Human Factors in Design, Engineering, and Computing

HUMAN FACTORS IN ENGINEERING

Manufacturing Systems, Automation, and Interactions

Edited by
Beata Mrugalska
Tareq Ahram
Waldemar Karwowski

CRC Press
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This book addresses aspects of human factors in engineering and provides a detailed discussion of novel approaches, systems engineering tools, artificial cognitive systems, and intelligent technologies and automation. It presents applications in diverse areas, including digital manufacturing, transportation, infrastructure development, and cybersecurity.

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Human Factors in Design, Engineering, and Computing

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Contents

Preface

Competing in the global market is essential to business competitiveness in today's manufacturing industry. Manufacturers need to focus on innovations in product development, quality improvement, optimizing production schedules, reducing delivery time, and offering competitive value for consumers. It can be achieved by optimizing all elements of manufacturing processes, such as production methods, equipment, procedures, control, and information systems. Advanced information technologies that transfer human skills and manual activities to automated systems influence these processes and procedures. However, human operators are still important in manufacturing systems and should not be undermined or neglected.

Manufacturing companies must effectively manage the variety of complex factors associated with different aspects of advanced production systems and services. This book offers a unique perspective that blends the research from individual contributions presenting important domains in current manufacturing and production management applications. The covered topics include quality, health, and safety-oriented management models, human factors and ergonomics, analysis of organizational culture, as well as the consideration of the psychophysiological states of employees and work design. Further, we discuss the impact of strategic orientation and supply chain integration and provide many practical examples from diverse areas of applications. Special attention is given to the automotive industry, which constitutes the background for these studies. The competitive factors, productivity challenges, and the circular economy and lean manufacturing systems in the context of sustainability are discussed. Selected topics are devoted to developing system architectures, data analytics, and improving process and product quality. The modeling and simulation of epidemiological services are also presented. The last part of the book is devoted to quality improvement and process control of exemplary product parameters.

We believe that the strength of this book is embedded in its relatively intuitive and readable style, which illustrates the theory with practical examples. We hope this book will not only reach the students of production engineering, management, and applied psychology areas but also serve as a useful reference for researchers, practitioners, and industrial managers. We also hope to inspire others to focus their research on human aspects of contemporary production and service challenges.

We would like to express our gratitude to the authors who contributed to this book. Without their research and development efforts, this book would not have been possible.

Beata Mrugalska
Waldemar Karwowski
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Editor Biographies

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Tareq Ahram is presently working as an assistant research professor and lead scientist at the Institute for Advanced Systems Engineering at the University of Central Florida, USA. He received a Ph.D. degree in Industrial and Systems Engineering from the University of Central Florida, in 2008, with a specialization in human systems integration and large-scale information retrieval systems optimization. He has served as an invited speaker and a scientific member for several systems engineering, emerging technologies, neuro design, and human factors research, and as Invited Speaker and Program Committee Member for the U.S. Department of Defence Human Systems Integration and the Human Factors Engineering Technical Advisory Group. He serves as the Applications Subject editor member of *Frontiers in Neuroergonomics*, and the executive editor of the *Journal of Human-Intelligent Systems Integration*.

Waldemar Karwowski is currently working as Pegasus Professor and Chairman, Department of Industrial Engineering and Management Systems, and Executive Director, Institute for Advanced Systems Engineering, University of Central Florida, Orlando, USA. He holds a Ph.D. in Industrial Engineering from Texas Tech University. He is Past President of the International Ergonomics Association (2000–2003), and Past President of the Human Factors and Ergonomics Society (2007). He has over 500 publications focused on human performance, safety, cognitive systems engineering, human-centered design, neuro-fuzzy systems, nonlinear dynamics, neurotechnology, and neuroergonomics. He serves as Co-Editor-in-Chief of *Theoretical Issues in Ergonomics Science* journal (Taylor & Francis, Ltd), Editor-in-Chief of *Human-Intelligent Systems Integration* (Springer), and Field Chief Editor of *Frontiers in Neuroergonomics*.

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1 A New Ergonomics Management Model for Supply Chains

Iván Francisco Rodríguez-Gámez, Aidé Aracely Maldonado-Macías, Beata Mrugalska, Ernesto Lagarda Leyva, Juan Luis Hernández Arellano, and Yordán Rodríguez

CONTENTS

1.1 INTRODUCTION

Nowadays, management systems play a crucial role in the development of organizations as they allow them to fulfill the proposed objectives. Recently, more and more organizations have been implementing management systems in different fields such as quality (QMS) (Sfreddo et al., 2021; Rodríguez-Mantilla et al., 2020; Ingason, 2015; Psomas & Kafetzopoulos, 2014), environment (EMS) (Gunawan et al., 2020; Pacana & Ulewicz, 2017; Disterheft et al., 2012), health and safety (HSMS) (Morgado et al., 2019; Cąliş & Buÿükakinci, 2019a; Mohammadfam et al., 2017), and have emerged to generate integrated management systems (IMS). However, the latter have considered ergonomic aspects (Nunhes et al., 2019; Lima Marcos et al.,

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2018; Domingues et al., 2016; Ifadiana & Soemirat, 2016; Yazdani et al., 2015a; Santos et al., 2013) although a proper management system for this discipline is lacking.

On the other hand, ergonomics management (EM) is used in the most recent research. However, it is usually related mainly to implementing ergonomics-related programs, even in IMS. However, in the absence of a clear and more accepted definition in the literature, it is difficult to conceive this term as a management system model proposed for quality, environmental, and even health and safety management systems (HSMS). Therefore, the term ergonomics management remains a "work-in-progress" concept. Even though modern approaches for quality management, as well as those for health and safety, have been clarifying some domains and characteristics through various models and standards, there is an opportunity for research considering them in the design of an ergonomics management model to extend its scope to the evaluation of entire supply chains (SC). In addition, the sustainable approach in supply chain ergonomics management from social sustainability (SS) perspective has received insufficient attention in both supply chain management (SCM) and supply chain sustainability issues addressed by researchers Korkulu and Bóna (2019) and Goethe et al. (2022). Although it is recognized that attempts have been made in the literature to establish a theoretical frame of reference for assessing SS through ergonomics that is mostly accepted for assessing social sustainability in supply chains, this objective has not yet been fully achieved. There are discrepancies and a lack of consensus among authors on its scope and conception (Simões et al., 2014). Additionally, Seuring (2012) states that social issues are little addressed in sustainable supply chain design, and some authors agree that there is a lack of research on sustainable supply chain management (SSCM) practices (Hong et al., 2018).

These findings evidence the need to consider the ergonomics approach for evaluation and improvement in the supply chain as a priority; so, researchers and stakeholders must have a better comprehension of the impact that ergonomics management has on employees' well-being and quality of life. In addition, the literature has recognized that the management and application of ergonomics generate economic benefits for those companies that have been successful in their implementation (Ciccarelli et al., 2022; Maldonado-Macías et al., 2021; Naeini et al., 2018; Sultan-Taïeb et al., 2017; Pereira Da Silva et al., 2012; Tompa et al., 2008). Therefore, an ergonomics management model must strongly emphasize the social sustainability of companies and SC. Accordingly, this chapter aims to conduct a systematic literature review of management systems and models to establish the basis for designing an ergonomics management model applicable to companies and to those SC in which they participate.

1.2 MAIN TOPIC LITERATURE

The International Organization for Standardization (ISO) defines a management system as a set of elements of an organization that are interrelated or interact to establish policies, objectives, and processes to meet the goals established by the organization. Such elements consider the structure of the organization, roles and responsibilities, planning, operation, performance evaluation, and continuous improvement. These are key elements of management that should be included in the design of any management system. The aforementioned literature review shows an overview of management systems, as well as standards that can be used in the conformation of the ergonomics management model. A quality management system (QMS) focuses on achieving the quality policy and quality objectives that drive to meet the company and customer requirements. The QMS is articulated through the facility integrity organization: its policies, procedures, and processes that are required to successfully achieve quality management of the facility (Deighton & Deighton, 2016).

On the other hand, HSMS refers to functions, processes, and tangible practices associated with occupational safety. According to ISO 45001:2018, an HSMS is to provide a framework for managing health and safety risks and opportunities. Their implementation is a strategic and operational decision for an organization. There are several HSMS-related standards available for companies to adapt and use. Regardless of the HSMS chosen, these systems are designed and based on a continuous improvement process to control hazards and risks to an acceptable level and improve worker health and safety (Labodová, 2004). One of the root causes of many industrial disasters is the absence of an HSMS (Bhasi et al., 2010; Haas & Yorio, 2021).

1.2.1 Relevant Management Standards and Models

In terms of standards and management models, two relevant ones are widely accepted by organizations to meet the needs of their customers and stakeholders through quality management. On the one hand, the implementation and certification of quality systems according to ISO 9000 is undoubtedly the most popular methodology. On the other hand, certification based on the European Foundation for Quality Management Model (EFQM) is gaining ground in improvement processes (Bayo-Moriones et al., 2011). By 2020, the ISO 9001:2015 standard was awarded 916,842 certifications worldwide (International Standard Organization, 2021). EFQM is currently used by more than 800 organizations across Europe (Gómez-López et al., 2019). Although both models focus on quality management, there are some important characteristics in their implementation approaches. Thus, ISO 9001:2008 promotes the adoption of a process approach model when developing, implementing, and improving the effectiveness of a quality management system to enhance customer satisfaction by meeting customer requirements (ISO 9001:2008, Quality Management Systems—Requirements). ISO 9000 standard proposes a process-based quality management system, as presented in Figure 1.1. Similarly, the EFQM 2020 model is based on process management as an accepted good practice since its objective is to help the sustained and sustainable growth of an organization through the continuous increase of value for all stakeholders by the efficient management of the transformation processes, plans, and projects. In addition, it has its management tool called RADAR (Result, Approach, Deploy, Assess, and Refine), whose function is to identify how the organization is working and what could be improved. The vision of the process approach makes it easier for organizations to adopt or manage any process, through identification, design, execution, measurement, and control. Considering these two main process-based models, when ergonomics is considered requirements or inputs must be processed and solutions or fulfillments are generated. Accordingly, ergonomics management can adopt some similarities of QMS to develop its proper model.

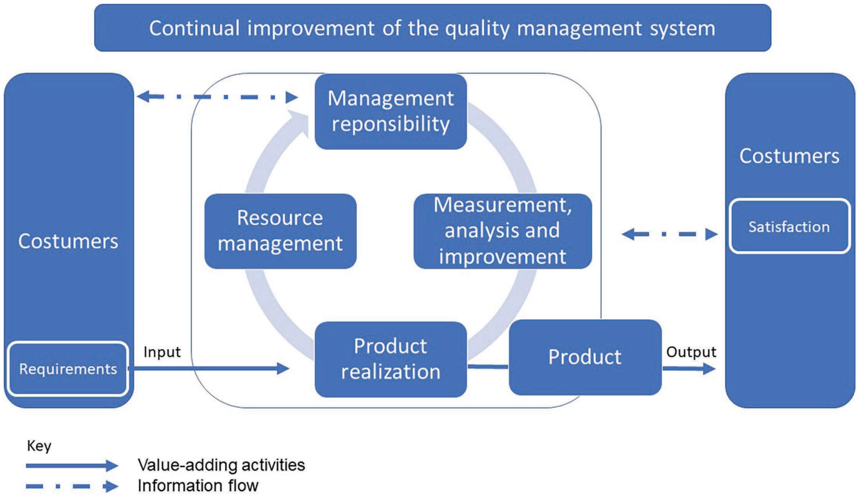

FIGURE 1.1 Process-based quality management system adapted from *ISO 9001:2008(En), Quality Management Systems—Requirements* (www.iso.org/obp/ui/#iso:std:iso:9001:ed-4:v2:en).

1.2.2 Plan, Do, Check, Act Model, Applied Health, and Safety Standards

The PDCA cycle is a systematic process designed to obtain valuable learning and knowledge for the continuous improvement of a product, process, or service. It is used by QMS, EMS, HSMS, and Information Security Management Systems (ISMS), regulated by ISO, as well as in Total Quality Management (TQM) models. This management model is based on four phases aimed to develop continual improvement:

- *Plan:* Establish the objectives of the system and its processes and the resources needed to deliver results following customer's requirements and the organization's policies, and identify and address risks and opportunities.
- *Do:* Implement what was planned.
- *Check:* Monitor and (where applicable) measure processes and the resulting products and services against policies, objectives, requirements, and planned activities, and report the results.
- *Act:* Take actions to improve performance, as necessary.

This model has been used for versions of ANSI/AIHA/ASSE Z10–2012. This management system can be effectively implemented not only to achieve significant safety and health benefits but also to have a favorable effect on productivity, financial performance, quality, and other business goals (Manuele, 2014). For example, it has also been used in the development of a tool for analyzing the performance of the requirements of the safety management systems through the reporting and measuring of the defined Key Performance Indicators (Valdez Banda & Goerlandt, 2018). In addition to obtaining effective results in the implementation of the PDCA-based approach to Environmental-Value Stream Mapping (E-VSM), it can be an effective alternative to improve the green performance of operations as well (Garza-Reyes et al., 2018). Finally, PDCA has been used to strengthen the relationship between lean manufacturing and ergonomics (Nawawi et al., 2018). Accordingly, this is evidence that this cycle can be applied successfully to all processes, and its versatility can improve the quality management system as a whole, EMS, and HSMS.

In terms of health and safety standards, the most commonly used standards are OHSAS 18001 and ISO 45001 (Hoque & Shahinuzzaman, 2021). Any HSMS has some common elements which ensure health and safety for the employees and workers, such as policy, organizing, planning, implementing, evaluating, and taking actions for improvement (Yanar et al., 2020). It is widely implemented in organizations worldwide (Mohammadfam et al., 2017). Figure 1.2 shows how the

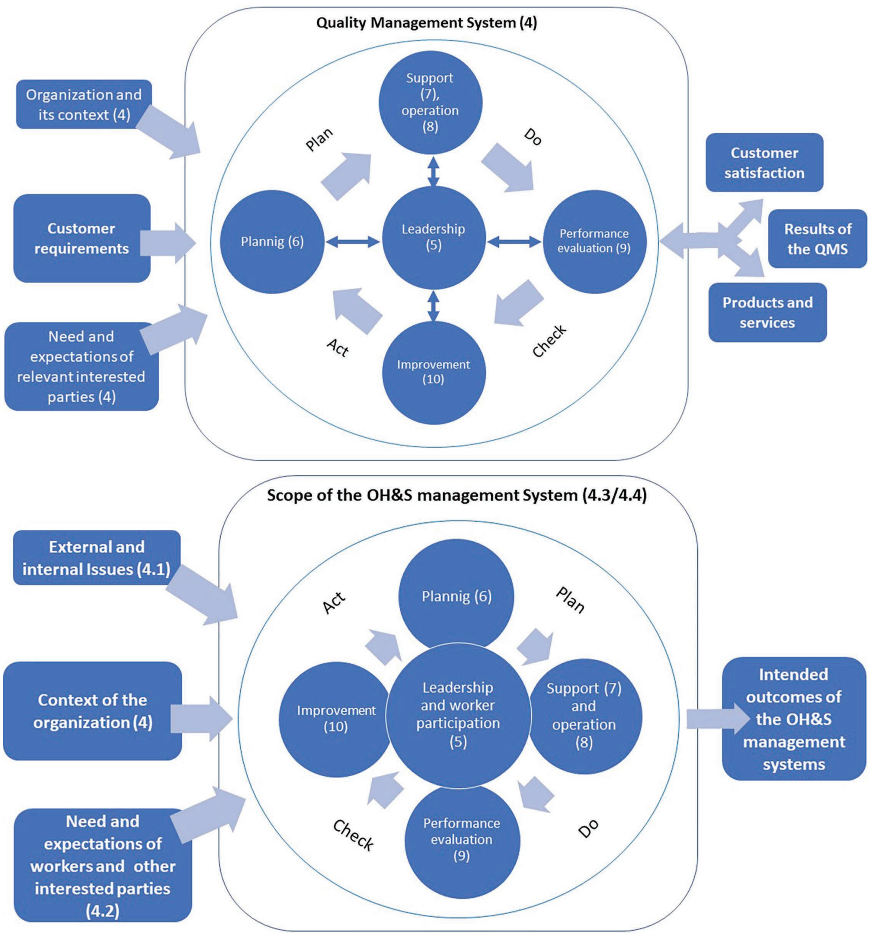

FIGURE 1.2 ISO Standard in the PDCA cycle for QMS and HSMS adapted from the quality management system is the first diagram, *ISO 9001:2015(En), Quality Management Systems—Requirements* (www.iso.org/obp/ui/#iso:std:iso:9001:ed-5:v1:en). The second diagram is the health and safety management system, *ISO 45001:2018(En), Occupational Health and Safety Management Systems—Requirements with Guidance for Use* (www.iso.org/obp/ui/#iso:std:iso:45001:ed-1:v1:en).

requirements of the ISO standards can be grouped in the PDCA cycle for both management systems.

The aforementioned literature review shows an overview of management systems, as well as existing models, and standards that can be used in the conformation of the ergonomics management model. These have been successfully implemented in several organizations in various sectors and countries (International Standard Organization, 2021). Other relevant aspects refer to their systemic approach providing an integral perspective and implementation in the organizations by determining the internal and external aspects that can influence the results, as well as their synergy and systematic process for the achievement of results. In addition, some of the advantages found are among others the full control of compliance obligations, a significant reduction in injury indexes (in the case of safety and health management), a reduction in the associated costs, and an improvement in the corporate image (Campailla et al., 2019) as well as the positive and significant effects on operational performance (Fahmi et al., 2021). Besides, one of the strongest aspects is the structure of the standards based on the ten main clauses of the ISO high-level structure. This feature leads to a high potential for integrating altogether requirements into a single integrated management system (Darabont et al., 2019).

1.3 METHODOLOGY

This research used the SLR following the PRISMA Declaration (Liberati et al., 2009), as retrieved from its website: www.prisma-statement.org/. The document describes the sources of information, the search parameters in the databases, the refinement of the results, the final selection of the identified findings, and an analysis of the results. Figure 1.3 shows the five stages in which the process was structured.

1.4 RESULTS

The results obtained during each stage of the SLR are shown in the following sections.

1.4.1 Database Selection

The search was conducted in the ScienceDirect, ProQuest, SpringerLink, and Emerald Insight databases as these are the most widely used in the engineering, supply chain, safety, and ergonomics fields, according to the analysis of other systematic literature reviews associated with this topic.

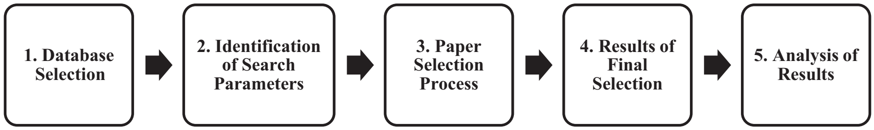

FIGURE 1.3 Stages of the literature review process for this research.

1.4.2 Identification of Search Parameters

The scope for the SLR for all databases covered journal articles published between 2010 and 2021, which featured keywords in both their title and content. Logical operators were also considered. Both parameters used were ("ergonomics management systems" OR "safety management systems" OR "quality management systems") AND ("supply chain").

Inclusion criteria:

1. The paper is published in a scientific journal.
2. The paper is available in English.
3. The paper reports on management systems related to the prevention of injuries and health impairment of personnel in work activities to provide better workplace designs.
4. The paper reports on safety or ergonomics or quality management systems used in the supply chain.

Exclusion criteria:

1. Duplicated papers
2. Papers include conference posters, abstracts, short papers, and unpublished works.
3. Papers to address the food safety management systems (SMS) in the supply chain.
4. Papers fail to address the management systems in the supply chain.

1.4.3 Paper Selection Process

A total of 1,135 articles were found after the initial search through the four databases (ScienceDirect, ProQuest, SpringerLink, and Emerald Insight). Figure 1.4 shows the selection process, as well as the results of the screening once the selection and exclusion criteria were established. The results of each stage in the selection process are also featured. It should be noted that the screening process was based on the analysis of all papers in their entirety.

1.4.4 Results of Final Selection

Figure 1.4 shows the 39 papers that met the inclusion criteria for the final selection. Next, Table 1.1 shows the total of articles selected, which were in turn classified by year of publication, author, management systems implemented or evaluated, standards, and management models.

1.4.5 Analysis of Results

As a result of the process mentioned earlier, three different management systems, three standards, and three management models were identified in the 39 articles

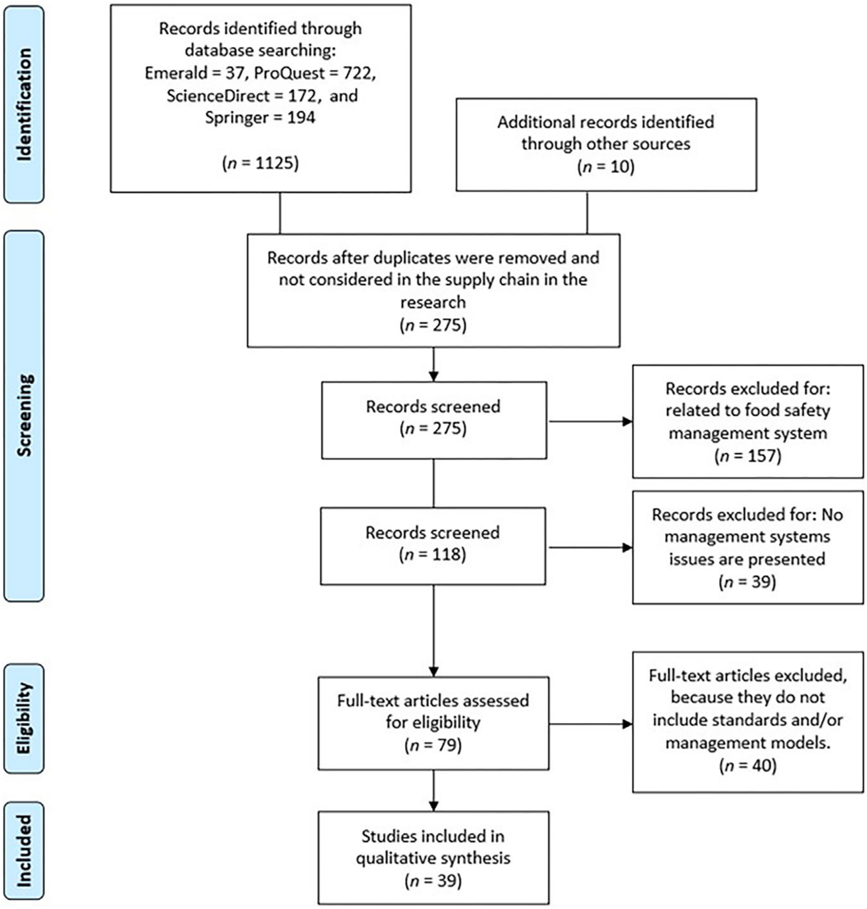

FIGURE 1.4 Paper selection process.

selected. These can be the basis for proposing an ergonomics management model. As seen in Figure 1.5, the analyzed literature showed a growing interest in the subject studied since publications addressing it increased fivefold during the established period. For the last eight years, the annual number of publications has been above two, while in previous years, the annual average was 0.5 publications per year. This suggests that the topic is far from being exhausted, and its popularity among researchers is still rising. Therefore, it is safe to say that further unique studies regarding this field of knowledge will continue to appear soon.

Another relevant aspect refers to the papers' most studied management systems. Figure 1.6 shows the 39 articles classified by percentages according to the systems type. As can be seen, an area of opportunity lies in developing investigations related to the implementation, evaluation, or design of the ergonomics management system (EMS). However, one of the most common forms of intervention related to this issue within organizations is the implementation of ergonomics programs to fit the job

TABLE 1.1
Characteristics of the Selected Articles

Year	Author/s	Management Systems			Standards and Management Models					
		HSMS or SMS	QMS	EMS	ISO 9001	ISO 45001	OSHAS 18001	EFQM	TQM	PDCA
2011	(Liu et al., 2011)	X								X
2011	(Bayo-Moriones et al., 2011)		X		X			X	X	
2014	(Poli et al., 2014)				X					X
2014	(Wu et al., 2014)	X								X
2014	(McGuinness & Utne, 2014)	X			X		X			
2014	(Ferreira Rebelo et al., 2014)	X			X		X			X
2015	(Asgher et al., 2015)		X					X		
2015	(Kafetzopoulos et al., 2015)		X		X					
2016	(dos Santos et al., 2016)			X					X	X
2016	(Mohammadfam et al., 2016)	X					X			X
2017	(Zimon, 2017a)		X		X					
2017	(Zimon, 2017b)								X	
2017	(Zimon, 2017c)		X		X					
2017	(Zimon & Malindžák, 2015)		X		X					
2017	(Fonseca & Domingues, 2017)		X		X					
2017	(Suárez et al., 2017)							X	X	
2017	(Sadegh Amalnick & Zarrin, 2017a)	X	X	X				X		
2018	(Hohnen & Hasle, 2018)	X					X			X
2018	(Muhamad Khair et al., 2018)	X	X		X		X			
2018	(Hallberg et al., 2018)		X		X					

(Continued)

TABLE 1.1 (Continued)
Characteristics of the Selected Articles

Year	Author/s	Management Systems			Standards and Management Models					
		HSMS or SMS	QMS	EMS	ISO 9001	ISO 45001	OSHAS 18001	EFQM	TQM	PDCA
2019	(Varella & Trindade, 2019)			X						X
2019	(Refaat & El-Henawy, 2019)		X		X					
2019	(Morgado et al., 2019)	X				X				
2019	(Cąliş & Buÿükakinci, 2019b)									
2019	(da Silva & Amaral, 2019)	X				X	X			
2019	(El Manzani et al., 2019)		X		X				X	
2020	(Zimon et al., 2020)		X		X					
2020	(Uhrenholdt Madsen et al., 2020)	X				X	X			
2020	(Swuste et al., 2020)	X			X				X	X
2021	(Grijalvo & Sanz-Samalea, 2020)		X		X					
2021	(Medina-Serrano et al., 2021)		X		X					X
2021	(García-Aranda et al., 2021)		X					X	X	
2021	(Markowski et al., 2021)	X				X	X			X
2021	(Rudakov et al., 2021)	X				X	X			X
2021	(L. Fonseca et al., 2021)							X	X	
2021	(Haas & Yorio, 2021)	X				X	X			X
2021	(Tebar Betegon et al., 2021)		X		X					
2021	(Hoque & Shahinuzzaman, 2021)	X				X	X			
2021	(Bagodi et al., 2021)		X		X					

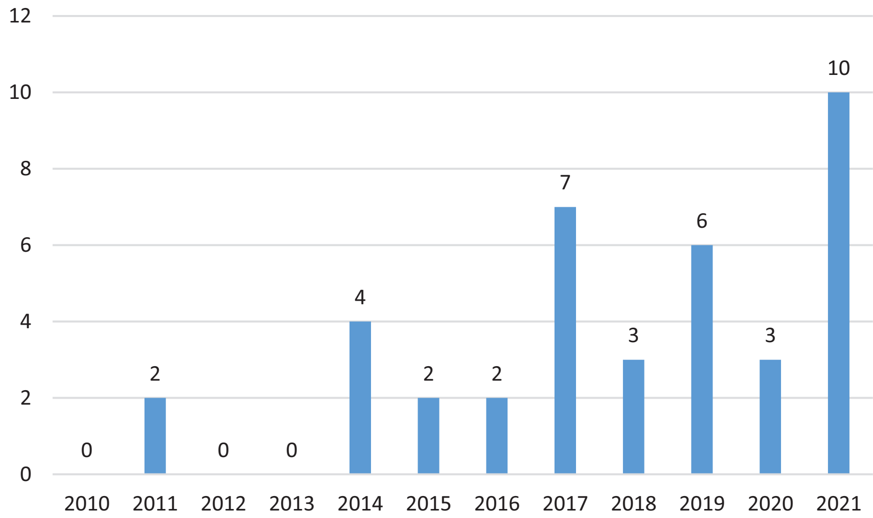

FIGURE 1.5 Year of publication of final selections.

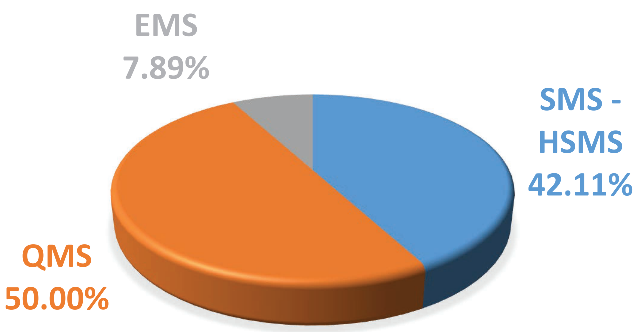

FIGURE 1.6 The proportion of the evaluated management system on the supply chain.

to the worker's abilities and capacities by reducing the physical and mental workload. Unfortunately, these programs sometimes lack a proactive and participatory approach (Fernandes et al., 2015). In addition, most of the time, these are considered separate initiatives by top management and struggle to get a priority place at the table as product quality, worker safety, and profitability have.

Furthermore, a key element found in the literature is ergonomics auditing, as it is used to track improvements and provide a standard for the ideal and mature program. Alpaugh-Bishop (2012) considers that the key elements for the success of the program should be audited as follows:

- Management commitment/foundation for success/program infrastructure
- Ergonomics training/awareness

- Identifying problematic jobs/understanding MSD hazards/ergonomics analyses
- Selecting ergonomics solutions/implementing solutions/communicating success
- Health care management/return to work/physical demands descriptions
- Proactive ergonomics/design ergonomics

Ergonomics program managers must overcome obstacles to effectively sustain results and demonstrate how ergonomics initiatives fit naturally with the organization's continuous improvement philosophies (Monroe et al., 2012). Under this context, organizations need to integrate a systematic ergonomic improvement process to identify and reduce employee exposure to risk factors. Munck-Ulfsfält et al. (2003) suggested that ergonomics is not a separate entity but a strategy which facilitates compliance.

On the other hand, the articles were analyzed considering the number of standards and management models used in each paper. Figure 1.7 shows the percentages of papers found per aspect. It can be noted that the standards most frequently used are ISO 9001 for their nature in quality management systems, while the least used is ISO 45001 in safety management systems. OSHAS 18001 will be withdrawn and organizations should migrate to ISO 45001 by March 2021, as the latter ensures greater compatibility with ISO 9001 and 14001, which facilitates the formation of an integrated management system. As for management models, PDCA is the most widely used in research related to the supply chain.

Additionally, the articles were analyzed considering the relation between standards and management models used to evaluate or design the management systems. For this purpose, their nature and adaptability are considered. The articles reviewed show a greater frequency of use of 18001 standard and the PDCA model (six articles), followed by the option of ISO 9001 and PDCA (four articles), and in the third option,

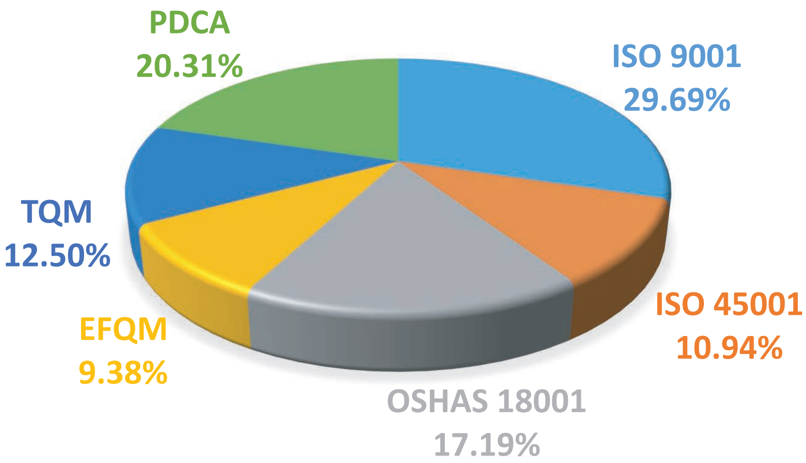

FIGURE 1.7 The proportion of the number of standards and management models used in each paper.

ISO 45001 and PDCA (three articles). The 9001 standard is related to OSHAS 18001, TQM, and EFQM, confirming that this is the standard with the greatest adaptability. The PDCA model is the most used for the development of management systems. This was confirmed by Poli et al. (2014), Haight et al. (2014), and Haas and Yorio (2016). It is important to note that the new version of ISO 9001: 2015 seeks to be less prescriptive and more focused on managing the entire supply chain, requires greater management commitment, is also less bureaucratic, and is more friendly for organizations (Zimon, 2017c). Regarding the focus of ergonomics management systems, three types of research were identified:

1. Concerning this research, dos Santos et al. (2016) studied the implementation of the Participatory ergonomics management system using TQM tools, aimed at adapting workstations, the workplace, and work conditions to comply with Brazilian Labor Legislation. This model has proven effective in identifying ergonomic problems in workstations, production processes, and working conditions and has allowed the implementation of ergonomic actions. However, there is no global application in the supply chain or an approach to macroergonomic problems, as its focus is microergonomic.
2. The purpose of this research is to present an integrated framework for the performance of the human resource (HR) with respect to the factors of health, safety, environment, and ergonomics (HSEE) management system, and also the criteria of European federation for quality management (EFQM) as one of the well-known business excellence models. A questionnaire was designed to evaluate the company's performance using the fuzzy data envelopment analysis (FDEA) and intelligent algorithm based on an adaptive neuro-fuzzy inference system (ANFIS). Furthermore, the impact of the factors on the company's performance and their strengths and weaknesses are identified by conducting a sensitivity analysis of the results. Similarly, a design of the experiment is performed to prioritize the factors. In this research, the integrated management model is not implemented. Nevertheless, it is used for the evaluation of the organization and only addresses the ergonomics aspects in three questions of the evaluation instrument.
3. Varella and Trindade (2019) presented the following as the objective of their research and management model in ergonomics that has been certified in Brazil by the representative body of ISO (International Organization for Standardization), ABNT (Brazilian Association of Technical Norms), and has been showing good results, through documented, registered, and controlled actions, respecting the PDCA cycle management system. The program involves several actions (planned, controlled, and documented) based on the ergonomics of the activity (whose main objective is to understand the work to transform it) and in the national legislation, covering the ergonomic workplace analyses (which contemplate the three dimensions of ergonomics—physical, cognitive, and organizational), execution and validation of projects of ergonomic improvements (conception and

correction), investigation of work-related out- patient complaints, follow-up of return to work processes, and inclusion of people with disabilities in workstations, training (both work-related and non-work-related issues) and actions aimed at the well-being and quality of life of the employees, with relaxation, strengthening, and postural alignment activities in a place inside the company equipped with professionals specialized in Physical Education and Physiotherapy. Therefore, with the combination of the activity's ergonomics concepts and the PDCA cycle management model, it is possible to propose steps for an ergonomics program that seeks the continuous improvement of the work processes and the constant validation of the actions performed by it. The model's main activities are as follows:

- Recording of program ergonomic procedures.
- Annual census of all existing jobs in the company, for subsequent preparation of the annual planning for the implementation of Ergonomic Work Analysis.
- Elaboration and control of visits and technical opinions requested by the medical department or by the areas of the company.
- Request, follow-up, and validation of ergonomic improvements validated by the personnel.
- Participation in the projects of new models and new workstations of the company.
- Training related to ergonomics.
- Support other programs.
- Management of the Labor Gymnastics Program and the "Ergonomics Center": space for quality of life at work, where physical activities of different modalities (Pilates classes, functional training, postural orientations, relaxation, among others) are carried out for all employees.

These articles agree that the participation of employees or specialists in ergonomics management is necessary and may be increased due to the implementation of these models. Furthermore, in the case of the Sadegh Amalnick and Zarrin (2017b) research, leadership was shown to be a significant element in system performance. Therefore, both elements should be considered in the design of the ergonomics management model. On the other hand, the lack of models or management systems for the evaluation and/or prevention of the lack of ergonomics in organizations facilitate integration with existing management models in organizations such as those related to quality, environment, health, and safety. Lewandowski (2000) emphasized the importance of integrating ergonomics as a general concept in a total quality management system. He suggested that to achieve the effects of continuous improvement of occupational health and safety and quality, ergonomics must be considered in management processes.

In the case of MSDs, Yazdani et al. (2015b) confirmed the insufficient literature describing the integration of assessment and prevention in management systems. This lack of information may isolate the prevention of MSDs, which hinders the prevention of these disorders at the organizational level. In addition, it has been observed that ergonomics activities are rarely incorporated into integrated management systems or occupational health and safety systems of companies (Caroly et al., 2010). However, De Oliveira Matias and Coelho (2002) assert that the benefits of incorporating ergonomics into different management systems could be improved by integrating ergonomics into these management systems.

HSMS is a formalized framework for organizations to manage workers' health and safety through the association of arrangements, the planning and review, and the program elements that work together to enhance safety performance. In implementing these systems in organizations, there is evidence that they can address and mitigate workplace risks (Yazdani et al., 2015a). Similarly, the purpose of ergonomics is to identify, analyze, and reduce occupational hazards by adapting the workplace and conditions to the characteristics of the operator. This affinity facilitates its integration to the HSMS and, therefore, to a standard within this system, such as the Occupational Health and Safety Assessment Series (OHSAS 18001:2007), the ANSI Z10 standard, and ISO 45001:2018, among others.

Emily J. Haas and Yorio (2021) made a comparison between the OSHAS 18001 and ANSI Z10 standards, considering as elements to compare leadership development, responsibility, and accountability; risk management; emergency management training, culture enhancement, communication, and collaboration; reinforcement and recognition; change management; resources and planning, work procedures, and permits; occupational health; incident investigation; behavior optimization; engineering and construction; contractor management; assurance, documentation, and information management, detecting the lack of leadership development, culture improvement and behavior optimization in both standards, while the particular case of ANSI Z10 lacks change management and resources and planning as aspects within its implementation. On the other hand, the authors Rostykus et al. (2016) propose integrating ergonomic aspects to ISO 45001, as this model can be used as an effective system to manage ergonomics.

Another way to compare standards and management models is through their structure or requirements that make them up; for this purpose in Table 1.2, the comparison is shown and those aspects that are lacking in terms of ISO 45001 are identified.

Regarding the comparison of ISO 45001 with ANSI Z10, we can see in the table that ISO 45001 has more requirements. At the same time, ANSI Z10 lacks an exclusive element for determining legal requirements, action planning, conformity, and assessment and does not consider an audit program. On the other hand, when comparing ISO 45001 with EFQM, we find some difficulty due to the different methodological approaches (e.g., attributes to measure, variables, measurement scales); however, we can rescue aspects related to the commitment with stakeholders such as customers, people, companies and interest groups, governors, society, partners, and suppliers, which can facilitate the inclusion of the ergonomics management system that we are seeking to develop. Even the EFQM model is considered vital to manage an organization that wants a long-term sustainable future; some approaches suggest the implementation of ISO 9001 and then using the EFQM to achieve excellence through sustainable and outstanding results (Fonseca et al., 2021).

TABLE 1.2
Comparison between QMS and HSMS

	Health and Occupational Safety Management Systems		Quality Management Systems		
PDCA Cycle	**ISO 45001:2018 Occupational Health and Safety Management Systems—Requirements with Guidance for Use**	**ANSI ASSE Z10–2012 (R2017) Occupational Health and Safety Management Systems**	**RADAR**	**European Foundation for Quality Management (EFQM)**	
	5. Leadership and worker participation	**3.0 Management leadership and employee participation**	**Approaches**	**Direction**	**1. Purpose, vision, and strategy**
	5.1 Leadership and commitment	3.1 Management Leadership—3.1.1 Occupational health and safety management system			1.1 Define purpose and vision
	5.2 OH&S policy	3.1.2 OHS policy			1.2 Identify and understand stakeholders needs
	5.3 Organizational roles, responsibilities, and authorities	3.1.3 Responsibility and authority			1.3 Understand the ecosystem, own capabilities, and major challenges
	5.4 Consultation and participation of workers	3.2 Employee participation			1.4 Develop strategy
Plan	**6 Planning**	**4.0 Planning**			1.5 Design and implement a governance and performance management system
	6.1 Actions to address risks and opportunities	4.1 Review process			**2. Organizational culture and leadership**
	6.1.1 General	4.2 Assessment and prioritization			2.1 Steer the organization's culture and nurture values
	6.1.2 Hazard identification and assessment of risks and opportunities	5.1.1 Risk assessment			2.2 Create the conditions for realizing change
	6.1.3 Determination of legal requirements and other requirements				2.3 Enable creativity and innovation

	6.1.4 Planning action				2.4 Unite behind and engage in purpose, vision, and strategy
	6.2 OH&S objectives and planning to achieve them	4.3 Objectives		**Execution**	**3. Engaging stakeholders**
	6.2.1 OH&S objectives				3.1 Customers: build sustainable relationships
	6.2.2 Planning to achieve OH&S objectives	4.4 Implementation plans			3.2 People: attract, engage, develop, and retain
					3.3 Business and governing stakeholders—secure and sustain ongoing support
					3.4 Society: contribute to development, well-being, and prosperity
					3.5 Partners and suppliers: build relationships and ensure support for creating sustainable value
Do	**7 Support**		**Deploy**		
	7.1 Resources	4.4 Allocation of resources			5.5 Manage assets and resources
	7.2 Competence	5.2 Education, training, awareness, and competence			3.2 People: attract, engage, develop, and retain
	7.3 Awareness				
	7.4 Communication	5.3 Communication			4.2 Communicate and sell the value
	7.4.1 General				
	7.4.2 Internal communication				

(*Continued*)

TABLE 1.2 (Continued)
Comparison between QMS and HSMS

	Health and Occupational Safety Management Systems		Quality Management Systems	
PDCA Cycle	**ISO 45001:2018 Occupational Health and Safety Management Systems—Requirements with Guidance for Use**	**ANSI ASSE Z10–2012 (R2017) Occupational Health and Safety Management Systems**	**RADAR**	**European Foundation for Quality Management (EFQM)**
	7.4.3 External communication			
	7.5 Documented information	5.4 Document and record control process		
	7.5.1 General			
	7.5.2 Creating and updating			
	7.5.3 Control of documented information			
	8 Operation	**5.0 Implementation and operation**		**4. Creating sustainable value**
	8.1 Operational planning and control	5.1 OHSMS operational elements		4.1 Design the value and how it is created
	8.1.1 General			
	8.1.2 Eliminating hazards and reducing OH&S risks	5.1.2 Hierarchy of controls		4.3 Deliver the value
	8.1.3 Management of change	5.1.3 Design Review and management of change		4.4 Define and implement the overall experience
	8.1.4 Procurement	5.1.4 Procurement and 5.1.5 Contractors		
	8.2 Emergency preparedness and response	5.1.6 Emergency preparedness		
Check	**9 Performance evaluation**	**6.0 Evaluation and corrective action**	**Assess and refine**	**5. Driving performance and transformation**
	9.1 Monitoring, measurement, analysis, and evaluation	6.1 Monitoring, measurement, and assessment		5.1 Drive performance and manage risk
	9.1.1 General			5.2 Transform the organization for the future

	9.1.2 Evaluation of compliance				5.3 Drive innovation and utilize technology
	9.2 Internal Audit	6.3 Audits			5.4 Leverage data, information, and knowledge
	9.2.1 General		**Result**	**Result**	**6. Stakeholder perceptions**
	9.2.2 Internal audit program				**7. Strategic and operational performance**
	9.3 Management review	**7.0 Management review**			
		7.1 Management review process			
		7.2 Management review outcomes and follow-up			
Act	**10 Improvement**				
	10.1 General	6.2 Incident investigation			
	10.2 Incident, nonconformity, and corrective action	6.4 Corrective and preventive actions			
	10.3 Continual improvement	6.5 Feedback to the planning process			

TABLE 1.3
Ergonomics Management System Constructs and Domains

PDCA Cycle	ISO 45001:2018 Occupational Health and Safety Management Systems—Requirements with Guidance for Use	
	Constructs	**Domains**
	5 Leadership and worker participation	5.1 Leadership and commitment
		5.2 Policy
		5.3 Organization roles, responsibilities, and authorities
		5.4 Consultation and participation of workers
Plan	6 Planning	6.1 Actions to address risks and opportunities
		6.2 Objectives and planning to achieve them
DO	7 Support	7.1 Resources
		7.2 Competence
		7.3 Awareness
		7.4 Communication
		7.5 Documented information
	8 Operation	8.1 Operational planning and control
		8.2 Emergency preparedness and response
Check	9 Performance evaluation	9.1 Monitoring, measurement, analysis, and evaluation
		9.2 Internal audit
		9.3 Management review
Act	10 Improvement	10.1 General
		10.2 Incident, nonconformity, and corrective action
		10.3 Continual improvement

Considering these findings, the decision was made to adopt ISO 45001 as a structural element and the PDCA cycle, both of which are relevant and considered key to the development of the EMS. As for the domains to be considered in the ergonomics management system, these are shown in Table 1.3; these domains are classified for each construct and under the PDCA cycle. In addition, leadership and worker participation are integrated into the model.

1.5 THE OPPORTUNITY OF ISO 45001 FOR ERGONOMICS MANAGEMENT IN THE SUPPLY CHAIN

From the initiative stage, ISO 45001 sought to ensure a "robust and effective set of processes to improve occupational safety in global supply chains" (Hemphill & Kelly, 2016); in other words, a sustainable solution to promote occupational health and safety in global supply chains. This standard is based on the PDCA model; iterative process organizations use to achieve continuous improvement. Therefore, it can be explored as a value-added capability for global supply chains. The proposed structure in ISO 45001 associated with safety management systems provides a common framework and terminology for managing hazards in the workplace. This same framework can be applied to identify systematically, control, and verify the reduction of related risk factors.

Rostykus et al. (2016) state that aligning how the organization addresses ergonomics through a management system allows Occupational Safety and Health professionals to communicate and engage business leaders in a way they are already familiar with. In addition, they confirm that ISO 45001 is a model that can be used as an effective system for ergonomics management. Additionally, the opportunities of ISO 45001 to contribute to proposing an ergonomics management model are identifying hazards, communicating them, and addressing the analysis and mitigation of known hazards. In addition, there are other opportunities related to system improvement; within these are the identified ergonomic assessments and other injury prevention assessments (ISO 45001, 2018). Thus, to perform a practical implementation, it is important to consider whether starting an EMS from scratch or developing from an existing program, they are essential for success:

1. Evaluate the current ergonomics program/process based on a management system model.
2. Define common goals, measures, requirements, roles and responsibilities, and standard tools in a baseline document on which all department and site ergonomic improvement processes are based.
3. Obtain the buy-in, sponsorship, and participation from key leaders.
4. Implement the ergonomic improvement process at each location or department through the sponsor, subject matter experts, and engineers. Ensure they use standard assessment tools for consistent reporting and tracking, and share practical improvements and best practices. Track progress and metrics regularly.
5. Audit each site/department's ergonomics management system to ensure compliance with business requirements; identify best practices and opportunities for improvement; and engage leadership to refine their plans and focus on sustaining the process.

1.6 CONCLUSIONS

This chapter shows an overview of the management systems used in the SC, through a literature review covering the period from 2010 to 2021. The methodology followed the PRISMA Guidelines and proved effective in identifying the models and standards of the quality, health and safety, and ergonomics management systems, as well as their domains and features. As confirmed, the objective of this research was met to establish the basis for designing an ergonomics management model that allows the evaluation of companies.

Thirty-nine researches were identified that met the inclusion criteria, of which 50% were related to QMS. These systems are the most used for evaluation and implementation in organizations. From the SLR, leadership, employee participation, and the audit of compliance with the management system requirements are considered fundamental elements for the design of the EMS.

In addition, the ISO 9001 standard and the PDCA cycle stand out; however, ISO 45001 was chosen as the basis for the EMS since it is compatible with ISO 9001, it is also based on the PDCA cycle, and due to its nature, ergonomics is highly related to health and safety management systems, since both focus on risk analysis from its field of action. Not forgetting that within its regulatory framework, it establishes an opportunity for inclusion and thus improves the working conditions and health of the worker.

The purpose of an ergonomics management system is to contribute to the social sustainability of the SC through an evaluation system that provides an ergonomics management index, which gives an overview of the management level of the practices adopted in each element of the SC, as well as globally throughout the SC. This will require the integration of other key elements such as corporate social responsibility and collaboration, cooperation, and coordination between the SC links that comprise it since through these practices, the interaction of the links is enabled, and better performance of the sustainable SC is obtained (Dias & Silva, 2022).

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Ergonomic Work from Home Recommendations Using TRIZ

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Digital Twin, Servitization, Circular Economy, and Lean Manufacturing

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