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Life cycle exposures to hazards from existing and newly developed products and production processes, demands from external stakeholders for compliance with regulations, requirements from internal stakeholders for connecting management systems to lean company initiatives and market pressures have motivated U.S. based semiconductor companies to adopt an integrated-lean approach to environment, safety and health management systems. This research was exploratory by nature and used qualitative methods, specifically a Delphi study to develop an integrated-lean management system framework and case studies to examine the management, structural, and financial strategies used by semiconductor manufacturing firms that support lean enterprise management. A review of the literature on management systems shows how the research was grounded in previous research and how this research goes beyond previous research in important ways. Delphi study results were obtained from judgments from a panel of experts who participated in reviewing existing management system elements and implementation practices similar in nature into an integrated-lean framework. Case study findings were obtained from an analysis of triangulated evidence extrapolated from in-depth interviews with operations and environment, safety and health managers and management system representatives, a review of internal documents and tours of the facilities. The results offer (a) insight into what an integrated-lean management system framework looks like, (b) the motivations by semiconductor companies for pursuing integration and, (c) the management, structural and financial strategies deployed by the sample of semiconductor companies that support lean outcomes valued by stakeholders.

Integrating Environment, Safety and Health Management Systems in Support of Lean Outcomes

by
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I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

Travis Kruse, Author

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CHAPTER I

INTRODUCTION

Environment, safety and health management systems (referred to as management systems for the remainder of the dissertation) are the means to characterize and control exposures to workers and the environment (Wilkinson & Dale, 1999) and proven to be of value to operational performance (Matias & Coelho, 2002). Management systems have clear objectives, elements and detailed implementation practices and are used contingent on an organizations functional intention. For example, the International Standards Organization (ISO) 14001 aims to protect the environment and suggests activities for controlling environmental aspects and minimizing impacts from operational activities (Bergeron, 1997). And the Occupational Health and Safety Assessment Series (OHSAS) soon to be replaced by ISO 45001 aims to protect workers and suggests activities for controlling exposures to safety risks and minimizing impacts arising from operational activities (Fernandez-Muniz, Montes-Peon, & Vazquez-Ordas, 2012).

Typically management systems have been driven by exposures to hazards from existing and newly developed products and production processes and focused on combining exposure assessment practices with toxicology and regulatory standards for characterizing and controlling operational risk to workers and the environment (Arora & Cason, 1996; Bowen, 2000; Haight, Yorio, Rost & Willmer, 2014; Santos, Barros, Mendes, & Lopes, 2013). For the most part, management systems have been structured as standalone schemes and focused on environmental or occupational safety and health concerns with corporate social responsibility, risk management, and business continuity gaining prominence. As the number of standalone management systems continue to emerge and require regular updates there is a growing interest to integrate them into a single management system (Karapetrovic & Casadesus, 2009) for supporting the lean enterprise

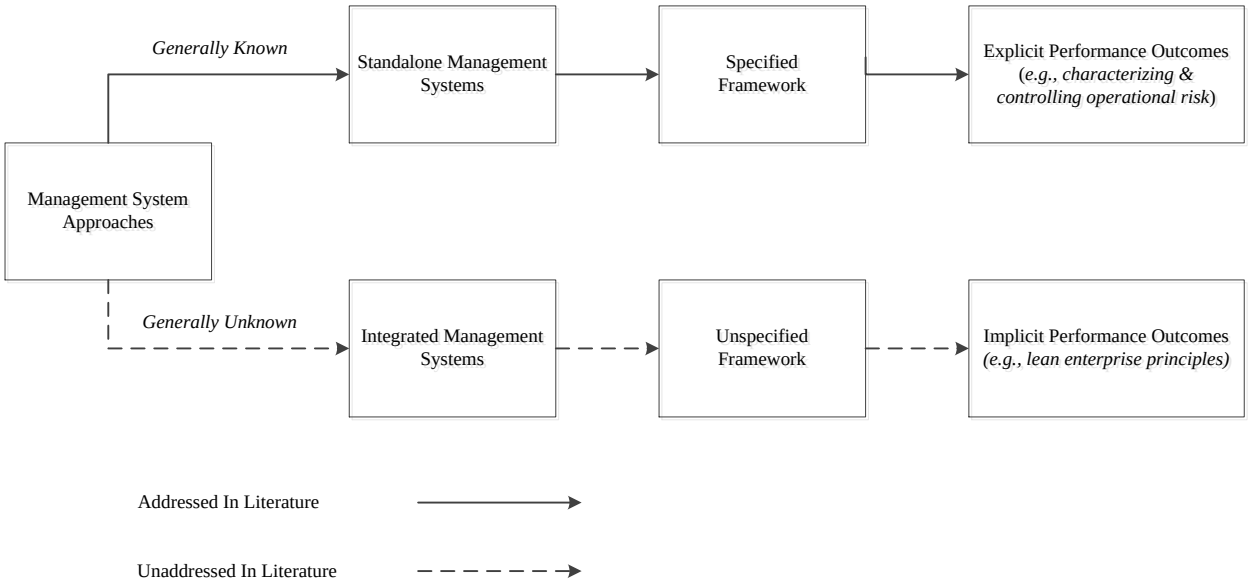
movement in today's high-performance driven organizations. In high-performance driven organizations, lean management principles represent a way to simultaneously improve environment, safety and health and organizational performance (Longoni, Pagell, Johnston & Veltri, 2013; Womack & Jones, 1996) and push that the economic, environmental and safety implications of decisions be explicitly considered.

Both the environmental literature (Darnall, Henriques, & Sadorsky, 2008; Rondinelli & Vastag, 2000; Sroufe, 2003) and the occupational safety and health literature (Bottani, Monica, & Vignali, 2009; Haight et al., 2014; Robson, Clarke, Cullen, Bielecky, Severin, Bigelow, Irvin, Culyer & Mahood, 2007) address the need to integrate existing standalone management systems. However, the blueprint of what an integrated-lean operating framework looks like that meets internal and external demands is missing (Rocha et al., 2007) and the management, structural and financial strategies that support lean outcomes have not been addressed (Matias & Coelho, 2002). One would expect that a problem of this kind would attract attention from researchers; yet, empirical research is lacking. Building on that supposition, is the purpose of this dissertation.

1.1 Purpose of the Research

The purpose of this research was to develop an integrated-lean management system framework and examine the management, structural and financial strategies used by a sample of semiconductor companies for supporting lean outcomes. Figure 1.1 shows what is known and (generally) unknown about the constructs and relationships of interest.

Figure 1.1
What is known and (generally) unknown about the constructs and relationships



1.2 Research Significance

The existing research on management systems is supportive of this study's relevance and significance. This research contributes to the literature on integrated-lean management systems by making theoretical and applied contributions. The theoretical contribution occurred in two ways. First, the research considered environment, safety and health management systems simultaneously and provided a conceptual framework and specification (e.g., elements and implementation practices) of what an integrated-lean management system framework looks like that supports lean management principles, and second the research provided insight into the strategies used by semiconductor manufacturers and how they unfold to support lean outcomes. The applied research contributions include (a) for semiconductor industry managers, the research provides a way to support lean outcomes such as value maximization, waste minimization and risk reduction, (b) for educators, the research provides a way to arrange learning experiences for students on what an integrated-lean management system framework that

supports lean outcomes looks like, (c) for researchers, the study provides a means to expand on the major insights gleaned from this under-researched area and to inspire new research questions that confirm the usefulness of the framework and strategies in other industry sectors, (d) for students, the research provides a way to enhance their understanding of the role that an integrated-lean management system plays in supporting lean outcomes for the firms they may eventually serve and, (e) for standards committees, the research can assist in guiding decision-making toward the development of an integrated management system standard that meets the needs of internal and external stakeholders while being congruent with lean enterprise principles.

1.3 Basic Assumptions

Based on the existing literature assumptions were made in forming the specific aims of this research work. The research assumes that a number of standalone management systems are available and being used by semiconductor firms and that these systems are adaptable for integration into a single management system by semiconductor managers. An integrated-lean management system will have value to semiconductor managers who have responsibility for designing, implementing and continually improving management systems in the organizations that they serve. And that the exploratory and inductive nature of this research and the use of qualitative methods, used effectively in prior research, will generate valid and reliable answers to the research questions and be of value to internal and external stakeholders and to management system practitioners – the ultimate user of this study.

The remaining dissertation is organized around the following chapters. Chapter 2 - Literature Review shows how the dissertation is grounded in previous management system research and explains how this research goes beyond existing research in ways that are important. Chapter 3 – Methodology describes the study participants, data collection and analysis procedures, and the

protocol for answering the research questions. Chapter 4 – Results discusses the findings of the study. Chapter 5 - Conclusion offers suppositions of the study and suggestions for further research. A bibliography listing the published scholarly work used in the research follows chapter 5.

CHAPTER II

REVIEW OF LITERATURE

The literature review is organized around two themes and explains how the dissertation is grounded in previous management system research and how this research goes beyond previous research in ways that are important.

2.1 Advancements in Management Systems

Through the decades, private sector organizations have relied on management systems to guide and control organizational activities (Fresner, 1998), to improve operating capabilities (Melnyk, Sroufe, & Calantone, 2003) and to maximize organizational competitiveness (Koehn & Datta, 2003). All private sector organizations – profit or not-for-profit, large or small, complex or simple – have a management system that can be classified as either formal or informal. Formal management systems are externally certified with a well-defined organizational structure and strict operating procedures. Informal systems are internally developed, non-certified, not extensively structured and operate with lenient procedures.

Early on, management systems were fixated on well-ordered lines of assembly and chains of command as a way to control mass production (Mintzberg & Van de Heyden, 1999), followed by quality control standards to provide a level of value within the production and supply chain (Labodová, 2004) and an engineering and operations management approach was emphasized later for assuring that products and processes are effectively and efficiently improved (Matias & Coelho, 2002). Later, life cycle exposures to hazards from existing and newly developed products and production processes along with market pressure and pressure from internal

stakeholders (i.e., owners, shareholders, managers, employees) and external stakeholders (i.e., suppliers, insurers, government and non-government organizations) have motivated organizations to adopt standalone management systems (Darnall et. al., 2008; Haight et al., 2014; Santos et al., 2013). Today, management systems are expected to (a) accommodate both vertically and laterally within the organizational structure and capable of balancing environment, safety and health and economic concerns in transparent ways (Asif, Fisscher, Bruijn, & Pagell, 2010), (b) be in compliance with environment, safety and health laws and that major risks and liabilities are properly controlled (Gallagher, Darnall, & Andrews, 1999), (c) act both as an internal management tool and as a way of demonstrating a company's environmental and safety commitment to its customers and clients (Boiral, Olivier & Roy, 2007) and, (d) be supportive of lean enterprise principles (Holdsworth, 2003).

Generally, management systems are designed to operate as either standalone (i.e., run separately and requiring single management) or integrated (i.e., run as multiple similar systems requiring joint management). The most prominent standalone systems include the Environmental Management System (ISO 14001), the Occupational Health & Safety Assessment Scheme (OHSAS 18001), the Eco-Management and Audit Scheme (EMAS), the American National Standards Institute (ANSI Z10), the California Injury & Illness & Prevention Plan (CA-IIPP), and the Occupational Safety & Health Administration's Voluntary Protection Program (OSHA VPP). Table 2.1 is a description of these systems. Moreover, these management systems were employed to build the integrated-lean framework.

Table 2.1
Prominent Standalone Management Systems

Prominent Management Systems	System Description
Environmental Management International Organization for Standardization 14001 (ISO 14001) Est. 1996	Sets out the criteria for an environmental management system. It maps out a framework that an organization can follow to design, implement and continually improve an environmental management system.
Occupational Health & Safety Assessment Series (OHSAS) (OHSAS 18001) Est. 1999	Internationally applied British Standard for occupational health and safety management systems. It exists to help all kinds of organizations put in place demonstrably sound occupational health and safety practices that protect workers.
Eco-Management and Audit Scheme (EMAS) Est. 1993	A management arrangement developed by the European Commission for companies and other organizations to evaluate, report, and improve their environmental performance.
American National Standards Institute (ANSI-Z10) Est. 2012	Set of safety and health guidelines to promote the integration of occupational safety and health into the overall business management system. The Z10 standard provides an overall blueprint for widespread safety, financial, operating, quality and other organizational benefits.
California Injury, Illness & Prevention Plan (CA-IIPP) Est. 1989	Written workplace safety program for employers to develop and implement an effective incident prevention plan. The IIPP is intended to improve workplace safety and health and reduce costs thru management engagement and employee involvement.
Occupational Safety and Health Administration Voluntary Protection Program (OSHA VPP) Est. 1982	Promotes effective worksite-based safety and health. In the VPP, management, labor, and OSHA establish cooperative relationships at workplaces that have implemented a comprehensive safety and health management system.

Based on the descriptions of the standalone management systems it shows that all provide a means to guide environment, safety and health practices separately and to meet both internal and external stakeholder needs and market demands. However, standalone systems produce extra administrative and operational activities and cost (Matias & Coelho, 2002); whereas integrated-lean management systems are viewed as an all-inclusive operating system based on the common elements, definitions and implementation practices that exist among the standalone management systems (Honkasalo, 2000; Holdsworth, 2003). Much of the literature on integrated management systems is focused on organizations that have adopted at least two formal management systems such as ISO 14001(Environmental Management) and OHSAS 18001 (Occupational Safety and

Health). While integrated management systems offer a means to jointly guide environment, safety and health practices in more cost efficient ways (Honkasalo, 2000; Holdsworth, 2003; Karapetrovic & Casadesus, 2009) there are logistical concerns such as underestimating the differences in scope between systems (Pheng & Pong, 2003) and perceiving that integration is simply merging management systems into one operating system (Wilkinson & Dale 1999; Labodová, 2004).

The professional literature shows that management systems have developed into mature areas of research and practice and that there are large areas of overlap and redundancies between standalone and integrated management systems. The overlap has contributed to the confusion and inefficient management which has further driven the need to identify a more efficient mechanism to develop, implement and maintain these systems. Table 2.2 displays the redundancies between standalone management systems. Yet, lost in the literature is an understanding of what an integrated-lean management system framework would look like and an understanding of the management, structural, and financial strategies that support lean management outcomes.

Table 2.2
Redundancies between Management Systems

*EMAS	*ISO 14001	ANSI Z10-2005 OSHMS	*OHSAS 18001	*OSHA VPP	California IIPP
Policy requirements					Employee/management involvement
Hazard & risk assessment					
Legal & other requirements		Internal & regulatory policies procedures, worker comp. info	Legal & other requirements	Remain in compliance	
Objectives, targets & programs					no explicit element
Resources, roles, responsibility, authority					
Competence, training, awareness		no explicit element	Competence, training, awareness		
Communication		no explicit element	Communication		
Documentation		no explicit element	Documentation		no explicit element
Document Control		no explicit element	Document control		no explicit element
Hazard prevention & operational control					no explicit element
Emergency preparedness & response		no explicit element	Emergency preparedness & response		no explicit element
Monitoring & measurement		no explicit element	Monitoring & measurement		no explicit element
Compliance evaluation					no explicit element
Nonconformity, corrective & preventive action; incident investigation					
Records control		no explicit element	Records control	Recordkeeping	
Audit & inspection					
Management review & evaluation					no explicit element
External reporting	no explicit element				

*External certification available

An environmental management system is an internal management tool to systematically manage environmental performance, and helps in the identification of potential environmental impacts arising from organizational activities, setting appropriate objectives, establish programs to achieve corporate environmental goals and review activities to ensure that corporate environmental policy is being properly carried out (Bergeron, 1997). The goal of environmental management system is to help organizations ensure that their operations comply with environmental laws and major environmental risks, liabilities, and impacts are properly identified, minimized, and managed.

The origin of environmental management system dates back to 1972, when the United Nations organized a Conference on the Human Environment in Stockholm and launched the United Nations Environment Program (Corbett & Kirsch, 2001). This early initiative led to the establishment of the World Commission on Environment and Development and the adoption of the Montreal Protocol and Basel Convention. In 1992, the first Earth Summit was held in Rio-de-Janeiro. This summit served to generate a global commitment to the environment (Jiang & Bansal, 2001). In the same year, British Standards Institution (BSI) Group published the world's first environmental management systems standard, BS 7750. One year later, in 1993, Council Regulation 1836/93 was adopted in Europe creating the Eco-Management and Audit Scheme (EMAS) with a view to allow companies to voluntarily participate in an environmental management scheme. The scheme is open to industrial sector companies operation in the European Union and the European Economic Area (EEA) and focused on environmental performance. This provided the template for the development of the ISO 14001 standard in 1996, by (ISO) which has representation from committees all over the world (Clements 1996, Brorson & Larson, 1999). The standard shares many common traits with its predecessor ISO

9001, the international standard of quality management (Jackson, 1997). As with ISO 9001, ISO 14001 acts both as an internal management tool and as a way of demonstrating a company's environmental commitment to its customers and clients (Boiral et al., 2007). Since 2006, hundreds of U.S. facilities have certified their environmental management system to ISO 14001. As of December 31, 2016 (ISO) contacted accredited certification bodies and reported that 346,189 organizations held ISO 14001 certificates, which is an 8% increase from 2015. Much of this annual adoption can be attributed to the results delivered by environmental management systems along with supply chain pressures to become externally certified.

During the late 1980's organizations worldwide began to recognize the need to improve health and safety performance and do so with an occupational health and safety management systems (Santos, et al., 2012). A safety and health management system is part of an organization's management system used to recognize, evaluate and control exposures to hazards that exist in the workplace. There are several U.S. based management system standards in circulation today including, but not limited to OSHA's Voluntary Protection Partnership Program (VPP), the American National Standards Institute (ANSI) Z10-2012, the California Injury and Illness Prevention Program (IIPP) and proprietary customized management systems. However, they all have similar program elements and none are internationally recognized, which has become an increasingly greater need for companies who wish to compete in an international marketplace. In addition, before 1999, there was a proliferation of occupational safety and health national standards and certification schemes to choose. This caused confusion and fragmentation in the market; undermined the credibility of each individual scheme; and potentially created trade barriers (Romero, 2012). Recognizing this problem, an international collaboration called the Occupational Health Safety and Assessment Series Project Group was

formed to create a single unified management system approach. The Group comprised representatives from national standards bodies, academic bodies, accreditation bodies, certification bodies and OSH institutions, with the United Kingdom's national standards body providing as the secretariat. Drawing on the best of existing standards and schemes, the OHSAS Project Group published the OHSAS 18000 Series in 1999. The Series consisted of two specifications: requirements for a safety and health management system and implementation guidelines.

OHSAS 18001 exists today to help organizations put in place sound occupational health and safety activities. The OHSAS 18001 specification applies to all types and sizes of organizations and accommodates diverse geographical, cultural and social conditions that wish to:

1. Establish an OH&S management system to eliminate or minimize risk to employees and other interested parties who may be exposed to OH&S risks associated with its activities
2. Assure itself of its conformance with its stated OH&S policy
3. Demonstrate such conformance to others
4. Implement, maintain and continually improve an OH&S management system
5. Make a self-determination and declaration of conformance with this OHSAS specification
6. Seek certification/registration of its OH&S management system by an external organization

There are several reputable safety and health management system frameworks in circulation today, OHSAS 18001 is widely seen as the world's most recognized occupational health and safety management systems standard which aims to certify a safety and health system that is able to create and maintain safe workplace conditions and protect employees from workplace injuries and illnesses (Fan & K.Y. Lo, 2012). Per the British Standard Institute (BSI), as of 2005 around 16,000 organizations in more than 80 countries were using the OHSAS 18001 specification. By 2009 more than 54,000 certificates had been issued in 116 countries to OHSAS standards. One

of the many benefits of the this standard is that it defines the minimum safety and health management elements that must be met by an organization, but also provides the flexibility for organizations to meet the standard requirements in a manner, which fits the organization's operations, culture and business objectives. Safety and health management system adoption is expected to grow exponentially as the international standards organization succeeds with the development and eventual release of ISO 45001.

2.2 Research Conducted on Integrated Management Systems

An organization has an integrated management system if it has a formal set of processes that allow for the shared measurement, monitoring, controlling and continuous improvement of both environment and safety and health. Since the mid1990's there has been a growing body of studies on management system integration. For example, Marcus, (1996) shared insights into how integrated management systems have been used to increase corporate profits. Wilkinson and Dale, (1999) studied the integration of quality, environmental and health and safety management issues at five manufacturing companies and managements attitudes to possible integration. They found that less interest is shown in occupational health and safety management systems, ISO 14001 was preferred to EMAS and those organizations that have embraced total quality management principles were more likely to pursue integration than those that have not. They also found that integration was seen more readily by those organizations having high hazards. Honkasalo, (2000) researched the integration of occupational health and safety matters into environmental management systems. This study explains that companies can avoid duplicated measures and find optimal solutions, because the principles of prevention are similar in environmental management and safety management. This research concludes that the integration of occupational health and safety matters into environmental management systems

can help companies to avoid duplicated measures and find solutions that handle both environmental and safety risks in an optimal way and introduces a new perspective into industrial ecology. Matias & Coelho, (2002) discuss the advantages and disadvantages of integration and also call out the absence of an integrated management system standard. They conclude that the activity of integration lends itself well to total quality management. Pheng & Pong, (2003) studied the integration of ISO 9001 (Quality Management Systems) with OHSAS 18001 in the construction industry. They surveyed construction firms in Singapore to examine the difficulty and cost benefit of integration of OHSAS 18001 and ISO 9001. Koehn & Datta, (2003) provided insight in the development of a quality, environmental and safety integrated management system within a construction company. This study found that a positive quality, safety, environmental and productivity outcome was obtained as a result of the integration effort. Research by Labodová, (2004) on the evolution of management systems and the increasing desire and feasibility to integrate these systems into one system for each company was studied. The research examined a risk analysis based approach to integration suggesting a new theoretical model, which was tested in two case studies. The research concluded that the theoretical model had no conflicts and could be used in any kind of company including small manufacturers.

Rancour, (2005) discussed the relationship between the Malcolm Baldrige framework and integrated management systems sharing his perspective on how the two aid in continuous improvement and business excellence. Jørgensen, Remmen, Mellado, (2006) research focused on the ambitions associated with integrated managements systems. Specifically, three ambition levels of integration were reviewed: from increased compatibility of system elements over coordination of generic processes to an embeddedness of an integrated management system (IMS) in a culture of learning and continuous improvements. The research concluded that

integration is the solution and depending on the understanding and level of ambition behind an integrated management system, it is a solution to many different problems. Integration as correspondence between different standards with cross-references and perhaps even a common handbook can give several administrative benefits for organizations such as to save time and resources and to secure an alignment between the demands of the different standards.

The research concluded that the duplication of work tasks and confusion between different standards existed and that management commitment, employee motivation and participation were the major challenges to integration efforts.

Hansen, (2006) found that an effective safety, health and environmental management system is good management and should be viewed as part of the company's overall business strategy with results of efforts being reported to key stakeholders on an annual basis. By implementing an integrated management system, a company can: measure performance, reduce cost, increase profit margins, increase competitiveness, facilitate the return to work of injured workers, reduce incident frequency and severity rates or lost time, reduce damage to equipment, inventory or product loss, and generation of hazardous waste, increase regulatory compliance and improve employee and public relations. A study carried out by Zeng, Shi, & Lou, (2007) resulted in a model for implementing an integrated management system in Chinese companies. It was concluded that the major problems for Chinese companies to operate multiple parallel management systems included: it causes complexity of internal management, it lowers management efficiency, and it incurs cultural incompatibility, causes employee hostility, and increases management costs. The survey also examined the internal and external factors that affect the implementation of an integrated system. The internal factors include: (1) human resources, (2) organizational structure, (3) company culture, and (4) understanding and

perception. The external factors consist of: (1) technical guidance, (2) certification bodies, (3) stakeholders and customers, and (4) the institutional environment. Azadeh, Mohammad, Fam & Nouri, (2007) researched the joining of management systems with ergonomics in the context of a gas treatment facility with the idea that the integration of management systems is highly transferrable to an occupational ergonomics strategy within a firm. Rocha et al., (2007) applied an emphasis on the integration of sustainable development into existing management systems noting that one of the biggest challenges facing its implementation is the lack of a framework for the integration of sustainable development into mainstream business systems. To address this issue the research presented an integrated management system that provides guidance on the integration of sustainable development into every level of the organization. Salomone, (2007) provided insight into integrated management systems in Italian companies specifically quality, environment, safety, and social responsibility systems. The findings from the study highlight that although geographical area and company sector have some influence on the perceived benefits and obstacles to integrating management systems; company size exerts the greatest influence. Bernardo, Casadesus, Karapetrovic & Heras, (2008) analyzed the extent to which environmental management systems were really integrated with other management systems across 435 organizations. Overall, 362 of those organizations indicated that they had integrated all or at least some of their standardized management systems. Karapetrovic & Casadesus, (2009) analyzed how the implementation of the environmental management system has been carried out in organizations having more than one standardized management systems in a region of Spain. They reviewed four different management system standards used for registration, the order in which they were implemented, the time required for each implementation, as well as the scope of integration into a single integrated management system. They found that the research

confirms the notion that a high percentage of organizations with an environmental management system in accordance with the ISO 14001 also have at their disposal a QMS certified in ISO 9001. Additionally they found that despite the environmental impact of many of the participant companies almost all of them began the standardization of their management systems by implementing only the QMS (86%), or the QMS and the EMS simultaneously (11%). Asif et al., (2010) investigated how integration unfolds in practice. This study found that management systems can be streamlined through a number of structural, functional and operational changes that lead to lean production outcomes. Santos et al., (2011) characterized the management system integration situation of Portuguese businesses to identify benefits, drawbacks and difficulties associated with the certification process and to characterize the level of integration that has been achieved. A survey was carried out by the research team and found that the main benefits of the integration included costs reduction, increased employee training and easier regulatory compliance. de Oliveira, (2013) investigated the integration of management systems such as ISO 9001, ISO 14001 and OHSAS 18001 in Brazilian companies, specifically focusing on integration planning, development, and control and improvement. The result of the study yielded a guideline for manufacturing companies to use for integration between quality, environment and safety. Abad, Dalmau & Vilajosana, (2014) studied the integration of multiple standalone management systems into a single management system in Spain due to the high adoption rate of externally certified management systems. Their results point towards the existence of three levels of integration. Findings indicated that smaller firms achieve higher levels of integration and that managers do not perceive the integration of management systems as a long-term strategic tool. The benefits following the integration depend on the level of integration achieved. Jespersen, A.H., P. Hohnen, and P. Hasle, (2016) studied the challenges

associated with psychosocial risk. They specifically investigated how two Danish municipalities transformed the general safety and health management systems audit guidelines into internal audit practices capable of targeting the psychosocial risks. The results show that the municipalities experienced difficulties in transforming the general audit guidelines into practical models, and found that this led to significant variations in audit practices.

In summary, while the past research helps support the fact that integration is occurring including why and how it is occurring, it is somewhat deficient in a couple of aspects such as lacking a framework and offering ways to contribute to lean outcomes. The way that this dissertation study goes beyond existing management system integration research is by constructing an integrated-lean framework that takes into consideration other prevalent management systems frameworks outside of ISO 14001 and OHSAS 18001 and by soliciting feedback from an expert panel on what it should look like. In addition, this research used a case study approach to understand the specific motivations for integrating management systems and the management, structure and finance strategies used to achieve lean outcomes.

CHAPTER III

METHODS

This research was exploratory and inductive in nature, and used qualitative methods, specifically a Delphi technique and a series of case studies to answer the research questions. The nature of exploratory research is it provides focus for a research inquiry (Armstrong, 1970), insight to a research problem that has not been reached yet (Stebbins, 2001), understanding into the circumstances surrounding a research problem (Eisenhardt, 1989), and direction needed to develop a conceptual framework comprised of key constructs and presumed relationships among them (Miles & Huberman, 1994).

The research was inductive versus deductive in nature because of the need to link information to the research problem for developing the conceptual framework (Eisenhardt, 1989; Glasser & Strauss, 1967). An inductive conceptual framework building approach begins with an identified problem, reviews information relevant to the problem and explains patterns (Thomas, 2006). The conceptual framework developed for this study is a structure of what has been gleaned based on previous studies and a systematic ordering of ideas about the phenomenon that is being studied (Camp, 2001). In a deductive approach to theory building the research steps are reversed. The researcher starts with reading theory or frameworks published by other researchers, and then develops and tests hypothesis that either confirm or reject the theory of conceptual framework with data (Teddlie & Tashakkori, 2009).

A qualitative research design provides a valid way for building a conceptual framework from published information (Glaser & Strauss, 1967; Harris, 2003; Miles & Huberman, 1994; Myers, 2008), understanding research problems in their operational context or setting (Atieno, 2009), and is well suited to answer ‘‘how and why’’ questions than quantitative methods (Yin, 2009).

Where quantitative research is mainly concerned with the testing of hypotheses and statistical generalizations, qualitative research does not usually employ statistical procedures or other means of quantification, focusing instead on understanding the nature of the research problem rather than on the quantity of statistical characteristics (Strauss & Corbin, 1994).

3.1 Research Purpose and Questions

The purpose of this research was to develop an integrated-lean management system framework and examine the strategies used by semiconductor firms that support lean management outcomes. A solution to this problem was contingent upon answering the following research questions.

Research Question 1: What does an operating framework of an integrated management system look like for supporting lean management outcomes?

Research Question 2: What were the motivations and the management, structural and financial strategies employed by a sample of semiconductor firms during the integration of their lean management system?

Research Question 3: What were the lean outcomes from the strategies employed by the semiconductor companies?

3.2 Methodology for Answering Research Question 1

The methodology to answer research question 1 (*i.e., what does an operating framework of an integrated management system look like for supporting lean an management outcomes*) was to link existing information by way of a literature review to the research question (Eisenhardt, 1989; Glasser & Strauss, 1967) and employ a Delphi study as a systematic, interactive forecasting method that relies on a panel of experts in the field of study (Dalkey & Helmer, 1963; Hsu & Sandford, 2007).

3.2.1 Linking Literature to the Research Question 1

A review of seventy-one (71) peer reviewed journal articles relevant to management systems started the study and each article was categorized into two (2) streams to provide a summary of the significant literature on the topic of management systems. The first stream speaks to the advancements in management systems and the second stream speaks to the research conducted on management system integration. Table 3.1, displays the literature streams and supporting articles.

Table 3.1
Literature Review Streams

Streams	Supporting Articles
Management Systems Advancements	(*Management System Papers*) Corbett et. al., 2005; de Oliveira, O.J., 2013; Heinrich et. al., 1950; Romero et al., 2012; Santos et. al., 2011 (*Environmental Papers*) Andrews et.al.,1999; Begley,1996; Boiral et. al., 1997; Brorson et al., 1999; Clements et. al., 1996; Darnall et. al., 2000; Darnall, 2001; Darnall et. al., 2008; Gallagher et. al., 1999; Gbedemah, 2004; Jespersen et. al. 2016; Jiang et. al., 2003; Johnstone et. al. 2009; Matthews, 2004; Melnyk et. al., 2003; Morrow et.al., 2002; Rondinelli et. al., 2000; Yosie, 1998; EMAS; ISO 14001 (*Safety & Health Papers*) Aalders et. al., 1997; Bennett 2014; Costella et. al., 2008; Fan et. al., 2012; Gallagher et. al., 2003; Hale et al., 1997; Makin et al. 2008; Robson et. al., 2007; Santos et. al., 2013; Santos-Reyes et. al., 2002; Wilkinson et. al., 1999; OHSAS 18001; OSHA management system fact sheet; OSH Voluntary Protection Program, California Injury Illness and Prevention Plan; ANSI Z10
Management System Integration Research	(Integration Research Papers) Asif et. al., 2009; Asif et. al., 2010; Asif et. al., 2013; Beckmerhagen, I. A., et al. Bernardo et. al., 2009; Celik, 2009;; Fresner et. al., 2004; Hansen, 2006; Holdsworth, 2003; Honkasalo, 2000; Jackson, 1997; Jorgensen et. al., 2006; Jorgensen, 2008; Karapetrovic et. al., 2009; Koehn et. al., 2003; Labodová, 2004; Marcus et. al., 1996; Matias et. al., 2002Nouri et. al., 2007; Oliveira, 2013; Rancour, 2005; Rocha et. al., 2007; Salamone, 2008; Santos et. al., 2011; Singh, 2009; Sui Pheng et. al., 2003; Wagner et. al., 2007; Wilkinson et. al., 1999; Zeng et. al., 2007

3.2.2 Linking Delphi Panel Member Responses to Research Question 1

A Delphi study was employed to help answer research question 1 because it is a widely used and accepted method for gathering data from respondents within their field of expertise (Hsu & Sandford, 2007); while structuring group communication processes on a specific real-life issue (Delbecq, Van de Ven, & Gustafson, 1975). The Delphi method was well suited to the current

research study because it called for judgments about a real-life environment, safety and health management issue from experts on the subject of management systems. The purpose of the technique is to extract ideas from subject matter experts and to build-consensus by employing multiple iterations (Dalkey & Helmer, 1963; Dalkey, 1969; Linstone & Turoff, 1975; Lindeman, 1981; Young & Jamieson, 2001). Prior to conducting the Delphi study, a pilot test was conducted with six (6) management system company representatives to (a) run-through the Delphi process and verify its efficiency and effectiveness, (b) tryout questions and to determine their usefulness, and (c) improve the skill of the researcher when conducting the larger Delphi study. In the real study, Delphi iterations contained responses from the panel during a series of rounds in which each round every panel member responded to a series of questions. Panel member responses were then collected, summarized and returned to panel members that best reflected the position of the entire panel and the individual panel members own position. A summation of comments makes each panel member aware of the range of opinions and the reasons underlying those opinions (Ludwig, 1994) and allowed panel members to change or modify their comments based on the comments provided by the other Delphi members (Hsu & Sandford, 2007). Fundamental to the Delphi method is the ability to provide anonymity to reduce the effects of certain members from dominating the process (Hsu & Sandford, 2007). Confidentiality in the study was maintained by use of private electronic communication and private telephone conversations to solicit and exchange information from the Delphi members (Hsu & Sandford, 2007).

3.2.2.1 Selecting and Qualifying the Delphi Panel

Choosing panel members is the most important step in a Delphi study because it directly relates to the quality of results generated by the combined expertise of the panel (Powell, 2003).

There are two key aspects to panel selection: panel size and expert qualification. No concrete guidance was found in the literature regarding panel size. Adler & Ziglio, (1996) suggest that with a similar group of experts, reasonable results can be obtained with small panels of 10-15 experts. Delbecq et al., (1975) recommend that researchers should use the minimally sufficient number of subjects. However, what constitutes an optimal number of subjects in a Delphi study never reaches a consensus in the literature (Hsu & Sandford, 2007). Murphy, Black, Lamping, McKee, Sanderson & Askham, (1998) believe that as the number of experts increase, the reliability of a composite judgment increases; and there is very little empirical evidence of the effect of the number of participants on the reliability or validity of a consensus building process. However, the literature supports that the number of participants should vary according to the scope of the problem and resources (e.g., money and time) available (Delbecq et al., 1975; Fink, Kosecoff, Chassin, Brook, 1984; Hasson, Keeney, & McKenna, 2000; Van Zolingen & Klaassen, 2003).

There is no set standard for selecting Delphi panel participants in the literature (Hsu & Sandford, 2007) and the definition of what constitutes a Delphi expert remains ambiguous (Kaplan, 1971). Typically to be eligible to participate, panel members are required to have similar backgrounds and experiences concerning the issue, capable of contributing helpful inputs, and, willing to revise their initial or previous judgments for the purpose of reaching consensus (Pill, 1971; Oh, 1974). Potential panel members for this study were contacted via telephone to solicit their participation and were instructed about the research, specifically the purpose of the study, the research method, the process for confidentiality, and the protocol established by the Oregon State University Institutional Review Board (IRB). Five (5) of the fifteen (15) experts contacted declined to participate due to personal time constraints and

company research participation policies. The confirmed panel of experts included ten (10) panel experts. Table 3.2, displays the Delphi panel members and qualification criteria.

Table 3.2
Delphi Panel Selection and Qualification

Sample N= 15 contacted; N = 10 agreed Composition of Panel Members Management Systems Certified Lead Auditor Group (N=4) Semiconductor Management Systems Representative Group (N =4) Management System Researcher Group (N =2)	
Selection Criteria	Expertise Required
Management System Representative	Involved in the design, implementation and continuous improvement of a management system for a semiconductor company
Management System Certified Lead Auditor	Certified by Exemplar Global
Management System Researcher	Publication in peer reviewed journals, textbook or chapter authors, publication in conference proceedings, presenter at international or national conferences

3.2.2.2 Data Collection

The approach for answering research question 1 advanced thru three rounds of getting quality responses from Delphi panel members. According to Cyphert & Gant, (1971), Brooks, (1979), Ludwig, (1994) and Custer, Scarcella, & Stewart, (1999) three rounds are often sufficient to collect the needed information and to reach a consensus. Table 3.3, displays the Delphi rounds, questions and activities.

Table 3.3
Delphi Rounds, Activities and Questions

Rounds	Delphi Activities (Researcher)	Delphi Questions (Panel Members)
Round 0	Activity 1: Explain to panel members the purpose, scope, methodology of the research, their role and tasks in the research, anonymity, confidentiality, security and the requirements and protocol of the Oregon State University Institutional Review Board (IRB)	No questions asked
Round 1	Activity 2: Explain round 1 procedures and assign DQ1 and DQ2 questions to panel	DQ1: Is there a need to construct an integrated-lean management system as an all-inclusive operating framework based on the common elements and implementation practices that exist among
	No activities	

		standalone systems? If so, why? If not, why not? DQ2: If so, what should be included in the integrated-lean management system that would meet the needs of today's high-performance lean driven organizations?
Round 2	Activity 3: Summarize responses from DQ1 and DQ2 and request the panel to modify their comments based on a review of the other panel member comments, if needed. Convey panel modifications to gain final consensus from panel on DQ1 and DQ2 questions Activity 4: Explain round 2 procedures and provide panel members with copies of the six-(6) standalone management systems typically used by semiconductor companies and the corresponding Table 2.2 key elements of standalone management systems DQ3 and DQ4 questions	No questions asked
	No activities	DQ3: Are there elements in the six-(6) standalone management systems that overlap? If so, please indicate DQ4: What elements in the six-(6) standalone management systems need to be added and deleted?
Round 3	Activity 5: Summarize responses from DQ 3 and DQ4 and request panel members to modify their responses based on a review of the other panel member comments, if needed Activity 6: Convey panel modifications to gain final consensus from panel on DQ3 and DQ4 questions Activity7: Explain round 3 procedures and provide the framework (version 1) of merged, added and deleted integrated-lean management system elements and assign DQ5 question.	No questions asked
	No activities	DQ5: Please review the framework (version1) of the integrated-lean management system and indicate whether you agree or disagree with the consolidation, additions and deletions.
	Activity 8: Summarize responses from DQ5 and request panel members to modify their responses based on a review of the other panel member comments, if needed Activity 9: Convey to panel member modifications to gain final consensus provide the framework (version 2) the integrated-lean management system of elements with	No questions asked

	corresponding definitions and implementation practices and assign DQ6 question	
	No activities	DQ6. The following framework (version 2) provides revised elements with corresponding definitions and implementation practices. Please review the framework and indicate if you agree or disagree. If you disagree, provide comments explaining why.

3.3.1 Methodology for Answering Research Questions 2 – 3

A series of case studies helped to answer research questions 2 *(i.e., what were the motivations and the management, structural and financial strategies employed by a sample of semiconductor firms during the integration of their lean management system*) and research question 3 (*i.e., what were the lean outcomes from the strategies employed by the semiconductor companies*). Qualitative case study methods are particularly suited to new research explorations (Eisenhardt, 1989), bringing a conceptual framework into sharper focus (Yin, 2009), and studying problems within their context using a range of data sources (Baxter & Jack, 2008). Case studies are useful in management system research because of flexibility and rigor (Baxter & Jack, 2008) and case research on management systems differs from case research in the wider social science field in that, management system researchers are mainly interested in examining operational systems of a company to build conceptual frameworks (Hill, 1999).

3.3.1.2 Case Selection

The traditional way of case selection is to identify potential cases, and then to select a random or stratified sample from that case population (Eisenhardt, 1989; Yin, 1994). However, in qualitative case research cases are selected according to different criteria to control for extraneous variation and help to define the limits for generalizing the findings (Eisenhardt, 1989; Yin, 1994). Non-random samples based on specific conceptual underpinnings are suggested for qualitative case research (Eisenhardt, 1989; Miles & Huberman, 1994).

The four case studies performed in this research took place in operational settings of semiconductor companies and carefully chosen to be in line with the purpose of the study and research questions. When extending an emergent idea random selection of cases is neither necessary nor preferred; but should be congruent with the research problem (Eisenhardt, 1989). In building the conceptual framework and answering research questions, two and three replication logic rather than sampling logic was used (Voss, Tsikriktsis, & Frohlich, 2002) and each case relied on theoretical sampling where cases were chosen to pursue the development of conceptual ideas, not statistical reasons (Glaser & Straus, 1967). As Petigrew, (1988) noted, given the limited number of cases, which can usually be studied, it makes sense to choose cases in which the system of interest is transparently observable. And according to (Voss et al., 2002) and (Eisenhardt, 1989) the goal of theoretical sampling is to select cases likely to replicate or extend the conceptual framework.

Semiconductor firms who participated in the case studies were from the state of California. Collecting data in a single state removes many issues created by different environment, safety and health regulations and or enforcement routines from other states (Pagell, 2004). The sample of semiconductor firms was taken from the list of Semiconductor Industry Association (SIA) member companies who also submit an annual self-assessment questionnaire to the Electronic Industry Citizenship Coalition (EICC). Table 3.4 displays the case study selection criteria. Cases were selected from semiconductor companies that are considered front-runners regarding the integration of their management systems and mature in their environment, safety and health practice. According to (Asif et al., 2010), front-runners are companies who are early adapters of operational frameworks and known to have established the implementation of the conceptual framework for a minimum of three years. A three-year period is considered the cut-off point

between young and mature companies (Ahire, 1996). For this research, studying front-runner and mature semiconductor companies provided insight into the management, structural and financial strategies that support lean outcomes. This insight should be of practical value to the semiconductor industry as well as other manufacturing industries. There were six (6) criteria used for case selection. Criteria #1 required that the prospective company be a member of the Semiconductor Association (SIA). Criteria #2 required that the prospective company participate in the annual submission of an Electronic Industry Citizenship Coalition (EICC) questionnaire. Criteria #3 requires that an integrated management system intended to support lean enterprise principles $\geq$ 3 years has been in place. Criteria #4 stipulates that organizations must have an OSHA recordable injury rate of < than the industry average. Criteria #5 requires that there be zero (0) regulatory violations resulting in significant impact to workers or the environment. Lastly criteria #6 requires that operations are present in California and subject to California regulations.

Table 3.4
Case Study Selection Criteria

No.	Criteria	Description
1	Semiconductor Industry Association (SIA)	Must be a member company of the Semiconductor Industry Association (SIA) and have a NAICS code of 3344
2	EICC participant	Required to submit an annual self-assessment questionnaire to the Electronic Industry Citizenship Coalition (EICC)
3	Front-Runner and Mature	Must have an integrated management system intended to support lean enterprise principles $\geq$ 3 years
4	OSHA recordable injury rate < industry average	OSHA recordable injury rate of < industry average
5	ESH compliance violations	0 regulatory violations in last 3 years resulting in significant impact to workers or the environment
6	Geographical location	Must have operations located in California

3.3.1.2 Data sources and collection

Sources of data included semi-structured interviews, information from management system internal documents, and facility tours. These sources were used in past exploratory and case studies conducted by (Pagell 2004; Longoni et al., 2013). Environment, safety and health managers, management system representatives and operations personnel who were critical to the integration of management systems in their respective facilities were interviewed. Available information from internal documents was reviewed to provide documented evidence of management system activities and outcomes gathered from site tours. Tours from each semiconductor facility allowed for a visual check and comparison of each company's management system and outcomes. According to Pagell & Wu (2011) tours provide important insight into how work is done and can serve as validation of interview responses. Table 3.5 displays the types of case study data sources reviewed.

Table 3.5
Case Study Data Sources

Interviews →	Primary source of data of constructs
Facility Tour (validation of interview responses) →	On site observation of operational activities
Internal Documents:	Indication of system activities & outcomes
Management System Manual	Guidebook of system practices
Management System Reviews →	Level of performance outcomes of system audits
Organization Charts	Information to support structural decision making
Policies and Procedures	Information that describes system logistics
Corrective/Preventive Records	Information that describes accidents/incidents

Interviews lasted approximately 90 minutes, recorded, transcribed and notes taken. A two-person team conducted the interviews; one-member took notes while the other member led the interview. One of the advantages of this approach is the close collaboration between the researcher and the participant, while enabling participants to tell their stories (Crabtree & Miller,

1999). According to (Eisenhardt, 1989), the use of two or more interviewers enhances the creative potential of the research team and convergence of observations increases confidence in the findings. Table 3.6 displays the case study protocol.

Table 3.6
Case Study Protocol

Constructs	Case Study Questions
Construct 1: Company Description (i.e., products & services, sales, # of employees, # of ESH staff)	1. How would you describe your company's semiconductor products and services? 2. What were the company sales in 2016? 3. How many employees work for your firm 2015? 4. How many ESH specialists are on staff?
Construct #2: Contextual Factors (i.e., controls and ways to classify the cases, scope of management system, ESH regulatory violations, prior standalone management systems used). Note: Contextual factors in this research are factors other than the specific management system practices and outcomes. The assumption is that contextual factors are beyond the organizations short-term control	5. Does your management system cover single or multiple facilities? 6. During the years 2014-2016 what type of environmental regulatory compliance violations did the company incur? (administrative violations not applicable) 7. During the years 2014-2016 what type of occupational safety and health regulatory compliance violations did the company incur? (administrative violations not applicable) 8. What standalone management systems did your company employ prior integration? 9. Who were the stakeholders of the integrated-lean management system?
Construct #3 Motivations (i.e., primary reasons for developing an integrated-lean management system	10. What motivated the company to develop an integrated-lean management system?
Construct #4: Strategies (i.e., the management, structural and financial approaches used in the integrated management system to support lean outcomes	11. What was the strategy used to manage the integrated-lean management system? 12. What was the strategy used to organizationally structure the integrated-lean management? 13. What was the strategy used to finance the integrated-lean management?
Construct #5: Lean Outcomes (i.e., the added value, waste minimized and risk reduced derived from strategies)	14. What value was derived from the integrated-lean management system strategies? 15. What waste was minimized as a result of the integrated-lean management system strategies? 16. What risk was reduced as a result of the integrated-lean management system strategies?
Facility Tour: (i.e., a visual check of each company's management system activities and work)	17. What is your understanding of the integrated-lean management system? 18. Was it necessary to implement the integrated-lean management system? 19. Has the new system changed your job routines? 20. What are positive impacts of the integrated management system? 21. What are negative impacts of the integrated management system?
Document Review: (i.e., documented evidence of management system activities, key elements and lean outcomes)	22. What records are available to help support the integrated-lean management system?

Data Analysis

Coding and analysis was performed after all the case data was collected to reduce the potential for confirmation bias influencing the results (Miles & Huberman, 1994). The case study protocol provided a template for documentation of information gathered in each case. All data was placed into a codebook to allow a chain of evidence to be established (Miles & Huberman, 1994; Glaser & Strauss, 1967). To limit bias from affecting the analyses the two-member team performed the coding. After each case was coded, analysis was conducted in two stages; within-case analysis to answer the research questions for each individual case and cross-case analysis to determine patterns for the entire sample. Within-case analysis provided a description of the relationships of interest in each case, with the end-result being a detailed narrative supported by data, figures, tables, and quotes. Cross-case analysis provided patterns in the entire sample.

Responses to each interview question for each case were compiled using qualitative data analysis tools (e.g., pattern matching and conceptual framework building).

CHAPTER IV

RESULTS

Chapter 4 presents the essential findings of the study and a discussion of how and why relationships between the research constructs exist. The purpose of this research was to develop an integrated-lean management system framework and examine the strategies used by semiconductor firms that support lean outcomes. A solution to this problem was contingent upon answering the following three (3) research questions:

Research question 1:
What does an operating framework of an integrated management system look like for supporting lean management outcomes?

Research question 2:
What were the motivations and the management, structural and financial strategies employed by a sample of semiconductor firms during the integration of their lean management system?

Research question 3:
What were the lean outcomes from the strategies employed by the semiconductor companies?

4.1 Answering research question 1

The methodology to answer research question 1 was to (a) review the management system literature and link information from peer-reviewed journal articles and, (b) employ a Delphi study as a systematic, interactive forecasting method that relied on a panel of experts in the field of management systems. The Delphi study consisted of three (3) separate rounds, six (6) questions and nine (9) researcher and panel member activities. Table 3.3 displays the Delphi rounds, activities and questions.

Round 1 individual questioning began soon after panel members were briefed about the purpose, scope and methodology of the research, their role and tasks in the research, how anonymity, confidentiality and security would be maintained and the requirements and protocol

of the Oregon State University Institutional Review Board (IRB). During this time the researcher assigned two (2) questions for panel members to think about and address.

Round 1 - Delphi Question #1

This question called for panel members to decide if there was a need to construct an integrated management system as an all-inclusive operating framework based on the common elements and implementation practices that exist in the standalone management systems. And, if so, why? And if not, why not? Table 4.1 displays panel member responses to Delphi question #1 followed by essential findings.

Table 4.1
Panel Member Responses to Delphi Question #1

Panel Member	Yes	No	Is there a need for an integrated-lean management system as an all-inclusive operating framework? And if so, why? And if not, why not?
A	x	-	There is a trend for firms these days to manage ESH risk under one umbrella organization known as ESH. To efficiently and effectively manage ESH risk factors it makes sense to have one integrated framework to do so. Organizations interested in reducing direct and indirect costs will operate one effective management system for ESH. Management system continual improvement initiatives are easier to execute and more effective with a singular system.
B	x	-	An integrated-lean framework would be very beneficial to organizations looking to advance their ESH program and blend it with operational work practices and operating norms. Integrated systems are needed due to the excess operational expense that comes with managing multiple independent systems.
C	x	-	For organizations that have external certifications requiring annual internal and external audits, blending and consolidating desperate systems into one makes good business sense.
D	x	-	Several management system standards exist today and have various differences among them, but mostly similarities. Developing a single framework to help facilitate the merging of requirements in a way that meets the various international standards is a good approach to eliminating waste and improving efficiency.
E	x	-	If developed with international standards in mind, an integrated system would help organizations of various sizes meet multiple standards using one system. This would bring about operational improvements in most if not all areas of the value stream by minimizing waste. There are too many systems out there today that are intended to accomplish the same goal. Experts should work together to establish one system.
F	x	-	A singular framework will reduce waste and improve operational excellence, meet international standards, enable better use of information such as corrective and preventive actions.

G	x	-	Most international manufacturing organizations today are required to be ISO 14001 certified. Firms should integrate safety and health with ISO 14001 requirements and with other relevant standards.
H		x	Although having an integrated-lean framework would help and could be done, organizations that have competent management system representatives should be able to review the legal and other requirements pertinent to their organization and devise a lean integrated system with help from their internal business partners. Standards are now being revised to support the increase in integration initiatives that many firms are embarking on.
I	x	-	An integrated framework is necessary to have one efficient system to deal with ESH issues and to conduct business internationally. It would be helpful for these businesses to operate under one effective management system; ISO has published a book to encourage the integration of management system standards, but the design criteria is absent other than reliance on ISO 9001 and 14001. There are other standards that should be considered other than the ISO standards.
J	x	-	Management systems revolve around a plan, do, check and act model. Many of the barriers or enablers associated with an effective management system overlap in the ESH. Operations will be continually improved. Better align workers to focus on ESH and operational issues simultaneously. Better structure to communicate with stakeholders.

Delphi Round Findings:

1. 90% (9/10) panel members agreed with the need to construct an integrated-lean management system as an all-inclusive operating framework based on the common elements and implementation practices that exist in the standalone management systems.

2. 60% (6/10) panel members, in particular, members (A, D, E, F, G, I) indicated that the integrated-lean management system should meet the specified international requirements driven by most international supply chains. These supply chains require that their key vendors that supply materials are in compliance with internationally accepted environmental, safety and health standards.

3. 100% (10/10) panel members indicated that considerable overlap exists in the various standalone management system standards and that integration should help organizations to standardize and better manage activities associated with environment, safety and health risks, while increasing overall organizational efficiency and effectiveness.

4. 10% (1/10) panel member commented that there was no need to construct an integrated lean-management system as an all-inclusive operating framework. This member felt that there are complex operational concerns and incompatibility between standards. In addition, organizations should have the internal capacity and competency in place to integrate the system without a framework to guide them. The panel member agreed to participate in the remainder of the Delphi to contribute to the framework development for those who may prefer it.

Round 1 - Delphi Question #2

This question called for panel members to indicate features that should be included in an integrated-lean management system that would meet the needs of today's high-performance lean driven organizations. Table 4.2 displays panel member responses to Delphi question 2 followed by essential findings.

Table 4.2
Panel Member Responses to Delphi Question #2

The integrated-lean management system should include:	Panel Member										%
	A	B	C	D	E	F	G	H	I	J	
Requirements for written Policies	x	x	x	x	x	x	x	x	x	x	100%
Requirements for a risk assessment process	x	x	x	x	x	x	x	x	x	x	100%
Review of applicable legal and other requirements	x	x	x	x	x	-	x	x	x	-	80%
Requirements for management system goals & objectives	x	x	x	x	-	x	-	-	-	-	50%
Resources, roles and responsibilities within the system	x	-	x	x	x	-	x	-	x	x	70%
Requirements for education and training	x	x	x	x	x	x	x	x	x	x	100%
Requirements for internal & external communication	-	-	x	-	x	x	-	-	x	x	50%
Requirements for management system documentation	x	x	x	x	x	x	-	-	-	-	60%
Control of documentation Methodologies	-	-	x	-	x	x	-	-	x	x	50%
Requirements for operational and engineering controls	-	x	x	-	x	-	-	-	-	-	30%
Requirements for emergency preparedness and response	-	-	x	x	x	x	x	x	x	-	70%
Effective means for monitoring and measurement	x	x	x	x	-	x	-	-	-	-	50%
Methods for the evaluating compliance and conformance	x	x	-	x	x	x	x	-	-	-	60%
Methods for effective corrective and preventive action	x	x	x	x	x	x	x	x	x	x	100%
Requirements for the control of records	x	-	-	x	x	-	-	x	-	-	40%
Requirements for audits and assessment	x	x	x	x	x	x	x	x	x	x	100%
Requirements for incident investigations & root cause	x	x	x	x	x	-	-	-	-	-	50%

Delphi Round Findings:

1. Responses provided by the panel members regarding what should be included in an integrated-lean management system that would meet the needs of today's high-performance lean driven organizations were aligned with elements found in the two most predominant environmental, safety and health management system standards today (ISO 14001 and OHSAS 18001).
2. 100% (10/10) panel members agreed that the integrated-lean management system should include requirements for written polices, risk assessment, education and training, methods for effective corrective and preventive action and audits and assessments process.
3. 80% (8/10) panel members agreed that having a process to stay abreast of legal and other requirements was a critical element that should be included in the integrated-lean management system.
4. 70% (7/10) panel members agreed that it was necessary to have elements of the integrated-lean management system dedicated to resources, roles and responsibilities and emergency preparedness and response.
5. 60% (6/10) panel members agreed that management system documentation and methods for evaluating compliance and conformance were key elements of the integrated-lean management system.

Round 2 started after responses from DQ1 and DQ2 were summarized and panel members were provided the opportunity to modify their comments based on a review of the other panel member comments, if needed. Then, each panel member was provided copies of the six (6) standalone management system standards typically used by semiconductor companies today. These included the Environmental Management International Organization for Standardization 14001, the Occupational Health & Safety Assessment Series (OHSAS 18001), the Eco-Management and Audit Scheme (EMAS), the American National Standards Institute (ANSI-Z10), the California Injury, Illness & Prevention Plan (CA-IIPP), and the Occupational Safety and Health Administration Voluntary Protection Program (OSHA VPP).

Round 2 - Delphi Question #3

This question called for panel members to state if there were elements in the standalone management system standards that overlap and could be merged. Table 4.3 displays panel member responses to Delphi question #3 followed by essential findings from the data.

Table 4.3
Panel Member Responses to Delphi Question #3
(x = element present in standard; - = element not present in standard)

Management System Elements that Overlap and Should be Merged									
#	Merged Elements	ISO 14001	OHSAS 18001	EMAS	ANSI-Z10	VPP	CAL OSHA IIPP	Panel Responses	% Agreement
1	Policy Requirements	x	x	x	x	x	x	A,B,C,D,E,F,G,H,I,J	100%
2	Risk Identification /Assessment	x	x	x	x	x	x	A,B,C,D,E,F,G,H,I,J	100%
3	Legal and Other Requirements	x	x	x	-	-	-	A,B,D,E,F,J,I	70%
4	Objectives, Targets, Improvement	x	x	x	x	-	x	A,B,C,D,E,F,I	70%
5	Resources, Roles, Responsibility	x	x	x	x	x	x	A,B,C,D,E,F	60%
6	Competence, Training, Awareness	x	x	x	x	x	x	A,B,C,D,E,F,G,H,I,J	100%
7	Internal & External Communication	x	x	x	x	x	x	A,B,C,F,H,I	60%
8	Documentation/Records Management	x	x	x	x	-	x	A,B,C,D,E,F	60%
9	Operational/Hazard control	x	x	x	x	x	x	A,B,C,D,E,F,G,H,I,J	100%
10	Emergency Prep. and Response	x	x	x	x	x	-	A,B,C,D,E,F,G,H,I,J	100%
11	Monitoring & Measurement	x	x	x	x	x	x	B,C,D,G,H,I	60%
12	Evaluation of Compliance	x	x	x	x	x	x	A,B,C,D,E,F,G,H,I	90%
13	Corrective & Preventive Action	x	x	x	x	x	x	A,B,C,D,E,F,G,H,I,J	100%
14	Internal and External Audit	x	x	x	x	x	x	B,D,F,I,G,H,J	70%
15	Incident Investigation	-	x	x	x	x	x	A,B,C,D,E,F,G,H,I,J	100%
16	Management Review	x	x	x	x	-	-	A,B,C,D,E,F,G,H,I,J	100%
17	External Reporting	-	-	x	-	-	-	A,D,E,F	40%

Delphi Round Findings:

Upon a review of the various standards by the panel seventeen (17) merged elements surfaced from the exercise.

1. 100% (10/10) panel members suggested that key elements of policy requirements, risk identification and assessment, competency training and awareness, operational hazard control, emergency preparedness and response, corrective and preventive action, incident investigation and management review could be developed based on the merging of the six standalone management system standards.

2. 90% (9/10) panel members suggested that evaluation of compliance emerge as a key elements based on the merging of the six standalone management system standards.

3. 70% (7/10) panel members suggested that key elements of legal and other requirements, objectives, targets and improvement and internal and external audit could be developed based on the merging of the six standalone management system standards.

4. 60% (6/10) panel members suggested that key elements of resources, roles and responsibilities, internal and external communication, documentation and records management and monitoring and measurement could be developed based on the merging of the six standalone management system standards.

Round 2 - Delphi Question #4

This question called for panel members to identify what standalone management system elements needed to be added and deleted. Table 4.4 displays panel member responses to Delphi question #4 followed by essential findings from the data.

Table 4.4
Panel Member Responses to Delphi Question #4

Framework of Fused Elements, Added, Deleted Elements							
No.	(A) Fused Elements	ISO 14001	OHSAS 18001	EMAS	ANSI Z10-2005 OSHMS	OSHA VPP	California IIPP
1	Policy	Environmental policy	OH&S Policy	Environmental policy	Management must first establish a safety and health policy and communicate the dated and signed information to all employees.	Corporate Leadership & Commitment to Safety and Health	Fully involve all employees, supervisors, and management
2	Risk Identification & Assessment	Environmental aspects	Hazard Identification, risk assessment and determining controls	EMAS requires organization to carry out an environmental review of all environmental aspects	Documenting and reviewing all equipment and processes to determine risk factors; Conduct a hazard analysis to identify potential and existing hazards; Identifying the hazard, controls, and severity	Baseline Hazard Analysis Hazard Analysis of Routine Activities	Hazard Assessment Identify the specific workplace hazards and employee exposures
3	Legal and Other Requirements	Legal and other requirements	Legal and other requirements	Legal and other requirements	The documentation review should include internal and regulatory policies procedures, worker comp. information	Be in compliance	Compliance
4	Objectives, Targets and Programs	Objectives, targets and programs	Objectives and Programs	Objectives, targets and programs	Establish appropriate objectives and plan	Planning	Standard does not cover
5	Resources, Roles, Responsibilities, Authority & Consultation	Resources, roles, responsibility and authority	Resources, roles, responsibility, accountability and authority and participations and consultation	Resources, roles, responsibility and authority including employee involvement	Employees have a personal responsibility to comply with all safety and health rules established by management Employees must also have the opportunity to participate in any safety related planning, implementation, evaluation, and corrective/preventive actions geared toward addressing hazards in the workplace.	Authority and Line Accountability Contract Employees Employee Involvement	All managers, supervisors and lead personnel are responsible for implementing and maintaining the IIPP in their work areas
6	Competence, Training and Awareness	Competence, training and awareness	Competence, training and awareness	Competence, training and awareness	Standard does not cover	Safety and Health Training	Effective Training and Instruction
7	Internal and External	Communication	Communication	Communication including with the	Standard does not cover	Communication	Communication

	Communication			public			
8	Documentation	Documentation	Documentation	Documentation	Standard does not cover	Written Safety & Health Management System	Standard does not cover
9	Control of Documents	Control of documents	Control of Documents	Control of documents	Standard does not cover	Recordkeeping	Recordkeeping
10	Operational & Hazard Control	Operational control	Operational Control	Operational control	Implementation and Operation Applying specific controls and applying risk-reducing methods; hazard identification and control measures, methods, severity.	Hazard Prevention and Control	Standard does not cover
11	Emergency Preparedness and Response	Emergency preparedness and response	Emergency Preparedness and Response	Emergency preparedness and response	Standard does not cover	Standard does not cover	Standard does not cover
12	Monitoring, Measurement	Monitoring and measurement	Performance measurement and monitoring	Monitoring and measurement	Standard does not cover	Trend Analysis	Standard does not cover
13	Evaluation of Compliance	Evaluation of compliance	Evaluation of compliance	Evaluation of compliance	Evaluation and Corrective Action – Documented management evaluations	Audit and inspection	Standard does not cover
14	Corrective and Preventive Action	Nonconformity, corrective action and preventive action	Nonconformity, corrective and preventive action; Investigation	Nonconformity, corrective action and preventive action	Evaluation & Corrective Action	Hazard Reporting Hazard Tracking; Accident/Incident Investigations	Hazard Correction in timely manner; Accident/ Exposure Investigation
15	Internal and External Audit	Internal audit	Internal Audit	Internal audit	Standard does not cover	Routine Inspections	Routine inspection
16	Management Review	Management Review	Management Review	Management Review	Management Review	S&H Management System Evaluation; Mgmt. involvement	Standard does not cover
17	Behavior and Culture	New element added based on Delphi					
18	Management Engagement	New element added based on Delphi					
19	Employee Participation	New element added based on Delphi					

Delphi Round Findings

1. The external reporting element from EMAS was removed as EMAS was the only standard driving the key element. In addition, many organizations make this data available in the form of the Corporate Social Responsibility Report.
2. An element for Behavior and Culture was added.
3. An element for Management Engagement and Employee Participation was added.

Round 3 began after responses from DQ 3 and 4 were summarized and panel members were provided the opportunity to modify their comments based on a review of the other panel member comments, if needed. At this time an explanation of round three (3) was given and panel members were presented version #1 of the integrated-lean management system.

Round 3 - Delphi Question #5

This question called for panel members to review version #1 framework and indicate agreement or disagreement with the consolidation, additions and deletions. Table 4.5 displays panel member responses to Delphi question #4 followed by essential findings from the data.

Table 4.5
Panel Member Responses to Delphi Question #5

Panel Member	Agree	Disagree	Consolidation, Addition, Deletion Responses
A	x	-	The consolidation of fused elements including the addition of a Behavior and Culture, Management Engagement and Employee Participation elements will be helpful, but require further definition to determine effectiveness.
B	-	x	An explicit element attributed to Management Engagement will improve any organization's management system. The removal of the external reporting element makes sense for companies not subject to European Union requirements not seeking EMAS certification. Element is missing for management of change
C	x	-	The consolidation, additions and subtractions make sense, however external EMAS certification cannot be achieved without publishing an external performance report. Documentation and Control of Records could be merged as well to further lean out the system.
D	x	-	The fused elements make sense and should save organizations time and money if defined properly. Having a dedicated element for employee participation will enable organizations to be more specific and action oriented towards employee involvement in the overall system.
E	x	-	The elements could work if defined properly in a manner to meet the six

			standards mentioned in this study. If expert members believe there is an explicit need for elements pertaining to active management engagement and employee participation I support it, however there are effective management systems today that are not explicit. Considering that most performance data can be made available upon request I see little value to the EMAS external reporting requirement, so I support the motion for subtraction.
F	x	-	The blended modifications are well informed and make sense based on the standards referenced. The framework should serve as a useful tool for organizations looking to modify or create an integrated ESH management system. For those organizations seeking EMAS certification, they can simply add the external reporting requirement to their management system.
G	x	-	The blending approach appears to reflect the necessary elements of the 6 standards referenced. To confirm the blending the definition and implementation approach must meet the standard requirements.
H	-	x	The fused elements could work as listed, but the information necessary to make a more informed decision relies on the implementation; more specificity regarding implementation is required
I	x	-	The framework does a nice job of consolidating the various management system standards the semiconductor and other industries are subject to. If deployed in a manner to meet all standards this framework would help lean out inefficiencies and meet various standards under one initiative
J	x	-	The fused elements could work as long as the implementation occurs in a manner that meets the standards specifications. Formally listing elements that address management engagement, employee participation and behavior and culture could be helpful for some organizations, however flexibility as to how these elements are met should be employed.

Delphi Round Findings:

1. Upon review 80% of the experts agreed with the consolidated elements, additions and subtractions.
2. Expert panel member B disagreed as he felt there was a need for an additional element for management of change.
3. Expert panel member H required further clarity around implementation practices.

Round 3 Delphi Question #6

Prior to DQ6 the researcher conveyed to panel member modifications of DQ5 to gain final consensus of version #1 and provided the framework (version 2) the integrated-lean management system of elements with corresponding definitions and implementation practices is displayed in Table 4.6. The definitions and implementation practices were constructed by taking the common features of each standard covered in this study.

Table 4.6
Revised Definitions and Implementation Practices

1. ESH Policy

Definition: Overall intentions and direction of an organization related to its ESH performance formally expressed by top management.

Lean Implementation Practices: An organization's ESH policy should be appropriate to the nature and ESH impacts of its activities, products and services and includes commitment to continual improvement and prevention of ESH impacts. The policy should include a commitment to comply with legal requirements and with other requirements to which the organization subscribes. The policy should be documented and communicated to all persons working on behalf of the organizations and made available to the public.

2. ESH Risk Identification & Assessment

Definition: The process of identifying and evaluating ESH risks associated with the activities within the scope of the ESH management system.

Lean Implementation Practices: An organization should conduct and inventory of routine and non-routine operations and activities within scope of the management system and conduct a documented ESH risk assessment using a methodology that allows the organization to assess risk levels and the adequacy of controls. The organization should use this assessment proactively to determine significant risk factors, measuring the effectiveness of operational controls and to maintain and continue to improve the ESH management system. When determining controls the hierarchy of controls (1. elimination, 2. substitution, 3. engineering, 4. administrative and 5. personal protective equipment) should be used. The risk assessment process must take into consideration change including, but not limited to process, people, environment and product.

3. ESH Legal and Other Requirements

Definition: The process of determining applicable ESH related legal and other requirements including standards to which the organization subscribes related to its ESH aspects.

Lean Implementation Practices: Organizations should document an inventory of applicable legal and other requirements associated with their operations and establish processes to be informed of and manage applicable emerging requirements. The organization should ensure that applicable legal and other requirements are taken into account when establishing, implementing and maintaining its ESH management system. The evaluation process should remain up-to-date.

4. ESH Objectives, Targets and Programs:

Definition: Objectives pertaining to what the organization is trying to achieve consistent with the ESH policy. Targets are specific performance measures tied to the objectives as a way to measure performance. Programs are methods including accountability and timeframe for achieving the objectives and targets.

Lean Implementation Practices: Organizations should establish objectives and targets that are meaningful, achievable, reflect the needs of the organization and drive performance improvements. Top management and employees should be included in developing the objectives, targets and programs. Routine performance reviews against the stated objectives and targets should be reviewed on a routine basis through a management review. Performance improvements and consideration of legal and other requirements should be incorporated when establishing ESH management system targets.

5. ESH Resources, Roles, Responsibilities, Authority and Consultation

Definition: Management shall ensure the availability of resources essential to establish, implement, maintain and improve the ESH management system including outside consultation when necessary. Roles,

responsibilities and authorities shall be defined, documented and communicated in order to facilitate effective ESH management including the appointment of a specific management representative.

Lean Implementation Practices: Organizations should utilize their ESH risk assessment along with the objectives and targets of the management system to provide input into the resourcing strategy of the organization. Resources should be competent and capable to help the organization meet their management system objectives and address the risk profile of the organization. Responsibilities for ESH should be identified and documented job descriptions or other related documents. Organizations should appoint a top management representative for the overall ESH management system.

6. ESH Competence, Training and Awareness

Definition: Organization's method to ensure that any person performing tasks on its behalf that have the potential to contribute to significant ESH impacts are competent on the basis of education, training or experience.

Lean Implementation Practices: Organizations shall develop a written process to conduct a training needs assessment associated with risk factors identified in the ESH risk assessment and meeting the regulatory compliance requirements provided in the ESH legal and other requirements register. The organization should develop a method to develop, deliver and measure the effectiveness of the training and competency of persons working under its control aware of ESH risk factors and controls, their role in achieving success of the management system and consequences of departure from specific procedures. Training procedures should consider the different levels of risk, language and literacy skills and responsibility.

7. ESH Internal and External Communication

Definition: Process for internal and external communications between various organizational stakeholders including employees, visitors, contractors and external interested parties.

Lean Implementation Practices: Organizations should develop a documented process outlining the methods used for internal and external communication associated with the ESH management system. How the organization receives, documents and responds to ESH communication from external interested parties should be documented along with the decision whether to communicate externally about its significant ESH risk factors.

8. ESH Documentation, Control and Records Management

Definition: The method by which the organization documents, controls and maintains the ESH Management System documentation including records.

Lean Implementation Practices: Organizations should have a documented ESH management system, which included the ESH policy, objectives and targets, description of the scope and main elements of the system and their interaction. Documents including records determined by the organization to be necessary to ensure the effective planning, operation and control of processes that relate to its significant ESH risk factors should also be identified. Procedures should be established that permit approval of documents for adequacy prior to release, change management and ensure documents and records are legible, readily identifiable with defined retention periods.

9. ESH Operational and Hazard Control

Definition: The method for how an organization identifies and documents operational hazards and the associated control strategy.

Lean Implementation Practices: Organization should identify, plan and integrate those operations and activities associated with significant ESH risk factors consistent with its ESH policy, objectives and targets in order to ensure that they are carried out under specified conditions. The organization should have a documented procedure to control situations where the absence of adequate controls could lead to deviation from the ESH policy, objectives and targets. The procedures and requirements should be communicated to suppliers, contractors and other stakeholders.

10. ESH Emergency Preparedness and Response

Definition: The method organizations use to prepare and respond to emergency situations that can lead to adverse ESH impacts.

Lean Implementation Practices: Organization should establish, implement, maintain and test documented emergency procedures to identify potential emergency situations and incidents that may have an adverse ESH impact. The organizations should include who and how it will respond to them. The organization should respond to actual emergency situations and accidents and prevent associated adverse ESH impacts.

11. ESH Monitoring and Measurement

Definition: The method organizations use to monitor and measure key characteristics of its operations that can have a significant ESH impact.

Lean Implementation Practices: Organizations should develop procedures that include how it will document information to monitor qualitative and quantitative performance associated with critical operational controls and conformance to the ESH management system objectives and targets. The organization should ensure that verified monitoring and measurement equipment is used and maintained including associated records.

12. ESH Evaluation of Compliance

Definition: The process for periodically evaluating regulatory compliance with applicable ESH legal requirements and other requirements to which the organization subscribes.

Lean Implementation Practices: Organizations should develop procedures to evaluate ESH regulatory compliance and maintain associated compliance records.

13. ESH Corrective and Preventive Action

Definition: The process organizations use to eliminate the cause of a potential or detected nonconformity to the ESH management system.

Lean Implementation Practices: Organizations should establish, implement and maintain procedures for dealing with actual and potential nonconformity to the ESH management system. Organizations should take corrective and preventive action. The procedure(s) should include requirements for:

- identifying and correcting nonconformities and taking actions to mitigate their ESH impacts
- investigating nonconformities
- determining their causes and taking actions in order to avoid their recurrence
- evaluating the need for actions to prevent nonconformities
- implementing appropriate actions designed to avoid their occurrence
- recording the results of corrective actions and preventive actions taken
- reviewing the effectiveness of corrective and preventive actions taken

14. ESH Internal and External Audit

Definition: The process organizations use for obtaining audit evidence and evaluating it objectively to determine the extent to which the ESH management system audit criteria set by the organization are fulfilled.

Lean Implementation Practices: Organizations should develop a systematic, independent and documented process for conducting internal and external audits aimed at evaluating the effectiveness of the ESH management system. The audit process should include responsibilities and requirements for planning and conducting audits, reporting results and retaining associated records, determination of audit criteria, scope, frequency and methods. Selection of auditors and conduct of audits should ensure objectivity and the impartiality of the audit process.

15. ESH Management of Change

Definition: The process used by an organization for managing change that has the potential to contribute adverse ESH impacts if not controlled in advance.

Lean Implementation Practices: Organizations should develop a process to assess the ESH impact of internal and external changes. The process should require that the proposed change(s) be evaluated prior to change implementations, so that any necessary controls can be taken prior to the introduction of the changes. A hazard identification and risk assessment should be carried out before any modification or introduction of new work methods, materials, processes or machinery. Employees and other affected stakeholders should be included in the assessment as necessary.

16. ESH Behavior and Culture

Definition: An organization's method for measuring and assessing ESH behavior and culture for purposes of achieving and sustaining the ESH management system policy, objectives and targets.

Lean Implementation Practices: Organizations should develop a process that allows the firm to assess the attitudes, behaviors and overall ESH behaviors and culture to understand how others feel about the ESH management system and overall culture. The process should include an employee and stakeholder feedback mechanism. Results should be periodically reviewed in the ESH management review(s) including continual improvement actions.

17. ESH Management Engagement

Definition: An organizations method displaying how management is actively involved in the ESH management system including resource allocation, risk identification and control and reinforcement of positive ESH practices.

Lean Implementation Practices: Organizations should identify objective methods of displaying management engagement within the ESH management system. Measures of effectiveness of management engagement should be implemented and monitored.

18. Employee Participation
Definition: An organization's method displaying how employees are actively involved in the management system including risk identification and control and providing input into the design and improvement of the management system.

Lean Implementation Practices: Organizations should develop a documented method for how employees participate and interact within the management system. Measures of effectiveness of the employee participation should be implemented and monitored.

19. ESH Management Review

Definition: An organization's method to review ESH management system performance to objectives, targets and strategies with upper management.

Lean Implementation Practices: Organizations should establish a formal review process at planned intervals, to ensure its continuing suitability, adequacy and effectiveness. Reviews should include assessing opportunities for improvement and the need for changes to the ESH management system, including the ESH policy, objectives, targets and strategies.

DQ6 question called for panel members to review the definitions and implementation practices and agree or disagree. Panel members were asked to provide an explanation for any disagreements. Table 4.7 displays panel member responses to Delphi question #4 followed by essential findings from the data.

Table 4.7
Panel Member Responses to Delphi Question #6

Delphi Expert	Agree	Definition & Implementation Practices Comments
A	x	The revised elements, definitions and implementation practices are well integrated and should help firms develop a single framework to establish a new or revise existing ESH management systems. The explicit requirement for behavior/culture is an important addition. During implementation ESH managers should still reference the various standards as a check point.
B	x	The revised framework appears comprehensive and easy to follow and does a nice job calling out requirements for management engagement and management of change. I will consider using this framework to help organizations I support.
C	x	The definitions and integration practices are well blended to meet the six standards. The merging of documentation and control of records further leans out redundancy among the standards. This framework should give ESH managers a high degree of confidence when architecting their management system.
D	x	The revised definitions and implementation practices are melded in a way that should result in successful certification to OHSAS 18001 and ISO 14001, which are the most prevalent externally certified ESH management systems. The addition of the employee participation element will help organizations with this very important aspect.
E	x	The framework seems well established and should serve useful to the ESH community. EMAS certification would require the external publishing of a public environmental statement.
F	x	The new framework including revised definitions and implementation practices blends the various standard requirements and makes it easier for people to use. The framework will also help meet the CA-IIPP and OSHA VPP requirements; however consultation should occur with OSHA during implementation for further validation.
G	x	The framework is well established and founded in existing management system standards; if deployed correctly this system would help organizations meet the various standards requirements.
H	x	The definitions and implementation practices are designed in a manner that the lean-system would pass the requirements established in the standards referenced. To achieve EMAS certification a written annual report detailing environmental performance would be required.
I	x	The definitions and implementation practices help solidify my previous comments; this system should help organizations large and small with deployment of a new or continuous improvement of an existing system
J	x	The system is slightly different than the OHSAS 18001 and ISO 14001 requirements. It has more elements or is constructed in way to accommodate the other referenced standards. If deployed in a manner to meet the standards referenced in the study I would agree this is a lean approach.

Essential Finding:

1. The expert panel reviewed the revised elements, definitions and implementation practices and confirmed agreement with the integrated framework.

4.2 Answering research questions 2 and 3

A series of four case studies were deployed to help answer research questions 2 and 3. The four case studies took place in operational settings of semiconductor companies based in California and carefully chosen to be in line with the purpose of the study and research questions. All four cases participating in the study are considered front-runners regarding the integration of their management systems in the semiconductor industry. A case study protocol was developed using five (5) protocol constructs including company descriptions, contextual factors, integration motivations, strategies and lean outcomes. The construct responses and data were obtained through interviews, on-site facility tours and internal document review.

Construct 1 Case Descriptions

The first construct focused on understanding the company description of each case. Specifically interviews took place to detail the type of semiconductor firm, products and services, 2016 sales, number of employees and number of ESH staff members. Table 4.8 displays the results from construct 1 case descriptions.

Table 4.8
Construct 1 Case Descriptions

Case # Company Type	Description (Products and Services Provided)	2016 Sales (Revenue)	No. Employees	No. ESH Staff
#1 Integrated circuit manufacturer	High volume manufacturer of integrated circuits	5.5 billion	18,000	75
#2 Semiconductor capital equipment manufacturer (A)	Leading supplier of wafer fabrication equipment and services to semi industry	6.2 billion	9,100	29
#3 Semiconductor capital equipment manufacturer (B)	Supplier of equipment, services and software to enable the manufacture of semiconductor chips for electronics, flat panel displays for computers, smartphones and televisions, and solar products	9.6 billion	14,600	80
#4 Semiconductor device manufacturer	Designer, manufacturer and marketer of semiconductor products including power semiconductors, microcontrollers, security controllers, radio frequency products, and sensors.	7.6 billion	36,300	12

Construct 2 focused on contextual factors such as the scope of the integrated-lean management system (single or multiple sites), management systems deployed prior to integration and 3 year regulatory history (2014-2016). Table 4.9 displays the results from construct 2 case descriptions.

Table 4.9
Construct 2 Contextual Factors

Company Description	Mgmt. System Coverage	Mgmt. Systems Deployed Prior Integration	2014-2016 environmental compliance violations	2014-2016 safety & health compliance violations	Lean-Integrated Mgmt. System Stakeholders
Case #1 Integrated circuit manufacturer	Multiple Sites (5)	OSHA VPP ISO 14001 OHSAS 18001	0	0	(External) Suppliers (Internal) Workers, Fab Operations (ex. manufacturing, logistics), ESH, Supply Chain Management
Case #2 Semi-conductor capital equipment manufacturer	Multiple Sites (4)	ISO 14001 EMAS OHSAS 18001 CA-IIPP	Administrative violations for delinquent reporting	0	(External) Customers, Stockholders, Industry Groups (Internal) Workers, Lab/Fab Operations,

(A)		SHARP			ESH, Investor Relations, Communications, Quality
Case #3 Semi-conductor capital equipment manufacturer (B)	Multiple Sites (10)	ISO 14001 OHSAS 18001 OSHA VPP CA-IIPP Bizsafe	0	Administrative violations related to OSHA recordkeeping	(External) Customers Industry Associations (Internal) Workers, Operations, ESH, Facilities and Maintenance
Case #4 Semi-conductor device manufacturer	Multiple Sites (16)	ISO 14001 OHSAS 18001 CA-IIPP	0	0	(External) Customers, Stockholders (Internal) Workers, Manufacturing, Warehouse and Supply Chain Management, ESH, Human Resources

Construct 3 sought to determine the organization's motivations for the development of an integrated-lean management system. Table 4.10 displays the primary motivations for development of integrated-lean management system.

Table 4.10
Construct 3 Primary Integration Motivations

Cases	Motivations
Case #1 Integrated circuit manufacturer	Pressure from management to structure organizational activities around the company's lean management system
Case #2 Semi-conductor capital equipment manufacturer (A)	Reduce cost ESH management Efficient use of resources Consistent ESH management Improve compliance Aligned ESH and lean strategies Reduced complexity
Case #3 Semi-conductor capital equipment manufacturer (B)	Address ESH hazards and regulations under one system Reduce non-value added activities and required waste Resource reduction
Case #4 Semi-conductor device manufacturer	Meet stakeholder concerns Easier collaboration Lean ESH operations Maximize value Reduce cost of ESH ownership Cross-site problem solving & solutions Consolidation of ESH risk controls

Construct 4 was intended to understand the management, structural and financial approaches used to in the integrated management system that support lean outcomes. Table 4.11 displays a summary of case responses for integrated-lean management system strategies.

Table 4.11
Construct 4 Integrated-Lean Management Strategies

Integrated-Lean Management System Strategies			
Cases	Strategies		
	Management	Structure	Finance
Case #1 Integrated circuit manufacturer	Identify best practices and scale to support MS Developed MS strategic plan Conducted semi-annual performance reviews	Determine MS linkage to lean strategy; developed organization from there Inventory high hazard work activities; developed job descriptions	Operational business units within the organization
Case #2 Semi-conductor capital equipment manufacturer (A)	Integrate management systems across company Help each operational team identify risk control synergy Measure continual improvement Incorporate customer and stakeholders requirements Establish integrated management reviews	Organized operations leaders and workers to participate and take ownership in MS activities Equipped managers with information and tools that add value to their work, stressing prevention and continuous improvement	Funding provided by the Global Quality organization; cost allocated among operations and engineering functions
Case #3 Semi-conductor capital equipment manufacturer (B)	Develop cross-functional teams to leverage business processes Conduct audits of the system annually Annual MS reviews	Combined elements and implementation practices from applicable industry standards Applied continuous improvement organized around procedures, work task instructions, checklists & recordkeeping	Facilities and Real-estate manages MS cost; cost is dispersed among the operations and product groups
Case #4 Semi-conductor device manufacturer	Goals and objectives set around greatest risk identified in ESH aspects and impacts assessment Common MS manual for strategy & business processes Design for ESH upfront Inventoried stakeholder requirements to custom fit system	Organized each business operation into cross-functional teams with cross function management system activities Conducted inventory of routine operational risks affecting worker ESH Inventoried ESH regulations relevant to operations Value creation occurs across all functional processes	General support function cost center; no allocation

Construct 5 sought to determine the lean outcomes from the strategies employed by the semiconductor companies. Lean outcomes for purposes of this study were defined as value realized, waste minimized and risk reduced. Table 4.12, 4.13 and 4.14 displays the lean outcomes.

Table 4.12
Construct 5(A) Value Realized

Company Descriptions	Value Realized
Case #1 Integrated circuit manufacturer	Better compliance from suppliers seeking to meet customer requirements Greater level of investor confidence related to contingent liability Standardization of ESH business processes across the enterprise reducing cost and increasing business effectiveness
Case #2 Semi-conductor capital equipment manufacturer (A)	ESH supply chain requirements consolidated making it easier for suppliers to comply Higher level of ESH performance keeping workers safe and protecting the environment Customer satisfaction has increased; retention as a strategic supplier Reduced operational and managerial cost Fewer incidents at customer site contributing to higher level productivity
Case #3 Semi-conductor capital equipment manufacturer (B)	Overall operations more effective as less incidents occurred since deployment of the management system Customer satisfaction has increased; retention as a strategic supplier Reduced operational and managerial cost
Case #4 Semi-conductor device manufacturer	ESH Supply chain requirements consolidated into one location and made more clear Greater level of investor confidence related to contingent liability Higher level of ESH performance keeping workers safe and protecting the environment Customer satisfaction has increased; retention as a strategic supplier

Table 4.13
Construct 5(B) Waste Minimized

Company Descriptions	Waste Minimized
Case #1 Integrated circuit manufacturer	Redundant IT systems eliminated such as incident tracking systems
Case #2 Semi-conductor capital equipment manufacturer (A)	Less customer audits of supplier Less headcount required due to system consolidation and efficient operations Cost savings due to consolidated continued improvement projects Less policies, procedures and paperwork Integration and consolidation of audits; doing more with less
Case #3 Semi-conductor capital equipment manufacturer (B)	Fewer customer orchestrated audits of supplier Easier access to leading indicators associated with less external inquiries and required communication to retrieve information Cost savings as a result of integrating systems and activities Less internal and external ISO audits Less meetings Less, but enhanced business processes Fewer customer requests or inquiries about how ESH works as the lean integrated management system was provided to all customers
Case #4 Semi-conductor device manufacturer	Less customer audits as external confidence and understanding of the system and results is clear and transparent due to external publication Reduced overall administrative cost due to an integrated system Less ESH staff required due to efficiency gains through integration Consolidated ESH management review resulting in less meetings Consolidated business processes such as incident tracking, policy and procedures, risk assessment and regulatory tracking

Table 4.14
Construct 5(C) Risk Reduced

Company Descriptions	Risk Reduced
Case #1 Integrated circuit manufacturer	Less financial risk for investors as greater control and understanding of ESH risk factors for the firm have been deployed Better and more comprehensive root-cause analysis of incidents across the enterprise has led to less repeat incidents and a reduction in overall risk outside of just safety risk Standardization of a comprehensive risk assessment methodology and process has improved processes and allowed for a better understanding and scrutiny of organizational risk, which prevents false positives
Case #2 Semi-conductor capital equipment manufacturer (A)	Less risk for customers as there is an enhanced systems approach to managing ESH risk factors; ESH risk controls get incorporated into inspection forms at the customer site Less risk to customers as field service engineers from the equipment manufacturer perform work at the customer locations. The field service engineers have a better understanding of ESH risk factors, not just safety Consistency and standardization around personal protective equipment hazard assessments, job hazard analysis and overall business processes has reduced organizational risk. Assessing activities for ESH risk during the same assessment has reduced the number of risk assessments required and had led to better focus on the assessments completed. For this reason the risk assessments are of higher quality with a more comprehensive approach to effective risk control measures.
Case #3 Semi-conductor capital equipment manufacturer (B)	Less risk for customers as there is a proactive and systematic approach to managing ESH risk factors Less risk for investors as greater control and understanding of ESH risk factors for the firm have been deployed A consolidated ESH regulatory register provided a one-stop-shop approach for staying abreast of regulatory requirements. This made it easier for internal operations and engineering to become aware of the regulatory changes and comply thus reducing the regulatory risk of citation for the company.
Case #4 Semi-conductor device manufacturer	Less risk to the supply chain as the integrated management system requires that suppliers incorporate design for ESH into product development, which reduces the ESH life-cycle risk for suppliers, customers and end users of products The operational risk was reduced through the deployment of the IMS as it required the risk controls identified in the integrated ESH risk assessment process to be incorporated into work instructions on the manufacturing floor. This incorporation made the ESH requirements accessible at the point of operation and embedded with how work was being performed.

Facility tours provided a visual check of each company's activities and work to validate responses provided during the in-depth interviews, which included physical observation, discussions and document review. Table 4.15 displays the facility tour responses as to the understanding and need of the integrated-lean management system.

Table 4.15
Understanding and Need of Integrated-Lean Management System

Company Descriptions	Job Role	What is your understanding of the Integrated-Lean Management System?	Was it necessary to implement the Integrated-Lean Management System?
Case #1 Integrated circuit manufacturer	Fab Manager	System designed to address and confront ESH risk factors across our fabrication facilities in a way that delivers predictable results	Absolutely; there are many expectations and requirements that can confuse employees and other stakeholders. Having a single system helps us make ESH easier, reduce cost and keep people safe
Case #2 Semi-conductor capital equipment manufacturer (A)	Lab Supervisor	Program to help each department understand hazards related to our operations and the protective measures and business processes used to execute.	Yes; there are too many requirements to keep track of and safety needs to be easy for our lab technicians. Our company is subject to internal and external audits, so any opportunity we have to consolidate or streamline this work is smart business.
Case #3 Semi-conductor capital equipment manufacturer (B)	Equipment Technician	System to help us do our jobs safely and understand the many customer and company requirements in place.	Yes, the integrated system was needed to help streamline training requirements and expectations from our internal company and customers as we are commonly faced with differing customer training expectations. The integrated system helped to consolidate the training requirements and customer expectations in a way that allowed us to do our jobs safety and more efficient.
Case #4 Semi-conductor device manufacturer	Shipping and Receiving Supervisor	The system was developed with the help of each department, which allowed us to provide input into how we manage our specific hazards and risk. The system is intended to make safety part of what we do and not secondary	Yes. Prior to the integrated system we had different groups doing different things; the system was needed not only to help standardize and consolidate ESH business processes, but to help us meet customer and regulatory requirements easier.

Table 4.16 displays the facility tour responses related to job changes as a result of the integrated-lean management system.

Table 4.16
Job Routine Changes as a Result of Integrated-Lean Management System

Company Descriptions	Job Role	Has the new system changed your job routine?
Case #1 Integrated circuit manufacturer	Fab Manager	"The management system has made my job more efficient and effective as I now have a better understanding of the ESH risk factors in the fab and ESH performance indicators as opposed to just safety. During my floor walks or GEMBA walks I have a wider lens to assess ESH risk controls and behaviors."
Case #2 Semi-conductor capital equipment manufacturer (A)	Lab Supervisor	"I am more aware of lab ESH risk factors than before and more engaged in ESH as a part of my responsibility. Business processes have been reduced therefore I spend more time analyzing the data and cross-trends and correlate them with our overall lab performance."
Case #3 Semi-conductor capital equipment manufacturer (B)	Equipment Technician	"I feel more informed about environmental risk factors like spill prevention requirements. Prior to integration we were heavily weighted toward safety controls, which are the most important, but our customers require that we have training in other areas of ESH as well."
Case #4 Semi-conductor device manufacturer	Shipping and Receiving Supervisor	"My inspections and involvement in audits has been reduced. We have consolidated our management walk-throughs to incorporate safety, environment, security, quality and productivity. The management system helped us lean out inefficiencies and really help use zone in on comprehensive operational risk factors rather than just safety."

Table 4.17 reflects the responses related to positive and negative impacts of the integrated-lean management system.

Table 4.17
Positive and Negative Impacts of the Integrated-Lean Management System

Company Descriptions	Job Role	Positive Impact of Integrated Management System	Negative Impacts of Integrated Management System
Case #1 Integrated circuit manufacturer	Fab Manager	"Our operational efficiency has improved and our company now incorporates safety and ESH into new process development and decision making. This will lead to long	"Although audits are a good thing, our company is externally certified to several MS standards, so we still have more

		term sustainable results, which is exactly why we deployed the IMS."	audits than we prefer due to the external audit requirements."
Case #2 Semi-conductor capital equipment manufacturer (A)	Lab Supervisor	"We have seen many positive impacts in our labs in areas like knowledge gain or cost reduction, however there has been a significant reduction in incidents and a higher level proactive reporting and self-management of ESH issues, which I think speaks to the positive culture shift in our labs and overall company."	"We still have some groups who resist change in our new management system strategy, which should change over time as results continue to improve."
Case #3 Semi-conductor capital equipment manufacturer (B)	Equipment Technician	"From my technician perspective I would say that we feel the company is doing a better job of ensuring we are meeting customer and company requirements and we are more engaged than ever before in ESH due to more education and training in this space and how it all ties together."	None referred to as significant
Case #4 Semi-conductor device manufacturer	Shipping and Receiving Supervisor	"There has been much investment and improvement in process improvement, which I attribute to the integrated management system initiative. We are using the system outputs to drive meaningful change at the company level and department level like here in the Shipping and Receiving Department."	None referred to as significant

In each case specific document were reviewed to validate the management system activities, framework, strategies and lean outcomes. Documents reviewed in each case are represented in Table 4.18.

Table 4.18
Integrated-Lean Management System Document Review

Cases	Documents Reviewed
Case #1 Integrated circuit manufacturer	Management system manual Integrated ESH commitment policy Corporate ESH policies and procedures ESH Corrective & preventive actions register ESH organization charts
Case #2 Semi-conductor capital equipment manufacturer (A)	Management system manual Management review presentations 6-S program documents Integrated safety training matrix Integrated ESH audit system

Case #3 Semi-conductor capital equipment manufacturer (B)	External industry facing presentations Internal employee training Management reviews ESH goals and objectives and continuous improvement initiatives External ISO surveillance audits and schedules On-line policies and procedures table of contents
Case #4 Semi-conductor device manufacturer	Management system manual Corporate Social Responsibility Report ESH committee meeting minutes New hire orientation training records Work instruction in various departments

Table 4.19 presents the Delphi aligned elements that were identified to be present in each case and across cases.

Table 4.19
Delphi aligned elements present in Integrated-Lean Management System Cases

No.	Expert Aligned Integrated Elements from Delphi	Case#1	Case#2	Case#3	Case#4	% element present in all four (4) case studies
		Integrated circuit manuf.	Semi. capital equipment manuf. (A)	Semi. capital equipment manuf. (B)	Semi. device manuf.	
		Elements observed to be merged in case studies (Yes/No)				
1	Policy & Procedure	Yes	Yes	Yes	Yes	100%
2	Risk Identification /Assessment	Yes	Yes	No	Yes	75%
3	Legal and Other Requirements	Yes	Yes	Yes	No	75%
4	Objectives, Targets and Programs	Yes	Yes	Yes	Yes	100%
5	Resources, Roles, Authority and Consultation	Yes	Yes	Yes	Yes	100%
6	Competence, Training and Awareness	Yes	Yes	Yes	Yes	100%
7	Internal and External Communication	Yes	Yes	Yes	Yes	100%
8	Documentation, Control and Records Management	Yes	Yes	No	Yes	75%
9	Operational/ Hazard control	Yes	Yes	Yes	Yes	100%
10	Emergency Preparedness and Response	Yes	Yes	Yes	Yes	100%
11	Monitoring and Measurement	Yes	Yes	Yes	Yes	100%
12	Evaluation of Compliance	No	Yes	No	No	50%

13	Corrective and Preventive Action	Yes	Yes	Yes	Yes	100%
14	Internal and External Audit	Yes	Yes	Yes	Yes	100%
15	Management of Change	No	No	Yes	Yes	75%
16	Behavior and Culture	No	Yes	No	No	25%
17	Management Engagement	No	Yes	No	No	25%
18	Employee Participation	No	Yes	No	No	25%
19	Management Review	Yes	Yes	Yes	Yes	100%
% elements present in integrated-lean management system by case		72%	94%	67%	72%	-
% elements present in integrated-lean management system for all cases		78% (56/72)				

Within-case analysis

Within case analysis was conducted to provide descriptions of the relationships of interest in each case, with the end-result being a narrative supported by the data tables listed above.

Integrated Circuit Manufacturer (Case #1)

The integrated circuit manufacturer is a large firm (employment size > 18,000, revenue of $5.5 billion, multiple 200 mm and 300 mm fabrication plants in the United States, Southeast Asia and Europe with 75 environmental health and safety staff members) that produces integrated circuits in high volume mostly for semiconductor companies. The organization was founded in 2009 and grew out of acquisition. The lean-integrated management system covers five major manufacturing locations. The organization was subject to three standalone management systems with OSHA VPP, California Injury Illness and Prevention Plan, ISO 14001 and OHSAS 18001.

While operating in an exceedingly competitive environment, the leadership team realized the need to confront environmental, health and safety risk factors in a consistent and cost effective manner and in a way that supported the company's lean management strategy. As a result the

management strategy for the deployment of the integrated-lean management systems was to meet stakeholder requirements through the development of a core infrastructure that would promote integration in ESH operating procedures and norms. Operational activities and records were redesigned to align with the new integrated procedures and documentation. Best practices were identified among various organizations, improved and scaled in a way to stretch across the enterprise. The company was able to capitalize on the best practices brought forth from various organizations to create scalable singular subsystems, which leaned out waste and improved quality in overall operations. The ESH department worked jointly with each business unit to develop department/areas specific annual strategic plans. The strategic plans include objectives and targets focused on reducing and controlling risk, complying with regulations and meeting stakeholder requirements. To ensure the objectives and targets were met each department hosted semi-annual performance reviews and conducted an annual high level review with senior-level management.

In the process of developing a structure to carry out the integrated-lean management system the organization first compared the objectives between the companies lean and management system strategies to understand the linkage. From there they conducted an inventory of high hazard work activities and roles and responsibilities within the management system and developed job descriptions that fit the integrated system. From a financial perspective the management system cost is dispersed among internal operational stakeholders groups (ex. manufacturing, ESH, research and development, logistics, etc.)

The integrated circuit manufacturer invested in efforts to combine their environmental, health and safety standalone management systems. The integration of the management system led to significant value including better compliance from their supply chain who was seeking to meet

customer requirements, greater level of investor confidence in the company's ability to manage risk in the form of contingent liability and reduced cost and increased business effectiveness across the enterprise due to the standardization of ESH business processes. The elimination of redundant information systems such as the incident investigation and tracking system also allowed the organization to focus on root cause and continual improvement. This consolidation reduced the occurrence of repeat incidents as the organization witnessed much improved incident investigation and causal analysis synergies.

As the corporate management system representative summed up,

"Our company has grown through acquisition thus the need to standardize ESH practices and other organizational activities were critical to our success from an operations perspective and are paramount to waste and risk reduction. If we had not integrated our management systems our operational expense would be 3X what was actually necessary and we would not have a good indicator of predictable performance in ESH. Integrating management systems is just smart business."

The integrated lean management system received significant support from key stakeholders including customers who required a system that met multi-national standards. Integration provided employees and technicians a better comprehension of their processes and associated risks.

Semiconductor Capital Equipment and Service Supplier (Case #2)

The semiconductor capital equipment company is a leading manufacturer of wafer fabrication equipment and services to the semiconductor industry (employment size > 7,300, revenue of $6.2 billion, multiple sites in the United States, Asia, Europe, India and the Middle East, and 29 environmental health and safety staff members). The capital equipment supplier designs and builds products for semiconductor manufacturing, including equipment for thin film deposition, plasma etch, photoresist strip, and wafer cleaning processes. Repeated throughout semiconductor manufacturing, these technologies help create transistors, interconnect, advanced

memory, and packaging structures. They are also used for applications in related markets like micro-electro-mechanical systems (MEMS) and light-emitting diodes (LEDs).

The company works in a highly regulated environment. It employed separate management systems ((ISO 14001, OHSAS 18001, EMAS, California Injury Illness and Prevention Plan and the OSHA Safety and Health Award and Recognition Program (SHARP) for the effective management of environment, safety and health. The need for the integration of their management systems was realized in favor of one holistic and over-ruling management system for ESH as operational leaders learned over time that stakeholders are of immense importance to establishing and maintaining their management systems in a way that yields meaningful, predictable and repeatable results. In addition, due to the merger with a similar capital equipment company, operational leaders were pressured to:

- Reduce operational cost across the enterprise (including ESH management)
- Improve ESH performance and compliance
- Utilize resources efficiently
- Reduce complexity of business processes through standardization (including ESH processes)
- Align with company's focus on lean principles

As the Corporate ESH Director shared:

"The semiconductor industry in California is a highly sensitive and regulated sector that utilizes complex hazardous chemical and processes that must be controlled. Deviations from our management system principles can result in unnecessary risk, which can be detrimental to our operations and industry. Integrating our management systems aligns well with our need to control the risk, reduce cost and meet industry and investor expectations to operate safe and responsible facilities."

To transform the standalone systems into an executable integrated-lean management system, management started a stakeholder dialogue process to decide on the business imperatives, risk and stakeholder needs and set the direction.

This helped management formulate the organizational policy, objectives, and strategy as per identified stakeholder requirements. The strategy then was translated into an organizational management system meant to promote joint care of environment, health and safety in an integrated manner. The administrative imperatives (such as management reviews, organizational systems and responsibilities, and training and auditing), documentation, and operations were then redesigned and carried out in an integrated manner. The individual environmental, and health and safety management manuals were integrated into a single ESH Management System manual. The manual then resulted in generation of integrated procedures, processes, work instructions, and records. The support activities such as training and audits were also integrated.

Integration resulted in significant value including consolidation of ESH supply chain requirements, customer satisfaction, reduced operational cost and a higher level of ESH performance as measured by incident rates, compliance assurance and employee involvement.

Organizational waste was minimized as well as the integrated-lean system yielded less customer audits due to greater transparency resulting in higher customer confidence, less headcount required to manage the consolidated system, less policies and procedures and fewer internal audits as audit protocols were simply merged. In addition continuous improvement projects were launched further contributing to waste minimization.

Risk reduction for internal and external stakeholders was also a key result. In this case risk was reduced for customers as field technicians servicing equipment at customer locations were

now inspecting ESH risk factors and controls as opposed to just safety. In addition, the customer now has one of their key suppliers (Case #2) using a systematic approach to managing ESH, which led to a greater focus on prevention initiatives and overall system health, which could be measured. Standardization of ESH business processes such as job hazard analysis, risk assessments and work instructions made ESH easier for the users thus reducing risk of confusion related to multiple processes.

Transition from standalone management systems to an integrated-lean approach also introduced a number of behavioral changes, which occurred in terms of greater buy in of the new singular system and was reflected in enhanced employee motivation and reduced labor hours. The integration also improved coordination and integration with external stakeholders (such as suppliers, customers, and regulators). Support and understanding between organizational activities across different departments and across organizational levels was observed.

Semiconductor Capital Equipment and Service Supplier (Case #3)

The semiconductor capital equipment company is a leading supplier of equipment, services and software to enable the manufacture of semiconductor chips for electronics, flat panel displays for computers, smartphones and televisions, and solar products (employment size > 14,600, revenue of $9.6 billion, multiple sites in the North America, Asia, India, Europe, Middle East, 80 environmental health and safety staff members).

The capital equipment and service supplier produces a variety of equipment, services and software products for both local and international high technology customers. This company competes with a number of local and international competitors and endeavors to employ state-of-the-art operations. Becoming certified in quality, environment, and occupational health and

safety was an important initiative to achieving operational excellence as this company is subject to CA-IIPP, ISO 14001, OHSAS 18001, OSHA VPP and Bizsafe standalone systems. Over time management realized that the advantages of certification were being eroded as more and more competitors obtained certification. The need to integrate the standalone systems arose as a result of business leaders striving for operational efficiencies, reduction in non-value added activities and required waste and resource consolidation.

The integration process started with the formation of a cross-functional team consisting of members from the operations, ESH, quality, and maintenance departments. The main objective was to merge the existing management systems through bolting together the common elements of the individual systems employed. The stated objective of the integration was operational improvements that support lean outcomes such as reduction of waste, reduced risk and greater performance.

As the Vice President of Operations commented:

"ESH risk control measures and processes are integrated into every aspect of our operations and we consider this critical in achieving our ESH and/lean management objectives."

The integration effort began with the company's management system manual, which was redesigned and served as a blue-print for how the system should work. This followed with the integration of operating procedures, work tasks and work instructions where it made sense. Operational activities and records management were modified to align with the new integrated procedures and documentation. Supporting activities such as auditing were integrated, which lead to efficiency and effectiveness gains. The integrated-lean management system costs are managed by the Facilities and Real-estate group, however costs is shared among the operations and product group who make up the primary internal stakeholder groups.

Significant value was realized as the company gleaned a higher degree of operational effectiveness and optimization resulting in lower cost. Since deployment of the system and maturation the organization has incurred less incidents and customer driven supplier scorecards have improved. Required waste has been reduced as there are fewer customer orchestrated audits as customer trust has increased. Fewer external inquiries as the integrated management system leading indicators and system description were made more transparent in the company's corporate social responsibility report and provided to target customers. Fewer audits have resulted due to management system consolidation and business process enhancement.

Semiconductor Product Manufacturer (Case #4)

The semiconductor product manufacturer is a leading designer, manufacturer and marketer of semiconductor products including power semiconductors, microcontrollers, security controllers, radio frequency products, and sensors (employment size > 36,300, revenue of $7.6 billion, multiple sites in North America, Asia, Australia, Europe, India and the Middle East, and 12 environmental health and safety staff members). This company is subject to CA-IIPP, ISO 14001, OHSAS 18001 and OSHA VPP standalone systems.

The need to subscribe to various management system standards is a result of supply chain pressures. The desire for integration arose from operational leadership's request for better collaboration between ESH and other operations functions and the need to align with the company's lean management philosophy. They also felt that a singular system would help drive cross-site problem solving and solutions as opposed to site specific remedies. In addition, ESH required a better method to meet the various stakeholder concerns and requirements around safety, risk management and environmental issues in a cost effective manner. In addition, the

global risk manager was driving an initiative to gain a better handle on enterprise risk and was seeking a methodology to inventory and assess critical operational control strategies across enterprise for effective risk mitigation.

As the Sr. Director, Operations explained:

"Supply chain pressures mainly through external management system certification requirements originally forced our organization to adopt management systems. Overtime we got smarter with deployment and implementation and began to integrate our management system. This decision created a culture of achieving high results in the most cost effective manner."

Cross-functional teams with representation from each business unit were established. This resulted in five cross-functional teams consisting of five different business units. Each team conducted two types of inventories (1) an inventory of routine operational risks affecting workers safety and health and the environment by area of assignment and (2) an inventory of environmental, safety and health regulations or standards relevant to their assigned operations. This information helped inform the common management system manual that explained risk factors, business processes and strategy. Goals and objectives were set around the risk factors yielding the highest risk as identified in the ESH aspects and impacts assessment. Financing the management system activities occurred through a general support function cost center. Capital expense projects related to the system were paid for by the specific organization or department who played a role within the system.

The integrated-lean management system provided value by consolidating the ESH supply chain requirements into one location, which made them easier to locate and comply with. Investor confidence grew as the management system provided for better control over contingent liability. The firm experienced a higher level of ESH performance and higher scores on customer ESH scorecards.

Waste was minimized during integration as less customer audits occur as external confidence and understanding of the system and results is clear and transparent due to external publication of the management system. Consolidated business processes such as incident tracking, policy and procedures, risk assessment and regulatory tracking created internal efficiencies. Overall administrative costs are less due to the consolidation of business processes and activities. As a result of the efficiency gains some ESH staff were re-purposed to work on operation excellence initiatives. In addition fewer meetings occur due to combination of activities such as ESH management reviews and audits.

Risk reduction was also a beneficial by-product of integration. Risk from the supply chain was reduced as the integrated management system requires that suppliers incorporate design for ESH into product development, which reduces the ESH life-cycle risk for suppliers, customers and end users of products. Operational risk was reduced through the deployment of the integrated-lean management system as it required the risk controls identified in the integrated ESH risk assessment process to be incorporated into work instructions on the manufacturing floor. This incorporation made the ESH requirements accessible at the point of operation and embedded with how work was being performed thus reducing risk.

Cross-case analysis

Cross-case analysis was performed to arrange the four cases to assess potential patterns and relationships. Several groupings were tried; the cases were organized by the 5 constructs deployed including company descriptions, contextual factors, motivations, strategies and lean outcomes.

The case companies had 2016 revenues ranging between five and ten billion, between nine-thousand to forty-thousand employees with an ESH staff between twelve and seventy-five per organization. All cases are considered manufactures in the semiconductor industry with operations based in California. Some facilities who manufactured semiconductors or had many more employees adopted the same practices as semiconductor equipment manufactures with fewer employees.

During the in-depth interviews it was identified that all four cases were subject to multiple management system standards, which created a level of complexity in regards to how environmental, health and safety was managed enterprise wide. In all cases each organization deployed an integrated-lean management system that covered multiple sites and standards. More specifically, each site was required by their supply chain and/or legal requirements to meet California Injury Illness and Prevention Plan, ISO 14001 and OHSAS 18001 requirements for ESH and submitted annual Self-Assessment Questionnaires to the Electronic Industry Citizenship Coalition (EICC), which drove transparency throughout the semiconductor supply chain relative to ESH and other performance measures. In addition, the integrated circuit manufacturer (case #1) and both semiconductor capital equipment companies (cases #2 and 3) subscribed to OSHA regulatory partnership programs such as the Safety Health Awards & Recognition Program (SHARP) and the OSHA Voluntary Protection Program (VPP).

Due to multiple requirements management system representatives at each company were motivated to manage these systems under one management system. External stakeholder groups for all semiconductor firms involved in the study related to the integrated-lean management system included stockholders, suppliers, customers and industry associations. Internal stakeholders included workers, operations, supply chain management, ESH department, Quality

department, Investor relations, and Human Resources department. All internal stakeholders indicated that integrating their management systems would improve their efficiency and effectiveness and reduce overall costs.

There were some unique drivers with each case pertaining to the motivating factors associated with the implementation of an integrated-lean management system, but more similarities than differences. Essential findings related to motivating factors for integration include pressure to be in line with the company's lean management initiatives dominated the drive towards integration along with market pressures from customers who demanded certification to multiple management system standards. Each company was pressured to develop, implement and continually improve their respective management system in a manner that reduces cost and increases performance and maintains compliance with existing and emerging regulations. Each company experienced pressure from internal stakeholders and from their supply chain and customers to integrate their management systems. Lastly each company was motivated by management to reduce complexity of managing multiple standalone management systems.

Essential findings related to the management, structural and financial strategies among each case were also analyzed. Approaches to management strategy included the identification of best practices within different departments or at different sites and scaled as appropriate. Each company developed a management system operations manual describing key elements and implementation practices, which served useful to anyone (including internal and external stakeholders) interested in understanding how the system works. Development of strategic plans that incorporate stakeholder requirements and governed by frequent management reviews was a common theme. In addition, each company deployed goals and objectives for purposes of

continual improvement and executed against a routine audit protocol to ensure critical controls and elements of the management system remain in good operational health. All cases subscribed to a multi-stakeholder approach and process consistency was universally agreed to reduce risk as the thought was that involvement from the right groups at the right levels would result in greater level of knowledge and understanding of the system, which entail would result in enhanced results as affected stakeholders had input into the issues and ultimate architecture of the integrated system.

Strategies to structure the integrated-lean management system assured that departments and units took ownership and verified that the management system was linked to the organization's lean strategy. Chief responsibility for the system was primarily delegated to the management system representative and in each case the representative reported to the environmental, safety and health leader. In all cases an inventory of work activities based on risk and management system needs drove the development of key roles and position descriptions. Objectives and targets were established for the management system along with continuous improvement plans and cascaded throughout the organization.

With exception the semiconductor device manufacturer (Case #4) the financial strategies deployed across the cases was very similar in nature. The device manufacturing company funded the management system resources through a general support group cost center and not dispersed or allocated among internal operational stakeholders or users of the management system. Support groups include those internal functions not involved directly with manufacturing (ex. ESH, HR, Quality, Finance). The other three cases had a centralized finance strategy for the management system meaning the managerial activities were managed by one

group, however that group would distribute or share the cost among internal operational stakeholder groups (ex. engineering, manufacturing, logistics).

Lean outcomes for purposes of this study were defined as value realized, waste minimized and risk reduced. Value extracted as part of this study across each case extended to both internal and external stakeholders. Investors received a greater level of confidence due to presence of a measureable system to address ESH risk. Clarity of ESH requirements was brought to supply chain members required to conform to customer requirements. All cases experienced reduced operations and managerial cost due to efficiency gains through consolidated procedures and business processes. Customers satisfaction increased due to presence of integrated-lean ESH management system as it enables higher level of compliance and transparency. ESH performance improvements (leading and lagging) as well as confidence in future state compliance was also coined as a value and output of the integration efforts.

Waste minimization was also a lean outcome and occurred across all companies mainly related to the elimination of duplicate systems, resources, business processes and procedures. Fewer, but more comprehensive audits resulting in efficiency and effectiveness gains occurred. Less customer and investor inquiries and audits due to the presence of a transparent system, which helped address many routine customer questions. And overall fewer meetings including management reviews due to the consolidation of multiple systems were all forms of waste minimized.

The last lean outcome related to reduced risk as the consolidation of environmental, safety and health business processes and systems including training universally made it easier for workers to understand risk factors and controls. Integrated environmental safety and health risk assessment processes provided for a more effective risk assessments by ensuring environmental

and health risk is considered in addition to safety. A more comprehensive approach to the deployment of operational risk controls leading to more effective control strategy made risk control easier to understand and measure in most all cases.

Facility tours were conducted at each of the four case study locations in California. The intention of the facility tours was to validate responses provided during the in-depth interviews, which included physical observation, discussions and document review. Throughout the tours engagement with line management occurred with individuals ranging from fab managers, lab supervisors, equipment technicians and shipping and receiving supervisors. In addition, some company leaders provided additional perspective on the value of the integrated-lean management system. Line management was able to articulate their strategic understanding of the integrated-lean management system specifically its intent to protect the workers and the environment, increase knowledge around ESH risk factors and controls and make managing ESH easier. During the tours individuals were asked about the usefulness of the integrated management system. There was unanimous alignment with the need to integrate mainly due the multitude and complexity of the various standards and requirements leading to confusion and the need to standardize and eliminate organizational waste due to differing programs and systems.

Additional questions were asked related to how to the integrated-lean management system changed job routines. The integrated management system changed job routines in positive ways. For example, a fab manager mentioned that the management system helped make his job more efficient and effective as a result of obtaining greater knowledge of the ESH risk factors and ESH performance indicators as opposed to just safety. The fab manager indicated that technicians have a much wider lens when walking the fab environment to assess ESH risk controls and behaviors. A lab supervisor in case study #2 (semiconductor capital equipment

manufacturer A) was able to spend more time analyzing data and cross-trends due to consolidated business processes and correlate them with overall lab performance in areas like quality and productivity.

Positive impacts in all cases were recorded in areas such as operational efficiency, knowledge gain, incident reduction, cost reduction, higher employee and management engagement and process improvements due to the push for continuous improvement and leading indicators around management system elements. The only negative impacts recorded pertain to the external audit criteria that come with maintaining multiple external certifications.

Document reviews provided a key mechanism in data collection. During each site tour the researcher was able to review documents that helped describe and explain the integrated-lean management system and related outcomes. The documents provided supportive information to the in-depth interview response and subsequent validation.

Throughout the facility tours and review of documentation it was verified that many of the integrated management system key elements identified by the Delphi panel members were in place by the front-runner semiconductor companies. In all four cases it was found that 78% of the Delphi panel aligned elements were present and although it was clear that all cases had emphasis on behavior and culture, management engagement and employee participation only one of the cases (Case #2 semiconductor equipment manufacturer A) had those elements specifically listed in their integrated-lean management system manual.

Table 4.20 provides a high level overview of cross-case themes resulting from information provided by each of the four cases involved in the research study.

Table 4.20
Cross-Case Themes

Cross-Case Analysis	Contextual Factors	Motivations	Management Strategy	Structural Strategy	Finance Strategy	Value Realized	Waste Minimization	Risk Reduction
All Cases	Multiple site coverage Supply chain requirements for multiple standards No significant regulatory violations (External Stakeholders) Stockholders, Suppliers, Customers, Industry Associations (Internal Stakeholders) Workers, Operations, Supply Chain Mgmt. ESH, Quality, Investor Relations, HR	Pressure to be in line with the company's lean management initiatives Market pressures Develop, implement & improve Reduces cost increases performance Improve compliance Reduce complexity	Identification /scale of best practices Mgmt. system manual Strategic plan Management review, Stakeholder requirements Audit protocol, Goals and Objectives Multi-stakeholder approach Process consistency	Department and area ownership Linked to organization's lean strategy. Chief responsibility lies with management system representative Mgmt. rep reports to ESH leader Risk and management system needs drove key roles and position descriptions	Centralize funding under management system representative's organizational cost center Funding allocated per management systems annual strategic plan and level of internal operational stakeholder involvement	Greater investor confidence Clarity of ESH requirements for supply chain members Reduced operations and managerial cost Consolidated procedures and business processes Increased customer satisfaction ESH performance improvements Compliance confidence	Fewer, but more comprehensive audits Elimination of duplicate systems, resources, business processes and procedures Less customer inquiries and audits Fewer meetings including management reviews	Consolidation of ESH business processes and systems including training has made it easier for workers to understand risk factors and controls Integrated ESH risk assessment process enables more effective risk assessment More comprehensive operational risk controls leading to more effective control strategy

CHAPTER 5

CONCLUSION AND DISCUSSION

This chapter presents the conclusions of the study and recommendations for further research. While there are many studies on management systems, this study responded to the calls for integrated-lean management system framework that would support the lean enterprise movement in today's high-performance driven organizations.

It can be concluded that standalone management systems that operate separately and require single management can be combined into an integrated-lean management system and it was bore out in the Delphi study. The literature review suggested and it was supported by the Delphi panel members that there are areas of overlap in the standalone management system elements and practices that justify their integration into a single management system. Moreover, the Delphi panel members when examining the elements, definitions and implementation practices that were combined suggested that there were no issues and that the final framework provided sufficient detail on what an integrated-lean management system would look like and be implemented. Second, it can be concluded that the outcomes of lean such as value added, reduced waste and risk were supported by specific management, structural and financial strategies adopted by the sampled companies and this was bore out in the case studies. Thus, this research adds important knowledge about the strategies available and being used by companies to the literature on the lean-integration of management systems. The three strategies support the overall intent of management systems for continuous improvement. These conclusions provided a valid and accurate description of what an integrated-lean management system framework looks like and how the strategies unfold and contribute to lean outcomes in the sampled companies.

The research structure used several types of constructs and sources of data and the data analysis procedures helped to alleviate researcher bias which gave reliability and credibility to the results. And the research structure provides other researchers the ability to replicate the study under similar conditions and to be able to achieve similar results. The findings are expected to be generalizable to other semiconductor facilities as well as other high performance driven companies that are interested in the integration of their standalone management systems so long as these companies have similar motives and pressures experienced by the companies in this study. Examples of motives and pressures experienced by companies in this study included: motivations to protect workers and the environment and to control life cycle exposures to hazards from existing and newly developed products and production processes; pressure from external stakeholders to maintain compliance with regulations and conformance to industry standards, internal stakeholder pressure to connect management systems to lean company initiatives, and market pressure that shows customers and the supply chain that the company is committed to environmental and safety and health performance. And the sources of data used in the study were used in past exploratory and case studies conducted by other researchers.

While this research was exploratory and inductive in nature and used qualitative methods, it has some limitations, specifically the responses from Delphi and case study respondents. Although the Delphi technique is a widely used and accepted method for obtaining judgments about real-life management system issues from experts in the field of study their responses can be somewhat restricting due to their theoretical beliefs concerning management systems, their current role within the organizations they serve, and their recent management system research and applied work experiences. Moreover, the case studies while being useful in bringing the integrated-lean framework into a sharper focus and in examining strategies that support lean

outcomes the responses from operations managers, environment, safety and health managers and the management system representatives may have been somewhat influenced by the degree of pressure placed on these individuals from internal and external stakeholders as well as the market. Conducting this research at the same point in time and in a limited geographic area may also be limiting factor. Although the use of a single US State provided important controls for the study such as avoiding issues created by different environment, safety and health regulations and or enforcement routines from other states. It also limited the sample and the generalizability of the findings. Future research needs to be explored with a larger sample that includes a variety of settings and in geographical places other than California. The study design was strong enough and can suggest that the findings reflect what experts on management systems suppose and how the strategies unfold and contributing to lean outcomes in the companies sampled. The constructs measured displayed good psychometric properties and the analysis and interpretation procedures should be considered accurate and dependable. The results provide strong evidence that in this sample at this specific period of time it was possible to integrate management systems and see how the management, structural and financial strategies unfold in the companies studied and how they support lean outcomes. The study was limited to the strategies and in making statements about how they support lean outcomes not in making statements about causation. Future research that captures a wider array of strategies, especially other strategies associated with how companies operate (e.g., technical requirements, information management, performance evaluation and research and development) will be needed. Such research will need to be conducted across time to be able to clearly show the causal chain that connects strategies to lean outcomes.

In summary, this study responded to calls for developing an integrated-lean management system framework that supports lean outcome and a first study examining the strategies adopted by companies that support the outcomes. While the research was rigorous and the results clear, there is a great deal of future research needed. For example, future research would need to incorporate corporate social responsibility, corporate sustainability, risk management, and business continuity into the integrated-lean framework when management system standards are developed for these concerns. In addition, as concerns for continuous business performance increases in organizations, organizations will be required to make transparent the costs linked to integrated-lean management systems. Future research into the cost of owning standalone and integrated management systems would go a long way in making the overall business case for management systems to internal stakeholders.

BIBLIOGRAPHY

Abad, J., Dalmau, I., & Vilajosana, J. (2014). Taxonomic proposal for integration levels of management systems based on empirical evidence and derived corporate benefits. *Journal of Cleaner Production*, 78, 164–173.

Adler, M., and Ziglio, E. (1996). Gazing into the Oracle: The Delphi Method and its Application to Social Policy and Public Health. London*:* Jessica Kingsley Publishers

Ahire, S. (1996). TQM age versus quality: an empirical investigation. *Production and Inventory Management Journal* (37.1):18.

Armstrong, J.S.(1970). How to avoid exploratory research. J. *Advertising Research*, (10), 27-30.

Arora, Seema, and Cason (1996). Why do firms volunteer to exceed environmental regulations? Understanding participation in EPA's 33/50 program. *Land economics*: 413-432.

Asif, M., Fisscher, O. A. M., Bruijn, E. J., & Pagell, M. (2010). An examination of strategies employed for the integration of management systems. *The TQM Journal*, *22*(6), 648-669.

Asif, M., Fisscher, O., Bruijn, E., & Pagell, M. (2010). Integration of management systems: A methodology for operational excellence and strategic flexibility. *Operations Management Research*, 3, 146–160

Atieno, O. P. (2009). An analysis of the strengths and limitation of qualitative and quantitative research paradigms. *Problems of Education in the 21st Century*, 13, 13-18.

Azadeh, A., Mohammad Fam, I., & Nouri, M. A. (2008). Integrated health, safety, environment and ergonomics management system (HSE-MS): an efficient substitution for conventional HSE-MS. *Journal of Scientific and Industrial Research*, 67, 403-411.

Baxter P., Jack S. (2008). Qualitative case study methodology: study design and implementation for novice researchers. *Qualitative Report*, 13(4):544–559.

Bergeron, P. (1997). The ISO 14000 series of environmental management standards. In: OECD Proceedings – Cleaner Production and Waste Minimization in OECD and Dynamic Non-Member Economies. *OECD, Washington*, pp. 253–261.

Bernardo, M., Casadesus, M., Karapetrovic, S. and Heras, I. (2009). How integrated are environmental, quality and other standardized management systems? An empirical study. *Journal of Cleaner Production*, 17, pp. 742–750.

Boiral, Olivier, and Marie-Josée Roy (2007) . ISO 9000: integration rationales and organizational impacts. *International Journal of Operations & Production Management* 27.2 : 226-247.

Bottani, E., Monica, L., & Vignali, G. (2009). Safety management systems: Performance differences between adopters and non-adopters. *Safety Science*, *47*(2), 155-162.

Bowen, J. The ethics of safety-critical systems. *Communications of the ACM* 43.4 (2000): 91-97.

Brooks, K. W. (1979). Delphi technique: Expanding applications. *North Central Association Quarterly, 54* (3), 377-385.

Brorson, T., Larsson, G., (2009). Environmental Management: How to Implement an Environmental Management System Within a Company or Other Organization, third ed. EMS AB, Stockholm, Sweden.

Camp, W.G., (2001). Formulating and evaluating theoretical frameworks for career and technical education. *Journal of Vocational Education Research*, 26(1).

Clements, Richard Barrett (1996). Complete guide to ISO 14000. Saddle River, New Jersey: Prentice Hall Direct.

Corbett, C.J., and Kirsch, D. (2001). International diffusion of ISO 14000 certification. *Production and Operations Management* 10.3: 327-342.

Crabtree BF, Miller WL (1999). Doing qualitative research, 2nd edition. California: Sage

Custer, R. L., Scarcella, J. A., & Stewart, B. R. (1999). The modified Delphi technique: A rotational modification. *Journal of Vocational and Technical Education, 15* (2), 1-10.

Cyphert, F.R., & Gant, W.L. (1970). The Delphi Technique: A tool for collecting opinions in teacher education. *Exploring the potential of the Delphi Technique by analyzing its application.* Symposium conducted by AERA in Minneapolis, Minnesota, USA.

Dalkey, N.C., and Helmer, O. (1963). An experimental application of the Delphi method to the use of experts. *Management Science Vol. 9*, 458-467.

Dalkey, N. C. (1969). An experimental study of group opinion. *Futures, 1* (5), 408-426.

Darnall, N., Henriques, I., & Sadorsky, P. (2008). Do environmental management systems improve business performance in international settings? *Journal of International Management*, 14, 364-376.

Delbecq, A., Van de Ven, A., and Gustafson, D. (1975). Group techniques for program planning: A guide to nominal group and Delphi processes. Glenview, Illinois: Scott Foresman Company

de Oliveira, O.J., (2013). Guidelines for the integration of certifiable management systems in industrial companies. *Journal of Cleaner Production* 57, 124–133.

Eisenhardt, K., (1989). Building theories from case study research. *Academy of management review* 14.4, 532-550.

Fan, .i, and KY Lo, C., (2012). A tough pill to swallow: The impact of voluntary occupational health and safety management system on firms' financial performance in fashion and textiles industries. *Journal of Fashion Marketing and Management* 16.2: 128-140.

Fernandez-Muniz, B., Montes-Peon, J. M., & Vazquez-Ordas, C. J. (2012). Safety climate in OHSAS 18001-certified organizations: Antecedents and consequences of safety behavior. *Accident Analysis and Prevention*, 45, 745-758.

Fink A, Kosecoff J, Chassin M, Brook RH (1984). Consensus methods: characteristics and guidelines for use. *American Journal of Public Health* 74:979-983

Fresner, J., (1998). Cleaner production as a means for effective environmental management. *Journal of cleaner production* 6.3: 171-179.

Gallagher, D. R., Darnall, N., and Andrews, R. (1999). International Standards for Environmental Management Systems: A Future Promise for Environmental Policy? Twenty-First Annual Research Conference for the Association for Public Policy Analysis and Management Fall Conference: "Public Policy Analysis and Management: Global and Comparative Perspectives" The Washington Monarch Hotel, Washington, DC.

Glaser, B., & Strauss, A. (1967). The discovery grounded theory: strategies for qualitative inquiry. Chicago, Illinois: Aldin

Haight, J. M., Yorio, P., Rost, K. A., & Willmer, D. R. (2014). Safety management systems: Comparing content & impact. *Professional Safety*, 59(05), 44-51.

Harris J. and Roberts, K. (2003). Challenging Barriers to Participation in Qualitative Research: Involving Disabled Refugees. *International Journal of Qualitative Methods, 2* (2), 1-17.

Hasson, F., Keeney, S., & McKenna, H. (2000). Research guidelines for the Delphi survey technique. *Journal of Advanced Nursing, 32* (4), 1008-1015.

Hill, B (1999). A conceptual framework for understanding information seeking in open-ended information systems, *Educational Technology Research & Development*, 47, 1, 5–27.

Holdsworth, R. (2003). Practical applications approach to design, development and implementation of an integrated management system. *Journal of Hazardous Materials*, 104, 193-205.

Honkasalo, A. (2000). Occupational health and safety and environmental management systems. *Environmental Science & Policy, 3*(1), 39-45.

Hsu C and Sandford BA (2007). The Delphi Technique: making sense of consensus. *Practical Assessment, Research & Evaluation 12*: 10.

Jackson, S.L. (1997) The ISO 14001 Implementation Guide: Creating an Integrated Management System. New York, NY: Wiley & Sons

Jespersen, A.H., P. Hohnen, and P. Hasle (2016). Internal audits of psychosocial risks at workplaces with certified OHS management systems. *Safety Science, 4*: 201-209. DOI: 10.1016/j.ssci.2015.12.013

Jiang, Ruihua Joy, and Pratima Bansal (2003). Seeing the need for ISO 14001. *Journal of Management Studies* 40.4: 1047-1067.

Jørgensen T, Remmen A, Mellado M. (2006). Integrated management systems – three different levels of integration. *Journal of Cleaner Production* 14(8): 713–22.

Kaplan, L. M. (1971). The use of the Delphi method in organizational communication: A case study. Unpublished master's thesis, The Ohio State University, Columbus.

Karapetrovic, S., & Casadesús, M. (2009). Implementing environmental with other standardized management systems: scope, sequence, time and integration. *Journal of Cleaner Production*, *17*(5), 533-540.

Karapetrovic, Stanislav, and Jan-Jonker (2003). Integration of standardized management systems: searching for a recipe and ingredients. *Total Quality Management and Business Excellence* 14.4 (2003): 451-459.

Koehn, E., Asce, F., & Datta, N. K. (2003). Quality, environmental, and health and safety management systems for construction engineering. *Journal of Construction Engineering and Management*, 129(5), 562-569.

Labodová, A., (2004). Implementing integrated management systems using a risk analysis based approach. *Journal of Cleaner Production* 12, 571-580.

Lindman, B.A. (1994). Consensus of educational administrators on admission requirements, professional instruction, internship features, and evaluation of candidate competency for alternative routes into teaching licensure: A Delphi survey. Doctoral dissertation, University of Minnesota, Twin Cities.

Linstone, H., and Turoff, M. (1975). The Delphi Method: Techniques and Applications. Reading, MA: Addison-Wesley

Longoni, A., M. Pagell, D. Johnston, and A. Veltri (2013). When Does Lean Hurt? *International Journal of Production Research 51* (11): 3300–3320.

Ludwig, B. G. (1994). Internationalizing Extension: An exploration of the characteristics evident in a state university Extension system that achieves internationalization. Unpublished doctoral dissertation, Ohio State University, Columbus.

Marcus, P. (1996). Using EH&S Management Systems to Improve Corporate Profits. *Environmental Quality Management*, (11-21)

Melnyk, S. A., Sroufe, R. P., & Calantone, R. (2003). Assessing the impact of environmental management systems on corporate and environmental performance. *Journal of Operations Management*, 21(3), 329-351.

Miles, M., and Huberman, M. (1994). Qualitative data analysis: An expanded sourcebook, Thousand Oaks, California: Sage

Mintzberg, H., and Van de Heyden, L. (1999). Organigraphs: Drawing how companies really work. *Harvard Business Review*, 77, 87-95.

Murphy M.K., Black N., Lamping D.L., McKee C.M., Sanderson C.F.B., Askham J. (1998) Consensus development methods and their use in clinical guideline development. Health Technology Assessment 2(3).

Myers, P. M. D. (2008). Qualitative Research in Business & Management, Thousand Oaks, CA :Sage

Oh, K. H. (1974). Forecasting through hierarchical Delphi. Unpublished doctoral dissertation, Ohio State University, Columbus.

Pagell, M. (2004). Understanding the factors that enable and inhibit the integration of operations, purchasing and logistics. *Journal of operations management* 22.5: 459-487.

Pheng, L., and Pong, C. (2003). Integrating ISO 9001 and OHSAS 18001 for construction. *Journal of construction engineering and management*, 129(3), 338-347.

Pill, J. (1971). The Delphi Method: Substance, Context, a Critique and Annotated Bibliography. *Socio-Economic Planning Science*, *Vol. 5*, pp 55-71

Powell, C. (2003). The Delphi technique: myths and realities. *Journal of Advanced Nursing*, *41*(4), 376-382.

Ramasesh, R.V., Browning, T.R., (2014). A conceptual framework for tackling knowable unknown unknowns in project management. *Journal of Operations Management 32* (4), 190–204.

Rancour, T. P. (2005). SH&E management systems & business integration: The Malcolm Baldrige performance excellence framework. *Professional Safety*, *50* (10), 25-30.

Robson, L. S., Clarke, J. A., Cullen, K., Bielecky, A., Severin, C., Bigelow, P. L., Irvin, E., Culyer, A., Mahood, Q. (2007). The effectiveness of occupational health and safety management system interventions: A systematic review. *Safety Science*, *45*(3), 329-353.

Romero, J. (2012). Third Party Certification in ISO14001 & OHSAS18001. Do these Certifications Really Add Value? An Ecuadorian Experience." International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production. Society of Petroleum Engineers.

Rondinelli, D., & Vastag, G. (2000). Panacea, common sense, or just a label?: The value of ISO 14001 environmental management systems. *European Management Journal 18*(5), 499-510.

Salomone R. (2008). Integrated management systems: experiences in Italian organizations. *Journal of Cleaner Production* 16(16):1786–806.

Santos, G., Barros, S., Mendes, F., & Lopes, N. (2013). The main benefits associated with health and safety management systems certification in Portuguese small and medium enterprises post quality management system certification. *Safety Science 51*(1), 29-36.

Sroufe, R. (2003). Effect of environmental management systems on environmental management practices and operations. *Production and Operations Management 12* (3), 416-431.

Stebbins, R. A. (2001). Exploratory research in the social sciences. Thousand Oaks, CA: Sage.

Strauss, Anselm, and Corbin (1990). Basics of Qualitative Research: Grounded Theory Procedures and Techniques. Newbury Park, CA: Sage.

Teddlie, C., and Tashakkori, A. (2009). Foundations of Mixed Methods Research, Thousand Oaks, CA: Sage Publications.

Thomas DR. (2006). A general inductive approach for analyzing qualitative evaluation data. *American Journal of Evaluation* 27:237–246.

van Zolingen, S. J., and C.A. Klassen (2003). Selection processes in a Delphi . PRFO Proceedings study about key qualifications in Senior Secondary Vocational Education. Technological Forecasting and Social Change 70(4): 317-340.

Veltri, M. Pagell, D. Johnston, E. Tompa, L. Robson, B. C. Amick III, and S. Macdonald (2013). Understanding safety in the context of business operations: An exploratory study using case studies. *Safety Science vol. 55*, pp. 119–134.

Voss, C., Tsikriktsis, N. and Frohlich, M. (2002), "Case research in operations management", *International Journal of Operations & Production Management, Vol. 22* No. 2, pp. 195-291.

Wilkinson, G., & Dale, B. G. (1999). Integrated management systems: An examination of the concept and theory. *The TQM Magazine*, 11(2), 95-104.

Womack, J. P. and D. T Jones (1996), Lean Thinking: Banish Waste and Create Wealth in Your Corporation, N. York: Simon & Schuster

Wu, Zhaohui, and Mark Pagell (2011). Balancing priorities: Decision-making in sustainable supply chain management. *Journal of Operations Management 29.6*: 577-590.

Yin, Robert (1994) Case study research: Design and Methods. Beverly Hills, California: Sage

Yin R K (2009). Case Study Research: Design and Methods, Essential guide to qualitative methods in organizational research, 5th Ed., Thousand Oaks, California: Sage Publications

Young, S. J., & Jamieson, L. M. (2001). Delivery methodology of the Delphi: A comparison of two approaches. *Journal of Park and Recreation Administration, 19* (1), 42-58.

Zeng, S. X., Shi, J. J., & Lou, G. X. (2007). A synergetic model for implementing an integrated management system: An empirical study in China. *Journal of Cleaner Production, 15*(18), 1760-1767.