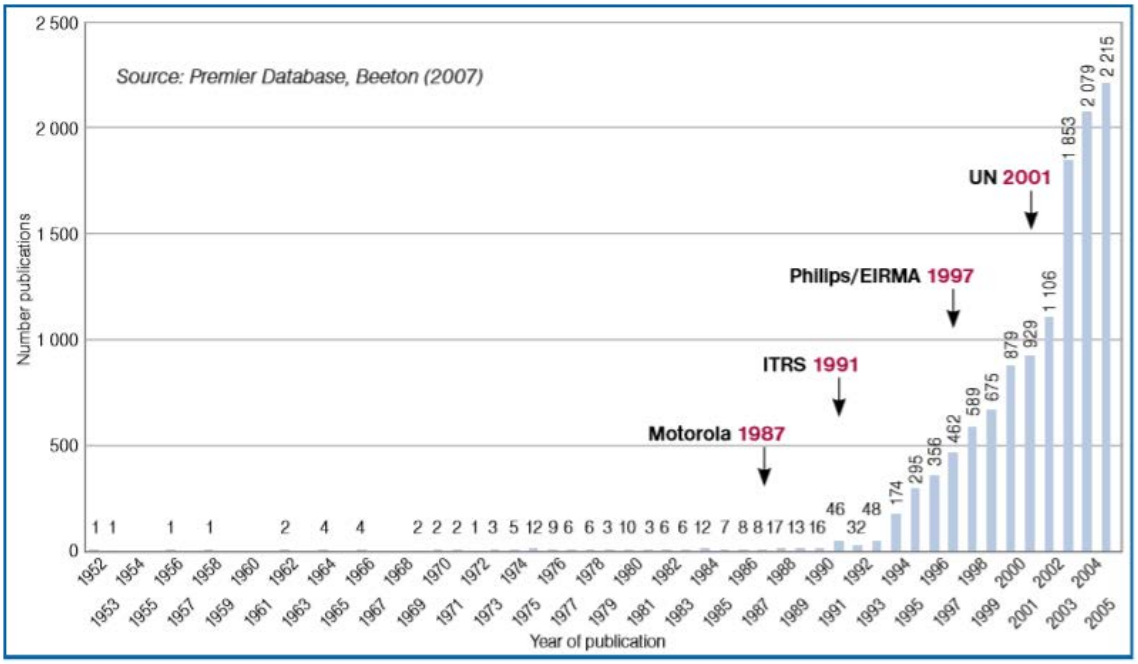

Figure 1. The Growth of Public Roadmaps. Source: Phaal & Miles (2008).

As shown above, there was an explosion of roadmapping from the early 1990s into the 2000s. A survey conducted by roadmapping practitioners Practitioners Phaal, Farrukh and Probert estimated approximately 10% of the surveyed 2,000 predominantly large United Kingdom (UK) manufacturing firms implemented technology roadmaps at least once (Phaal et al. 2001; Vishnevskiy, Karasey, Meissner, 2014). This demonstrates the wide distribution of roadmaps and affirms its wide dissemination in the mid- to late-1990s. It is evident that many organizations and industries realized they must solve fundamental challenges related to complexity, scale, change, uncertainty and the need to rapidly develop, produce, and deliver as a means of competitive advantage. This provides a strong justification for implementing roadmapping. Without roadmapping, these challenges may evolve into a range of difficulties for organizational and industry leaders. According to Peter Groenveld's *Roadmapping Integrates Business and Technology* piece, it is suggested that issues such as the following may occur:

- Disjointed/uninformed stakeholders;
- Misaligned plans and goals;

- Missed opportunities due to inefficient use of resources; and
- Elevated risks (Groenveld, 2007).

Roadmapping enables leaders from diverse sectors to set their organization's course towards a successful future and explore a host of new opportunities. These leaders are not looking to jeopardize their organizations. Unfortunately, poorly planned and improperly executed roadmaps abound. Failures have caused some companies and government organizations to refrain from using this powerful strategic process. This project provides a customizable guide on how to successfully conduct roadmapping, develop roadmaps, and avoid common roadmapping pitfalls. The subsequent section provides a complete list of project objectives, methodology and primary research question.

D. OBJECTIVES

Project objectives are to

- Provide a basic understanding of roadmapping and roadmaps;
- Provide a historical account of the evolution of roadmapping
- Define the roadmapping process and analyze its phases;
- Identify and define common roadmap types;
- Provide a guide on how to successfully conduct roadmapping and produce a roadmap;
- Identify common roadmapping pitfalls;
- Conduct a root cause analysis on common roadmapping pitfalls;
- Provide failure prevention recommendations;
- Identify and analyze the elements of successful roadmaps; and

- Encourage a wider adoption of roadmapping across the Department of Defense.

E. METHODOLOGY

This paper explores the idea of developing and implementing roadmaps across the DoD. Furthermore, this paper seeks to serve as a guide to help organizations and industry partners avoid common roadmapping pitfalls and reap the full benefits from roadmapping.

F. RESEARCH QUESTIONS

This project examines the following questions:

1. What is the value of roadmapping for the DoD?

2. Why do some roadmaps fail while others excel?

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II. ROADMAPPING

Chapter II delves into the concept of roadmapping as a valuable process for the DoD. This chapter describes benefits to roadmapping and examines common roadmap types such as strategic, technology, and product roadmaps.

A. ROADMAPPING OVERVIEW

A properly implemented roadmapping framework has the capacity to transform an organization's desire for the future, into an achievable outcome according to Seyfarth (2016). Furthermore, business strategies become cohesive and visualized through the formation of roadmaps. He lauds the roadmapping process enables strategic visions to be proliferated internally within the organization's ranks and externally with stakeholders. In other words, the roadmapping process is a great strategic communications aid; this most certainly benefits DoD organizations.

Roadmapping is as vital as its resulting document, the roadmap because it requires the engagement and alignment of multi-level and cross-functional stakeholders with a shared mission: produce results (Phaal, 2015). For the DoD, roadmapping may be applied to research and development (R&D) of weapons systems, production processes, logistics, individual projects, or entire programs (Groenveld, 2007).

An effective roadmapping process maximizes involvement through openness, solid teamwork and good communication. The desired result is a consensus. A consensus increases the probability of acceptance and continued implementation, monitoring, and revision (IEA, 2014). Ultimately, a consensus means programs are not starting with too many unknowns as highlighted by the GAO report.

The process of successfully building, implementing and maintaining a roadmap is less simple than describing the process, however. Roadmapping is sometimes marginalized as the act of creating a roadmap. Yet roadmapping requires a significant amount of strategic thinking, researching, planning, collaboration, and data analyses than what a roadmap should display. Various roadmap types exist. However, no matter the type, the roadmap

development process is critical to achieving buy-in and dissemination of an organization's strategic plan(s) (IEA, 2014).

B. BENEFITS OF ROADMAPPING

Roadmapping has provided a myriad of benefits to companies, industries, organizations, and governments worldwide. Roadmapping enables these entities to battle unstable markets and make sound decisions while minimizing potential risks (Seyfarth, 2016). Those that have successful roadmapping practices have experienced benefits such as those outlined by popular enterprise innovation management (EIM) website Sopheon. According to the website, benefits may include

- Reduced Research & Development (R&D) requirements;
- Increased profits;
- Enhanced forecasting/identification of emerging threats and opportunities;
- Optimized and well-informed decisions;
- Improved collaboration; open channels of communication;
- Increased stakeholder awareness;
- Elevated awareness of competition; easier to track;
- Improved long-term forecasting with sound, consensus-based data;
- Eliminated need to reorganize due to leadership changes;
- Reduced response time to volatility; and
- Increased stakeholder support and confidence (Seyfarth, 2016).

Roadmapping benefits abound. For the DoD in particular, technology-driven organizations focused on weapon systems, roadmapping can help set up more executable programs based on technology maturity levels, time, and expectation management through the collaboration of stakeholders, developers, and managers. Cost, schedule, performance,

and risk are at the core of all program management efforts. Undesired outcomes such as program delays negatively affect all four aspects and stimulate a cross-cutting ripple effect through the community. The report states “the cumulative cost growth in DoD’s portfolio of 96 major defense acquisition programs was $296 billion from first estimates, and the average delay in delivering promised capabilities to the warfighter was 22 months” (Sullivan, 2010, p. 1).

The message is clear: roadmapping enables the DoD to achieve better estimates, better investments, and a heightened sense of awareness and accountability for deliveries. However, effective roadmapping can certainly help mitigate many of the underlying problems that attribute to many DoD acquisition-based failures. A GAO report (Sullivan, 2010) provided the following:

> At the strategic level, DoD’s processes for identifying warfighter needs, allocating resources, and managing acquisitions, which together define its weapon system investment strategy, do not work together effectively. As a result, the department often fails to balance the competing needs of the warfighter and commits to more programs than available resources can support... At the program level, DoD’s culture and environment often allow programs to stat with too many unknowns. In other words, programs enter the acquisition process without a full understanding of requirements; with cost and schedule estimates based on overly optimistic assumptions; and with insufficient knowledge about technology, design, and manufacturing (p. 3).

The findings from that GAO report describe an urgent need for effective roadmapping to be implemented. Upon reading the subsequent section, continue to review the quotes from the report. This helps prove that the findings are indeed describing the process known as roadmapping.

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III. COMMON ROADMAP TYPES

Chapter III examines common roadmap types and compares publicly released roadmaps from various industries against generic schematics and formats developed by experts in the field of roadmapping.

A. ROADMAP OVERVIEW

Motorola spearheaded the concept of roadmaps in the 1970s with many companies and governments following soon thereafter (Groenveld, 2007). Figure 2 is an image of Motorola's first published roadmap from the 1980s. Motorola's first roadmap was characterized as a technology roadmap according to Phaal (2015). His literary works suggest that Technology Roadmaps (TRMs) are one of the most popular roadmap types used today. He references Motorola's roadmapping success because it provided a strategic common operating picture (COP) that depicted their plans and helped synchronize technology with product development (Phaal, 2015).

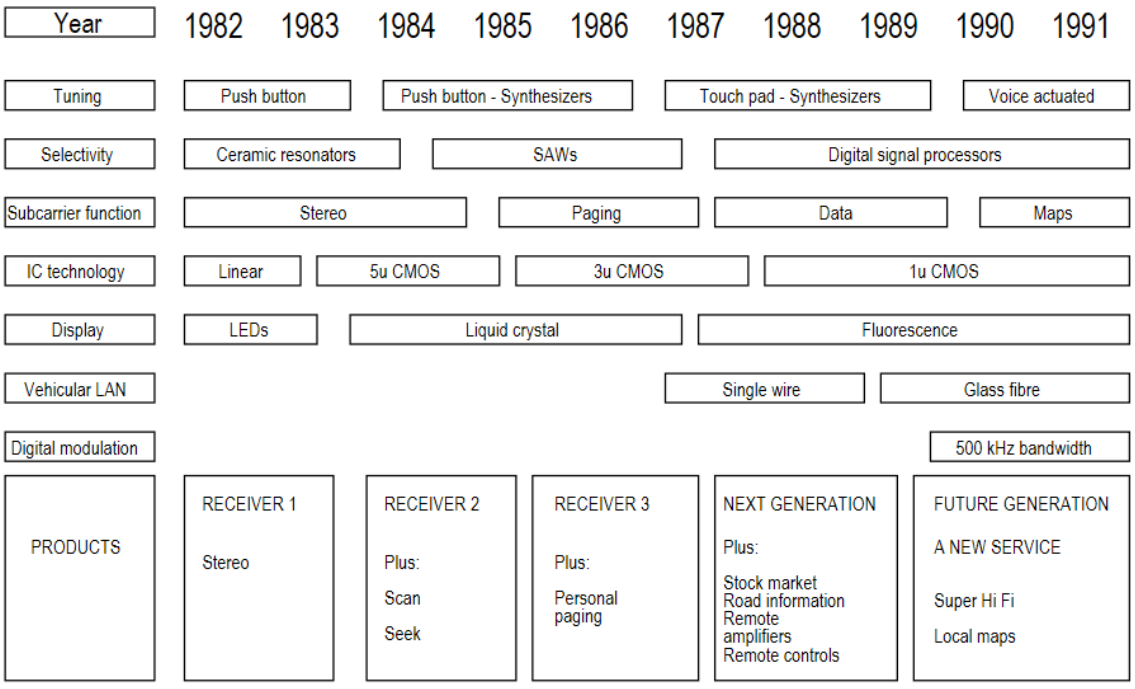

Figure 2. Motorola's First Published Roadmap. Source: Phaal (2015).

During the early stages of Motorola's implementation of roadmapping as a business process, CEO Robert Galvin provided the following definition for the term roadmap:

> A "roadmap" is an extended look at the future of a chosen field of inquiry composed from the collective knowledge and imagination of the brightest drivers of change in that field…Roadmaps communicate visions, attract resources from business and government, stimulate investigations, and monitor progress. They become the inventory of possibilities for a particular field…In engineering, the roadmapping process has so positively influenced public and industry officials that their questioning of support for fundamental technology support is muted (Galvin, 1998, p. 803).

This definition emphasizes the importance that knowledge and expertise play in the process, the forward-looking nature of the approach, its flexibility, and positive impacts due to consensus (Kostoff & Schaller, 2001; Phaal, 2015).

Roadmaps serve as forcing functions for capability gap identification and should be the foundation for solution planning; they act as a common operating picture for simple and complex solutions across a bevy of industries and products (Albright & Kappel, 2003). Specific products with short life cycles typically require three to four years; nonspecific products may extend to ten years or more (Groenveld, 2007). Roadmap time intervals are critical. The importance of time and its linkage between technologies, products, and strategies will be frequently discussed throughout subsequent sections of this project.

Various approaches to roadmapping exist and roadmaps can take many forms. This project focuses on the types for the DoD

1. Strategy;
2. Technology;
3. Science and Technology; and
4. Products

Phaal and Miles (2008) explain that these common roadmap types are typically represented with a temporal, system/process, or metaphorical illustrations. They present an analysis of greater than 400 visual roadmaps with typology types classified and sorted

based on percentages. Table 1 is an overview of their findings and Figure 3 illustrates each of their defined typologies.

Table 1. Roadmap Typologies, Information Structures, and Percentages. Source: Phaal & Miles (2008).

Type	Sub-type	%		
1) Temporal	1a) Single theme/sequential/linear	13,2	25,9	80,8
	1b) Graph/quantified	12,7		
	1c) Single theme/sequential/branched	7,2		
	1d) Multiple separate themes; sequential/linear/branched	36,7	48,4	
	1e) Multiple separate themes; sequential/linear/branched	11,7		
2) System/process	2a) System (structure, components, relationships)	5,0	16,7	
	2b) Process	11,7		
3) Metaphor	Roads, landscape, board game, funnel, etc.	2,5		

The data from Table 1 shows that over 80% of the evaluated roadmaps implemented a temporal typology. Of the temporal type roadmaps, over 48% look like Figure 3's 1d) and 1e) examples. This means a vast majority of the roadmaps had a high level of sophistication detailing multiple themes and paths. In some cases, that may be necessary, but too few, 7.2% of the roadmaps were single theme/sequential/branched. The premise of this project is to identify the reasons why some roadmaps fail and others excel. Later in this paper, roadmap pitfalls will be discussed on analyzed to help managers and executives avoid common mistakes.

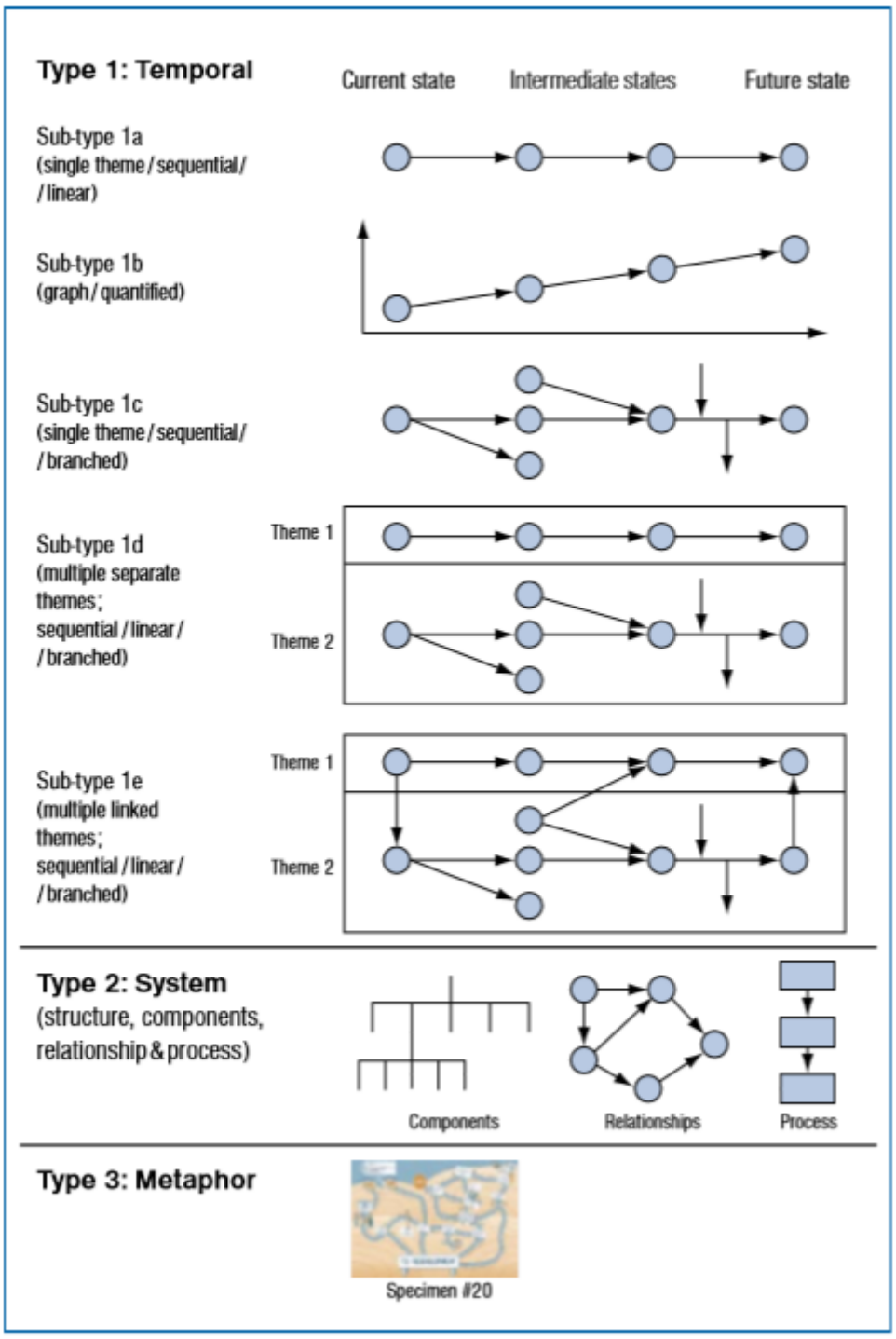

Figure 3. Graphical Roadmap Typology and Information Structures. Source Phaal & Miles (2008).

Roadmap flexibility and diversity is both good and bad. With so many roadmap options to choose from, it is clear why so many organizations/companies struggle with roadmapping—they do not know where to start. The subsequent sections provide clarity on the roles and definitions of the most common roadmap types.

B. STRATEGIC ROADMAP

Strategic roadmaps focus on long-term, mid-term, and short-term objectives and clearing the obstacles to success. They identify opportunities, threats, and specifics that activate an organization's mission statement but do not delve into implementation details (UNIDO, 2005). Typically, strategic roadmaps address the following five questions (Phaal, 2015; Seyfarth, 2016; Simonse, Hultink, & Buijs, 2015)

- Who are we trying to support/serve?
- What problem(s) do we want to solve?
- Where are we trying to go?
- When do we want to get there?
- How are we planning to solve the problem(s)?

According to an Ivey Business Journal article (Kukreja, 2013), "Strategy is all about making a series of unique decisions to get to a particular goal from a starting point." Figures 4 and 5 illustrate this definition. Figure 5 is a generic roadmap schematic that DoD organizations should consider in conjunction with the previously outlined questions or a tailored version as shown in Figure 4. The intent is to use a series of questions to identify and bridge gaps, define a path, and reach the goal or vision (Kukreja, 2013; UNIDO, 2005).

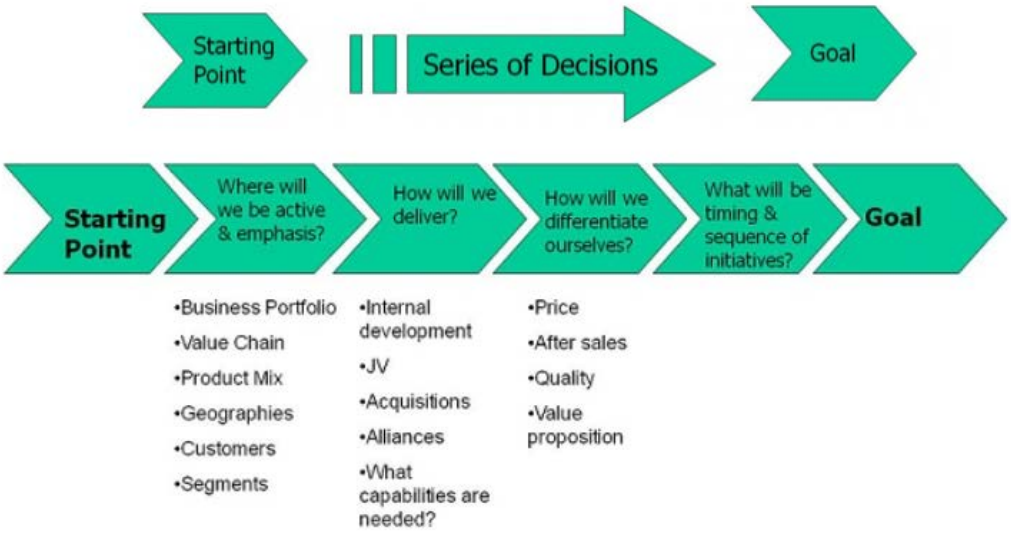

Figure 4. Illustration of Strategy Development Decision Process. Source: Kukreja (2013).

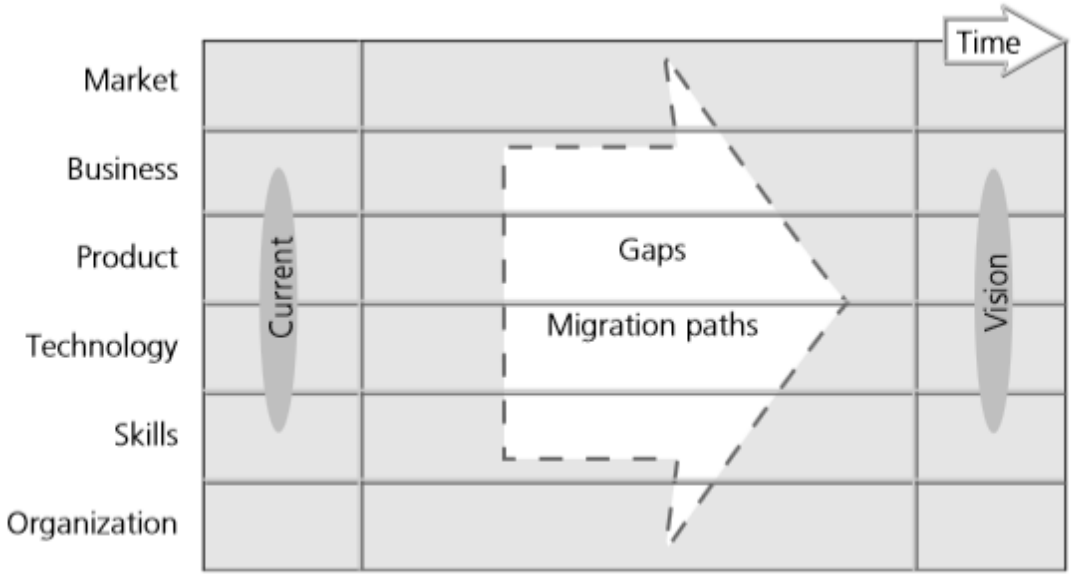

Figure 5. Recommended Strategic Roadmap Format for DoD Organizations. Source: UNIDO (2005).

Roadmaps are customizable and can be used for any business sector. Figure 6 is a representative strategic roadmap published online. The positives are the aesthetically pleasing layout and anyone can quickly comprehend the intent. However, the issue with

the Figure 6 roadmap is the missing component of time and the fact that it is not strategic. It does not highlight the current position, it does not articulate decisions, and it does not quantify when they will go from point A (current) to point B (future) as recommended by Kukreja (2013). In essence, there is no migration path as illustrated in Figure 5. "Strategic roadmaps" like Figure 6 provide general intent but cannot be tied to any particular strategic (Kukreja, 2013). Many organizations want to experience profit growth, provide innovation excellence through the development of great products or build immense value for the brand and be customer-driven, agile and deliver results but none of these represent the definition of strategy.

Figure 6. Strategy Roadmap. Source: Goodyear (n.d.).

C. TECHNOLOGY ROADMAP

Technology roadmapping is an increasingly popular methodology being applied by technology-driven organizations and industries in support of product and technology development and a means for technical-based strategic communications (Phaal et al., 2003). A technology roadmap (TRM) is a collaborative tool for technology planning and

coordination for corporations, governments, and entire industrial bases defines Cosner et al. (2007). Technology roadmaps are commonly used around the world as a technology-market planning tool. This is especially true when multiple stakeholder environments exist and the intended future must be clearly communicated as highlighted by Letaba, Pretorius, & Pretorius (2015). Cosner et al. (2007) proclaim that the technology roadmap summarizes the strategic plan to achieve short- and long-term goals through the use of core technologies. Their belief is that core technologies are implemented to realize product goals displayed on the product roadmap. Therefore, the technology roadmap has the ability to enable the product roadmap and to track the development of technologies to be integrated into a product solution (Cosner et al., 2007).

To effectively support strategic business endeavors, Phaal et al. (2003) indicate that organizations must have a willing culture and sufficient resources such as information, procedures, and tools. They also highlight that technology roadmaps are generally focused on setting R&D priorities and identifying needs for pilot and demonstration activities – items that again benefit the DoD. In essence, roadmapping moderates the array of requirements and imaginable solutions to the most promising efforts (Kostoff & Schaller, 2001). As a result, Bray & Garcia (1997) state that companies, governments, and industries can make better investment decisions based on information by

- Identifying requirements driven by innovation decisions and process improvements;
- Satisfying major product requirements through technology initiatives and alternatives;
- Identifying and selecting applicable alternatives (or multiple paths);
- Implementing apropos alternatives; and
- Establishing processes to ensure milestones and targets are met (Bray & Garcia, 1997).

According to Phaal, Farrukh, Probert (2003), technology roadmapping differs from other planning and analysis tools as it is driven by market pull rather than what they call technology push. They continue to state that market pull is needed for organizations to support future markets while technology push focuses on existing technology and immediate efforts ("Technology Roadmapping: A Guide for Government Employees," no date; Phaal et al., 2001; 2003).

Although the first (publicly recognized) roadmaps originate from the 1970s, significant changes to methodologies had not been realized until the early 2000s, when Dr. Robert Phaal and other practitioners distributed what they call 'T-plan' and 'S-plan' workbooks (Vishnevskiy et al., 2014). It was during that time when the growth of technology-focused roadmaps occurred. Technology push and market pull characterize technology roadmap options (Phaal et al., 2003). Technology push is generally recognized as innovation sparking a need, while market pull is a market-based need or requirement driving innovation and product development (Di Stefano, Gambardella, & Verona, 2012).

Figure 7's notional is TRM originates from the European Industrial Research Management Association (EIRMA). According to experts, this schematic illustrates the most common approach for technology roadmaps: a multi-layer, time-based chart with market, product, and technology links and gaps (Phaal et al., 2003). Figure 8 is a modified version of the generic technology roadmap. This schematic comes from Dr. Robert Phaal and colleagues. The schematic builds upon the foundation laid by the EIRMA and enhances the content.

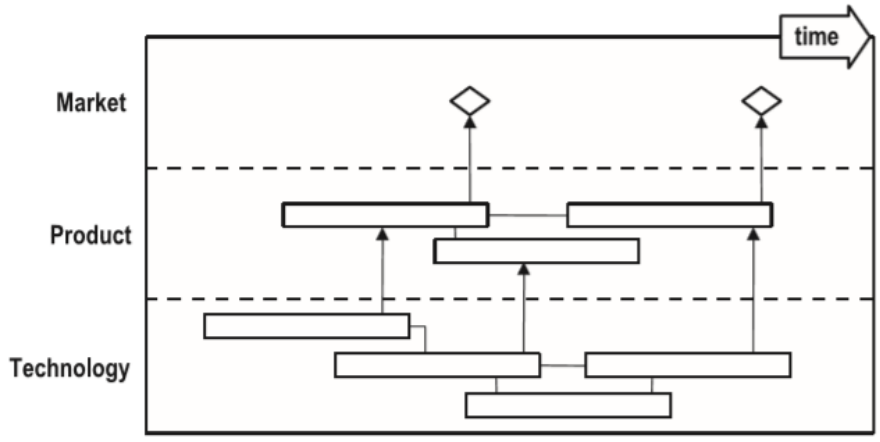

Figure 7. Technology Roadmap Schematic: Market, Product, and Technology Alignment. Source: EIRMA (1997); Phaal et al. (2003).

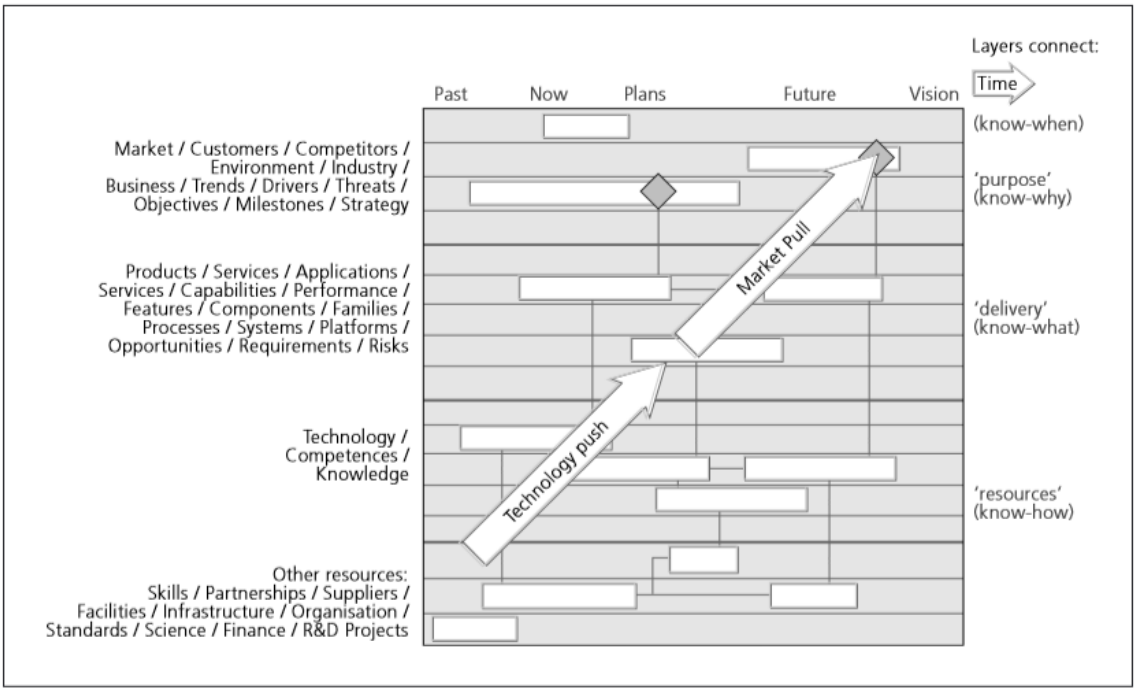

Figure 8. Modified Technology Roadmap Schematic. Source: Phaal et al. (2003); UNIDO (2005).

Figure 9 and Figure 10 (shown below) are tailored examples of the EIRMA concept. Figure 9 is a 5th Generation (5G) cellular technology roadmap from the European Union's 5G Public-Private-Partnership (5G PPP). What is intriguing about the 5G PPP roadmap is that it links existing or legacy technology with emerging technology. In short, it provides the technology push as shown in the original EIRMA schematic. The 5G PPP roadmap has dedicated lanes for topics of interest and each topic is tied to the component of time. Also, the roadmap provides insight into incremental capability increases, technology experiments, demonstrations, and commercialization.

The 5G PPP roadmap is merely a component of a 16 page 5G Vision. This is important because although the roadmap can stand on its own, providing detailed insights within a formal document elevates the content, displays another level of rigor and seriousness about the topic to stakeholders it also serves as invaluable reference material for the future. Some of the objectives from the 5G PPP are germane to this project and reiterate core concepts described in subsequent sections. Fitting objectives from the 5G PPP that reiterate core concepts within this project:

> Serve as a consensus-based platform for effective collaboration of players from industry, academia, research organizations and SMEs from both the terrestrial and the satellite communities; Reinforce the European industrial capability in communication network technologies; Support the emergence of global standards; and Help address non-technological barriers such as regulatory issues and spectrum availability (5G Vision, 2015, p. 15).

Key takeaways from the 5G PPP general objectives applicable to a variety of roadmapping projects are consensus-building, interdisciplinary SME collaboration, providing insight or reinforcing capabilities to stakeholders, maintaining situational awareness and understanding of the environment and barriers to success.

Figure 10 is an autonomous vehicle technology roadmap published by Jaguar Land Rover. This is a good roadmap because it integrates capabilities (y-axis) over time (x-axis) and links the capabilities to an industry-recognized autonomy level based on color. The roadmap shows how the organization will get to a full end-to-end autonomous system.

Each roadmap example exhibits characteristics of the generic schematic from EIRMA. Key features such as time, linkages, and evolution are vividly shaped into a graphical framework that tells a story.

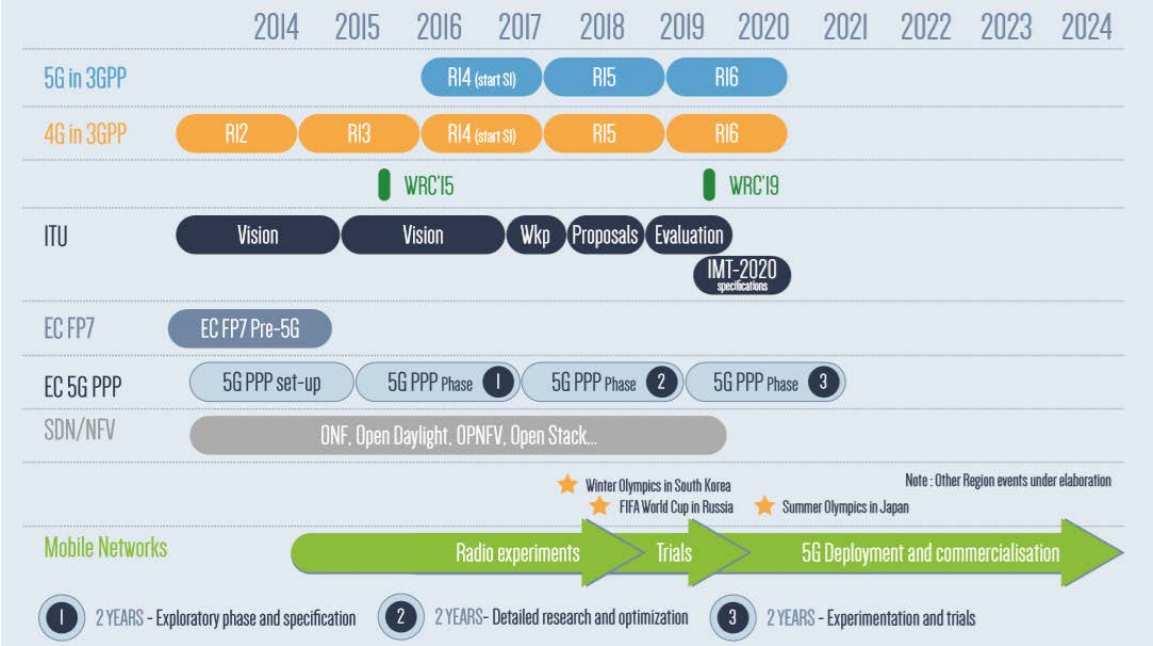

Figure 9. Representative Technology Roadmap—5G Pan-European Trials Roadmap. Source: 5G Infrastructure Association (2015).

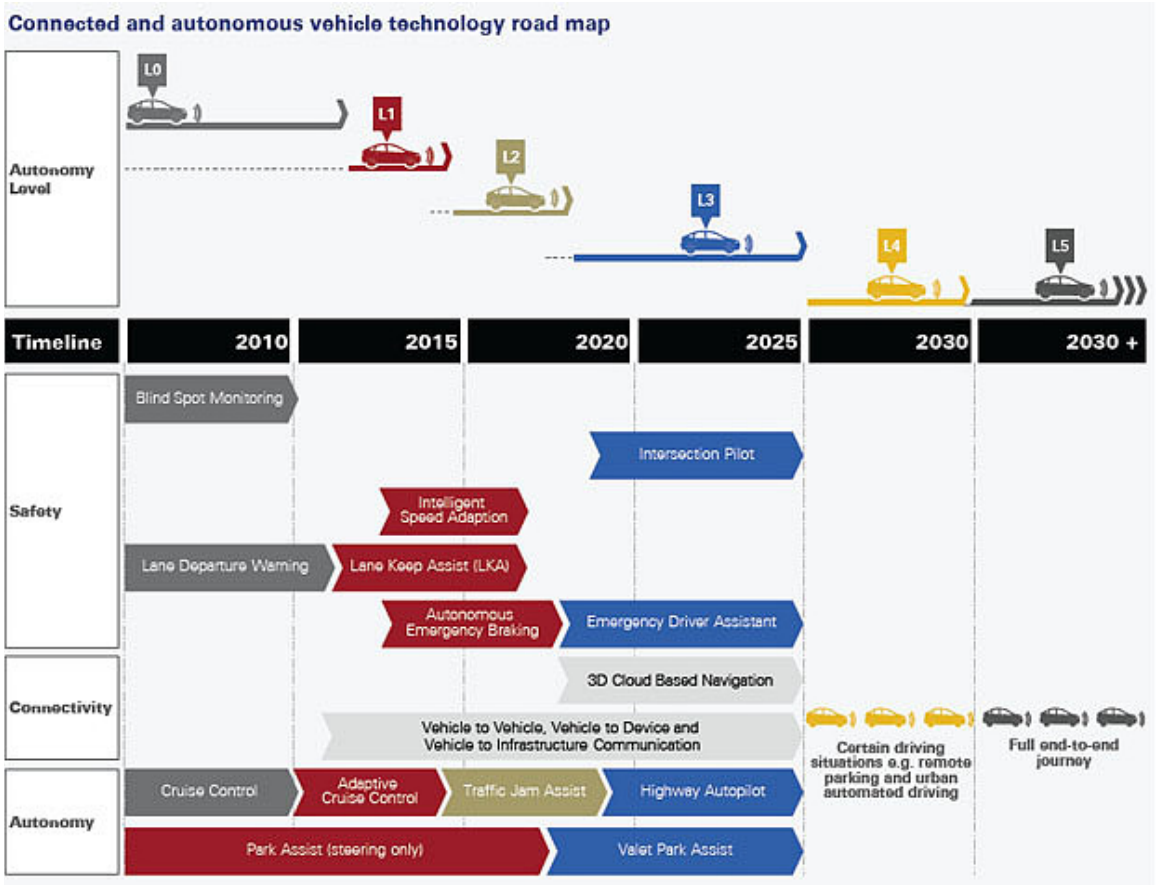

Figure 10. Jaguar Land Rover Autonomous Vehicle Technology Roadmap. Source: Tovey (2015).

D. PRODUCT ROADMAP

The product roadmap, submitted by Cosner et al. (2007), represents a high-level plan that provides new products and services with incremental performance growth and product feature evolution over time. The group reveals that product roadmaps provide turn-by-turn directions that describes where an organization is going and how it will get there. They also suggest that aspiring practitioners structure a product roadmap by featuring the idea/product name or by providing an estimated release date/glide path.

Figure 11 is an example of a common roadmap format. Unfortunately, this format fails to answer important questions. The roadmap from Intel provides the year, 2017, but fails to inform the audience of when each product will be released to the market al.so, it may not be intuitive to consumers unfamiliar with Intel processors which product provides

the most capability or appropriate capability. Since the roadmap is for a single year, this roadmap could benefit from providing quarters within the year and establishing product release points across the x-axis (time).

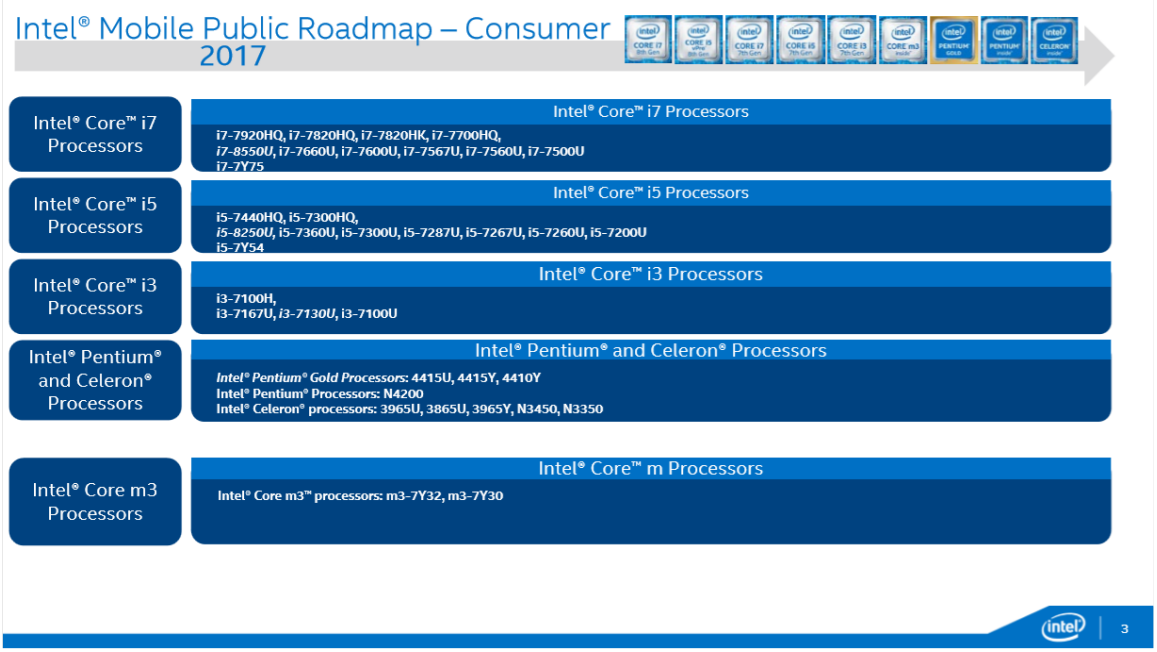

Figure 11. Intel's Mobile Public Roadmap for Consumer Products. Source: Intel (2017).

E. INTEGRATED ROADMAPS

Due to the apparent lack of standards and fragmented variety of roadmap approaches in industry, government, and academia as purported by Kostoff & Schaller (2001), one may encounter various hybrids of strategy, technology, and product roadmaps. Illuminated in their literary work, a common hybrid or integrated roadmap type is referred to as a 'product-technology' roadmap. As suggested, it appears that each of the common roadmap types may also be combined to formulate an integrated roadmap.

As indicated by Kostoff & Schaller (2001), the term 'product-technology roadmap' has been used in the science and technology (S&T) sector with some even referring to them as 'S&T roadmaps'. Figure 12 demonstrates their claim and represents a generic product-technology roadmap. Their belief is that no matter the type or nomenclature, all roadmaps

should function like conventional highway/GPS maps by providing a clear path through nodes and links. They offer a layman example and imply that a conventional highway map or software navigation application provides direction on a road (link), a travel duration or distance/length, and sometimes lane information (one lane, two lanes, etc.) and therefore, all roadmaps should have quantitative and qualitative attributes (Kostoff & Schaller, 2001).

As described in the previous strategic, technology, and product roadmap sections, the component of time—a quantitative attribute—is essential according to Phaal & Miles (2008). However, it appears that many roadmaps lack this key element. This is interesting as it is common knowledge that program managers favor quantitative attributes such as cost, schedule (time), performance, and risk because they facilitate effective program management. Kostoff & Schaller (2001) write that occasionally, GPS-based maps display qualitative attributes such as distinct visual indicators alongside a road to signify a scenic or dangerous path. Correspondingly, they assert that a certain technology roadmap's link (or road/path) could represent the potential effects—qualitative attribute—of a disruptive technology on products, strategies, or competing technologies. As illustrated by Figures 12 and 13, an S&T roadmap may have a change in the science layer that could impact technology, and inevitably end-products from different markets (Kostoff & Schaller, 2001).

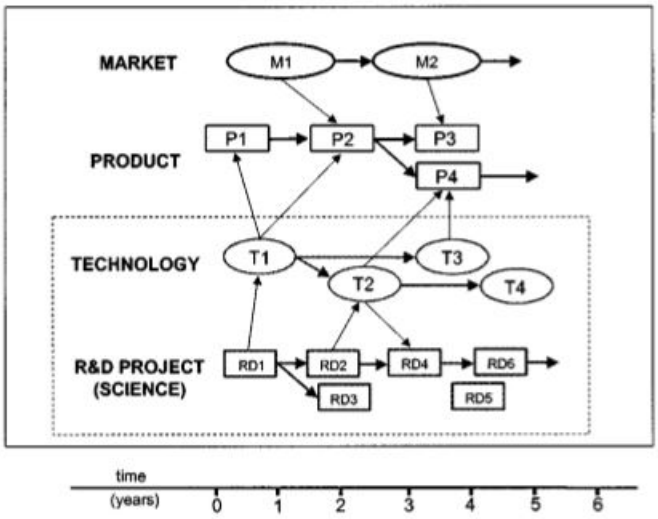

Figure 12. S&T Roadmap Template with Nodes and Links Adapted from "The Roadmapping Creation Process," Presentation. Source: Kostoff & Schaller (2001).

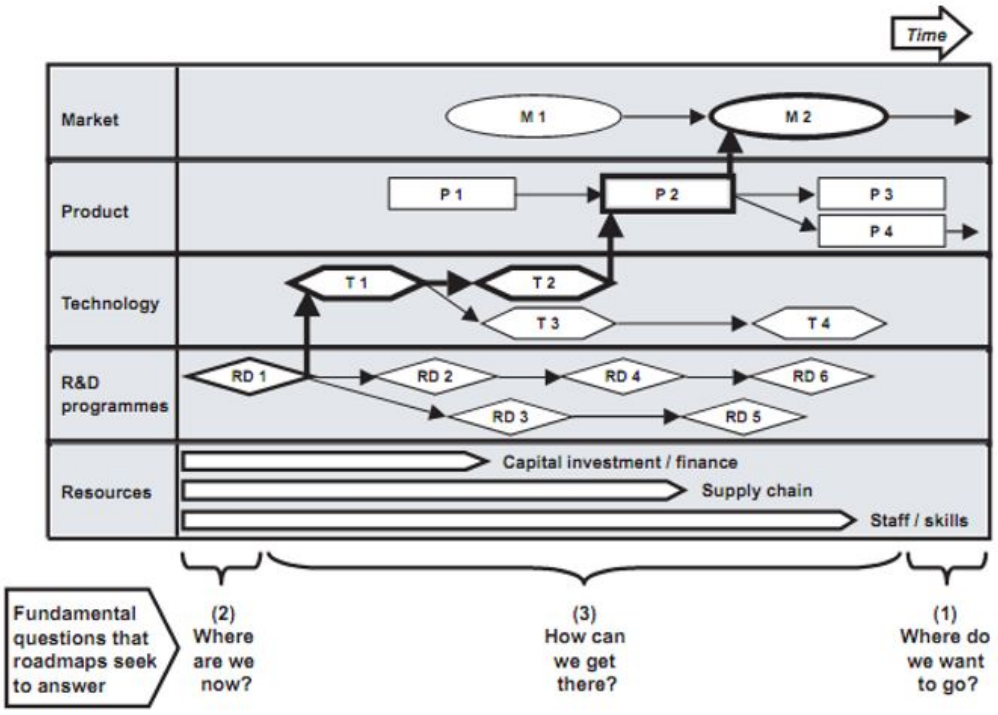

Figure 13. Modified Generic Multilayer Roadmap with Fundamental Questions. Source: Lange & Olof-Ors (2012).

Beeton, Phaal, & Probert (2008) highlight a very important issue in regard to roadmapping literature. They state that focusing on what a roadmap *is* rather than what it *does* seems to be lacking in literary works (Lange & Olof-Ors, 2012). A roadmap *is* a system and this concept will be explained later in the text.

Although the S&T roadmap is integrated, it is not fully integrated from a business/organizational perspective. According to Ho, O'Sullivan, & Phaal (2018), "existing academic literature on roadmapping is generally focused on science and technology-oriented roadmapping, without appropriate attention to the wider perspectives of the innovation system" (p.2). They argue a fissure exists between roadmapping practice and theory. Given the many interdependencies that exist within DoD acquisitions, the best roadmap type is a hybrid format linking pertinent areas that would affect the acquisition goal.

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IV. USE CASES

Chapter IV expounds upon Chapter III's theme that roadmaps can have different applications. DoD employees should be mindful of this when considering the implementation of roadmapping. According to Phaal et al. (2001), there are eight classification areas. Chapter IV presents those areas as use cases.

A. PLANNING OF PRODUCTS

One of the biggest misconceptions about roadmaps is that they are only product development tools. Roadmaps can and should be applied to a number of acquisition activities within the DoD. However, the most popular is indeed product development. Planning of products with product/technology/product-technology roadmaps is common. As shown in Figure 14, generations of products can be tied to technologies necessary for development.

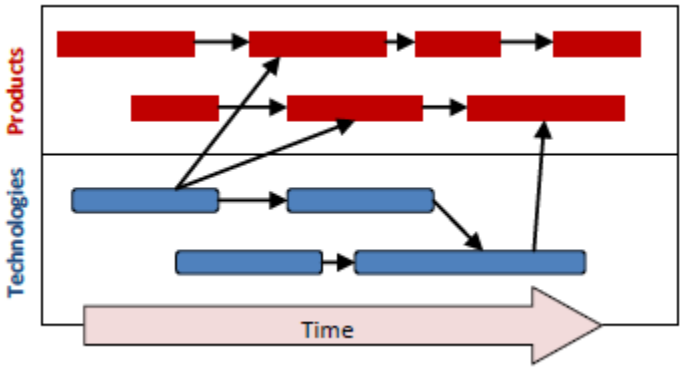

Figure 14. Basic Schematic: Linked Products and Technologies. Phaal et al. (2001); Bernal et al. (2009).

B. PLANNING OF SERVICES AND CAPABILITIES

Planning of services and capabilities can be focused on technologies that foster an organization's development or production capabilities that enable services such as test or training operations, system maintenance, logistics, etc. (Phaal et al., 2001; Bernal et al., 2009). Figure 15 provides an example.

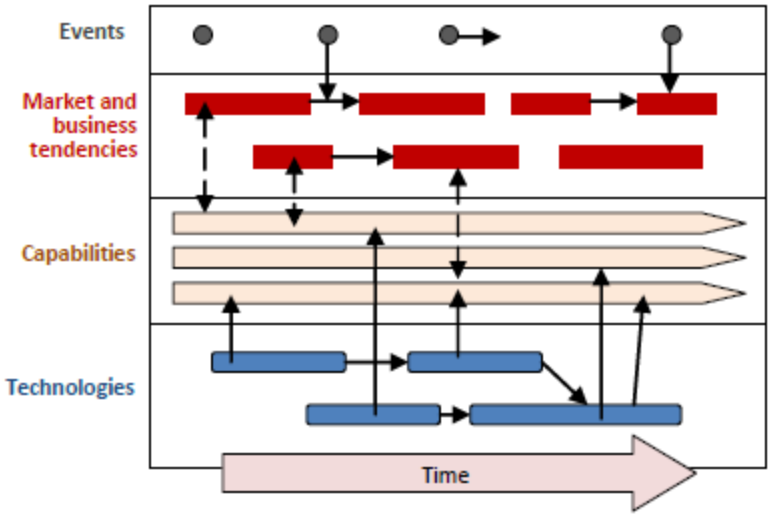

Figure 15. Schematic Linking Events, Markets, Capabilities, and Technologies. Source: Phaal et al. (2001); Bernal et al. (2009).

C. STRATEGIC PLANNING

The application of strategic planning delves into the assessment of different business opportunities and market tendencies at the strategic level (Phaal et al., 2001; Bernal et al., 2009). In many instances, this roadmap can be less technical as the focus is on a business strategy. However, the example is shown in Figure 16 links technology with the concepts of strategy and vision. Roadmapping is interdisciplinary.

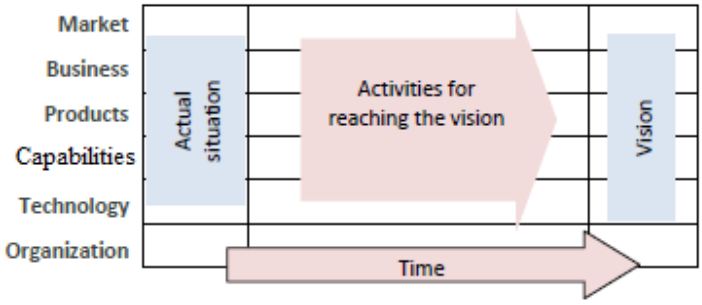

Figure 16. Strategy Roadmap Schematic Linking the Present to a Desired Future. Source: Phaal et al. (2001); Bernal et al. (2009)

D. LONG RUN PLANNING

At the national and regional levels, long run or long-range planning is often used for high-level long-term strategic initiatives.

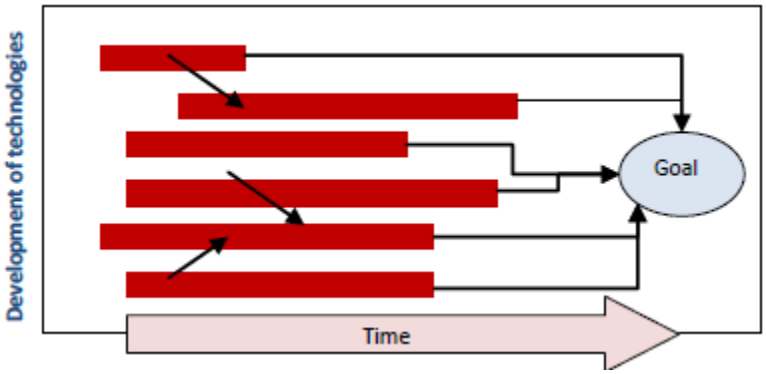

Figure 17. Schematic for Long Run Technical Planning. Source: Phaal et al. (2001); Bernal et al. (2009).

E. CAPABILITIES AND KNOWLEDGE PLANNING

In this case, the focus is on aligning knowledge capabilities with business goals. This is yet another example of why the education of roadmaps across multiple disciplines is a good approach. Product development is overemphasized. Product development is important and often the primary goal, but to improve product development and ultimately the status of an organization or business, other key factors must be considered. Figure 18 provides an example.

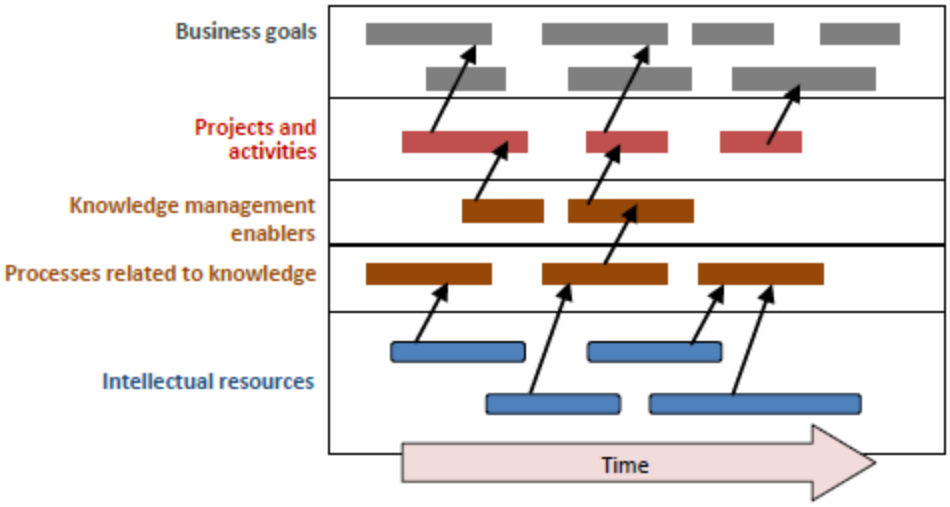

Figure 18. Schematic for Capabilities and Knowledge Planning. Source: Phaal et al. (2001); Bernal et al. (2009).

F. PROJECT PLANNING

Figure 19, a project planning roadmap, aligns different activities within a project with the development of various technologies (Phaal et al., 2001; Bernal et al., 2009). DoD acquisition employees should be familiar with this schematic as it is similar to the DAU Life Cycle Compliance Baseline Wall Chart presented to DoD acquisition professionals. This schematic dominates the DoD's roadmap use. This schematic focuses solely on the intended project or program. One of the key points of this project is that the DoD must expand its horizons and implement more roadmaps and better roadmapping techniques to improve acquisitions in support of Warfighter.

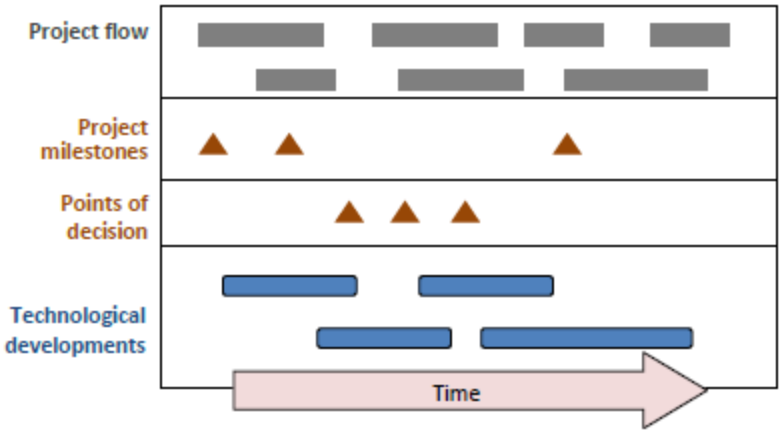

Figure 19. Schematic for Project Planning. Source: Phaal et al. (2001); Bernal et al. (2009).

G. PROCESS PLANNING

Roadmapping focused on process planning enables organizations center on a key area and manage knowledge in that particular area (Phaal et al., 2001; Bernal et al., 2009). Figure 20 provides a generic illustration.

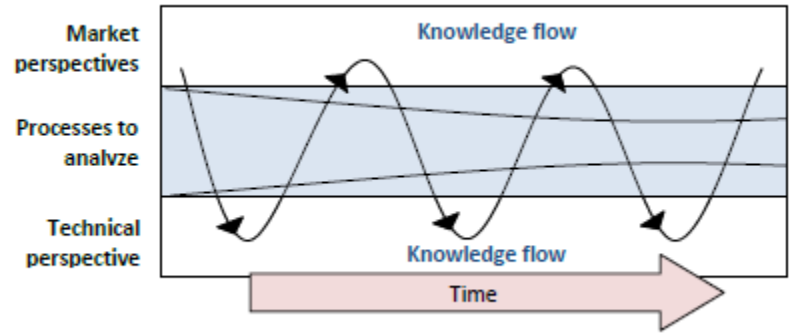

Figure 20. Process Planning Map. Source: Phaal et al. (2001); Bernal et al., (2009).

H. INTEGRATION PLANNING

According to Phaal et al. (2001), integration-planning roadmaps provide a vision on the evolution and integration of technologies. These maps link systems and products.

Through this linkage, new technologies or products can be derived (Phaal et al., 2001; Bernal et al., 2009). Figure 21 provides a visual representation.

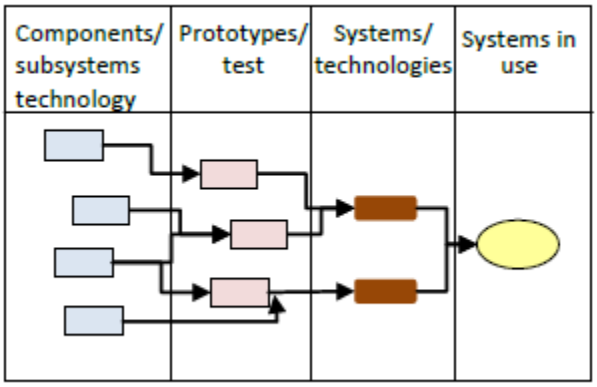

Figure 21. Integration Planning. Source: Phaal et al. (2001); Bernal et al. (2009)

V. BUILDING THE ROADMAP

Chapter V is a guide to help DoD employees quickly begin the development, customization, and implementation of roadmaps for various organizations. This chapter discusses core activities, phases and different approaches to developing roadmaps.

A. ROADMAPPING CORE ACTIVITIES

Phaal & Miles (2008) contend the architecture/layout of a roadmap needs to be developed considering type (e.g., technology, strategic, etc.), timeframe, and structure. They also declare that roadmaps should be viewed and treated as systems. They write roadmaps provide a "common language," linking stakeholders and organizations with a clear picture of the what, when, why, and how on markets, strategies, applications, processes, resources and many other items of interest across a diverse set of professionals with a common interest. IEA (2014) practitioners insist that most roadmaps take six to eighteen months to develop and consist of three core activities: Consensus Building, Expert Judgment, and Data Analysis.

1. Culture, Leadership, and Subject Matter Expertise

Many decisions must be made when roadmapping (Bray & Garcia, 1997; Kukreja, 2013). Subject matter experts must be assembled to help guide sound decisions and garner stakeholder buy-in (IEA, 2014). Assembling a team with the appropriate professionals is necessary. Rarely will one person possess an all-encompassing expertise level that negates the need for a group of experts (Lange & Olof-Ors, 2012). Roadmapping leadership is even more important. Someone must own the effort and be the final decision maker.

According to the "*Creating a Performance Culture"* article by Reid & Hubbell (2005), roadmapping provides leaders with an opportunity to develop a culture based on performance. They ascertain that an organization's actions and results are based on culture and state whether they are effective or not, many organizations develop strategies, yet, many lack the ability to successfully implement. An important question proposed by Reid & Hubbell (2005) is how many organizations can change directions and diligently make

the necessary adjustments to succeed? It seems that roadmapping requires organizations to do this. Therefore, roadmap leaders, managers, subject matter experts and others, must be open, manage their differences and stay focused on the goal (Reid & Hubbell, 2005). The appropriate personnel must be placed in the correct roles and team members must execute at an individual level to ensure the roadmapping process becomes a success. Leaders must empower roadmapping team members and give them the autonomy to make decisions (Hollingworth, 2018). Developing an optimized work environment that fosters productivity is the primary role for leaders in any business environment. American industrialist J. Irwin Miller's words capture it best

> You don't order anyone to do their best. You couldn't order Beethoven to write the Ninth Symphony. He's got to want to do it. And, so the head of a business (or a team leader) is an enabler rather than a doer. (Hollingworth, 2018, para. 21)

When strong culture and leadership exists, there will be effective processes; when there are effective processes, desired results will occur. Though broad in scope, culture, leadership, and subject matter expertise are essential for success.

2. Consensus-Building

The process of building a roadmap is difficult and requires dedication. The IEA (2014) emphasizes that a degree of trust must be nurtured within the development team to ensure a successful start and desirable finish. They contend that establishing early buy-in within the cross-functional team mitigates project risk and minimizes drastic changes later in the development process. Endorsed as equally important, is the need to incorporate external stakeholders as roadmaps mean different things to different positions. As with any team, a lack of openness and inclusion will impede progress; involvement and input by all members must occur during the workshop team activities (IEA, 2014).

a. Incorporating Expert Judgment and Consensus-Building

Core roadmapping activities such as consensus-building and expert judgment as described by the IEA (2014) should be conducted through structured vision and strategy sessions such as workshops. There are a number of roadmapping approaches; however,

workshops and roadmapping seem to be synonymous. Many practitioners (IEA, 2004; Phaal, 2008) assert that the priority for many workshop efforts is to establish or maintain buy-in, identify threats, generate courses of action and prioritize action items; practitioners contend that the outcome from these expert-led workshops should be draft roadmaps and relevant data.

3. Data and Analysis Efforts

Supporting consensus-building and expert judgment with sound data and analysis is endorsed by experienced by professionals from the IEA (2014) with significant roadmapping experience. They declare that data quality, volume, and the collection team's analytical abilities, affects the rigor and time spent on analyses in support of a roadmapping effort. In addition, it is important to note that teams should consider using various tools such as models to integrate data into a comprehensive framework in support of current and emerging requirements. Points to consider when conducting data and analyses activities

- Data-driven roadmaps increase the odds of consensus;
- The inclusion of stakeholders during data collection and analysis strengthens support but requires time and coordination; and
- Sufficient data analyses and modeling skills are required and teams should be staffed accordingly (IEA, 2014).

Consensus-building, expert judgment/SME support, data collection and data analyses are core activities that must be done across all roadmapping phases. In 1997, Sandia National Laboratories published the *Fundamentals of Technology Roadmaps.* The authors (Bray & Garcia, 1997) provided a roadmapping process that is often cited. Bray & Garcia recommended a three-phase approach to roadmapping for the Department of Energy (DOE). The next section discusses roadmapping phases for the DoD.

B. ROADMAPPING APPROACHES

According to Kostoff and Schaller (2001), roadmap variants can be grouped into distinct approaches. Those approaches are

- Expert-Based Approach
- Computer-Based Approach
- Hybrid Approach

Here is a brief overview of each approach.

1. Expert-Based Approach

One of the most popular approaches for roadmapping practitioners across the globe is to begin with a forum to solicit intrigued prospects for further collaboration; a workshop or clinic typically follows (Meng Li & Kameoka, 2003). In this approach, Kostoff & Shaller (2001) state that "the main focus is to draw on the knowledge and experience of the participants to subjectively identify structural relationships within the network and specify the quantitative and qualitative attributes of the links and nodes" (p. 136).

Working groups are assembled to classify and develop characteristics of the roadmap. In essence, knowledge-creating interactions are developed and flows of knowledge are shared as part of the roadmapping process (Meng Li & Kameoka, 2003; McMillan, 2003). Working groups are usually staffed with personnel from industry, government, and academia. Kostoff & Schaller (2001) confirms that oftentimes, these groups are subdivided according to in-house talent such as hardware engineering, software engineering, logistics, operations, etc. They also suggest that although the framework is laid by the readily available or resident expertise, organizations that lack the relevant expertise hire solicit help from external consultants to assist with the development of credible roadmaps.

a. T-Plan

Since 1998, The University of Cambridge's Centre for Technology Management has been developing facilitated workshop approaches involving over 120 collaborations with a variety of companies and business sectors. Cambridge has identified two approaches, the T-Plan and S-Plan, each based on the ever-important cross-functional participation (Phaal, 2015) or what the DoD calls "Integrated Product Teams" (IPTs).

The T-Plan is geared towards system level roadmapping/product-technology planning. According to Phaal et al. (2000), this process typically unites a total of 8 to 12 interdisciplinary members from across the organization or stakeholder group with a mission to create an initial roadmap; work is typically accomplished during workshops spanning four half-days (Phaal et al., 2000; UNIDO, 2005). The first workshop approach, T-Plan, supports the concept of 'fast-start' roadmapping as described by Phaal and colleagues. The T-plan is comprised of two parts: the standard approach and customized approach (Phaal et al., 2000; UNIDO, 2005). Each approach has different foci. Product planning drives the standard approach while the customized version delves into broader applications expanding upon the standard approach (Phaal et al., 2000; UNIDO, 2005; Phaal & Miles, 2008). Figures 22 and 23 are graphical representations of these workshops to help guide leaders throughout the process.

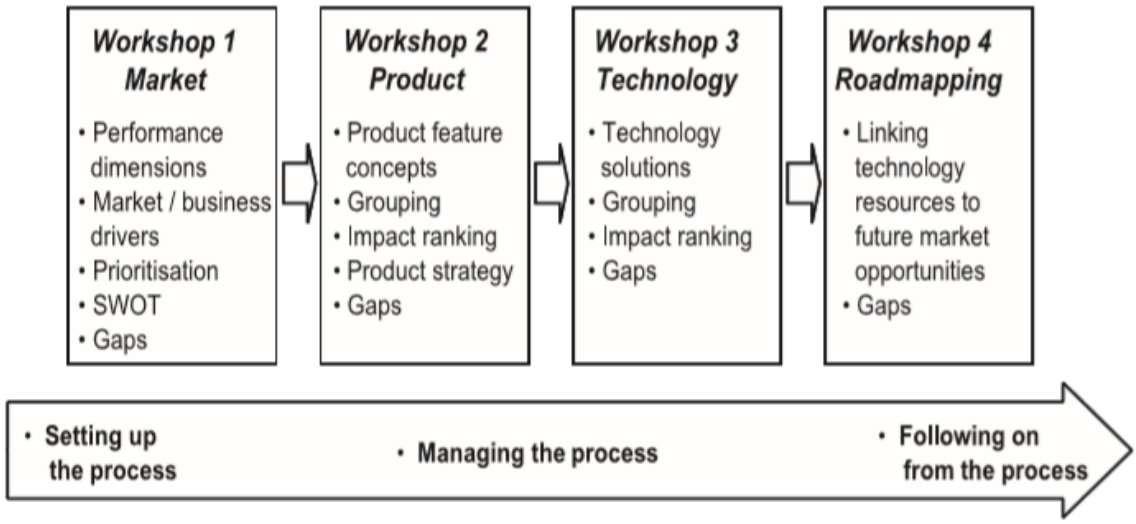

Figure 22. Standard T-Plan Process Steps. Source: Phaal et al. (2003).

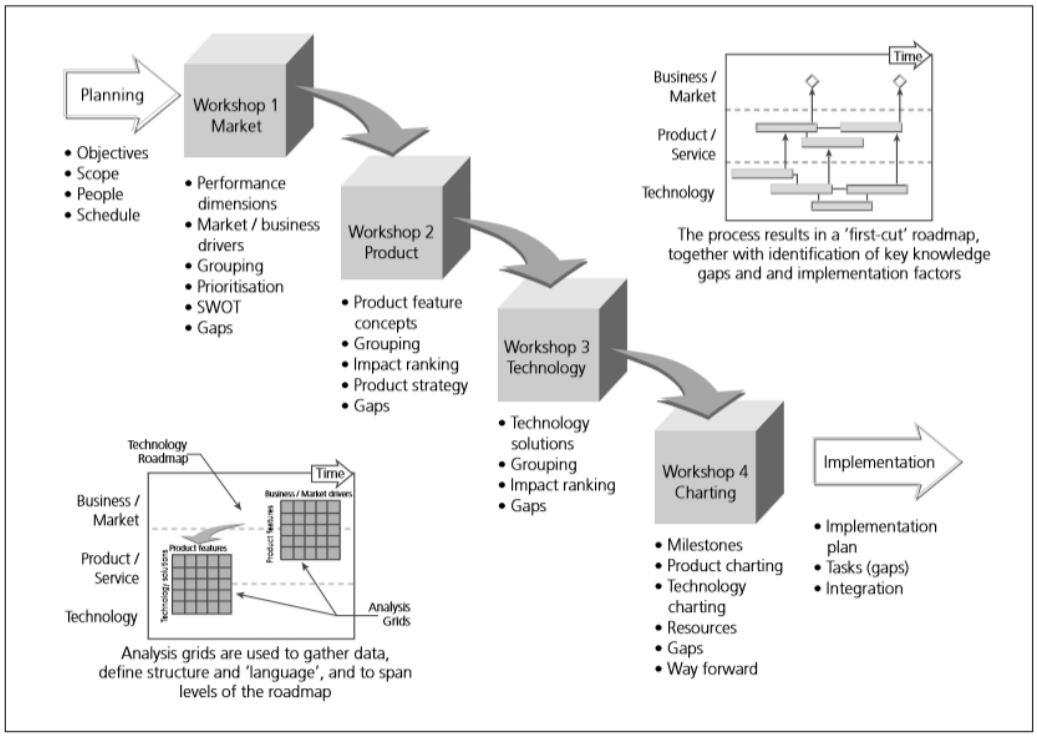

Figure 23. T-Plan with Linked Analysis Grids. Source: Phaal et al. (2003); UNIDO (2005).

b. S-Plan

According to Phaal & Miles (2008), the S-Plan utilizes a single workshop. They state that opportunities for innovation are developed through the examination of executable strategies; 15–25 participants are involved in the process. They also mention that the S-Plan focuses on the wide, unclear and unstable initial stage of the process funnel as shown in Figure 24.

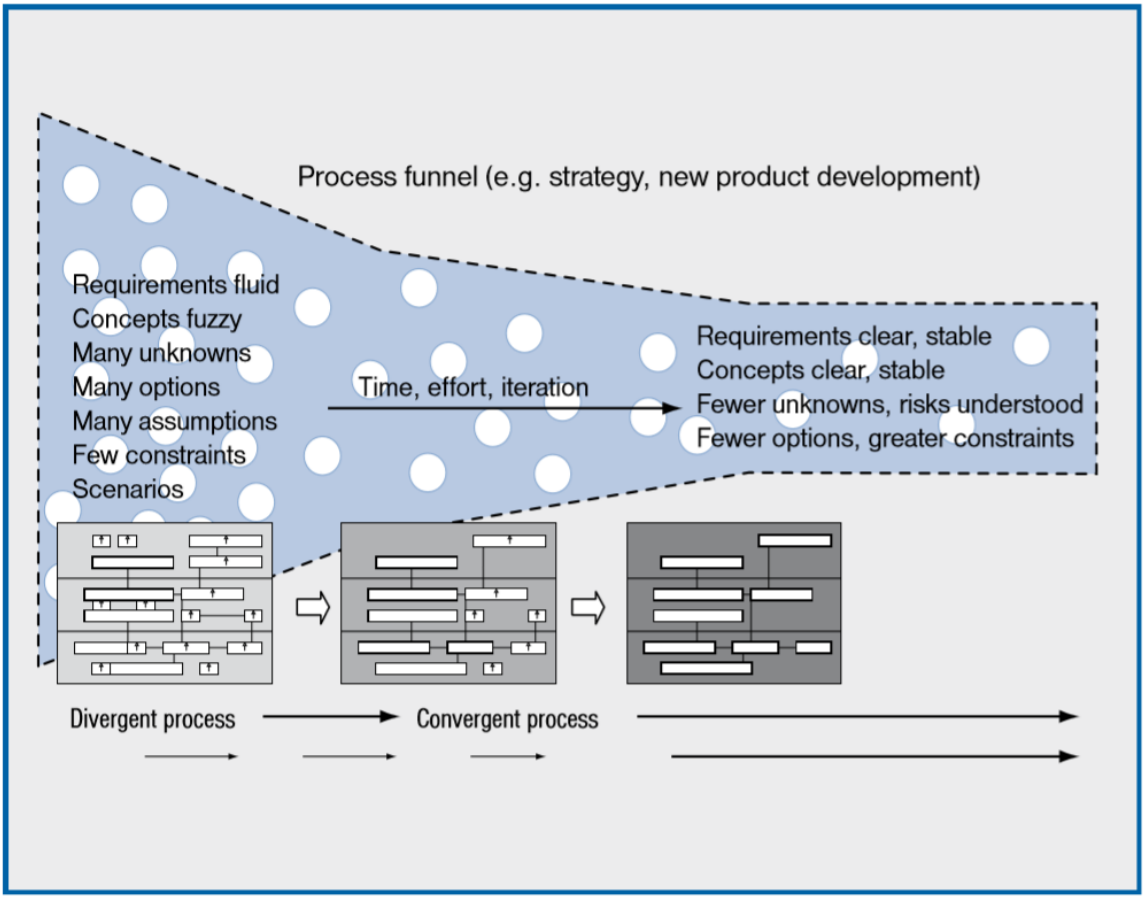

Figure 24. S-Plan Process Funnel. Source: Phaal & Miles (2008).

Phaal & Miles (2008) provide the S-Plan workshop framework, which is as follows:

- Strategic landscape: Considering the full scope of the business, the roadmap framework shares and capture perspectives from across the group of participants, identifying and prioritizing strategic issues for discussion.

- Opportunity identification: Drawing on the information in the strategic landscape, strategic options and opportunities for innovation are identified and prioritized.

- Opportunity exploration: Small groups use the roadmap framework to articulate the nature of the opportunity, map how it can be achieved, and identify key enablers and barriers.

- Review: Participants agree which opportunities to take forward, and how to do so (typically feeding into company innovation and strategy processes). (p. 18)

Spreading the roadmapping process throughout the organization speaks to a noteworthy culture change for participants not accustomed to creating, sharing, and implementing strategic, integrated plans such as roadmaps (Cosner et al., 2007). Visible and consistent support from senior leaders is key to the successful implementation of cultural change; the adoption of roadmapping into an organization is no different according to Cosner et al. (2007). No matter what plan the organization decides to implement, gaining and maintaining buy-in must be at the forefront.

2. Computer-Based Approach

According to Kostoff & Schaller (2001), objectivity separates the 'expert-based approach' from the 'computer-based approach'. In today's world of artificial intelligence and big data analytics, it should come as no surprise that a computer-based approach for roadmapping exists. However, the computer-based approach is devoid of expert biases, limitations, constraints, and agendas. They state following about the computer-based approach:

> The computer-based computational linguistics approach does not start from one point in time (as does the expert-based approach) and evolve either forward or backward in time. It generates the network at all points in the time domain of the source database simultaneously. Temporal changes are usually obtained by examining full spatial networks derived at different points in time. The citation approaches march forward in historical time from the cited papers to the citing papers to generate the temporal aspects of the citation network. (p. 136)

Structural relationships and source databases are key for the computer-based approach; this approach is primarily based on large textual databases describing engineering, technology, science, and products using computational analyses (Kostoff & Schaller, 2001). The lack of human interaction may be viewed as a positive by some; however, it can also be a negative. Nonetheless, computer-aided decision tools are becoming more prevalent (Kajikawa, Takeda, & Matsushima, 2010). Program managers and leaders must consider the strengths and weaknesses. In the case for the DoD, this

project recommends a blended approach that utilizes the computer-based method as a complement to the expert approach. Combining the two methodologies will inevitably provide the most value and efficiency for organizations DoD-wide. The computer-based approach is a relatively new roadmapping aspect and will most likely become a mainstay for years to come. Research into the computer-based approach is worthy of future research dedicated to the topic.

C. ROADMAPPING PHASES

1. Phase 1: Planning and Preparation

Organizations should diligently integrate roadmapping into their overall operational processes to ensure realization. Cosner et al. (2007) proclaim that planning for the adoption of roadmapping is just as important as actual integration. They advise that planning activities may be low-impact compared to the actual roadmap but they should not be treated as an under-resourced, inconsequential side activities. Their recommendation that organizations should plan for an integrated process implementation with current business processes as opposed to a discrete implementation of roadmapping will help alleviate support issues that if left unsolved, causes issues later in the project.

According to Cosner et al. (2007), the process of roadmapping begins by establishing a small multidisciplinary project team and team leader. Next, the leader oversees roadmap documentation and maintenance activities and typically uses one of three popular approaches to build it: central process, distributed approach, or a workshop approach. This project focuses on the workshop approach for DoD efforts.

Selecting the appropriate methodology positively affects expert judgment and consensus-building activities (Cosner et al., 2007). Whether the choice is the Central Process, Distributed Approach, or the ever-popular Workshop Approach, these methodologies enable project teams to formulate goals/milestones, identify gaps, establish priorities and assign tasks (Groenveld, 2007). Roadmapping teams should consider these five questions to help guide them towards solutions

- What does the organization want to achieve; what are the goals?

- What do we need a roadmap for products, strategy, other?
- If multiple roadmaps are necessary, will they be interrelated? If so, how?
- In what ways does the organization want to organize the roadmapping process?
- What type of monitoring and follow-up is required (Groenveld, 2007)?

Goals for the project team workshop typically include

- Obtaining SME consensus on assumptions, strategies, objectives, costs, performance, etc.;
- Identify and strategize against threats and barriers (e.g., technical, institutional, etc.); and
- Prioritize implementation strategies and action items (IEA, 2014)

No matter the roadmap type, the objective remains the same for all roadmapping teams early in the process: establish a consensus within a comprehensive group of SMEs through knowledge sharing and the principal objective of creating or adding value (Meng Li & Kamoeka, 2003; IEA, 2014). Familiarizing stakeholders with the methodology and iterative products throughout the process reduces implementation risk, cost, and time (IEA, 2014).

According to IEA practitioners (2014), roadmap goals should be supported by expert judgment, sound data, and thorough analysis. These goals help define baseline conditions and strategic routes: “Tasks can be accomplished by a team of analysts and technology experts with access to reliable data sources, analytical and modeling tools, and technology performance characteristics” (IEA, 2014, p. 7). Data analysis is time-consuming. Therefore, resources must be considered and managed to provide a quality product or effort. These factors and the analytical capabilities of the team will affect the output (IEA, 2014).

a. Leadership Commitment

Organizational adoption of a roadmap appears simple, but nonetheless requires significant effort by a variety of people (IEA, 2014; Phaal, 2008). Engaging senior leaders and stakeholders throughout the roadmapping process are key (IEA, 2014). For example, after Rockwell Automation's first roadmapping effort in 1995 (McMillan, 2003), their primary lesson learned was the commitment from senior leaders must be had before the effort can succeed. Steering committees and roadmap workshops can serve as the foundation for gaining and maintaining leadership commitment by showing that a well-coordinated process is in place (IEA, 2014; Letaba et al., 2015). Validation for roadmapping efforts occurs when buy-in is gained from critical stakeholders (Letaba et al., 2015).

b. Workshops and Steering Committees

According to IEA (2014), "most successful roadmapping efforts are led by a small steering committee whose members possess the knowledge and authority to make decisions regarding goals, scope, and boundaries" (p. 8). Ideally, the roadmap's leader and those involved will determine the committee's size and structure. A rule of thumb for committees led by senior government officials is three to six key decision makers. A bigger committee of 6 to 12 members is sufficient for efforts lacking top-level support; a committee this size enables a variety of interests to be represented. (IEA, 2014). Ultimately, the leader will make the final decision, but the committee involved with the process must believe that their expertise and views are being considered. Furthermore, committee members want to have a genuine opportunity to fundamentally influence the final decisions of the roadmap (Garvin & Roberto, 2001).

Establishing and implementing collaborative workshops is an excellent method for roadmap leaders to effectively leverage cross-functional subject matter expertise and foster creative solutions for the roadmap.

Workshops assemble partners and specialists identified in the planning and preparation phase. The IEA (2014) affirms multiple workshops may be required for the more intricate roadmaps addressing a bevy of issues. For instance, the first few workshops

may focus on innovation issues and include scientists, technologists and innovation engineers, while another set of workshops may concentrate on budgetary, policy, and administrative issues. Experts may include investors, controllers, policy creators, advocacy groups, and related shareholders (IEA, 2014). In short, collaboration is the key to roadmapping success. Maximizing the knowledge and expertise of the participants is critical. That makes identifying and communicating roles and responsibilities particularly important.

c. Roles, Responsibilities, and Stakeholders

Engaging the experts and stakeholders upfront and early in the process will increase the likelihood of roadmap buy-in and commitment (IEA, 2014). Identifying and engaging stakeholders is crucial for roadmap success. Like many other program or project-based efforts, getting the right people involved and maintaining an open dialogue for the purpose of buy-in is a critical objective for roadmapping. This process aids both the development and implementation of the roadmap. However, a balance must be considered. Balancing the maximization of buy-in and ensuring a manageable size and scope for the roadmap project must be maintained (Cosner et al., 2007). It is equally important to begin with topics important to the organization's future. This allows efforts to be focused on the development of a specific roadmap and the development of repeatable processes for future endeavors (Cosner et al., 2007).

To ensure collaboration and roadmapping success, all stakeholders need to understand their roles and responsibilities. A RACI (responsible, authorized, consulted, and informed) chart would help with this task. RACI is an obligation task grid that partitions roadmapping members into one of four classifications – R, A, C, or I (Costello, 2012).

Costello (2012) states that RACI is based on the premise that only one person will serve as the 'A' or be accountable for a specified project, in this case, the roadmap. This person owns the roadmap no matter the outcome. Next, the roadmap owner must select the 'R' personnel. According to Costello, the 'R' personnel will be responsible for executing tasks that will provide the desired outcome for the 'A'. Next are 'C' and 'I'. Costello states

traditionally ‘C’ has represented the term consulted, but a modification is suggested. ‘C’ can also represent “contributes” which is more action-oriented. Both terms work and this project combines the two: ‘C’ personnel are SMEs that should be ‘consulted’ and they need to provide their expert ‘contributions’ to support the roadmapping effort. Lastly, the ‘I’ personnel are the managers, stakeholders, etc., that must remain informed. The RACI process and diagram helps with correspondence to all participants and interested parties to ensure they remain appropriately engaged and the project remains on task (IEA, 2014).

d. Purpose and Scope

Practitioners (IEA, 2014) recommend a statement of purpose and scope be developed during Phase I. These practitioners assert that a statement of purpose and scope will guide teams and help them maintain focus for the duration of the roadmapping project. They also state that oftentimes, there is a strong tendency to add more requirements as the process advances; this is why it is important to thoroughly identify the needs upfront and obtain concurrence. This is the typical program management challenge known as scope creep. According to the GAO (Sullivan, 2010), one of the keys to stable Programs is a resistance to new requirements and adherence to commitments. According to the IEA, answering the following questions helps roadmapping teams adhere to commitments

- Purpose: Why is the roadmap being developed?
- Scope and objectives: What is the roadmap expected to do?
- Process: How will the roadmap be developed and implemented?
- Participants: Who will be involved? (IEA, 2014, p. 9)

These questions help the roadmapping team to remain committed to accomplishing the envisioned goals; stakeholders, current members, and prospective participants become unified and educated on the path forward (IEA, 2014).

e. Baseline Data and Analyses

Roadmapping, like many other acquisition efforts, requires the development of a baseline. Practitioners from the IEA (2014) view the planning and preparation phase as an ideal time to achieve baseline development. During this time, the IEA recommends that roadmap teams create a list of required data types addressing a roadmap's purpose, scope, and key objectives. For them, the baseline provides a reference point and enables the team to understand the present situation. They advise there are normally three broad topic areas for situation analysis: technologies, markets, and policies. The following should be considered to help generate additional details

- Technologies to be evaluated;
- Application of technologies and their markets;
- Policies affecting technologies and markets of interest (IEA, 2014)

Considering relevant roadmaps from other experts or working groups should also be viewed as aids for baseline development (IEA, 2014). Table 2 summarizes the key foci of technology, markets, and policies area that inform the roadmap's development.

Table 2. Technology, Markets, and Policy Focus Areas.
Source: IEA (2014).

Focus Areas	
Technology	Development Status
	Technology Performance
	Technology Costs
	Impacts
	Technology Potential
	Links to Other Technology Areas
Market	Suppliers
	Distributors
	Customers
	Market Penetration
	Existing Studies/Forecasts
Policy	Current Status & Requirements
	Existing Laws & Regulations

2. Phase 2: Visioning and Development

Successful roadmapping processes often include a visioning session enabling experts to meet, discuss, and define the desired future states (IEA, 2014). Visioning sessions typically include executives, technical experts, and leading researchers according to the IEA (2014) practitioners. Their guide suggests that at this phase, participants can utilize data analysis results to formulate alternative scenarios and projections. The guide also reveals the importance of allocating sufficient time for reviewing data and projections before visioning workgroup sessions; their goal is to verify the team understands the data and projections and suggests that others adopt this position. Lastly, the guide suggests that SME judgment can be a viable substitute for a lack of data.

After the roadmapping team establishes a vision, the roadmap development phase begins. The IEA practitioner guide from 2014 states that typical activities within the development phase include workshop sessions, drafts, roadmap reviews, and modifications. According to their research, they suggest that the average roadmap development time is approximately 6 to 18 months. This provides interested DoD organizations without roadmapping experience an estimation of delivery times. Roadmapping is a process that takes time and DoD organizations must work diligently and be patient if they want positive results.

The length of roadmap documents can vary from simple (1 – 5 pages) to extravagant (up to 100 pages or more) (IEA, 2014). It appears that roadmaps can also vary in quantitative detail and content. The IEA guide suggests that the best roadmaps consolidate their individual components with basic, easy-to-read, and convincing designs that convey key ideas to subject matter experts (SME) and non-SME groups alike.

When developing roadmaps, authors should consider a wide array of professionals in the audience. Excessively complex and specialized business, technical, or legal vernacular could put the roadmap out of reach for certain professionals; clear, succinct, basic dialect with complimentary figures is the best method to reach the entire audience expected to actualize the roadmap (IEA, 2014). However, there a times when the message

must be tailored to different audiences. A pair of quotes from the *Communicating the Future* article (Borchet, n.d.) puts it best:

> The effectiveness of communication - the accurate receipt and use of information - can be improved substantially by carefully defining intended audiences and by tailoring the level of information provided to each audience…the preparation of a one-size-fits-all message for all possible audiences and outlets is almost always ineffective and is a practice to be discouraged (Borchelt, 2001, p. 9).

The importance of a carefully constructed review process should not be underestimated. Like a graduate level thesis or any other formally published document, a series of expanding review cycles may be necessary after an organization's initial draft. Based on the IEA (2014) guide, the initial draft is typically distributed to the contributing members for review and comment. The guide also explains that it is important to set deadlines for comments and reviews to ensure the project remains on schedule; adequate time for a thorough review and well-thought comments should be allotted. During the next step, the guide recommends that comments be collected for review with the value-added suggestions being incorporate to bolster the draft map. The guide proposes that resolving conflicting suggestions and comments from the different reviewers are one of the most difficult tasks; consensus-based resolutions may not occur each time. This leaves authors or roadmap owners with the following options

1. Choose one position based on the views of the majority or the or the final decision maker; or

2. Present the opposing views in the roadmap, noting the minority viewpoint, if applicable. (IEA, 2014, p.16)

Once a decision is made, the IEA recommends that authors prepare a revised draft; revisions may range from fundamental reassessments of the strategy to simple text changes. They also note that identifying and resolving issues during the review cycle is critical for success and should be managed appropriately; acquisition managers should be familiar with this approach. After the appropriate amount of internal review cycles, the IEA recommends an external review should take place. Opposite internal reviews they contend external review(s) should incorporate a wider audience of experts so responses from those

unfamiliar with the roadmap process can be solicited; the goal is to obtain a fresh perspective that enhances the roadmap (IEA, 2014). However, practitioners from the IEA (2014) suggest external comments may simply confirm that the roadmap is sound and ready to be released.

3. Phase 3: Implementation, Monitoring, and Revision

The third roadmapping phase according to the IEA (2014) guide consists of implementing, publishing, monitoring, revisions, and expectation management. The guide suggests that there are many ways to formally publish roadmaps; they can be announced through a press release, conference, or through selective electronic distribution. The guide finds that national roadmaps or guides that impact wide networks require more elaborate launches than organization-based or company-focused roadmaps. Though a simple act, providing awareness of the roadmap's release to customers or those that must act upon the roadmap's recommendation(s) is one of the primary goals for this phase.

The final roadmap should outline a set of priorities over a defined time frame. The goal is to develop and socialize a strategy that explains how near-term and long-term priorities will be achieved (IEA, 2014). Ideally, the roadmapping team tracks the undertakings of different partners and assembles the results in a cohesive wellspring of information. Given the wide degree of national-level roadmaps and the wide range of SMEs associated with execution, tracking each activity could be difficult; checking progress through a devoted execution body assists with the incremental advancement of the roadmap (IEA, 2014).

Establishing progress indicators is a fundamental task within any roadmap process and requires SME consensus to guarantee legitimacy and achievement (IEA, 2014). Metrics will help keep the roadmap on track. For instance, if a roadmap expresses a multi-year design of accomplishing a 25% reduction in size for a wideband transceiver, the implementation team can examine this metric every year to monitor progress, taking a 3% to 5% yearly decrease as a positive indicator for possible achievement.

According to Cosner et al., (2007), at any point in time, the roadmap should signify an organization's best reasoning about its near-term and long-term operations. They

contend that a roadmap is a living document and should be periodically reviewed to determine the organization's trending status; an annual review is highly recommended. However, industries with short product cycles should conduct reviews more often.

VI. APPROACHES THAT INCREASE PROBABILITY OF SUCCESS

Chapter 6 provides phase-by-phase best practices, success factors based on a field expert's study and the importance of strong leadership is reiterated.

A. BEST PRACTICES

In 2003, de Laat & McKibbin, assessed 78 roadmapping initiatives on their ability to effectively support innovation policies and systems at the national and corporate levels. The assessment covered roadmapping initiatives from Canada, the United States, Europe, and Japan. Good practices and lessons from the study have been applied to the four phases

1. Phase 1

- Roadmapping priorities should clearly link with an organization's priorities;
- If there is an urgent need, it will be easier to obtain resources and stakeholder interest for the effort;
- It is imperative to involve stakeholders and decision-makers early and often (Phaal, 2015; IEA, 2014).

2. Phase 2

- Roadmaps are not one size fits all; they have to be customized for the mission;
- Maintaining interest and involvement in the effort must be managed
- Throughout the process, learning should be accommodated as roadmapping is inherently exploratory;
- To encourage positive communication and thinking, roadmapping teams must be open and willing participants sharing a common goal;

- How the roadmapping effort will be financed must be determined early. Research shows costs are usually shared between the participating SME organization(s) and the stakeholders (Phaal, 2015; IEA, 2014; Meng Li & Kameoka, 2003).

3. Phase 3

- The process of roadmapping is iterative and schedules for any roadmapping effort should be developed accordingly; review after the first iteration typically provides the highest value added;

- Roadmapping outcomes/impacts should be monitored and evaluated to support future efforts (Phaal, 2015; IEA, 2014).

B. CRITICAL ELEMENTS TO HIGH-QUALITY ROADMAPS

Figure 25 provides additional insight on best practices and success factors. This 1999 survey provides the top six success factors identified by professionals experienced with technology roadmapping process.

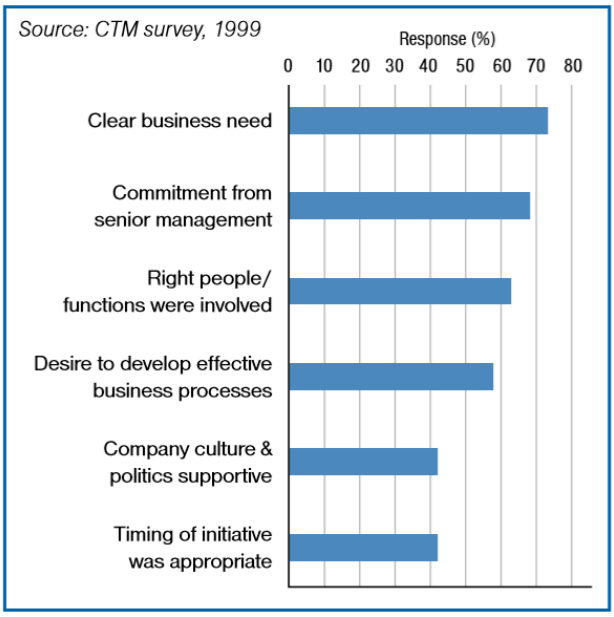

Figure 25. Top Six Roadmapping Success Factors. Source: Phaal & Miles (2008).

The responses from the 1999 roadmapping survey mirror some of the findings outlined in the May 2010 GAO report *Strong Leadership Is Key to Planning and Executing Stable Weapon Programs*. To summarize, the GAO (Sullivan, 2010) report concluded that a sound business case with disciplined execution managed by strong leaders capable of gaining senior leadership support produces desired outcomes or success. Figure 26 is a graphical representation of the GAO assessment that validates the top six roadmapping success factors.

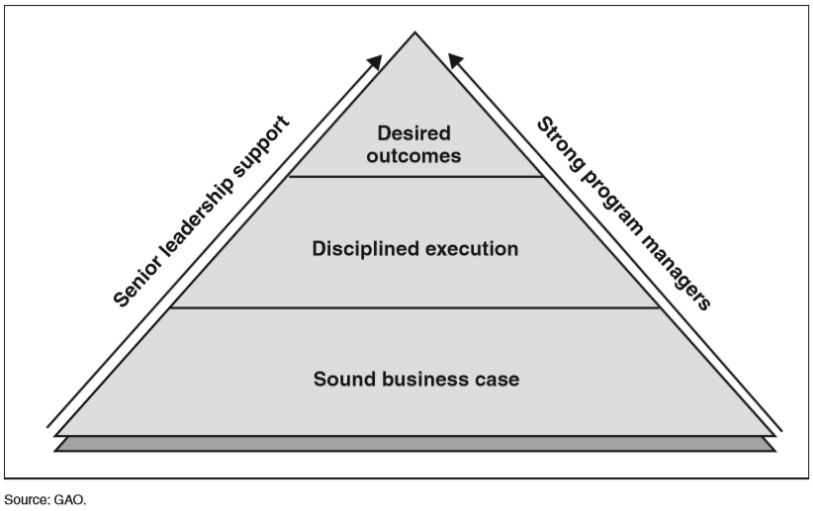

Figure 26. Key Factors That Enable Program Success. Source: Sullivan (2010).

According to contributions derived from Professor Ian Miles and Dr. Robert Phaal in the Practice on Roadmapping training course (Phaal & Miles, 2008) organizations interested in roadmapping should consider the following recommendations for success

- Establish a clear need;
- Ensure commitment from senior management and stakeholders;
- Plan carefully and customize the approach to suit the circumstances;
- Phase the process to ensure that benefits are delivered early;
- Ensure that the right people, functions, and organizations are involved;
- Link the roadmapping activity to other management processes and tools;
- Provide adequate support and resources;
- Keep it simple; and
- Iterate and learn from experience. (Phaal & Miles, 2008, p.19)

A clear understanding on an organization's direction through open dialogue and consensus is the true measure of effectiveness for roadmaps, not its prediction accuracy (Phaal & Miles, 2008).

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VII. SUCCESS IS NOT GUARANTEED

Chapter VII completes the 360-degree view on roadmapping by exposing of the difficulties with roadmapping. This chapter examines barriers to success and analyzes data to help prevent future roadmapping failures. An examination of roadmapping education is presented along with recommendations addressing the findings.

A. ROADMAPPING CHALLENGES AND ANALYSES

Thus, far, roadmapping and its by-product, the roadmap have been discussed in a positive manner. In many circles, the terms roadmap or roadmapping have developed such a negative connotation that it may be difficult to implement a truly beneficial process. The problem is this: many roadmaps are ill-fated from the outset because managers do not sufficiently identify mitigation strategies for the challenges or pitfalls that negatively affect efforts before, during, and after roadmap release (Kirsch, 2017). Unsolved challenges eventually lead to ineffective strategies preventing organizations from achieving their goals. Figure 27 highlights survey data outlining common roadmapping challenges.

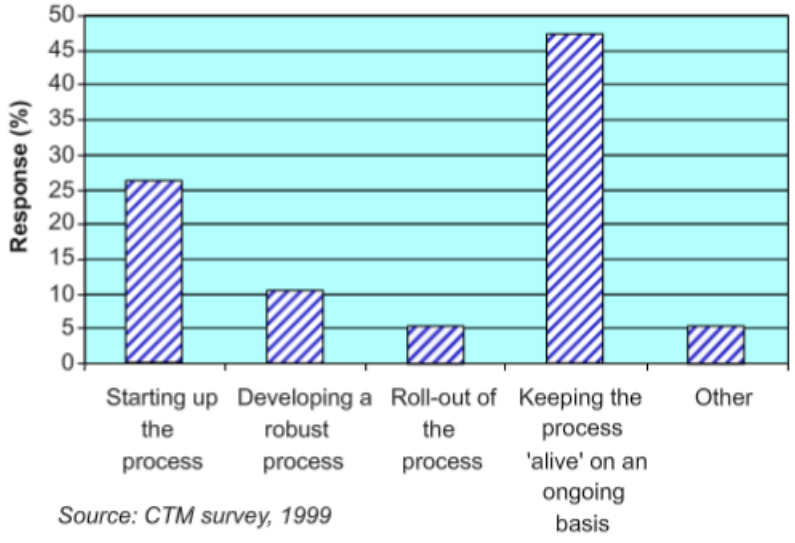

Figure 27. Roadmap Challenges. Source: Phaal (2006).

Figure 27's data indicates that it is difficult to start a roadmapping effort and it becomes increasingly difficult to establish a regimented process and keep all of the players engaged. One can conclude that some organizations may view roadmapping as too difficult. With this belief, either they do not attempt to implement the process, or they haphazardly try roadmapping resulting in a failed effort. These unfortunate outcomes are because some organizations do not support the effort with enough resources to ensure its success; they refuse to invest. The lack of support may be attributed to a silent disbelief in roadmapping as a useful strategic tool. One could argue that this inaction or lack of support is far from silent. It speaks very loudly. Laziness/ weak leadership will cause any effort to fail.

Compiled by Phaal, Farrukh, & Probert (2003), Figure 28 provides a comprehensive side-by-side list highlighting success factors and barriers to success. Special attention should be given to the higher values in Figure 28's graph; lack of data/knowledge is a major problem. Research has shown that literature published on roadmapping is sparse, with a vast majority of information coming from practitioners (Kostoff & Schaller, 2001). Without supporting data through research, market analysis or other methods, how can an organization establish a clear business need or strategic direction? In essence, the top-ranked barrier to success is linked to the top-ranked success factor. When there is a desire from senior management to properly resource the roadmapping effort, they will minimize employee distractions from other tasks or an initiative overload. Figure 28 lists "Desire to develop effective business processes" and "Initiative overload / distraction from short-term tasks" as the second highest success factor and barrier to success. This provides additional proof that success factors and barriers to success have interesting parallels. Organizations should take heed prior to starting a roadmapping effort.

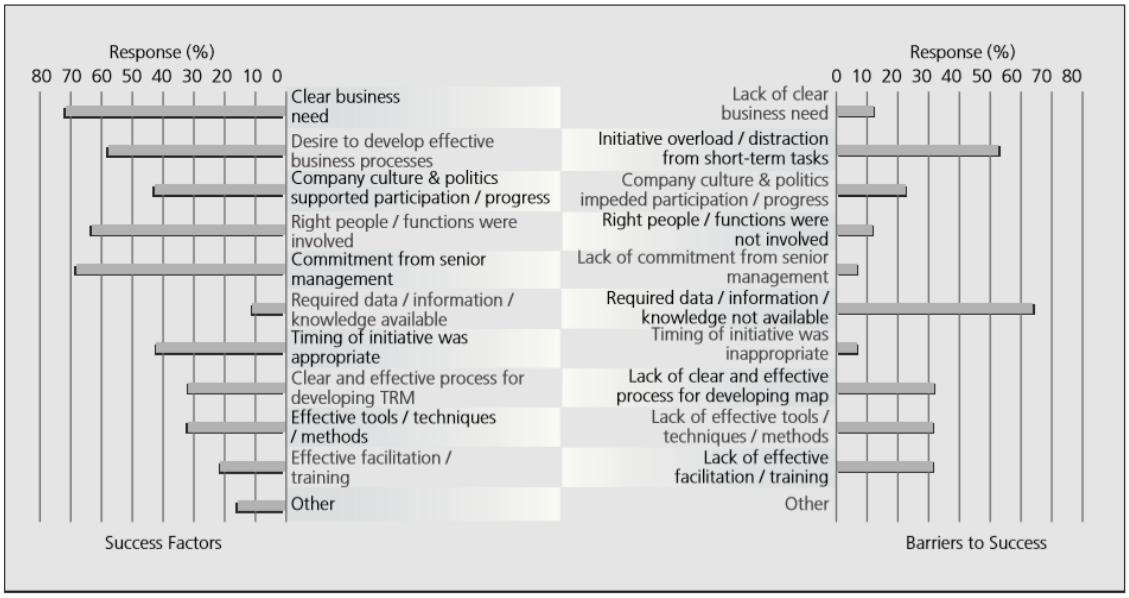

Figure 28. Roadmapping Success Factors and Barriers to Success. Source: UNIDO (2005); Phaal et al. (2003).

Pitfalls associated with the design of a roadmap by Phaal & Miles (2008) are shown in Figure 29. According to their work, once an organization crosses the initial barriers of deciding to implement roadmapping, dedicating the resources and collaborating with stakeholders, the result should be a roadmap. As discussed, roadmapping as a process has many challenges. Conversely, the result, or the roadmap, has a variety of pitfalls of its own. There are a number of horrible roadmaps on the Internet and many more—thankfully—that do not get published for a variety of reasons. It has to be discouraging to advocate for the implementation of roadmapping in an organization and receive internal buy-in, assemble a cross-functional team, establish processes and procedures, gain external buy-in and input from stakeholders and then produce a roadmap with the unsuccessful attributes found in poor roadmaps as illustrated and listed in Figure 29 (Phaal & Miles, 2008).

These design pitfalls produce unsuccessful roadmaps and should be avoided at all costs. Unfortunately, these pitfalls are the norm. Unless organizations are properly educated on the concept of roadmapping, this useful tool will continue to be misused or unused due to bad practices, and haphazard implementations. The topic of formal education and roadmapping is further discussed in the section titled: Roadmapping Education: Where is it?

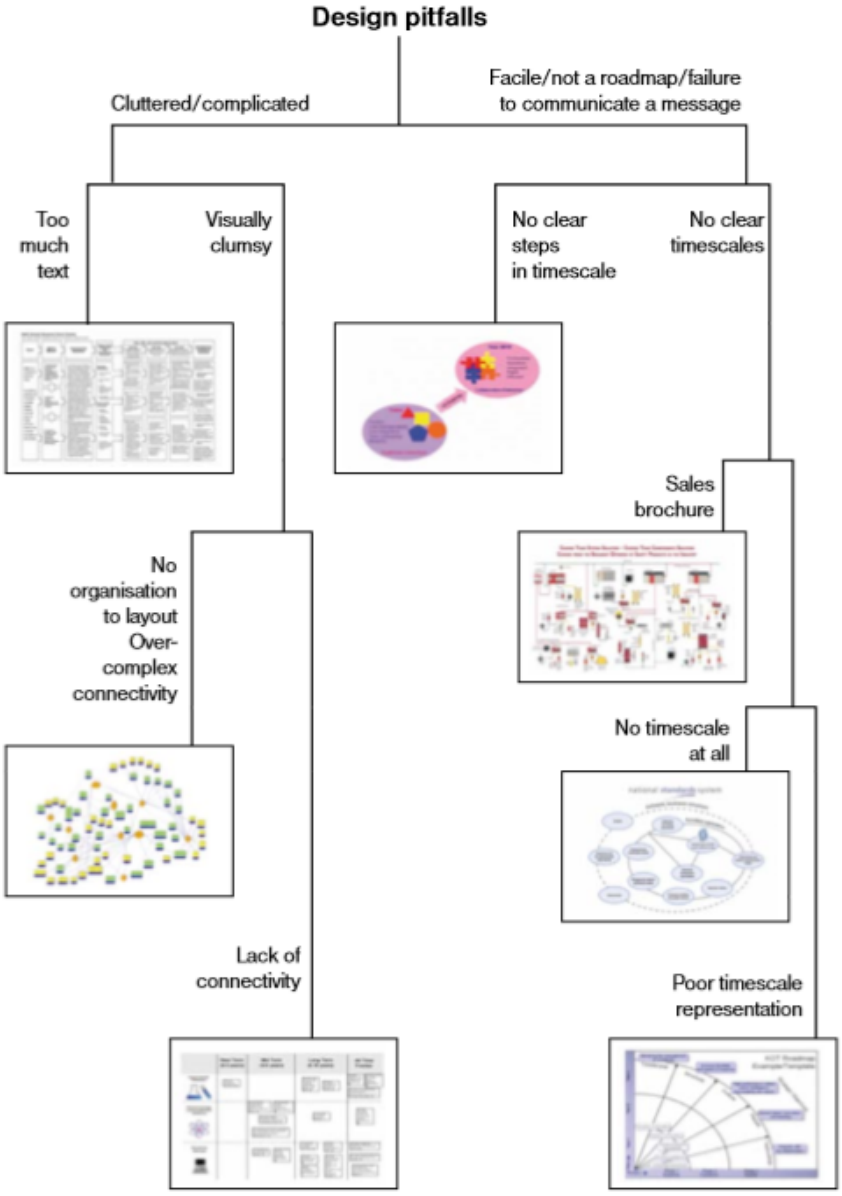

Figure 29. Design Pitfall Decision Tree. Source: Phaal & Miles (2008).

Providing empirical data and insights on practical roadmapping, an online survey (Abele & Schimpf, 2016) taken in Germany from July to September 2015 received 81 out of 156 responses and answers the following questions

- What is the content of roadmaps in companies?

- Where are they being used and how are they being integrated?
- Which source of information do companies access and by which methods are the roadmaps complemented?
- What challenges do the companies face and what is their recommendation for the practical use of roadmaps? (Abele & Schimpf, 2016)

This section combines data sets from the survey conducted by Fraunhofer IAO and TIM Consulting and other sources to help explain why roadmaps have not been as useful as organizations would like them to be. Figure 30 is from the study in Germany. The figure highlights content, applications, and timelines and states the number of responses (n = #, multiple responses) received. Under content, we see that a majority of the roadmaps contain products (79.7%), technologies (68.4%), projects (57.0%) and strategic alternatives and goals (44.3%). However, roadmap applications paint a different picture: strategic planning (77.8%), technology planning (66.7%), R&D planning (61.7%), and product and services planning (55.6%). The numbers indicate that roadmap content does not match the application, especially when it comes to products and strategy.

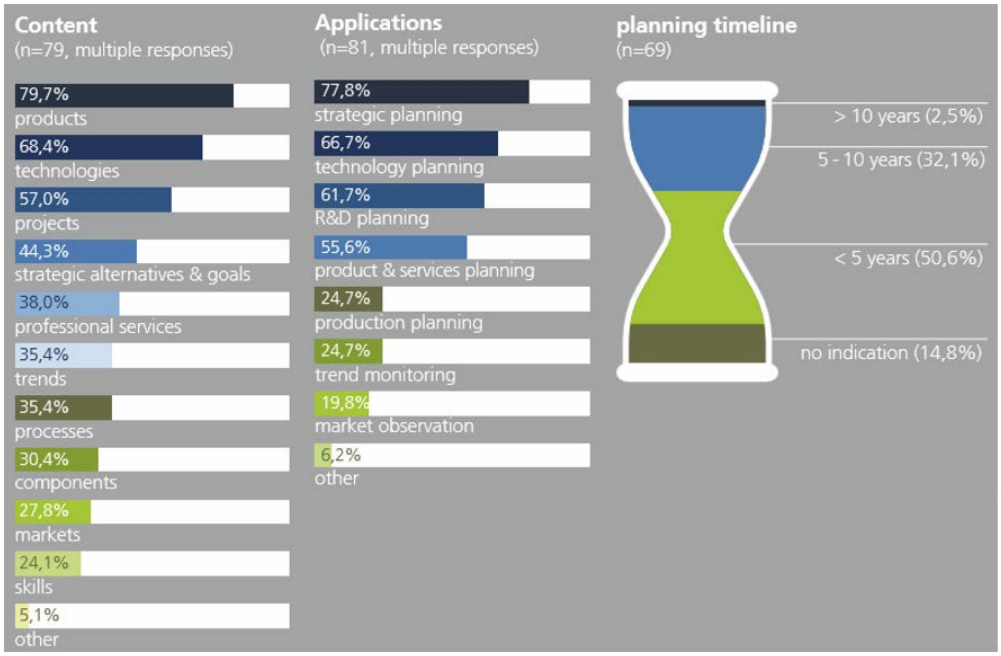

Figure 30. Roadmap Study Results from German Companies: Content, Applications, and Planning Timeline.
Source: Abele & Schimpf (2016).

The content versus application problem may stem from confusion. Organizations have to know what path they want to take and stay the course during their roadmapping process. The root cause of this mix-up stems from flaws in management curriculums across the globe and will be discussed shortly.

The third and final data set from Figure 30 is the planning timeline (Abele & Schimpf, 2016). This dataset did not receive multiple responses so it utilizes a scale of 100%. From the 69 responses, the study shows that 50.6% of roadmaps are less than 5 years, 32.1% are 5 to 10 years, 14.8% have no timeline, and 2.5% were greater than 10 years. As time is an essential roadmap component, to have 14.8% of the respondents with roadmaps that have no indication of time is shocking. With no indication of time, there is one less mechanism for organizational measurement of effectiveness. The numbers indicate that 14.8% of the respondents are willing to tell their stakeholders, customers, or end users the following: 'We'll get there, but we don't know when.' Hearing this from your dinner party while you wait patiently at the table, from your pilot as you fly the friendly

skies, or from the organization you have invested in, is not a great message. Time limits enforce accountability and responsibility. Some roadmaps fail because they are devoid of time.

Rarely discussed as an important ingredient for roadmapping is the establishment of aligned measures as a means to track progress. Failed roadmaps occur when measurements are taken based on ease instead of importance (Grossman, 2004). Measures of effectiveness must be considered and implemented early in the roadmapping process, prior to actually tracking anything. Oftentimes, implementing measures of effectiveness is avoided because it encourages accountability. Accountability is linked to responsibility for actions taken and some personnel want to avoid this. In turn, this marginalizes the roadmapping process and ultimately generates an unsuccessful roadmap. By making things concrete and visible, findings will be difficult to ignore thanks to a sound measurement strategy.

Now that the primary reasons why roadmaps are ineffective at times have been identified, data and data analyses from a study in Germany will help ascertain where roadmapping responsibilities lie.

The next data set addresses integration of the roadmapping process. Specifically, Figure 31 addresses responsible areas and defined processes. Under the responsible areas section (n = 54, multiple responses), the top 5 areas were product management (65.8%), technology and innovation management (53.4%), management (53.4%), research & development (47.9%), and corporate development and strategic planning (47.9%) (Abele & Schimpf, 2016).

This data points to management and technical personnel responsibility for the roadmaps in this study. This means the problems with roadmapping are program management and technical problems. To fix them, program managers and technical personnel must be equipped to address the pitfalls of roadmapping. Organizations should invest in professional development geared towards strategic development and more importantly the nuances of the roadmapping process. The data indicates management and technical personnel are a roadmap's driving force. The data validates what this project has

stated in various sections: communication across multiple business areas is key. A roadmap cannot be successful with only management input or technical input for that matter. The roadmapping process must incorporate various disciplines with predetermined roles and responsibilities.

Roadmaps experience significant issues when roles and responsibilities are not clearly defined. Unclear roles and responsibilities intensify data collection and intelligence gathering pitfalls throughout the process. Confusion and duplication of efforts due to unclear roles and responsibilities contribute to disappointing roadmaps and roadmapping efforts.

As discussed, involvement and consensus-building are requirements for the roadmapping process. Unfortunately, many organizations only want to create the illusion of a participative structure that provides everyone with a voice that impacts the organization's decisions. In reality, the desire is to have a workforce that buys into senior leaders without dissenting ideas. Poor roadmapping is linked to the concept that communication is secondary action in the process; the facade of open communication and consensus decision making underlies a tumultuous organizational path, poor planning, and ultimately a failed strategy (Borchelt, 2001).

Figure 31's Defined Processes section reiterates the fact that communication is critical to roadmapping. Internal and external communication is a large part of the process for any decent roadmapping effort. Every other process/action (e.g., updates, insert new buildings, remove obsolete objects, etc.) is a derivative of communication and is therefore linked.

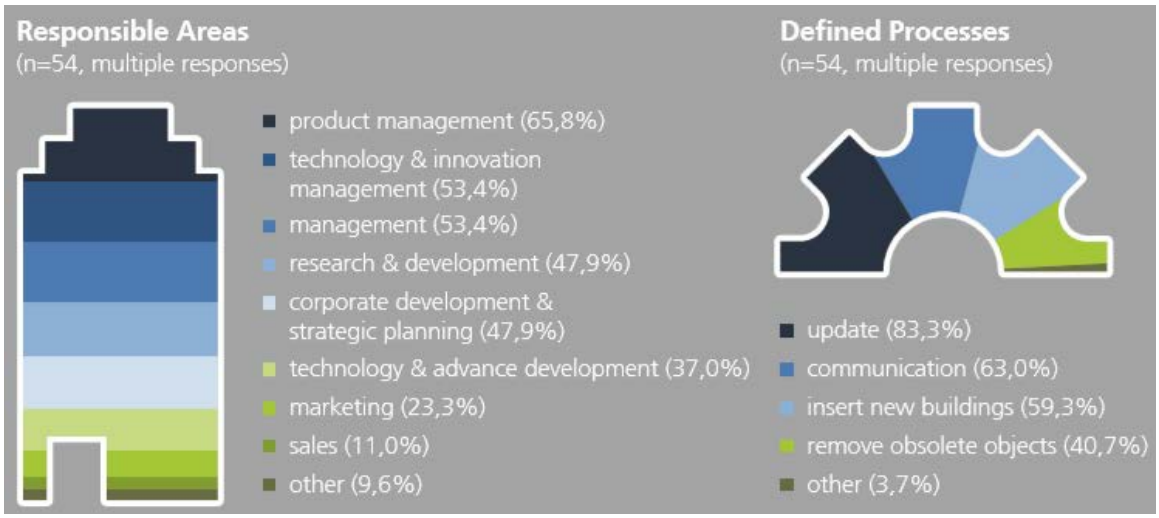

Figure 31. Roadmap Study Results from German Companies: Responsible Area and Defined Processes. Source: Abele & Schimpf (2016).

Figure 32, is comprised of surveys from Abele & Schimpf (2016), addressing what they call "sources of information" and "methods." Information or data collection is an important part of the roadmapping effort. Intelligence-gathering adds more value than raw data collection. Many organizations are full of data, but they typically lack the capacity to gather intelligence. Organizations struggle with the distinction between intelligence-gathering and data, leading to doomed roadmapping efforts. Murphy (2005) explains that the term 'competitor intelligence' is the observation and comparison of other participants in a given market against an organization's current and future operations. He also states that an organization's strategy is typically based on a need to maintain competitive advantages and gap closure on weaknesses. However, focusing too much on the competition is described as a perilous. The following excerpt proves that claim:

> Chan Kim and Renée Mauborgne of the Insead business school near Paris carried out an intensive study of some 30 companies across the world to uncover the factors which lead to high growth. They found that the less successful enterprises were the ones who were competitor fixated, devoting their energies to benchmarking themselves against their rivals and making incremental competitive improvements. The winners were those that concerned themselves less with their opponents and their industry's accepted wisdom. Instead they concentrated on 'breaking the mould' by looking at what *customers* wanted, rather than what suppliers were currently

> giving them, and devising innovations that delivered a radical improvement in value in the eyes of the purchaser (Murphy, 2005, p. 5).

The point is this: organizations should balance their amount of market analyses/competitor watching and ensure they do not lose sight of the customer/stakeholders. Many organizations/companies claim to be "customer-focused" or "customer-driven" but are they really?

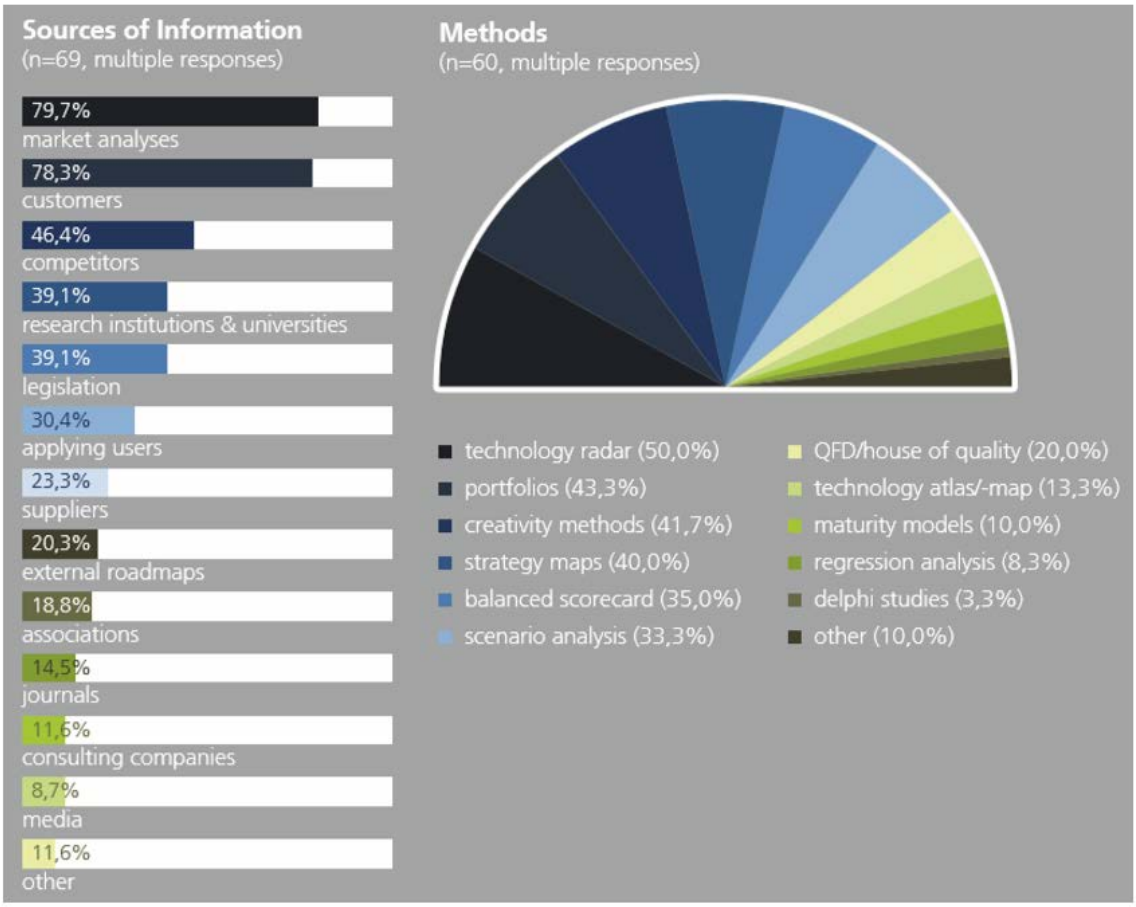

Figure 32. Roadmap Study Results from German Companies: Sources of Information and Methods. Source: Abele & Schimpf (2016).

Figure 32 highlights the sources of information used to generate the respondent's roadmaps from the study in Germany. 'Market analyses', 'customers', 'competitors', 'universities', 'legislation', and 'applying users' dominate. As part of the roadmapping

effort, organizations must analyze their market and competitors, routinely communicate with customers and end users, leverage academia and breakthroughs in research and understand policies associated with their genre of business or policies that could affect the overall market.

However, some roadmaps actually fail because of data and intelligence gathering. Usually, data gathering produces either too much irrelevant data or too little relevant data. When organizations gather too much data, no one uses it. When the data is insufficient, decision-making occurs with only limited information (Clark & Krentz, 2006). This forces roadmapping to rely heavily on the participant's experience and opinion. When strategy discussions are based on opinions instead of solid data, arguments occur within the team and factions develop. Adding to the chaos is data that becomes out of date before it is used. There are executives with spreadsheets full of statistics and reports but have no clue what to do with it.

It is clear that data collection, data analyses, effectively communicating the data and obtaining consensus in a timely manner are critical to the success of roadmaps. It is all about value; without this, the roadmapping process like many other business tools will be a failure (Manyika et al., 2011). Meng Li & Kameoka (2003) declare that the process of roadmapping should provide more value than serving as a communications tool for strategy; roadmapping is a knowledge acquisition process that dynamically serves as the catalyst for creativity/invention, data, analyses, and communication. Because of this, they assert that roadmapping can be viewed as a knowledge management tool for organizations that choose to implement it. They imply that focusing on purpose and value should be at the core of every roadmapping team. In essence, data analyses and information sharing become extremely vital in determining the added value for an organization. According to Manyika et al. (2011), collecting reams of data that add no perceivable value creates an assortment of distractions that waste time and slowly destroys team morale. For them, data presentation looms equally important and the belief is, those that collect data must effectively translate, consolidate, and communicate the information in a timely and convincing manner; this translates to efficiency and productivity being key elements in the overall process of roadmapping in the business, science, and technical environments.

Manyika and colleagues suggest that some roadmaps miss their mark because of irrelevant data, limited useful data, and ineffective data presentation due to weak analyses; poor data analyses presented to leadership cripples their ability to provide sound decision-making and effective strategies (Manyika et al., 2011).

In a broad sense, the McKinsey Global Institute exposes one of the root causes for roadmap failures. They ascertain that a deficiency in analytical skills exists. To quantify, the report from 2011 provides, "The United States alone faces a shortage of 140,000 to 190,000 people with deep analytical skills as well as 1.5 million managers and analysts to analyze big data and make decisions based on their findings" (Manyika et al., 2011, p. 3). The roadmapping process requires a cross-functional team to be analytical and use data to guide decisions and strategies. If that skillset is not part of the cross-functional team, there's a good chance the roadmap/strategy may come up short. Even if the skillset is available, personnel must be given the time to adequately parse, analyze, and present the data.

Roadmaps are to be living documents. The use of static-document word processors, spreadsheets, PowerPoint and other presentation applications do not bode well for the probability of a successful roadmap. At some point, the roadmap will require changes weeks or months into the development cycle or as resource levels fluctuate and external factors affect the organization and demand strategic adjustments (Radnor & Probert, 2004). However, if the roadmap is only a static document, making changes will be tedious and the likelihood of personnel making the necessary modifications weeks, months, or even years later are slim due to the challenges. Some notable issues that occur when roadmaps are merely static documents

- Business environments (e.g., threats, strengths, etc.) are dynamic, roadmaps will fall victim to obsolescence
- Configuration Management is difficult when multiple static documents are scattered throughout the organization or with various stakeholders (Kirsch, 2017).

Data from Figure 31 empirically confirms that roadmap updates such as the removal of obsolete objects and strategy adjustments should make up a large portion of the roadmapping process.

B. DESIRE TO ROADMAP IS STRONG

According to Figure 1 from Chapter I, a total of 11,738 roadmaps were publicly released from 1991 through 2005. When comparing 1991's roadmap total of 46 to 2005's total of 2,215, a staggering percent change occurred within that time period. The numbers clearly indicate that for many years, organizations have recognized roadmaps and consequently roadmapping, as a necessary element for organizational success.

In today's world, when someone wants to learn about a topic, they 'google it'. Google Trends is a useful data analytics tool that provides information such as search engine interests over time. When pulling 2004–2018 United States data on the search item: "How to roadmap," one will quickly notice that the Figure 33's graph has a gradual incline with periodic valleys. The data shows that the search item's popularity has been on the rise since 2016/2017. This data helps prove that the desire to roadmap is strong. However, the underlying question remains: Why do some companies/organizations fail at roadmapping while others succeed?

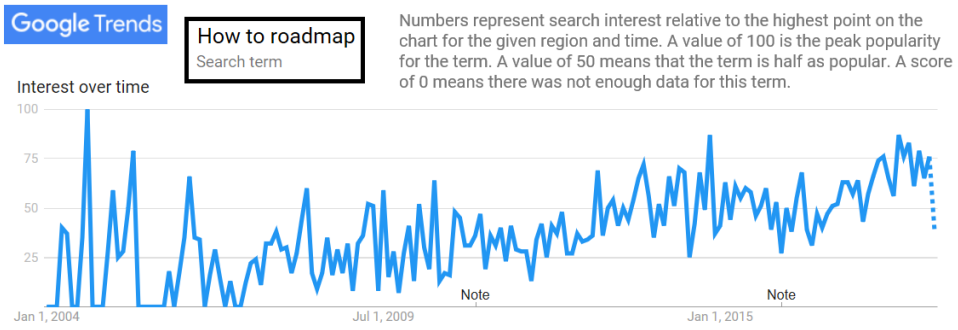

Figure 33. 2004–2018 Google Trends Web Search Results for the United States on Search Item "How to Roadmap,"

C. ROADMAPPING EDUCATION: A CAUSE FOR FAILURE?

In pursuit of understanding why some roadmaps fail, an additional question surfaced: Does academia provide formal education on roadmapping? Given the importance of roadmapping and the obvious adoption of this method across multiple sectors through the years (see Figure 1), one might assume that the top MBA programs provide the tools necessary for managers and leaders to successfully implement roadmapping in the companies/organizations they'll be leading.

According to Borrás & Edquist (2015), it is necessary to help visionaries cultivate expertise that transforms technical knowledge into innovation. A *Forbes* article (Stadler, 2015) titled, "How to Become a CEO: These Are the Steps You Should Take" stated that nearly 40% of Fortune 100 CEOs had an MBA with 60% coming from an elite school. A CBS News article (O'Shaughnessy, 2010) titled, "America's Most Popular Graduate Degrees" stated that about 1 out of every 4 men from 2008–2009 earned an MBA. During the same time period, 1 out of every 10 women earned an MBA making it the most popular master's degree for both genders. Based on this data, research was conducted on top MBA programs.

After a review of the top 15 MBA programs according to the U.S. News 2019 rankings (Boyington, 2018), only 20% had online catalogs that highlight roadmaps/roadmapping as an objective. These universities clearly acknowledge that organizational strategy and establishing competitive advantages are important for future leaders, but they do not adequately address the topic of roadmapping. This means it is safe to assume that nearly half of the Fortune 100 CEOs have not received adequate roadmapping expertise due to a lack of exposure. The article also states that only 27% of the Fortune 100 CEOs studied engineering or science.

In Lawrence Hrebiniak's *Obstacles to Effective Strategy Implementation*, it is noted that managers usually know less about strategy implementation and more about formulation; managers are not trained to execute but they are taught to plan (Hrebiniak, 2006). Roadmapping as a practice is strategic planning and execution. Hrebiniak presents the following case about MBA programs and execution:

> For example, in most M.B.A. programs, students learn a great deal about strategy formulation and functional planning. Core courses typically hone in on competitive strategy, marketing strategy, financial strategy, and so on. The number of courses in most core programs that deal exclusively with execution or implementation? Usually none. Execution is most certainly touched on, but not in a dedicated, elaborate, purposeful way. Emphasis clearly is on conceptual work, primarily planning, and not on doing (p. 12).

After recognizing that high-ranking MBA institutions do not properly address roadmapping/execution despite MBA graduates being placed in positions where roadmapping leadership should occur, research into other graduate-level programs was conducted. This project finds that the concepts of roadmapping are primarily scattered within engineering or science and technology-based programs such as Product Development or Technology Development programs to name a few. The term "roadmapping" or as suggested by Hrebiniak, "execution," does not seem to be the focal point. Hrebiniak's article (2006) accuses business schools of teaching the planning and execution of strategies in stovepipes/silos; this mirrors the findings on roadmapping education. The concept of roadmapping seems to be typically captured as part of a broader view of product design and innovation. This attributes to the dominant proliferation of technology and science-based roadmaps.

The identified problem is that according to the CBS News article (O'Shaughnessy, 2010), the top 10 master's degrees (Table 3) show that only small portion of graduate degrees come from the engineering field. Given the fact that product development/design and other offerings are subsets within the broader field of engineering, it is clear that roadmapping is not being formally taught in academia, as it should. Given the fact that many of the programs that provide roadmapping or similar concepts are engineering based, means that some variation of technology roadmapping dominates academia. Roadmapping is a tremendous product development tool but it is much more.

Table 3. CBS News Top 10 Master's Degrees for Men and Women. Adapted from O'Shaughnessy (2010).

	CBS News Top 10 Master's Degrees: Men		CBS News Top 10 Master's Degrees: Women	
1	Business Administration and Management	22.3%	Business Administration	11.4%
2	Electrical, Electronics & Communication Engineering	2.8%	Education	5.1%
3	Education Leadership & Administration	2.7%	Social Work	4.2%
4	Business/Commerce	2.5%	Elementary Education	3.8%
5	Education	2.2%	Curriculum and Instruction	3.6%
6	Accounting	2.0%	Educational Leadership & Administration	3.3%
7	Public Administration	1.6%	Special Education	3.0%
8	Computer Science	1.5%	Counselor Education/School Counseling	2.6%
9	Mechanical Engineering	1.5%	Nursing/Registered Nurse	2.1%
10	Computer & Information Sciences	1.4%	Reading Teacher Education	2.0%

Next, some universities that target Government/Military personnel were examined. The Defense Acquisition University (DAU's) offers training on roadmapping under the Science & Technology track. However, adding the material to the Program Management track would be ideal. The DoD's position is that the PM is ultimately responsible for the life cycle of weapon systems. PM's need to be trained on roadmapping, not just S&T professionals. Simply put, a major reason roadmaps fail is due to the lack of formal roadmapping education and experience. Many professionals do not know how to successfully navigate these waters.

As one can see, there is a disproportionate amount of academic support and professional development on a topic that governments, industries, and companies clearly value. In many cases, professionals are learning the roadmapping processes on-the-job which puts organizations at risk. Would it be acceptable if a surgeon learned to perform bypass surgery while on the job only to make avoidable mistakes because there is no avenue to gain experience prior to actual execution? Lack of education and training on roadmaps due to its placement within academic curriculums is a major contributor to the general failures of roadmaps.

D. REASONS FOR FAILURE

Recent evidence has revealed an upsurge in clumsy roadmapping efforts (Ho et al., 2018). In general, this paper attributes roadmap failures to the lack of education and training for professionals before being tasked with on-the-job roadmapping duties.

1. Roadmaps Are Not Viewed as Systems

Learning on the job typically yields uncoordinated and disjointed products. Naturally, this is the case for many roadmaps that do not provide the desired output or value. These fragmented maps attempt to individually solve a variety of complex and dynamic issues from different perspectives (Ho et al., 2018). Individualized roadmaps such as product-only roadmaps are typically disconnected from critical, interrelated aspects of the business chain (Ho et al., 2018). Many roadmaps fail because they are too individualized and lack the attributes of an integrated system with dependencies. Incoherent roadmaps can be systematically incorporated to stimulate the inclusive functioning of strategies, technologies, products, etc. (Ho et al., 2018).

First, roadmaps must be viewed as "systems" and practitioners must adopt a systems thinking mentality. As described by Cohen & Robbins (2011), "systems are defined as a set of components comprising ideas, objects, and activities that are interconnected for a purpose…Systems of interest are represented by system maps" (p.2). The roadmap viewed as a system takes on a new life. To generate successful roadmaps, it is highly recommended that DoD employees treat roadmaps like systems. Conversely, roadmapping efforts should be handled with the same level of interest and resourcing as high-profile programs and projects.

2. Roadmaps Are Improperly Developed

Despite its product roadmap focus, the following suggestions for failure are apropos for all types of roadmaps. According to Kirsch (2017), the list is as follows:

1. The roadmap is relegated to a list of features; this is not a 'roadmap'
2. The roadmap development team created a static roadmap document

3. The roadmap has configuration management issues throughout the organization/development team.

4. The roadmap fails to provide a clear, strategic path because there are too many details; details are not for roadmaps

5. The roadmap is geared towards insignificant items (e.g., the wrong priorities)

6. The development process was devoid of expectation management and the final product overpromises; roadmap has become unrealistic (Kirsch, 2017).

Roadmaps are more than a list of features and other details associated with a product. According to Kirsch (2017), feature-list roadmaps fail because of the following

- Leaders, stakeholders, and most people, in general, are not interested in a lengthy list of features
- Value cannot be quickly communicated
- Priorities cannot be clearly translated to the appropriate personnel necessary for execution; personnel cannot provide their best support if they cannot link value to the effort and decipher priorities (Kirsch, 2017).

Roadmaps need to be high-level strategic documents. Details are needed to develop the strategic plan but should be captured in other documents. A roadmap is not the place for details. Cramming unnecessary details into a roadmap buries the big picture in the minutiae. More egregious than an overly detailed roadmap is a roadmap that addresses the wrong priorities. Throughout this document, it has been stated that consensus building and buy-in are paramount. When roadmaps are developed without these key aspects, according to Kirsch (2017), roadmaps are ineffective in satisfying stakeholder needs and an organization's credibility is diminished.

3. Unrealistic Expectations

The most difficult pitfall to avoid for any organization or business is unrealistic expectations. Pressures on Program Managers to accomplish efforts that defy the laws of physics, economics, or other unrealistic feats must be properly managed. Managers and roadmapping teams must withstand the pressures of blindly saying yes. Managers must know the skillsets of the organization and scope work accordingly. Failure to heed these lessons may result in one of two problems: a strained relationship between management and the execution level of an organization will occur as the perception that management has created a high-risk situation looms or the roadmap becomes a paperweight because the organization will not effectively meet the promises outlined in the strategy (Kirsch, 2017).

For roadmaps to be effective, someone in the organization has to own it (i.e., be the 'A' in RACI). Oftentimes, leaders pursue roadmaps because they think it's expected of them and is just another mandated exercise – not because they believe there is value in the process and the resulting document (McMillan, 2003; Clark & Krentz, 2006). When leaders act in this manner, they perpetuate what is commonly referred to as the Abilene Paradox or 'group think'. The Abilene Paradox consists of a group that collectively agree to a plan or direction that contradicts what each person wants, yet no one in the group verbalizes their real position or true thoughts on the matter (CRM Learning, 2008). If leaders lack conviction about the importance of roadmapping, the process and the team is doomed from the beginning (Clark & Krentz, 2006).

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VIII. RECOMMENDATIONS

Chapter VIII recommends that defense department organizations (and industry partners) implement more roadmapping to help guide future weapon system development, strategies, and competitive advantages. As observed and reported by Cooper & Edgett (2009)

> Best-performing businesses develop a product innovation and technology strategy…Only 27.6% of businesses on average develop a…roadmap. Best performers are about twice as likely to use roadmaps as poor performers, 37.9% do versus 19%. Best performers are the top 20% of businesses… (p. 34)

Figure 34 illustrates their message and helps support this project's overall recommendation for more roadmaps. The subsequent sections provide additional recommendations.

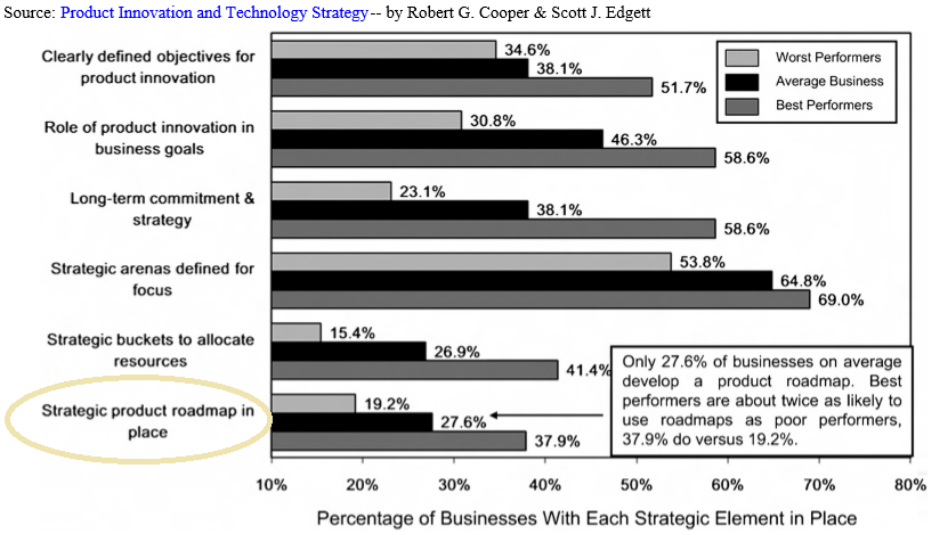

Figure 34. Best Performing Business Adapted from Cooper & Edgett (2009).

A. RECOMMENDATION 1: ESTABLISH A STRONG CULTURE FIRST

Organizations must establish a strong culture before implementing the process of roadmapping. The practice of roadmapping has existed for decades yet the wider acceptance and implementation of this concept remains fairly new and misunderstood (Kostoff & Schaller, 2001). Radnor & Probert (2004), state that organizations have an increased need for innovation cost-effectiveness and faster development speeds than years past. These needs produce an enhanced strategic focus, better cross-organizational or multidisciplinary integration, communication, and discipline. These should all lead to more coherent decision-making (Radnor & Probert, 2004). However, organizations must ask themselves if they are ready to execute at a higher level and invest to reach the next.

B. RECOMMENDATION 2: BE WILLING TO CHANGE

Organizations must be willing to change in a dynamic and competitive environment. If an organization's culture is weak or has limited organizational agility (Viaene, 2018), roadmapping as a process will fail. As GE CEO Jack Welch once stated, "When the rate of change inside an institution becomes slower than the rate of change outside, the end is near" (Viaene, 2018). Roadmapping benefits for the DoD abound. Roadmaps provide collective knowledge across the organization, uncover new opportunities and challenges and integrates with other tools to provide diverse insights with improved decisions through flexible, scalable, and efficient processes and products. More importantly, roadmaps help enable organizations to be responsive to change, a must for any DoD organization (Phaal et al., 2001 & 2003; Phaal, 2006). However, organizations must be willing to adopt a new approach before unlocking the benefits roadmapping has to offer.

C. RECOMMENDATION 3: ADVOCATE FOR MORE ROADMAPPING COURSES

There seems to be clear desire to implement roadmapping across industry and government sectors. In today's technology-driven world, the popularity of technology roadmapping is logical. However, when many organizations lack confidence in the effectiveness of their strategies, it should be clear that a lack of foundational knowledge

and experience a culprit. The inability to properly implement roadmapping as a stable business process for the benefit of organizations and stakeholders is a problem that must be addressed holistically.

As roadmapping becomes more prevalent in the years to come, academia should seek to provide future managers and executives with a better foundation geared towards process implementation, execution, and low impact opportunities to perform in various roles within the process. Early exposure to tools that capture and visualize an organization's present state, migration path and future will fundamentally solve bad roadmaps. While some institutions provide foundational education in the area of roadmapping, it is evident that a vast majority do not. In today's business/technologically driven world, it should be easy to identify institutions and programs (e.g. MBA, Program/Project Management, Industrial Engineering, etc.) that address roadmapping as a focal point. Roadmapping should not be buried in the middle of a syllabus. It is worthy of its own course.

Lack of academic support forces eager managers and executives to implement roadmapping without sound guidance on starting or maintaining the effort. This finding is at the core of poor roadmaps. Other factors such as lack of communication, no consensus, improper resourcing, etc., are key factors but the ultimate precursor is a deficiency of formal educational options dedicated to roadmapping.

D. RECOMMENDATION 4: DEVELOP ROADMAPS TO SUPPORT RESOURCING DECISIONS

Use roadmaps to gain or defend organizational resources (e.g. POM funding, etc.). Many organizations function in dynamic environments filled with a myriad of internal and external factors such as fluctuating resources and rapidly changing threats. These and other factors force stakeholder demands to shift in response to various stimuli. Roadmapping can help guide and align organizations with stakeholder requirements. Providing stakeholders with insights on the current possibilities of technologies helps define military and national strategies.

While some DoD organizations such as the Office of Naval Research (ONR) have effectively used roadmaps, many still do not. It is no secret that a number of organizations struggling with obtaining funds (e.g. POM dollars) while others struggle with spending funds. In both instances, a properly implemented roadmapping process would help resolve those challenges. For the organizations that struggle with obtaining funds, gaining stakeholder buy-in to resource organizational goals is the core problem. A properly implemented roadmapping process requires stakeholder involvement as outlined by various sources throughout this project. The roadmap provides visualization of the strategy and making it easier to justify funding—a common activity within the DoD.

IX. CONCLUSION

From the outset, this project asks if roadmapping is a decision-aid for effective DoD strategy development, strategic communications, and product development improvements? Or is roadmapping just another time-consuming process for DoD professionals? After reviewing a number of literary works from a variety of roadmapping practitioners from around the world, this project concludes that roadmapping is not another time-consuming non-value added process for DoD professionals. Roadmapping appears to be a highly effective decision-aid, strategy development tool, strategy communication aid, and catalyst for innovation adoption.

The value of roadmapping for the DoD may vary according to organizational charters/missions. However, anytime there is an opportunity to align organizations internally and externally with stakeholders, DoD leaders should consider it. Specific to the acquisition profession, roadmapping appears to offer possibilities to gain efficiencies at the organizational level and/or department level that leads to improved products, logistics, and services to the Warfighter—that is the goal, is it not?

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