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Design of a logistics management system to improve the adaptability and sustainability of an organization based on the Corporate Social Responsibility

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RESUMEN:

In the current global system, the coordination of the intra-organizational logistics management acquires vital importance to provide organizations with the capabilities and functionalities necessary to quickly adapt to market changes such as disasters, epidemics, economic crises, etc. that generates disruptions in the supply chain of materials, as well as information flows, and finances. In this context, an organization needs to be resilient to maintain its stability while satisfying the market demand, ensuring the quality and service levels at an optimized cost level, taking into account all the agents involved and the society in its related environment. For this, an effective execution and an efficient management of personnel, technological resources, physical assets as well as financial resources through business systems are essential in order to ensure the long-term viability of any type of organization.

In this context, this Doctoral Thesis aims to design a logistics conceptual model that improves the viability of the organization thanks to a logistics management capable of identifying and anticipating changes in the environment and preparing for it with potential changes and measures that allow adapting and optimizing the performance of the

organization thanks to the consideration and application of the concept of Corporate Social Responsibility. To fulfill this objective, several methodological elements have been used. First, the Viable System Model has provided a method for designing an organizational logistics' model with the goal of viability and sustainability. Secondly, systems theory has provided a systemic approach to the concept in such a way that it is analyzed, designed and improved as a whole, seeking a global approach. Thirdly, the study based on the different industrial revolutions has made it possible to identify the potential for improvement and potential causes of failure in any type of organization. Fourth, system dynamics, the generation of digital twins, and simulation using databases have made it possible to identify the interrelationships between parameters and factors, as well as to identify the influence of different management, planning, and control policies that allow the optimization of the logistics system. Finally, as simulation software, Vensim and Anylogic are used that allow the generation of digital models of an organizational system with its planning levels in different time horizons, strategic, tactical and operational, as well as considering all the flows of the system such as material, information , and financial flows.

Based on the objectives of adaptability and flexibility and taking into account the technologies and factors of the fourth industrial revolution, different case studies and applications are generated in different sectors for the validation of the conceptual model through the quantification of results thanks to the comparison of models, approaches and simulation policies in various scenarios. Through them, the advent of the fifth industrial revolution is concluded through the consideration and modeling of the human factor and its implications in organizational decision-making. In this context, the consideration of Corporate Social Responsibility in the human factor has turned out to be key for organizational performance, as well as for the sustainability of the agents involved in the value chain, including the related environment. In addition, based on the different case studies and the existing theoretical models of CSR, a CSR model is developed that considers all the agents involved with an organization to optimize its impact on both organizational indicators and the organizations involved in the supply chain as well as the related environment thanks to the consideration of social needs based on the Maslow pyramid, the Sustainable Development Goals, as well as the ESG criteria that generally allow to ensure the sustainability of both the organization and its stakeholders and the related environment.

Finally, it can be concluded that the conceptual model provides the mechanisms for the design and optimization of any intra-organizational logistics system to improve their impact both in the organization itself, as well as in the supply chain and in society thanks to a CSR model and to the objective parameters in different areas that contribute to the sustainability of the system since it is validated by having been applied in specific cases both in service and industrial organizations and in the primary sector, supporting that the concept allows optimizing the global system constituted by the organization, its agents, and the environment in their area of influence»

KEYWORDS:

Logistics, Supply Chain, Production Management, Service Management, Maintenance Management, Supply Planning, Distribution Management, Industry 4.0, Human Factor, Sustainability, Corporate Social Responsibility, Viable System Model (MSV), Dynamics of Systems, Vensim, Anylogic, Study Cases, Multisector »

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II Symbols / Abbreviations

Symbol / Abbreviation	Meaning
3 Ms	Three M, “man, material and machine”,
5 S	Seiri, Seiton, Seiso, Seiketsu and Shitsuke
6σ	Six Sigma, Six Sigma
A	After
aaS	as a Service
ABC, XYZ	ABC and XYZ analysis
AC / CW	Central warehouse
AM	Agile Manufacturing
AOG	Aircraft on ground
APS	Advanced Planning and Scheduling
AR	Augmented reality
AR / RW	Regional warehouse
ARIS	Integrated Information Systems Architecture
ATO	Assemble-to-Order (ATO)
B	Before
BA	Before and after
BBDD	Databases
BD	Big Data
BDE	Shop Floor Data Collection
BI	Business Intelligence
BM	Base model
BOA	Workload-dependent order release
BP	Before and in parallel
BPA	In parallel and after
BTO	Build-to-Order
C2C	Computer to Computer
C2H	Computer to Human
CAD	Computer-Aided-Design
CBM	Condition-Based Monitoring
CED	Committee for Economic Development
CEO	Chief Executive Officer
CIVAD	Collection, Improve, Validation, Application, Decision
CM	Classical SM

Symbol / Abbreviation	Meaning
CMI	Balance Scorecard
CONWIP	CONSTANT WORK IN PROGRESS
CP 1	Corrective and Pull
CP 2	Corrective and Push
CPM	Critical Path Method
CPPS	Cyber-physical production systems
CPS	Cyberphysical System
CRM	Customer Relationship Management
CS	Case study
CSP	Corporate Social Performance
CV	Coefficient of variation
DAFO	Weaknesses, Threats, Strengths, Opportunities
DCC / CLD	Casual Loop Diagram
DDDM	Data-driven decision making
DE4.0	Digital Ecosystems for the Fourth Industrial Revolution
DIIS	Dynamic Innovation Information System
DIN	Deutsches Institut für Normung, German Institute for Standardization
DMAIC	Define-measure-analyse-improve-control
DOE	Design of Experiments
DT	Digital Twin
EAF	Electric Arc Furnace
EBIT	Earnings Before Interest and Taxes
ECR	Efficient Customer Response
EOQ	Economic Order Quantity
ERP	Enterprise Resource Planning
ESG	Environment, Social, Governance
ETO	Engineer-to-Order
FIR	Forschungsinstitut für Rationalisierung
FMEA	Failure Mode and Effect Analysis
GRI	Global Reporting Initiative
GUVEI	Get, Use, Virtual, Expand, Improve
H2C	Human to Computer
H2H	Human-to-Human
HCI	Human Machine Interface
HF1	Malfunction of the human factor at the operational level
HF2	Malfunction of the human factor at the tactical, operational levels

Symbol / Abbreviation	Meaning
HF3	Malfunction of the human factor at the strategic, tactical, operational levels
HW	Hardware
I+D	Investigation and development
I4.0	Industry 4.0
IA	Artificial intelligence
IBM	International Business Machines Corporation
IM	Integrated Manufacturing SM
IML	Fraunhofer Institute for Material Flow and Logistics
IMR	Integrated manufacturing SM with Regulation
IMT	Innovation Management Techniques and Tools
IoT	Internet of Things
IPS	Instandhaltungsplanungssystem, maintenance planning system
ISO	International Organization for Standardization
ISR / SRI	Social Responsible Investments
IT	Information Technology
JiT	Just-in-Time
KPI	Key Performance Indicator
LM	Lean Manufacturing
LSQ	Global logistics and systems expansion towards TQM
MAD / DMA	Mean Absolute Deviation
MDE	Machine Data Recording
MES	Manufacturing Execution System
METRIC	Multi-Echelon Technique for Recoverable Item Control
MF	Failure modes
MFE	External Failure Modes
MFI	Internal Failure Modes
ML	Machine learning
MNEs	Multinational enterprises
MO	Market-oriented model
Modelo Aachener PPS	Aachen Production Planning and Control Model
MRO	Maintenance, Repair, Overhaul
MRP	Materials Requirements Planning
MRP II	Manufacturing resource planning
MSV, VSM	Viable System Model
MTBF	Mean Time Between Failures
MTO	Make-to-Order

Symbol / Abbreviation	Meaning
MTS	Make-to-stock
MTTR	Mean Time To Repair
NASA	National Aeronautics and Space Administration
NPO	Non-Profit Organization
NPR	Risk Priority Level
NWC	Net Working Capital
ODAM	On-Demand Air Mobility
ODS, SDG	Sustainable Development Goals
OEE	Overall Equipment Effectiveness
OEM	Original Equipment Manufacturer
OPM	Operational production management
OR	Operations Research
OTD	On-time delivery
P	Parallel
PA	In parallel and after
PCP / PPC / PPS	Planning and production control, Produktionsplanung und -Steuerung
PDCA	Plan, Do, Check, Act
PERT	Project Evaluation and Review Technique
PF / PP	Production plant
PF-1	Push and Fixed
PF-2	Pull and Fixed
PLC	Programmable Logic Controller
PLM	Product Lifecycle Management
PMP	Master Production Schedule
POLCA	Paired-cell Overlap Loops of Cards with Authorization
PP 1	Preventive and Pull
PP 2	Preventive and Push
PT	Production Technology
PV-1	Push and Variables
PV-2	Pull and Variable
QFD	Quality Function Deployment
QRM	Quick Response Manufacturing
RBV	Resource-based View
RCM	Reliability Centered Maintenance
RDT	Resource dependence theory
RFID	Radio Frequency Identification

Symbol / Abbreviation	Meaning
RI	Industrial Revolution
ROCE	Return on Capital Employed
ROI	Return on Investment, Return on investment
RP	Reorder-Point, Reorder-Point
RRHH	Human Resources
RSC	Corporate Social Responsibility
RSQ	Return on Service Quality
RT	Replenishment time
RTLS	Real-time location systems
S&OP	Sales and operations management
SC	Supply Chain
SCADA	Supervisory Control And Data Acquisition
SCM	Supply Chain Management
SCOR	Supply Chain Operations Reference
SD	System Dynamics
SGI	Innovation Management System
SIM	Social issues in management
SL	Service level
SM	Simulation Model
SMED	Single-Minute Exchange of Die
SMS	Service management systems
SPC	Statistical processes control
SPCMM	Generic software process capability/maturity models
SS	Safety stock
SW	Software
TBC	Time based competition
TD, DT	Doctoral Thesis
RAMI 4.0	The Reference Architectural Model Industry 4.0
TIC	Technologies of information and communication
TL	Control and prevention of technical limitations
TOC	Theory of Constraints
TPM	Total Productive Maintenance
TPS	Toyota Production System
TQM	Total Quality Management
TTM	Time-to-market
TTS	Transport, transshipment, and storage

Symbol / Abbreviation	Meaning
UE	European Union
UN PRI	United Nations Principles for Responsible Investment
UNGC	The United Nations Global Compact
USP	Unique Selling Proposition
US SIF	The Forum for Sustainable and Responsible Investment
VDI	Verein Deutscher Ingenieure
VDI-Richtlinie	Guideline of the association of German engineers
VR	Virtual reality
VSM	Value Stream Mapping
WCED	World Commission on Environment and Development
WIP	Work In Progress

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1. Introduction

1.1 Historical evolution, current situation and identification of the problem

1.1.1 Background: Historical evolution

In the last 60 years there has been a market transition from a focus on producers to a market focus on customers [1]. During the 1950s and 1960s, each operation within each stage of the supply chain tried to minimize its own costs, which defined a framework of internal operations within the company itself [2]. In the 1970s the scope was expanded to include the optimization of multifunctional processes [3]. On the other hand, quality issues came to the forefront of business management and Total Quality Management (TQM) was established [1]. The pressure on costs already established in the eighties, caused by the saturation of the markets and the growing competition, created new requirements for quality and efficiency in the management of business processes [4]. Later in the 1980s and 1990s, companies were challenged by a variety of product ranges and ever shorter Time To Market (TTM). Thus, the reaction time to the market emerged as a critical factor for the purpose of cutting TTM [1]. But it was in the 1990s, when companies recognized the need to look beyond the borders of their own companies to their suppliers, providers, and customers to improve the total value of customers and consumers. This movement, called supply chain management or demand chain management, changed the focus of companies from internal management of business processes to management across companies [5]. The development of supply chain management was driven in the 1990s by three main trends: customer orientation, globalization of markets, and establishment of an information society [1]. This led to a global integration of value chains and the optimization of global logistics networks in the 2000s [4]. The importance of logistics management will continue to increase in the future due to the requirements of an ever-changing business. The changeability of logistics systems is now the focus of scientific research [3].

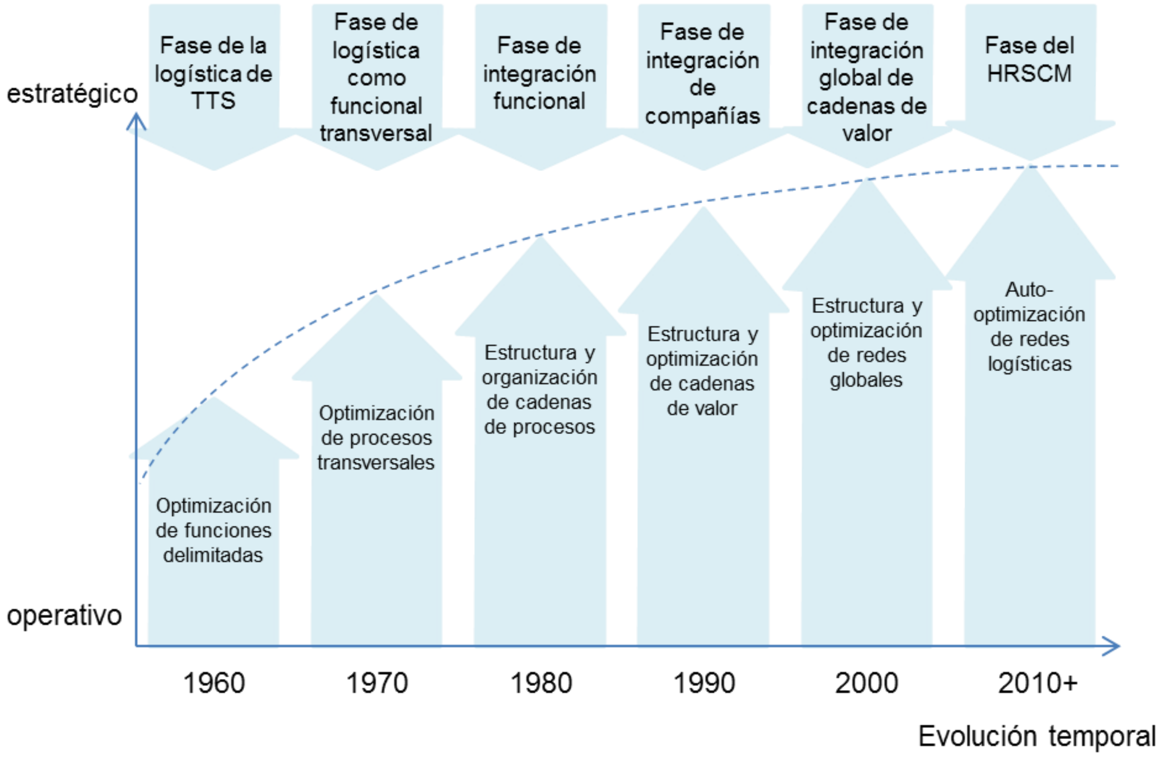

Ilustración 1: Development phases in logistics management (own elaboration based on [3])

1.1.2 Problem identification

Globalization and the increasing virtualization of business relationships have greatly expanded the complexity of logistics challenges since the 1980s. With the interconnection between product flows, logistics has only recently begun to consider the entire supply chain as one. company instead of considering only the company [3]. Global logistics flows have increased dramatically in recent years due to the globalized world economy, which has introduced challenges inherent in establishing international business [6]. This international competition is most evident when meeting the service level in terms of delivery date, delivery reliability and delivery method, which increases the pressure on supply flexibility [7]. In addition, demand volatility in almost all industry sectors appears to be higher than in the past due to shorter product and technology life cycles, sales promotions, quantity changes, and unplanned outages [8]. At the same time, many producers face volatile and non-transparent behavior in demand, causing large deviations in sales forecasts [9]. Other causes that originate this volatility are the variability caused by the final customers favored by the competition options, as well as by minimum quantities in production and deviations in delivery terms [10]. Thus, forecast errors have grown steadily in recent years, despite the use of information systems for this purpose [8]. The conventional response to this challenge of uncertainty is to increase the safety stock to guarantee the expected level of service [10].

The trends shown have led to an increase in the complexity of relationships and processes [11] between the agents of the supply chain. In this context, being able to cope with changing customer needs, demand volatility, and new product launches are becoming increasingly important factors in gaining competitive advantage [12]. This fact is changing the prioritization of supply chain objectives towards customer service, delivery performance and flexibility, instead of relying solely on costs [13]. With this objective, many companies are organized in cooperation networks to achieve synergies between them [14]. Through this intensification of cooperative work, the objective is to improve the adaptability of the supply chain as a whole and to provide a profitable supply to the market [15]. For this, robust and reliable plans are key to optimizing costs and ensuring the long-term success of the parties involved throughout the supply chain [16]. The objective of supply chain robustness is defined as the ability of a system to cope with disturbances, deviations, and changes without modifying the structure of the system [17]. This objective is continually increasing its relevance as a strategic objective for any type of organization to ensure its competitiveness and to provide the necessary services for the sustainability of the organization itself and the related environment. Therefore, the ability to adapt is a key challenge today, and even more so, after supply chain disruptions associated with unexpected events such as the COVID epidemic, supply crises of specific materials and components such as semiconductors, as well as due to the consequences of the war in Ukraine, the blockade of the Suez Canal, tsunamis, volcanoes, etc.

In this context, the current planning methods in most organizations are not appropriate for the existing processing and availability of information in real time, which generates unexpected deviations that cannot be corrected in the short term [18]. Despite this, conventional planning methods based on average values are widely used in practice [19]. In this way, with high frequency constant values are determined in the planning systems [20], updating the planning parameters in long intervals of time, generally annually [21]. Therefore, planning is carried out based on input data that is outdated and far from reality, which means that the quality of the planning is in many cases insufficient. Another aspect that limits the quality of planning is the performance of partial planning, which usually presents contradictory results, offering inconsistent solutions [22].

Disturbances in production and in the supply chain generate uncertainties that generate the need for coordination of planning processes, which has not been considered methodically, therefore, there is a need to develop new methodologies [23]. Therefore, the planning systems today due to the insufficient use of information lead to delays and deficits in the transmission of information that must be compensated with additional costs [21]. In this context, the success of the parties within a supply chain will be determined in the future by the ability to identify disturbances early to compensate for such problems with adequate planning models that ensure a high quality of planning [24]. This evolution is combined with the demands of customers who want to be served with shorter delivery times [25]. The success of the actors involved in a cooperative supply chain depends critically on the extent to which they are able to cope with the dynamic requirements of the market [6]. Robust systems avoid negative effects by identifying possible disruptions and allowing early adaptation [26]. Real-time information and its processing can give the right answer on how to deal with the ever-increasing dynamic requirements. However, the current planning and control logics do not provide the necessary support for this, which causes unexpected deviations in planning that cannot be compensated in the short term [17].

In a rapidly changing environment with increasing volatility in demand, shorter product life cycles, new technologies, and new business regulations, balancing supply capacity and market demand is a challenge for organizations around the world. In this context, an organization's ability to change as an adaptability characteristic is key to ensuring its viability. Consequently, global managers are under increasing pressure to make decisions faster. Although new technologies open new possibilities, many managers, even in well-established companies, do not have a system or a virtual digital twin that allows them to foresee the expected results of the decisions they must make. Neither complete information nor all the implications of a decision are adequately considered in most organizations. Because of this, many managers generally decide to start a data collection process for analysis as a basis for decision making. This process usually involves different areas. Therefore, the decision is delayed in time until the decision is made, which implies delays with negative implications such as the possible loss of profit generation or the worsening of customer service [27].

The need to respond to demand uncertainty is a necessity. The current situation, characterized by epidemic crises, product changes and deviations in the replenishment time, can generate shortages and a high level of inventory required to provide a given service level. People affected by potential supply shortages are at great risk [28] as it was the case with the global COVID-19 crisis when companies speculated on the supply side, reducing it to increase margins due to customer demand. In doing so, the purpose of a company to provide goods or services to society is not given. Further theoretical development is likely to be required and methods need to be developed that determine inventory levels based on measures other than cost. Furthermore, the use of cost minimization as a performance measure is unlikely to provide sufficient importance to meet the requirements of users and society. Generalizing, to consider models in terms of utility may be intellectually satisfying, but it leads to equally difficult measurement problems [29]. In this sense, COVID-19 had important economic consequences worldwide [28]. This situation demonstrated the future risks and the current fragility of the global health infrastructure, such as the lack of medical resources and equipment [30]. Consequences have included production stoppages due to lack of raw materials, while other producers have had to scale back or shut down production because finished products could not be shipped abroad. Therefore, there is an urgent practical need to increase the adaptability of organizations to be able to react to unforeseen events, such as COVID-19.

In this context, Industry 4.0 (I4.0), with cloud manufacturing, Internet of Things (IoT), big data analytics, and digital twins, can improve performance in these scenarios [31]. Recent research has pointed to the new opportunities to reduce the risks of disruptions using data-driven approaches, while analyzes of the evolution of COVID-19 provide significant evidence on the urgent need for digital twins of the supply chain [32]. In addition, simulation can help to determine the best policies to solve the adaptability challenges of organizations, such as analyzing the impact of investment and inventory planning, as well as Industry 4.0 approaches, such as the Industrial Internet of things [33].

1.1.3 Definition of the Research Topic

Since the first industrial revolution, each industrial revolution has resulted in advances in manufacturing [34], and the development of industry has had a profound impact on economic and social progress [35]. Human society has sought progressive improvements in the quality of life, which, in large part, has inspired these industrial revolutions [36]. For this purpose, efforts have been made in research, development, production, and management of complex industrial processes using the innovative production technologies available at that time [35]. In this context, today's companies compete more and more on time and quality [37]. Global competition is increasingly intense and the market, in addition to demanding higher quality, a greater variety of products and lower cost, also demands the delivery of products with shorter delivery times [38, 39].

Many approaches have been considered to make operations planning as efficient and flexible as possible. They all pursue and many theoretically achieve partial or total optimization of global production systems, making them efficient. However, when applying these theoretical models of logistics management to practice, information systems must be used as a vehicle to communicate the necessary information to be managed within the organization. The reasons why most of the applications of this type of concepts in information systems, such as in ERP (Enterprise Resource Planning) systems, have failed are: the delay or lack of information, the misuse of planning, lack of coordination or conflict of interest between departments, failure to consider the environment and the requirements of the end customer in a dynamic process of continuous improvement, leading these models to make strategic, tactical or operational decisions at the optimal time nor with the best consideration. In this process, the theoretical system is transformed by introducing distorting factors such as delays in communication, human errors, non-availability of facilities and machinery, logistics flow stops, quality failures, etc. because current production systems are subjected to the growing complexity of the production mix, the reduction of production batches, the increase in data transmission, etc. All this makes the theoretically effective, efficient, and flexible system to become a system that is only effective, efficient, and flexible to a certain degree. Thus, today a company is highly influenced by its environment. Furthermore, how to deal with it is a big challenge and in a highly competitive world it is essential to quickly adapt to changes to be successful. For all these reasons, the ability to choose and manage planning tools, as well as their application and use in information systems, acquire great importance as an indicator of competitiveness and therefore as a way of ensuring the long-term viability of an organization [40].

For all these reasons, this document attempts to respond to those managers and their planning challenges for decision support including key technical, managerial, and economic performance indicators [41]. In addition, based on the arguments presented, the research topic addresses, among others, improving inventory management in the face of highly uncertain demand [42] to reduce reaction times to changes, and the optimization of stocks for a required service level as a guide for managers [42]. Some of the situations mentioned above will depend on a specific event with unknown probability and unknown timing, leading to high risk levels and consequences [43] for society and organizations, for example COVID-19 or new entries to the market of competitors.

The current management and planning situation puts pressure on organizations to maximize the efficiency of their operations and on manufacturing to meet customer requirements. To achieve this goal, intra-organizational logistics management must not only manage what exists in its structure, processes, systems, and defined assets, but must also improve continuously to have a greater capacity for adaptation that ensures the viability of the organization in the long term. In this sense, a wide range of methodologies are available, including Lean Manufacturing (LM), Six Sigma (6σ, Six Sigma), Theory of Constraints (TOC), Quick Response Manufacturing (QRM, Quick Response Manufacturing) and Agile Manufacturing (AM, Agile Manufacturing) which are among the most popular methods in the academic literature [42, 44, 45]. Many separate philosophies have evolved to achieve competitive goals. Lean manufacturing provides operational efficiency and benefits to manufacturing companies [46]. The problem has been that the literature advocates "full" adoption of lean production principles, while empirical evidence indicates that partial adoption is more effective [47]. Regarding the research on implementation cases and results, it should be noted that it is still in a stage that needs to be developed [48]. Companies have to analyze, monitor, and make improvements to their existing manufacturing systems to meet market competition. Different companies use different methodologies, approaches, and tools to implement programs for continuous quality improvement. In addition, each company must use a selection process and a combination of different approaches, tools, and techniques that they can customize for their implementation [49]. However, none of them is capable of providing all the desired functions [50], so for that reason, the research topic will address the analysis of an approach that is concerned with how to cover all the necessary functions, including forms. in which these systems complement each other [51].

The growth of industrial productivity has always been influenced by the increasing capabilities of technologies. Now, the fourth industrial revolution is emerging, although it has not yet been fully implemented [52]. The integration of I4.0 technologies is expected to bring significant improvements [53]. In addition, this new industrial scenario requires a sociotechnical evolution of the role of the human factor in production systems, in which all labor activities in the value chain are carried out with intelligent approaches and based on information and communication technologies (ICT) [54]. Today, global competition is becoming more intense and new technological advances are constantly being developed. Therefore, to meet market requirements effectively, organizations must continually improve their overall operational performance. To achieve this goal, a wide range of enhancement strategies are available [39], such as those described above. In this context, the integration of both the spheres of lean manufacturing and other improvement strategies and Industry 4.0 is an important research field that needs to be explored extensively [55]. Several studies have studied the compatibility and integration of lean management and Industry 4.0 within an organization [56]. In this context, it should be considered that organizations have not implemented the full potential of Industry 4.0, although many researchers and companies are working on this topic [57]. However, there is still a long way to go to improve manufacturing to the required level [58]. Furthermore, although information technology (IT) is already at the heart of manufacturing, and technological innovations have been used by manufacturing companies for decades, they have provided limited benefits so far. In other words, the full potential of these technologies has not been exploited [59]. As a result, Industry 4.0 is increasingly being explored by academics, researchers, practitioners, and other relevant stakeholders. As a result, there are high expectations in both the research and business communities that such technologies will penetrate manufacturing supply chains and the service sector [60]. Previous academic research and white papers have summarized the main technologies related to Industry 4.0; however, these do not address how companies that offer or implement manufacturing technologies are adapting to implement and offer Industry 4.0 solutions [61]. Therefore, the effective implementation of Industry 4.0 technologies remains a research topic [54]. In addition, there is a lack of studies that provide empirical evidence on how these technologies are adopted in industrial companies [54]. In this context, several maturity models have emerged to provide recommendations for the future implementation of Industry 4.0-related technologies, techniques, and methods. Therefore, an organization can determine improvement potentials based on the maturity level results [62]. In this way, many companies face the challenge of evaluating the diversity of developments and concepts summarized under the term Industry 4.0 and developing their own corporate strategies [63] for the integration of the Industry 4.0 concept [61], resulting in a need to help organizations in their business transformation process to the Industry 4.0 environment and guide them to improve their capabilities [63]. From a sociotechnical perspective, it is recognized that the adoption of emerging Industry 4.0 technologies needs at least three complementary sociotechnical dimensions: work organization, human factors, and external environment [64]. To implement Industry 4.0 in a standardized way, one of the biggest challenges is how to convert data into valuable information that will facilitate decision making. With this objective, systems theory appears as a formal method of analyzing this challenge, since it focuses mainly on the interaction between the main components of the system and considers organizations as integral and complete entities [59]. In addition, there is a need for research in terms of the analysis of the return on investment (ROI) of advanced technological innovations of Industry 4.0 in organizations [59]. The definition of a suitable strategy to implement I4.0 technologies and the opportunities in business models are two important trends that should be further explored in further studies [61]. In addition, it is also necessary to study the effect of technologies related to Industry 4.0 on industrial performance; Although there are studies at the industry level, it is still necessary to study how these technologies impact industrial performance at the company level [54]. Based on the literature, the main research gaps can be summarized as follows:

1. Integration models of improvement strategies and Industry 4.0 technologies [56, 63].
2. Models and sequences for the successful implementation of I4.0 technologies within manufacturing organizations [54, 61, 63].
3. Models for the evaluation of the maturity to standardize the introduction of Industry 4.0 technologies, including the evaluation of the impact after its implementation [54, 63].
4. Models for the evaluation of optimization alternatives in Industry 4.0 environments [54, 59, 63].

5. Quantification models for the evaluation of specific use cases in Industry 4.0 environments [54, 59].

Based on the aforementioned research gaps, as well as considering that some of these gaps have been analyzed for decades [59], the research to be carried out acquires greater relevance and transcendence. Thus, the objective of the study is to address these challenges with a unique approach that goes from the generic perspective of the strategic integration of various methodological and technological optimizations to specific use cases through a continuous business transformation model based on functional maturity of the organization [65]. Currently due to the advent of the Industry 4.0 concept and digitization initiatives, many managers and companies act as “tech freaks”, forgetting any other strategy and method and focusing solely on developing and implementing new technologies. As a result, they have initiated and implemented technological projects related to I4.0 without considering a "360" evaluation, so they lack a real need and purpose and do not contribute more than the implementation of an "interesting technological device or system" incurring in the waste of different resources of the company, such as time, money, etc. Thus, the research aims to analyze the real needs of the organization in the main areas and factors for each function, as well as in the market that allows continuous business transformation that is aligned with the current and future organizational capabilities required. In addition, the research aims to analyze the main areas and intra-organizational factors to determine the current maturity level of organizational capabilities [65]. Even with a business transformation model and areas and factors to identify gaps in organizational capabilities, professionals are often confused about how to integrate improvement strategies and new technologies, as well as how to assess their suitability. For this reason, this paper seeks to provide a model for the integration of relevant improvement strategies and new I4.0 technologies that can be applied to any organization with a novel approach that serves as a guide to develop optimization roadmaps. In addition, the research develops an evaluation scheme for new initiatives within organizations [65].

After having analyzed the management (Run and Change) of an organization from its planning and control approach in its current situation (Run) as well as its changes based on improvement strategies and available technologies (Change), the topic of The research also considers Corporate Social Responsibility (CSR) as a central element of the TD, since all the planning and control of operations of any type of organization as well as any change or improvement that is introduced must be oriented towards the ultimate purpose of the organization. This purpose is defined by CSR in the company's relationship with its environment, reflecting the normative approach of the organization. The evolution of CSR research has been classified into three types of studies: before the introduction of CSR, of the results after its introduction and of the processes related to CSR such as decision making, the interpretation of groups of interest etc. [66]. With an increasingly interconnected global economy, as well as the globalization of social practices, visions of CSR in different institutional contexts may converge or establish different balances [67]. The dilemma arises in the role of multinational companies, which increasingly face the challenges of CSR simultaneously in multiple and diverse institutional settings. A specific challenge for multinationals is how they meet the expectations of their various stakeholders across national borders [68].

The usefulness of considering the concept of CSR, not only by companies but also by the State, is the improvement in competitiveness that has been presented in numerous studies. However, there is still the question of reconciling the economic orientation of the company with its social orientation [69]. Carroll suggests that four types of social responsibilities make up total CSR: economic, legal, ethical, and philanthropic; All these types of responsibilities have always existed to some extent, but only in recent years have ethical and philanthropic functions taken on a significant place [70]. In conclusion, to implement a CSR strategy in the culture of a company and make people understand the benefits of considering the CSR concept, it is required that senior managers clearly and consistently express their commitment to the strategic initiatives that they the organization decides to adopt [71]. According to Carroll (1991) "Social responsibility can only become a reality if more managers become moral instead of amoral or immoral" [70]. In this regard, it is key to investigate the CSR theories and models to be considered by an organization to improve its sustainability, applying it at all levels from regulatory to operational, allowing all projects, processes, and activities to be aligned with the values and principles as well as with the organizational strategy that allows optimizing the level of adaptability and resilience of the organization in the face of any event and future situation.

1.1.4 Justification of Research Interest: Current Situation

Throughout history, human beings have sought ways to satisfy their needs effectively and efficiently through the development of sciences that allowed the accumulation of knowledge that we now call culture. This culture has continued to evolve to this day. However, currently we do not use all the potentialities of this culture due to a substitution process [72]. In addition, the ways in which we have satisfied the needs of society have changed throughout history. First groups or communities were formed, then agriculture and livestock appeared, and the first communities were established in fixed places, and then there was a long period until the first industrial revolution in which the economy was based on agriculture, livestock, and processes to produce handcrafted goods such as military weapons. Thus, trade had a local and regional character until the appearance of global routes across the oceans, such as those initiated in the Age of Discoveries in Portugal and Spain. Finally, the first two industrial revolutions allowed the mass production and international trade of goods, and the third allowed information services to be accessible in a decentralized manner. Throughout this historical evolution, the satisfaction of needs has had varied responses, although always with a pattern: the possibilities and capacities to satisfy them have increased. However, the world of the 21st century is one in which the basic needs of millions of human beings are still not satisfied. Why? For centuries, states have presented social organizations and measures to alleviate the lack of distribution of goods and services, however states, companies, as well as non-governmental organizations have not managed to achieve adequate welfare rates in vast areas of our planet [72]. On the other hand, Lupton and Miller argued that when we do for those in need what they have the ability to do for themselves, we disempower them. Therefore, it is advocated to empower those who need it so that they can finally find their own solutions [73] and thus help to improve the global situation of meeting the society needs.

On the other hand, in the last two decades, the challenge for companies has changed from deciding whether to be socially responsible to how to carry out CSR strategically and effectively, with clear and demonstrable predictions of the beneficial impact on society. However, many companies face significant challenges, mainly for two reasons [74]:

1. The effectiveness of CSR efforts is often difficult to observe due to a lack of transparency in objectives.
2. Second, CSR encompasses multiple dimensions and conflicts between interest groups can arise. Managers face challenges in prioritizing and balancing aspects of CSR.

The first theme refers to the measurement of effects, and the second theme refers to the influence of the human factor in the prioritization and decision making of managers. Human motivation has a significant impact on the latter. Therefore, the human factor positively or negatively influences the performance of an organization within its area of influence. Today, managers can assess effectiveness but find it difficult to assess the behavior and efficiency of their employees. Also, in large companies, it can be difficult to track the reasoning and/or decision-making errors and deviations of various departments. Furthermore, optimization projects (internal or with external consultancy) generally require long periods of analysis and mapping processes to determine weaknesses and potentials for improvement. In this sense, the human factor within an organization is key to its organizational performance and impact on society. Human beings within organizations make decisions based on their motives. Therefore, the ethical values of each person have a significant influence [72]. Today, governments, private companies, and charities provide vast amounts of information on topics such as need satisfaction rates and the values of goods and services. Based on this information, it is necessary to develop a normative and methodological model to distribute resources without excess or scarcity, as in situations of food crisis [72].

Regarding the supply chain, the justification and interest of the research is consolidated from the point of view of intra-organizational logistics management. Manufacturers' markets that were stable in the past are now dynamic and uncertain, and prices have fallen in recent decades [75]. At this time, many manufacturers, such as companies in the metal sector, which work for specific needs and end market segments such as the steel industry, are under pressure; current overcapacity is destroying prices and profitability [76] and many producers have closed facilities, made layoffs, and gone bankrupt in recent years [77]. The excess capacity created has been fueled in recent decades by new investments by old market leaders, as well as by new companies from emerging markets, such as China, which now has two-thirds of the world's excess capacity, for example in steel [77], but also much of the world's capacity in other manufacturing sectors. In response to this situation, companies continually seek ways or methods to reduce costs and delivery times, as well as increase their external flexibility [75]. There is limited research in the literature related to supply chain management in the low-volume Engineer-To-Order (ETO) sector, in contrast to the extensive literature on the high-volume sector, particularly automotive and electronics [78]. Therefore, there is a need for research in production control, information systems, manufacturing systems and the coordination of sales and production [75], in short, although some sectors have been analyzed in more detail, all need to know the potential in methods, technologies, systems, organizational structures that will allow them to be competitive and sustainable in the short, medium, and long term. In this global market situation, today's producers need to work on their technological and organizational advantage. As for the technological advantage and the possibility of making use of it, it will depend on the frequency of innovation in the sector under consideration. On the first potential Unique Selling Proposition (USP), the technological advantage, almost does not exist anymore for the US, Japan, or Europe countries in many industrial sectors, as many companies around the world have access and have invested in new equipment in recent decades and years, mainly in developing countries [79], such as Korea, Taiwan, Brazil, and China [114]. This more or less pronounced development has occurred in most sectors due to globalization, economic cycles, and the increase in global exports of machinery, installations, and equipment that have caused that in many sectors and applications the technology-based competitive advantage is considerably lower than it was decades ago for countries like the US, Japan, or Europe. In these countries, companies are asking what options remain to improve their competitive position and shape a long-term profitable business model. Furthermore, restructuring programs based on cost cutting programs will not be enough to achieve sustainable returns. For this reason, producers must focus on the second potential USP, the competitive advantage based on the functionalities and capabilities of the organization and its human capital that allow improving quality and service as well as adapting to any possible environment and scenario. Therefore, companies have identified the need to optimize internal processes, thanks to improvement strategies, digitization, and the technologies of the fourth industrial revolution, as well as orienting themselves towards sustainability based on both economic and ESG criteria (Environmental, Social, Governance) based on CSR. Based on this, it is expected that they will lead to a systematic optimization of organizational processes and structures that ensure a better service level for end customers, while improving their ability to adapt to any scenario in the supply chain and the environment in which they operate. the area of influence.

On the other hand, it should be considered that there is a complex and multidimensional relationship between innovation and competitive advantage [80, 81], in which sustainability plays a primary role. Therefore, innovation must be characterized by sustainability [82]. By way of example, the competitiveness of steel production is based on a set of internal comparative advantages, such as labor costs, a consistent economic and foreign trade policy, long-term work experience, energy prices or an organization of the highly efficient work [83]. Based on this, the EU is losing competitiveness in those market segments in which it is not possible to apply other competitive advantages such as innovation, know-how or scientific and research results for commercial purposes [83].

In this context, sales and operations planning (S&OP) can improve an organization's alignment with its suppliers and customers, leading to positive effects on operational performance. Although S&OP practices are associated with positive effects, it is not clear how they are used to achieve these benefits [84]. Current gaps and challenges for S&OP research include the following:

- Gap 1: the integrated S&OP system approach: S&OP process as part of an integrated planning system in which strategic planning is transformed into operational plans. Therefore, these types of studies are absent in current S&OP research and the association of S&OP with risk management is a key area for S&OP studies [84]. As a result, this gap seeks to develop holistic approaches to integrate supply and demand balancing with strategic planning [85], as well as to develop operational measures and measurement approaches to operationally assess S&OP performance [84].

- Gap 2: S&OP in specific environments [84]:
  - Industry: S&OP analysis in all industries.
  - Organizational: Impact of organizational characteristics on S&OP.
  - Complexity: S&OP must handle different complex scenarios to manage the dynamic supply chain with variations and uncertainty using, for example, scenario planning as a key S&OP capability.
- Gap 3 – Collaboration in the supply chain and marketing function: less than 15% of theses related to the balance between supply and demand are published in academic journals. Considering the critical role that marketing and sales play in the demand side of the S&OP process, this lack of research studies in the area creates an opportunity to optimize supply chain collaboration [85].
- Gap 4 – Anticipate the effect of factors on demand: in S&OP for a supply chain, the producer must be able to identify and anticipate the effects on demand when a change in a factor occurs, such as in the product portfolio. Studies in this area seek to estimate how and why demand will change over the planning horizon, depending on various factors [86].
- Gap 5: Big data and predictive analytics: Research in this area can improve S&OP capabilities [87]. In addition, this area seeks to develop sales forecast management as an organizational capability [88].

But not only in the management of operations, production and sales, new approaches are necessary, maintenance is facing great challenges and opportunities. In the past, it was believed that each component of a complex system needed a complete overhaul after a certain time to ensure safety and optimal operating conditions, being this approach the basis for scheduled maintenance programs [89]. Studies in the aviation industry revealed that scheduled overhaul does not have much of an impact on the overall reliability of a complex item unless there is a dominant failure mode. These findings redefined maintenance thinking, by focusing on system function rather than operation [89]. Therefore, more companies and entire industries have been forced to increase their research, development, and design activities oriented towards system functions and system condition. On the other hand, in the literature there are concepts and mathematical formulations on how to solve the distribution of spare parts, for example, for aircraft fleets such as the METRIC model that provides a method to optimize supply, distribute the existing stock and redistribute the stock of spare parts. a network of spare parts for a given level of investment [90]. However, disposal options for specific industries in different business scenarios have yet to be explored. There is a need to develop comprehensive strategic decision models to identify the conditions under which each alternative should be selected. There are very few studies on disposition decisions, and it offers great potential for future research [90]. Future research in maintenance management seeks the development of optimization models capable of incorporating information on repair and maintenance strategy and engineering management policies [91]. In this context, the development of simulation-based models has a high potential to provide practical guidance with different maintenance strategies and policies [92]. In this sense, preventive maintenance and the frequency of preventive maintenance are a focus of research [128]. As an overview, the gaps in spare parts management lead to four future research areas: developing integrated approaches to spare parts management, defining managerial guidelines, developing maturity models as diagnostic tools, and evaluating the benefits of methods in modeling spare parts. theoretical models in case study applications [93]. In addition, the spare parts distribution strategy faces two different main options, the allocation of spare parts in a central warehouse or in local or regional warehouses [94]. These options address the strategic dilemma of defining push, pull, or hybrid push-pull distribution strategy when designing the structure of the distribution network.

Industrial companies still face great challenges because of unexpected failures. Due to increasing technical maturity, industrial sectors are also dealing with a large amount of data. In this context, production systems need to introduce sustainable alternatives based on new technologies to identify disturbances within the production system at an early stage and even prevent them before they occur [95]. Data mining technology provides new advances in failure prediction to reduce machine downtime, optimize resource utilization, and increase production volume with potential reduction in maintenance costs [96]. Most of the industrial processes that we know today are very specialized, depending on their parts and interrelationships. In this context, a system that deserves much more attention is systems built with parts that have multiple equilibrium states [97]. The demand for adaptive manufacturing systems has increased in recent years due to the constant changes in the market [98]. Furthermore, the joint impacts of decisions belonging to different productive areas that are traditionally considered in isolation, such as logistics, maintenance, and quality, are difficult to predict [99]. In this sense, digital twins (Digital Twin, DT) are a proven tool to support the evaluation and control of manufacturing systems [99], helping to increase the flexibility and robustness in unexpected conditions [38] of the manufacturing system. At the same time, if combined with computing, networking, and physical process capabilities, it can bring new functionality to management processes and support systems that will help organizations to have better, more automated architectures [100]. In addition, a DT model makes it possible to represent the current state of the manufacturing system and perform real-time optimizations, supporting decision-making and predictive maintenance based on the actual condition of the system. Research on DTs is still in the early stage, and there is a need for future research [38] that requires real-time synchronized simulations of production system operations to fully test them [101]. While independent simulation of certain aspects of product and manufacturing planning is possible, comprehensive simulation of complex manufacturing processes is costly and time-consuming, as interoperability between heterogeneous IT (information technology) tools generally does not occur [102]. Furthermore, current manufacturing has not reached the level of Industry 4.0, although many researchers and companies are working on this topic. Many current manufacturing systems are capable of covering some of the Industry 4.0 concepts [103]. There are various models pursuing the integration of I4.0 in an enterprise using different maturity models such as web-based self-assessment tools, etc. A well-known model is The Reference Architectural Model Industry 4.0 (RAMI 4.0) [104]. RAMI 4.0 was developed in 2015 and consists of several layers, hierarchical levels, and the product life cycle that represents the value stream [105]. RAMI 4.0 provides a holistic view of all the important aspects of I4.0 needed by different stakeholders and provides general guidelines for the entire organization but does not prescribe a specific modeling approach [106]. Therefore, this research aims to apply a novel methodology to model and evaluate manufacturing systems and processes suitable to consider all the relevant elements of any system and process in I4.0 environments [107]. However, there is still a long way to go to improve manufacturing to the required level [58]. Therefore, there is a need to investigate how to model self-organizing manufacturing systems, deduce their dynamic behavior and develop appropriate control methods. However, theories about self-organizing systems are not mature and complex systems research is still a hot topic [36]. Therefore, while RAMI 4.0 developed a holistic consideration for the implementation of Industry 4.0, the methodology and the specific application developed in this document provides general guidelines, areas, factors, and parameters to consider and model to evaluate any process and, by aggregation, any manufacturing system applicable to specific use cases, such as those related to I4.0 manufacturing environments.

Based on the arguments presented, the need to innovate is imperative, but at the same time, innovating is not easy. Innovation efforts over time have resulted in a multitude of failed innovation projects. Even large companies that were once pioneers and creators of entire markets failed to stay competitive when changes occurred [108]. Nowadays, innovation is no longer conceived as a specific result of individual actions, but rather as a holistic vision of innovation that leads to the challenge of transforming information into knowledge [109]. In this context, several countries chose to create innovation regulations that would help companies in the way they managed their innovation systems, processes, activities, or initiatives. The creation of these standards necessitated a unified international standard, the ISO 56,000 series. This seeks to reference some of the best practices among the different actors in the innovation process [109]. This series does not provide an integrated system for the management and monitoring of innovation projects [110]. Innovation is the basis for the development of human wealth. Therefore, innovation management plays a fundamental role in knowledge generation, resource allocation and investment planning. However, innovation management needs to consider organizational capabilities and goals in relation to their environment to remain competitive in the face of change [109, 110, 111]. Therefore, a continuous development of innovation is necessary to generate companies and maintain and improve the competitiveness of existing organizations. Therefore, an innovation strategy must be closely linked to the vision of the company and the global business strategy, and be based on complete and relevant information, both from within the company and from the market and the environment [112]. Research on the innovation process in and between organizations has evolved as a multidisciplinary effort. Most studies in the use of limited research traditions. Therefore, there is a research gap in the study of organizational innovation [113]. In addition, there is a lack of standards for the effective management of innovation projects according to their type [114]. The selection of innovation projects is a dynamic decision-making process that involves the evaluation, decision, and allocation of resources. In this context, there is a research gap on the quality of the decision-making process [115]. Considering that innovation does not always mean using the latest technology, innovation management techniques and tools can help companies adapt to circumstances and meet market challenges systematically [111]. According to Liberatone and Stylianou, only 14% of innovations are significantly successful. Several authors have shown that better innovation management can increase the chances of success. Consequently, the effectiveness of the innovation process must be evaluated using financial and non-financial criteria at all stages [116] with both qualitative and quantitative factors. In this sense, such an approach does not exist and, therefore, there is a gap in practice and research in the measurement of innovation performance [117]. The challenge is to adopt a new mindset to master a new innovation management model [118]. Innovation management needs to use new innovation evaluation methods at different steps of the innovation process [118]. In this context, there is a need to implement a systematic measurement of innovation activities over time based on a combination of quality management and innovation management in an integrated management system [109].

1.1.5 Justification of the thematic scope of the Doctoral Thesis

The Doctoral Thesis (TD) is included within the Industrial Technologies Doctorate Program in its Productive Systems research area, since the objectives and development of the thesis and associated publications deal with the intra-organizational logistics system with its associated flows such as the flows of material, information, financial, as well as the rest of the flows of an organization in its internal performance such as the flows of energy, personnel, etc. in their different time horizons. The focus resides in any type of organization, that is, in manufacturing industries and assembly lines, as well as in service organizations and the primary sector, both public and private. Therefore, a conceptual model is developed based on an extensive bibliographic review to derive an organizational systems design methodology that allows ensuring the sustainability of the organization, its stakeholders and the related environment through the application of the CSR concept that allows optimizing the satisfaction of business objectives, as well as social, environmental and governance objectives. Therefore, the organization intends to meet the objectives of meeting the needs of its stakeholders as well as the Sustainable Development Goals, seeking to act as an effective and efficient system. To verify this, it is implemented in different areas of the organization, analyzing the contributions to sustainability of each of the different parts of intra-organizational logistics based on a study of the current situation to derive scenarios and results for cases of application belonging to sectors of companies from the first sector, as well as from the industrial and service sectors to derive interpretations and conclusions on the normative, strategic, tactical and operational levels to improve the adaptability of the organization ensuring its sustainability and of the environment in which it influences at different time horizons.

1.1.6 Goals and Research Question

1.1.6.1 Research Question

Developing organizations capable of meeting present and future competitive needs is a challenge [3]. Therefore, many companies lose competitiveness due to a slow adaptation to their environment. In addition, in all sectors, organizations find themselves in an environment with increasing competitive pressure [119]. The main factors that favor this situation are the growing globalization and the consequent situation of competition that causes an intense reduction in product life cycles as well as a growing individualization of final products according to specific customer criteria [120]. In this context, human society seeks a progressive improvement in the quality of life, and industry has contributed to achieving this goal through the industrial revolutions [36]. Since the first industrial revolution, subsequent revolutions have resulted in manufacturing advances with increasingly complicated, automated, and sustainable processes in which machines are operated simply, efficiently, and continuously [34]. Self-optimization as a basic principle serves as an approach to handle complexity and unforeseen disturbances within supply chains, machines, and processes [121]. However, the standards for the implementation of smart factories have not yet been established [96].

Modern manufacturing plays an essential role in the world, especially in European countries. Approximately 17% of GDP (Gross Domestic Product) corresponds to industry, which also creates approximately 32 million jobs with various complementary occupations in the European Union [58]. However, in recent years, industries in European countries have faced many problems, such as population aging and competition from developing countries [58]. These issues have driven the development of industrial technologies to reduce labor, shorten product development time, efficiently use resources, etc., of which the cyber-physical system (CPS) and the Internet of Things (IoT) are two key technologies that have advanced in the last decade [58]. Key technology research not only refers to the integration of information technology as the main body, but also includes the traditional disciplines such as control theory, mechanical technology, and materials and energy [96]. In this context, the goal of the fourth industrial revolution is to achieve real-time interconnection, mutual recognition, and effective communication between humans, equipment, and products, and finally build a highly flexible and personalized intelligent manufacturing environment [122]. In particular, the relevance of DTs for the industry lies in their definition as virtual counterparts of physical devices. This allows its representation to reflect the current state of the system and perform optimizations [101]. A gap in current manufacturing is that it has not reached an Industry 4.0 level comprehensively, despite the efforts of many researchers and companies. All current manufacturing systems are capable of covering some Industry 4.0 concepts, mainly focused on interoperability [103]. Therefore, there is still a long way to go to improve manufacturing to the required level [58]. The fusion of the physical world and the cyber world creates a new form of production systems: the CPS [122]. CPSs are considered next-generation intelligent systems that integrate computing, communication, and control technologies. In this way, CPSs enable close interactions between cybernetic and physical components through human-computer interaction interfaces [122]. Through virtualization, companies can monitor physical processes and develop simulation models [123]. In this context, real-time information available to organization tasks is key to tracking and analyzing the state of the manufacturing organization that supports increased robustness to unexpected conditions [123]. However, there are some fundamental challenges and problems during the implementation of Industry 4.0 in current manufacturing industries, such as system modeling and analysis [34] to consider the joint effect of decisions belonging to several productive areas traditionally considered in isolation and with difficulty in its prediction, such as logistics, maintenance, and quality. DTs are particularly relevant when integrated into process control loops, as presented in process quality improvement [99].

Although a lot of research work has already been done in the field of production management, manufacturing companies still face huge challenges stemming from unexpected failures. To enable manufacturing companies to process the increasing data collected, usable models must be developed that provide alternative sustainable solutions [124]. Until recently, there has been no modeling method or methodology that can be used to fully model, analyze, and design complex manufacturing systems or to support most phases of these complex systems. Most of the available modeling methods are simply static graphical representations and are not well defined. Modeling requires a method that is simple and capable of supporting different levels of abstraction. Analysts and designers need to model basic manufacturing operations as well as relevant management decisions and information systems. Most authors agree that no single technique can model the functional, information, dynamic behavior, and decision aspects of systems [125]. This fourth wave of technological advances is driven by nine fundamental technological advances [126]. Most of these technologies are not recent innovations. However, it is the combination of technologies, business processes and data processing that makes Industry 4.0 such a novelty [127]. Industry 4.0 pursues rapid product development and a flexible and intelligent production system capable of coping with greater complexity in products, processes, and environments, trying to respond to the growing demand for personalized products with decreasing life cycles [128]. Industry 4.0 has enormous potential to meet customer requirements, improve flexibility, optimize decision-making, improve productivity, and resource efficiency, as well as create new services and respond to societal issues such as demographic change, work-life balance and to maintain a competitive high-wage economy. To achieve all these goals, three characteristics of Industry 4.0 must be implemented: a horizontal integration through the value network, an end-to-end digital integration throughout the value chain, and a vertical integration in the production system [129].

The COVID-19 pandemic has had significant global economic consequences [28]. This situation demonstrated future risks and the current fragility [14] of supply chains. Consequences have included production stoppages due to lack of supply of raw materials, while other producers had to scale back or stop production because finished products could not be shipped abroad. In addition, there may be an increase in obsolete products and materials when demand is low or products cannot be shipped, as has occurred during the COVID-19 pandemic, causing risks associated with oversizing stock levels and leading to higher costs and waste. Therefore, there is an urgent practical need to increase the adaptability of manufacturing and procurement systems to react to unforeseen events, such as COVID-19 [130]. In this context of fluctuating demand, long lead times, inaccurate forecasts, the wide variety of products and the impact of complex networks, current production planning and inventory control methods and systems, such as MRP (Materials Requirements Planning) they have deficiencies causing chronic problems and the risk of large variations, excesses and shortages for the supply to the customer affecting three main factors: inventory performance, service level performance and higher levels of expenses and waste [131]. In the current global system, procurement planning in the process and assembly industries acquires vital importance to provide companies with the production flexibility necessary to quickly adapt to changes through efficient management of stocks and procurement costs. The simulation of scenarios can help to solve manufacturing and inventory planning challenges [33] combined with classical material requirements planning. To date, many models have been developed to deal with uncertainty and determine the optimal inventory policy [132]. However, most inventory models are related to the classical cost analysis approach with uncertain input data accuracy [43]. The cause of the uncertainty has several reasons [132] such as the supply risks of a certain supplier that can cause shortages and production losses. Therefore, how to balance the procurement strategy and cost optimization while considering potential stock shortages is a key decision for managers. Companies face the challenge of having to master an increasing number of individualized product solutions and short lead times at the lowest possible cost with high market dynamics leading to fluctuating customer demand and rising costs, as well as changes in orders in the short term. To successfully produce despite increasing external volatility, flexible and adaptable production systems are required that can respond to new requirements in a short period of time [133, 134].

Additionally, service industries play an increasingly important role in our overall economy [135]. In this context, there is a need to investigate service management to provide methodological answers to the growing service sector [136]. On the other hand, CSR is a concept that has attracted worldwide attention and has acquired a new resonance in the global economy. The growing interest in CSR in recent years is due to the fact that globalization and international trade influence the complexity of business and create new demands for greater transparency and corporate citizenship [137]. The concept of CSR has developed over the years by expanding its scope of investigation compared to historical information and has been the subject of continuous public debate. Currently, CSR has become an area of scientific research conducted not only by psychologists, philosophers, sociologists, and economists, but also by business administration specialists and engineers [138]. Researchers often fail to integrate CSR aspects into organizational concept development and implementation. Many approaches have been studied to solve the problem of organizational alignment with the environment in service companies. However, most of them have failed for various reasons, such as lack of information, coordination or control that leads to making strategic decisions neither at an optimal time nor in an optimal way [139]. Furthermore, in practice an integrative approach to high performance CSR in non-profit organizations [140] is key to ensuring viability. To make this possible, information flows, as an element of interconnection in organizations, are a fundamental element. The information is necessary for the definition of policies, decision making, planning, control, coordination, etc. Problems with information flows have a negative impact on any organization.

In this sense, many companies have “separate kingdoms” in their operations, with employees who are more loyal to their specific business area than to the company itself where the challenge goes beyond the supply chain. As a result, for a business to be successful, a climate of trust, respect, and dedication must be developed by allowing other entities to have their fair share of mutual activities, thus enabling win-win situations [141]. Today, our society requires the collaboration of all entities to support its commitment to the community. This means meeting human needs by creating a sustainable environment for all human beings. In this context, a company must contribute to its area of influence. However, the company will only support these purposes if there is a benefit to its actions. Within a company and society, people play an important role. In addition, the needs of these individuals are classified according to Maslow's hierarchy of needs and self-interest [142].

Due to all the gaps, motivations and reasons stated, the purpose of this TD is to develop a conceptual and application model for organizational sustainability at three levels: the organization itself (with its functional areas), its supply chain and the environment in which it operates, the organization's area of influence. The starting hypothesis is that an organization that is built on the basis of principles of sustainability and collaborative work thanks to the consideration of the concept and theoretical perspectives of CSR using the structure of the Viable System Model (MSV) will have a positive impact on the achievement of short, medium and long-term goals at the three levels: organization, supply chain and environment in the area of influence, making it possible to increase its organizational sustainability by reducing risks in the face of any possible future scenario and event. Therefore, the final objective of this Doctoral Thesis can be summarized in the following primary research question:

- How can a conceptual and applied model be designed creating a digital ecosystem with simulation and databases for the improvement of the intra-organizational logistics in order to manage resources efficiently to be effective ensuring the long term viability of a company through the MSV and the control and systems theories considering the industrial revolutions towards the 5th industrial revolution that allows to ensure the adaptability and flexibility of the logistics system taking into account the sustainability of all the agents involved and the related environment thanks to CSR in the technical, organizational and human factor fields?

To answer the main research question, an answer must be given to the following secondary questions:

- What are the current logistics challenges of an organization?
- What are the logistics management models and tools, as well as their existing coordination in theory and in practice today?
- How can procurement logistics be managed in dynamic environments?
- How can production logistics be managed in dynamic environments?
- How can distribution logistics be managed in dynamic environments?
- How can maintenance logistics be managed in dynamic environments?
- How can services and after-sales be managed in dynamic environments?

- What models and systems for managing change through innovation and continuous improvement ensure organizational sustainability?
- What information systems are used for logistics management and what functions do they perform in the organization?
- What models and implications does the human factor and organizational decision-making have on organizational sustainability?
- What methods, improvement strategies, and functions have been developed throughout the industrial revolutions that increase organizational adaptability?
- What technologies, capabilities, and influence does the fourth industrial revolution have on a company's logistics management system?
- What are the theoretical and practical perspectives of CSR and sustainability?
- How can we design a methodological approach for integrated and dynamic organizational management that improves the stability of operations and encourages organizational change to ensure organizational sustainability considering CSR to respond to any event?
- How can the modules and tasks of an intra-organizational logistics system be identified and developed?
- How do the technologies of the fourth industrial revolution influence logistics activities?
- How can I4.0 improvement strategies and technologies be applied and integrated to improve the adaptability of the logistics system?
- How can new information ecosystems be designed to increase organizational sustainability thanks to CSR and the best techniques and technologies available in the fourth industrial revolution?
- How can organizational decision-making be managed to deal with the environment and be able to reduce internal and external risks to increase sustainability?
- How can be created a system of indicators oriented to added value throughout the supplier-producer-client supply chain, as well as sustainability criteria at the three levels of organization, supply chain and area of influence?
- How can a conceptual design model for intra-organizational logistics systems be developed to improve adaptability and sustainability by defining levels, objectives, modules, information flows considering a holistic approach of an organization as a socio-technical system?
- What regulation and auditing mechanisms must exist in an organization to ensure the viability of the company in the long term?
- How the human factor and the decision-making of key human factor roles can be modelled, as well as organizational decision-making?
- How can sustainability and CSR criteria be integrated into an information ecosystem at the operational, tactical, strategic, and normative levels?
- How can the interrelationships between factors be captured to model, simulate, and evaluate the conceptual model in case studies associated with the MSV modules and systems in different sectors and environments?

- How can data collection and storage capabilities, the possibilities of generating DTs, simulation techniques and data analysis be integrated into a model oriented towards sustainability within environments of the fourth industrial revolution?
- How can it be applied and what is the potential of the conceptual model and the case studies to reduce the internal and external risks of an organization?

1.1.6.2 Goals

In this TD the objective is to design a conceptual model for organizational logistics oriented towards sustainability based on the concept of CSR and its application as a management system consisting of databases, digital twins, and simulations with data analytics methods applicable to all areas of the logistics of an organization. For this, the methods of design, management, control, and improvement of the logistics of supplies, production, and distribution with orientation to the final client are considered, considering the organizational objectives towards sustainability through CSR. When considering CSR, the models to be developed have the objective of considering not only the organization but also the entire environment related to the organization in its area of influence, that is, at three levels: the organization, the supply chain, and the related environment, considering all the stakeholders of the organization. In this way, the main objective is the design, development, and application of conceptual and application models, for the generation of a logistics system with the necessary adaptation and flexibility capacities to be able to face the current and future challenges in the environment of the fourth industrial revolution to be sustainable thanks to the normative orientation through the consideration of CSR. The objective of the conceptual models is to provide integration models based on the study of the existing literature and best practices, as well as the design and development of new organizational models for the different logistics flows, as well as the design of conceptual frameworks for the different areas. organizational functional. The goal of these models is the rationalization of organizational management and control tasks to enable decision-making based on data, past experiences, and objective information that enable an optimal management and improvement framework. All this, seeking the optimization of planning as well as the preparation of measures in the event of any deviation from the plan, whether due to internal or external disruptions.

The objective of the application models is the validation of the conceptual model in different environment scenarios and its variables as well as for various organizational contexts. For this, the purpose seeks to apply the conceptual model through case studies and information ecosystems with databases, digital twins, simulation techniques and data analytics. For this, the analysis of the state of the art of logistics management is carried out, as well as the study of the available methods and tools. On the other hand, and after having studied the tasks and functions of logistics management, the design of a planning and coordination model for the logistics areas of an organization is pursued, including maintenance and service and after-sales management, continuous improvement, and innovation, using the current state of the art to quickly adapt to any future scenario and to the requirements of customers and users. In addition, to coordinate all functional areas with logistics flows, it is necessary to consider and model information systems and organizational decision-making. Based on the exposed arguments, the main objectives of the TD are reflected. They are raised in the first place, in two separate objectives, the sustainability objectives related to the management and control of an organization in the current state, the Run of the organization, and the change activities, the Change, to improve the capacities organizational goals in the face of any future scenario, that is, the sustainability objectives related to the minimization of risks in the face of any failure mode with internal and external origin that could compromise organizational viability. In addition, the objective is to reproduce the application results through measurable data and KPIs that allow analyzing the evolution of the organizational system. The definition of CSR and organizational objectives is vital for sustainability, in this way for both Run and Change, the doctoral thesis seeks to analyze and consider which approaches to CSR and organizational objectives make the organization more sustainable based on to the related environment in which it is found.

To improve the sustainability of the Run, it is sought to analyze the methods, systems, technologies, and organizational structure including the qualification of the personnel so that the sustainability of the current activities of a given organization is the best possible, improve its effectiveness, efficiency, and usefulness for the rest of the functional areas, of the organization, for the supply chain and the related environment. Therefore, one of the goals is to compare or generate management and control concepts that are applicable to generic or specific cases of activity sectors to achieve organizational objectives such as a certain level of production with a certain level of quality and service. of delivery by using the least possible number of resources, in such a way that it is effective in meeting the objectives, efficient in doing so with cost minimization, and useful since the quality and service provided allow customers or users or other functional areas develop their activities with a better state of the product or service that has been delivered to them. With this approach, the sustainability of the current state of any company is ensured, while the foundations are laid for its sustainability in future states, as well as through better knowledge of the possibilities in methods, technologies, systems, and organizations that could be applied. or be developed in the future through innovation and improvement projects, linking with the second part of the main objective.

To achieve the main objective, the continuous improvement of the organizational system is necessary, being continuous improvement the key for organizational development and sustainability [143]. In this sense, and even though there have been many theoretical and practical models that present optimization strategies, there has not been a guide on what strategic steps of the project must be implemented so that an organizational system reaches its best potential with a systematic improvement model. of the business that allows to secure its position in the market. Therefore, there has been little guidance on the sequences to follow or consider when designing and evaluating the impacts of optimization projects. Given the need to generate systematic models for the implementation of improvement strategies, I4.0 technologies, as well as the integration between both towards organizational improvement and sustainability [51], one of the research goals is the development of improvement models with sequences and steps with holistic and comprehensive approaches for organizations to improve their logistics system, contributing to its long-term sustainability, as well as identifying the impact of the different steps and measures of the sequence on target indicators. Therefore, this document analyzes a methodological model that can provide a reference framework for the design and successful execution of integrated improvement and optimization strategies in Industry 4.0 environments [51]. An integration model like the one presented in this document provides a platform for different continuous improvement strategies, I4.0 technologies, and innovations capable to interact and work together. This research is intended to help managers understand that these various continuous improvement approaches are not mutually exclusive.

In this context, several models will be developed to improve the performance and sustainability of operations within organizations, both at the organizational level and at the functional area level such as production, maintenance, or services. As a result, the objective of the work is to develop approaches focused on evaluating hypothetical scenarios for decision-making related to intra-organizational management at the three levels of organization, SC, and area of influence with consideration of CSR theories, the SDGs, ESG criteria, and the needs of the related environment. In this way, models are developed at the organizational level as well as at the functional area level. For this reason, some of the partial objectives of the conceptual and application models in functional areas are:

- Develop a methodology for procurement planning needs through simulations of scenarios to provide adaptability and flexibility mechanisms to industrial organizations, determining a differentiated procurement strategy based on the environment in the area of influence [130]. In this way, the aim is to improve management capacities to act in a timely and appropriate manner, as well as to optimize information systems to be a crucial support for processes and decision-making in volatile environments due to the lack of transparency as one of the biggest weaknesses of ERP supply chain management (SCM) systems, as they are not sufficiently integrated with each other to ensure holistic planning and control across networks. Consequences of this problem include: unrealistic delivery dates and consequent inadequate adherence to delivery dates [144].
- Generate an integrated S&OP methodology to support planning managers and employees in their decision-making processes when carrying out their sales and operations plans and functions in the three planning horizons of short, medium, and long term thanks to predictive capabilities and preventive planning made possible based on the preparation of policies and measures through the simulation of scenarios [145].
- Design a conceptual model for maintenance management and spare parts distribution management to optimize the coordination between strategies of the spare parts distribution network and maintenance activities [146].
- Develop a self-regulatory approach on how to design service and manufacturing organizations that meet the objectives of Corporate Social Responsibility (CSR), including economic responsibility, maximizing the efficiency of any service and manufacturing organization [139].
- Model the organizational functions with a holistic approach that allows evaluating the performance of the organization and identifying potentials for improvement. For this, the objective is to develop a conceptual model based on the evolution of the functions throughout the industrial revolutions to later model industrial organizations, considering all the common organizational functions in the respective areas of production, maintenance, quality, etc. in the three planning horizons: strategic, tactical, and

operational. Based on this, the goal is to provide a digital model of a manufacturing organization to optimize its design, management, control, and continuous improvement that allow the identification of potentials for improvement in the management, technical or personnel areas based on the historical background and current status of organizational functions [147].

- Provide a framework to model the human factor within organizations based on historical evolution and quantify its influence on the supply chain, as in the food SC. Based on this, it is intended to define the potential of the human factor in the fourth industrial revolution, as well as to analyze its influence on previous industrial revolutions [72].

1.1.7 Research hypotheses

The doctoral thesis is based on the following main hypotheses:

- Thanks to a new conceptual model for logistics management, considering the added value to the end customer within a supplier-producer-customer supply chain, the viability of a company can be ensured.
- The study of existing methods will allow the identification of different approaches, limitations and inefficiencies allowing the development of a model that considers them.
- The generation of conceptual models of logistics management will allow to know the methods, elements, and parameters to be considered in a global system that allows to improve the capacity of adaptation and flexibility in changing environments considering the developments of the fourth industrial revolution.
- The MSV provides the necessary platform to determine the interrelationships between areas and parameters that allow them to be optimized recursively, making continuous improvement possible.
- System dynamics (SD) and the causal loop diagrams (DCC) allow visualizing the interrelationships and types of influence between logistics parameters as well as their final influence on the customer.
- Simulation tools will allow the simulation and quantification of effects of different policies in different scenarios, helping to determine their impact on the global logistics system.
- Simulation models based on conceptual models that pursue adaptability and flexibility versus traditional models will present better results, thanks to the consideration of changing factors and their ability to adapt to meet the needs of the market and the end customer.
- The development of a dynamic market-oriented procurement approach will reduce the risks of delays or lack of supply while optimizing the use of production capacities and reducing costs.
- The integrated approach of S&OP is capable of predicting the behavior of the system, increasing the quality of the forecasts, the precision of the planning and the stability, as well as the customer service level.

- The generation of digital twin models of organizational systems will allow the optimization of the production and maintenance planning and control, enabling remote services.
- The distribution management models with the best techniques and alternatives will allow the optimization of the service and distribution costs both in new products and in the logistics management of spare parts.
- The methodology for developing information and innovation ecosystems and goal-oriented improvements will ensure the sustainability of the *Run and Change* thanks to a scientific approach based on data and information that assist decision-making and reduce risks thanks to a greater knowledge about the possibilities and implications as well as the better identification of gaps and innovation potentials.
- An industrial or service organization is able to adapt its capabilities to changes in the environment using the MSV structure as it is able to react faster and, therefore, the application of this model will have a positive impact on the achievement of short-, medium- and long-term goals of the organization. The MSV approach is expected to increase the adaptability of a company to face potential future scenarios, when making strategic, tactical, and operational decisions.
- The generation of an innovation and continuous improvement model applying the MSV together with the historical analysis of the evolution of functions, as well as the development of sequence models and integration of the capacities of the different industrial revolutions such as the I4 technologies and the relevant improvement strategies will ensure organizational sustainability thanks to an optimized *Change*.
- The generation of a methodology for the development of information ecosystems applying the possibilities of I4.0 such as simulation, data analytics, available technologies, and strategies and methods, will allow an optimized management and effective control through auditing of both the *Run and Change of the Organization.*
- A new concept to model and simulate the human factor decision making through the application of system dynamics will allow the analysis of its impact within the organizational action.
- Stakeholders considering CSR and the consideration of all stakeholders will allow organizations to be more effective when pursuing their sustainability in comparison to companies omitting the consideration of stakeholders or with stakeholders not considering the CSR concept.
- The appropriate consideration and selection of the CSR strategy helps an organization to increase its sustainability parameters considering economic and ESG criteria at the three levels of organization, SC, and area of influence.
- Based on the conceptual model, case studies (CS) were carried out in different sectors and in various situations. Through the simulation and analysis of the different scenarios and alternative decisions, it is expected to validate the conceptual model and its application to increase the organizational sustainability to verify the hypotheses previously raised.

- Based on the case studies, strategies and measures can be prepared for any risk, both internal and external, of the organization, to increase its sustainability and that of its area of influence.

1.2 Doctoral Thesis Structure

The structure of the TD is described in Figure 1. This document presents a summary of the TD. The scope includes any organization that was considering a process of improvement and transformation in its management towards sustainability, as well as those that already had an ongoing implementation or that had already implemented improvement methodologies and, therefore, the scope was designed. framework around these different scenarios to assess and predict the benefits and challenges associated with the different stages. Therefore, the structure followed in the thesis is shown according to Figure 1:

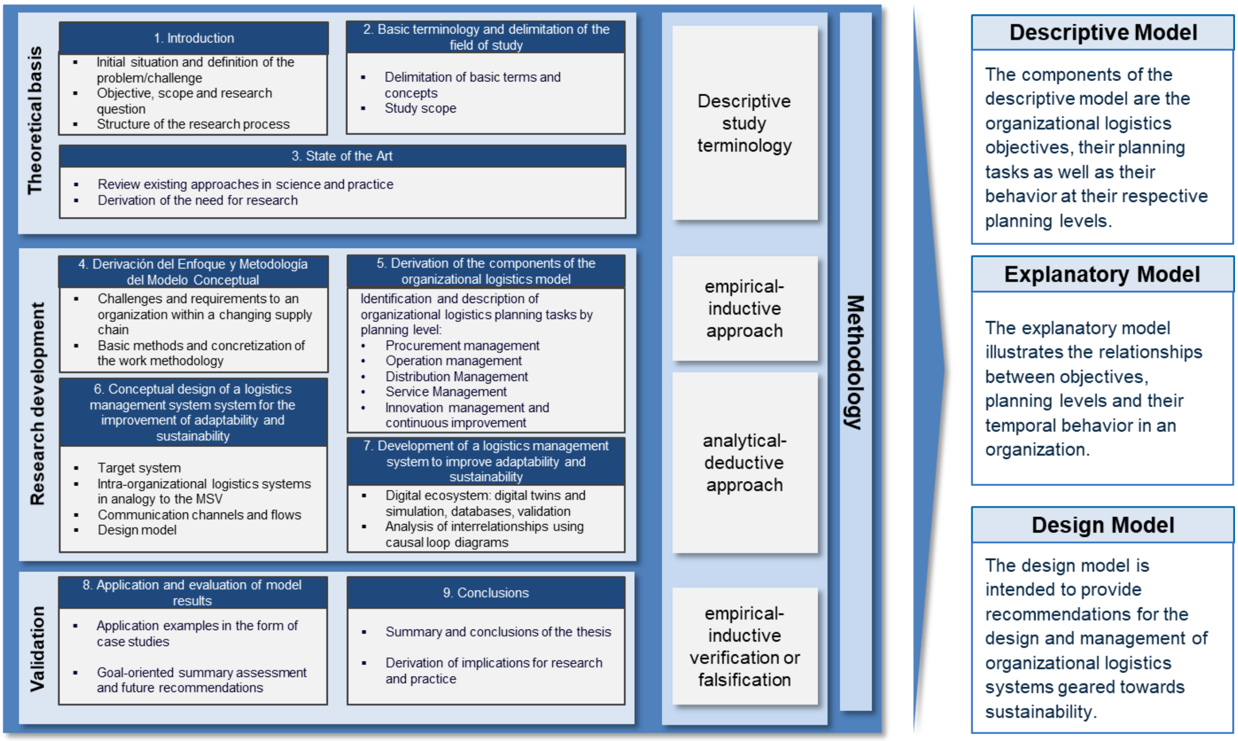

Figure 2: Structure of the doctoral thesis (own elaboration).

2. Research gap and methodology

2.1 Findings from which the need for research derives

Being able to carry out operations with efficient management of information, materials and financial flows with the lowest possible risk to maximize the overall value of an organization and optimize the impact on its related environment plays a fundamental role in global supply chains. nowadays. Furthermore, matching organizational capabilities and societal needs is a challenge for companies. In this context, all factors related to different planning horizons (long, medium and short term) of a given decision are often not considered holistically, leading to partial, suboptimal or even negative decisions. The reasons for this can range from a lack of information to a failure to consider various future scenarios or delays in the decision-making process. In addition, researchers often do not consider the state of practical fields when developing new concepts or creating concepts without coordinated work with organizations where they are already in testing or use phases. Therefore, it is necessary to develop integrated approaches to increase organizational capabilities and apply new methods and technologies to meet current and future challenges [40]. As a result, the fourth industrial revolution opens new opportunities to generate concepts, methods, tools and systems from the design to the end of the product and service life cycles to increase organizational competitiveness and ensure long-term sustainability. This TD seeks to provide a "Tool-box" for this purpose, considering the concept of CSR as a central element and with the integration of the human factor. The objective is to increase the efficiency of industrial, manufacturing and assembly organizations, as well as service organizations and the first sector including their related environments.

This thesis focuses on applied research of industrial management towards improving the adaptability of the supply chain while ensuring the sustainability of operations and intends that through the action of the organization in its value chain, it can contribute to overcome challenges both in the organization and in its related environment and society. Therefore, the topic of the thesis ranges from normative management associated with the concept of CSR, to strategic management oriented towards sustainability, through organizational transformation and supply chain management including production management, systems manufacturing and assembly, service management, human factor, information management and Industry 4.0 in the different time horizons (long, medium, short term) and at the different levels of planning from normative to operational to ensure the continuous improvement of the industrial and service organizations within the fourth industrial revolution.

Throughout the evolution, the satisfaction of needs has had varied responses, although there has always been a pattern: the possibilities, technologies and capabilities to satisfy them have increased. However, the world of the 21st century is one in which the basic needs of millions of human beings are still not satisfied. Therefore, the current global market situation calls for high adaptability as globalization makes outages a major risk for operations in existing global networks. Disruptions such as disasters, epidemic crises, product changes and socio-economic situations have significant global consequences for organizations, society and people if they are not properly managed with adequate methods and supporting technologies. Therefore, there is an urgent need, both in research and in the real world, to develop technological solutions to improve the management of industrial and service companies to increase their adaptability to any possible future event. In this context, Industry 4.0, the initiative created in 2011, with its developments in the cloud, the Internet of Things (IoT), big data analysis and digital twins, among other related technologies, can improve the performance and organizational sustainability. In these circumstances, and considering that it was the first time that an industrial revolution was predicted in advance, all types of organizations have the opportunity to decide how they will transform their business models and how they will shape their strategies, organizational models, future technologies, and systems as well as internal processes. In this context, the integration of the human factor in Industry 4.0 environments emerges as a concept to take into account when designing, developing, implementing and managing new technologies towards new business and organizational models [105].

The current global market situation pursues high adaptability. Globalization is no longer a theory, but a fact that makes disruptions a major risk to operations in existing global supply chain networks. COVID-19 is causing significant economic consequences globally. The consequences have included production stoppages due to a lack of raw materials, while other producers had to scale back or stop production because finished products could not be shipped abroad. Therefore, there is an urgent practical need to increase the adaptability of organizations to be able to react to unforeseen events, such as COVID-19. In addition, this situation has shown, among other sectors, the current fragility of the global health infrastructure, such as the lack of medical resources and equipment. Although many models have been developed to deal with uncertainty, the need to develop effective and efficient responses is more necessary than ever. People affected by the potential lack of supplies are at great risk as happened with the global crisis of COVID-19 when companies speculated with the supply of demand, reducing it to increase margins due to customer demand. In doing so, the purpose of a company to provide goods or services to society is not given. In this context, Industry 4.0 can improve the performance in scenarios with uncertainty [130].

As a result, many approaches have been developed and applied, both in theory and in practice, regarding these new opportunities enabled by the capabilities of the fourth industrial revolution. In this context, Corporate Social Responsibility (CSR) emerges as a concept that must be considered when designing, developing, implementing and managing new business and organizational models. All organizations when it comes to transforming their business models must assess how and what CSR strategy they will follow to adapt to current and future uncertain environments with the support of Industry 4.0 technologies and capabilities. Therefore, the CSR strategy is the central element for the development of any business model, since it determines the internal actions and, consequently, the impacts of those actions on the related environment of an organization. On this basis, CSR is a central decision element to transform and create business models, while on the other hand Industry 4.0 is here to provide solutions to our challenges together with the fact that, in our near future, COVID-19 and the associated uncertainty are the main challenge for states and organizations, whatever their sector and activity. As a result of the combination of topics mentioned, the relevance of the doctoral thesis presented is established. Moreover, this doctoral thesis seeks to empower researchers and junior and senior professionals to develop knowledge around strategies and the concept of CSR. In short, the subject of the doctoral thesis has an ever-increasing potential as well as the responsibility to provide decision-making guidance for managers and employees to create a better today and future by promoting sustainable business models, projects and activities.

2.2 *Methodological foundations: elements of the methodological concept*

To define the methodology, nine fundamental concepts are used:

At the system level:

1. systems theory;
2. modeling of systems;

At the organizational level in relation to the environment:

3. theories of Corporate Social Responsibility towards Sustainability;

At the level of supply chain and management of production networks:

4. Aachen PPS model;

At the organizational level:

5. Viable System Model;

At the level of tools and techniques for modeling and practical application of models:

6. databases (BBDD) and information;
7. digital twin (DT);
8. simulation: system dynamics, and to a lesser extent based on agents and events;
9. quality techniques and data analysis;

2.3 Derivation of the methodological concept: modeling, management, and evaluation of organizations as dynamic systems towards Sustainability and Adaptability

2.3.1. Modeling Methodology

The modeling of an organization carried out in this thesis considers three levels of impact as a result of the model:

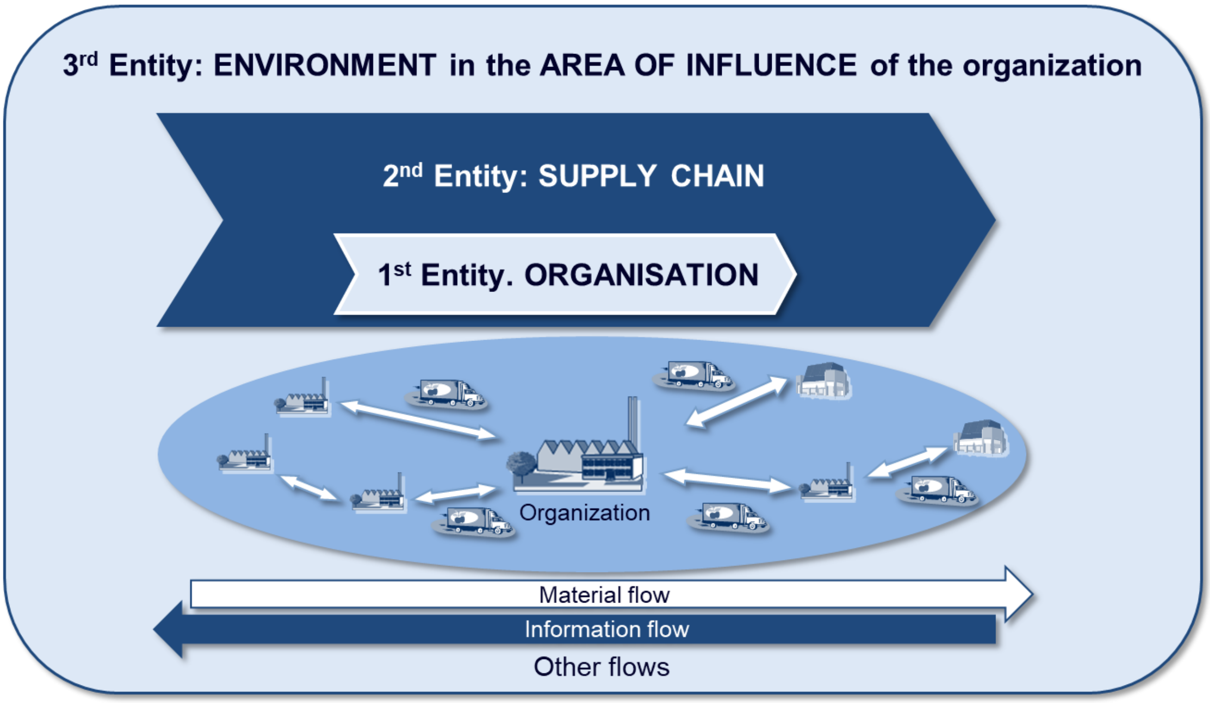

Figure 3: Entities in the design of the conceptual model: an organization, its supply chain and the environment related to the organization (own elaboration based on [142])

The methodology applies the methodological elements selected in chapter 4.2. of the DT based on existing literature. In addition, own methodological developments are considered supplemented with PDCA (Plan-Do-Check-Act) cycle methods, as well as with the generation of indicators for each function, area, and activity at the different levels of planning towards a multi-level model Balance Scorecard (CMI). In addition, although the organization is modeled on the basis of the VSM, the organization needs guidance for its management. Therefore, after having defined the generic conceptual framework, it is necessary to define the modules to identify the areas of improvement of the related capabilities. For that reason, the activities are grouped into nine different modules, as can be seen in Figure 3:

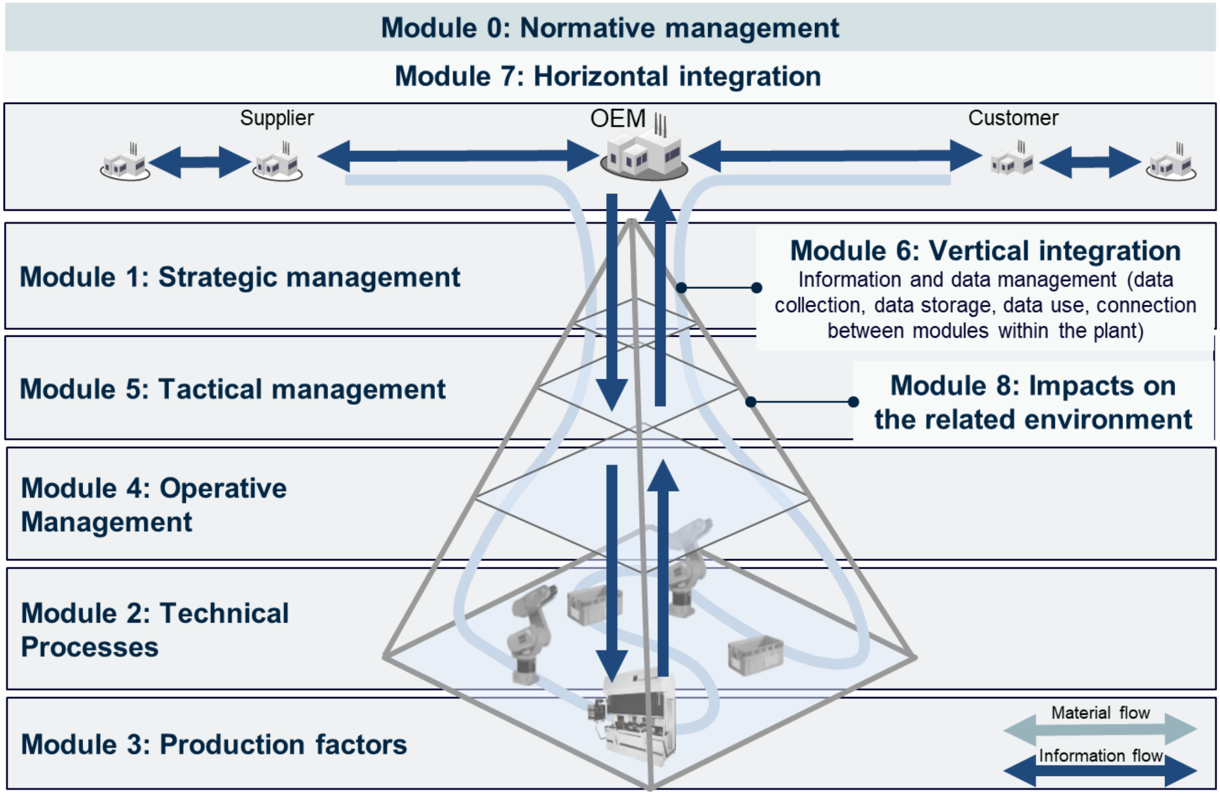

Figure 4: Evaluation modules of an organization (own elaboration based on [65])

Thus, it will be possible to determine the maturity level of the activities in each module. Before the existence of the organization itself, there is the normative management module or constitutive module (Module 0). Secondly, the strategic level must be defined (Module 1) which must follow the principles and the purpose marked by the normative level. Based on this, the necessary changes in the technical processes can be derived (Module 2), as well as the related production factors to realize the final processes and products (Module 3). Subsequently, the levels of operational management (Module 4) and tactical management (Module 5) can be determined, to then develop a vertical integration within the plant or production network (Module 6). Finally, the horizontal integration between the actors of the supply chain (Module 7) and the impacts of the action of the organizational system or production network on the environment and the ESG criteria (Module 8) will be evaluated.

On the other hand, an organization can be considered as a duality of functions, on one side *Run* and on the other *Change*. That is, it must maintain the stability of existing operations (*Run the organization*) while being able to change and innovate (*Change the organization*) to improve its capabilities and therefore gain adaptability and resilience to face and overcome any future event and risk for its viability. In this sense, the following conceptual framework provides a new paradigm for organizations by generating a five-layer model for socio-technical systems. In layer 4 we find what happens (*Layer 4: Life go*). At this level, the interaction of the elements that will result in the organizational performance takes place. It is composed by the organizational structure (4.4. Structure / Human Resources), by the technical elements of any type of asset (4.3. Inventory / assets), by the activities and processes of the organization (4.2. Activities / processes), as well as for the interaction of the above with users and clients of the organization's products and services (4.1. Users / clients). In *layer 3* we find planning and all its elements. On the one hand, the information systems of the organization (3.1), the methods (3.2), the level of organizational skills and individual qualification in all their levels, both cognitive, emotional, etc. (3.3), as well as the technologies used at any level of the organization (3.4). On the other hand, in layer 2 (*layer 2: Maintenance*) we find the maintenance that includes both the correction of faults and deviations of any element in levels 3 and 4 as well as its improvement thanks to quality techniques and methods. To do so, it considers all the flows and information of these levels for that goal. While the two levels 3 and 4 correspond to the *Run of an organization*, that is to say with the day-to-day operation. Layer 2 is concerned about ensuring the viability of the *Run* while applying to the extent of its possibilities improvements in the different areas, but always within the existing configuration, that is to say, it performs the function of *Change* within the organization but with a limited scope restricted to the framework situation of the organization at that time. Finally, we find level 1 (*Layer 1*) of project management where we find the focus of *Change* in an organization, normally motivated by improvement strategies and innovations and their management and implementation in organizations. *Change* can be motivated as improvement, *pull* approach, or as necessity, *push* approach. In this focus of change, it is important to ensure the consideration of five aspects:

1. Alignment with the organizational objectives and therefore with the purpose of the organization in relation to its environment thanks to the concept of CSR.
2. Consideration and evaluation based on ESG and ODS criteria, as well as economic criteria.
3. The consideration of all stakeholders based on CSR and sustainability models and theories.

The last two aspects derive from a correct definition of the first. Based on these aspects, it must be complemented with a correct evaluation of the environment (Aspect 4: Studies and market dynamics, competition, etc.), as well as a precise internal diagnosis of the needs to improve internal capacities to face any possible future scenario (Aspect 5). Based on these aspects, a prioritization and selection of projects must be carried out to which the last layer, *layer 0* of financing, will seek and provide the resources to enable the *Change* of the selected project portfolio with viable financing.

In order to correctly identify these last two aspects, it is necessary to determine a series of indicators based on a multi-level dashboard that allows the control of the evolution of the most important factors and parameters. In addition, thanks to the VSM, the different layers of the model as well as the different aspects can be modeled considering the environment and intra-organizational management, as well as the management of change, thanks to the strategic guidance of system 4 and its application through the system 3. Maintenance layer 2 is carried out through system 3* as well as through system 3. On the other hand, the application of layers 3 and 4 would be carried out both in levels 1, 2, and 3 depending on the scope of operations. Finally, layers 0 and 1 relate to the five aspects described as well as to the management levels of the viable system model, systems 5, 4 and 3. Taking into account the above, the thesis can generate a series of concepts and case studies associated thanks to it.

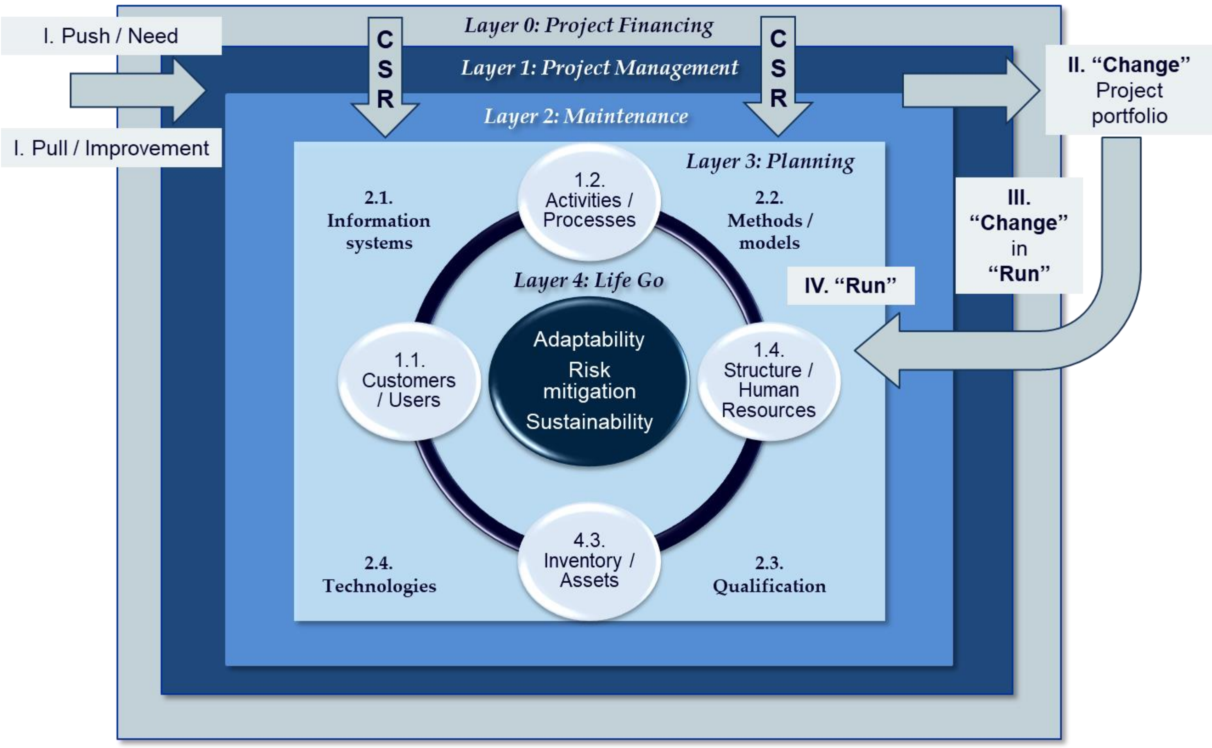

Figure 5: ***The magic management square*: *Run and Change* with stability ensuring sustainability** (own elaboration)

Now that, from a conceptual point of view, we have seen the fit between *Run and Change* and the different modules with the VSM, we go on to describe how an organization can be modeled systematically to improve decision-making at the different conceptual levels presented. In this way, the approach must respond to the needs of the fourth industrial revolution as well as the advent of the fifth industrial revolution, based on the human factor. Based on this, the following methodological concept is derived and specified, consisting of a methodology for the generation of Digital Ecosystems for the Fourth Industrial Revolution (DE4.0) [341].

For this, a reference framework is developed for a Digital Ecosystem based on a multiple set of BBDD of information, simulation, and digital twin, for the planning, implementation, control and monitoring of organizations and projects during their life cycle based on the Methodology Plan-Do-Check-Act, as shown in Figure 5 [341]. The DT model is based on sub-models of the organization, its supply chain and its related environment. A DT model together with a link to the databases of the organization's information system is the basis for carrying out simulations that allow analyzing policies based on hypothetical analyzes and statistical techniques [341]. The goal of these models is to improve the ability to face dynamic environments and reduce their volatility by predicting and managing changes through improved adaptability. It is achieved thanks to a combination of forecasting techniques, quality management, simulation and connection to external databases for the continuous improvement of an organization at all levels and in all areas. In this way, any change in any part of a given digital twin model can be evaluated, thus calculating the impacts and risks associated with any change and improving the adaptation capabilities of any organization in which this new digital ecosystem is applied for the management and improvement of existing information ecosystems.

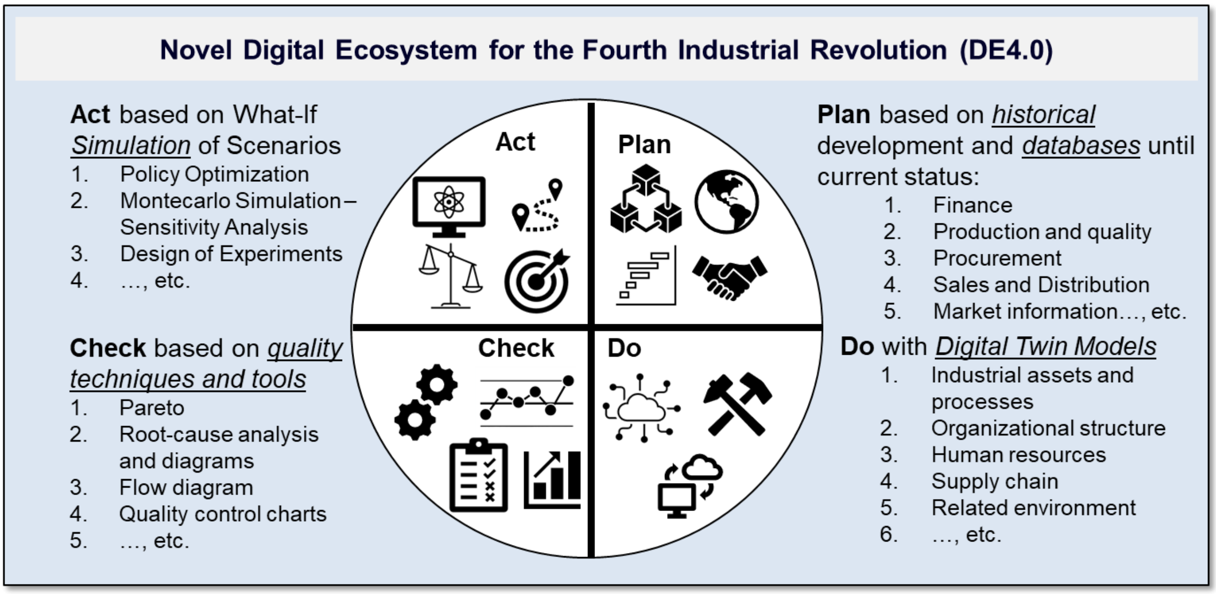

Figure 6: Digital Ecosystem for the Fourth Industrial Revolution (DE4.0) [341].

By applying the methodology of the digital ecosystem to innovation management models, the DIIS (Dynamic Innovation Information System) is developed, as seen in Figure 6 and which shows how it should develop first an innovation plan for any invention or innovation. It can be done using qualitative and/or quantitative data from outside and/or inside the company. From the outside, it would consist of open or private information, related for example, to a specific technology. Within the company, they would be the databases of the existing information systems, as well as the files within the digital or physical repositories. The *Plan phase* has a strategic character, since it must guarantee the alignment of the innovation plan with the objectives of the organization, as well as consider all the other functions and entities within the organization and the related environment to reduce the risks of innovation. To carry out the plan, the statistical analysis based on historical data can support the development of a plan that helps with subsequent agreements and commitments with partners and other functions [341].

In the *Do phase*, the plan becomes reality and, therefore, changes from a strategic perspective to an operational one. It is necessary to monitor the development of innovation, collect data and parameters and introduce indicators into the existing information systems and DBDD. To achieve this, a DT model provides the platform for monitoring the innovation implementation [341].

In the *Check phase*, all the data and information collected must be analyzed to evaluate the evolution of the innovation indicators and parameters, that is to say, a control-oriented phase. For this, the management and quality control techniques and tools represent a fundamental element to identify deviations and determine the risks of innovation [341].

Finally, in the *Act phase*, the DIIS derives measures to improve the innovation process based on the *Check phase* and the simulations of different policies as well as the statistical analysis to determine the impact of future planning after the adjustment proposed by the *Act phase*. As this step influences the policies and risks of the innovation management and control project, it also has a strategic management approach [341].

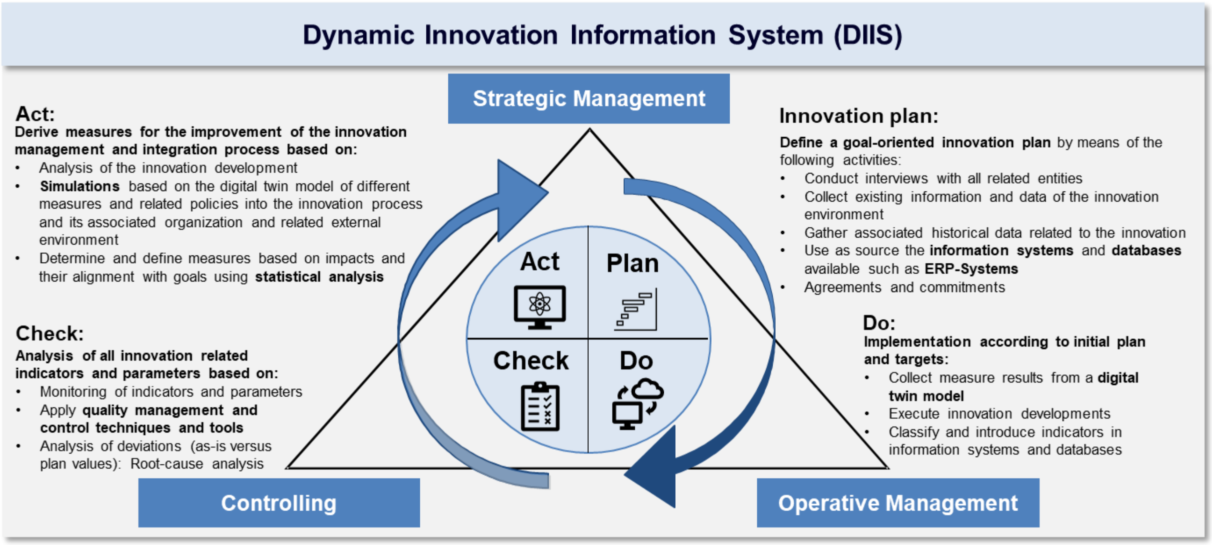

Figure 7: Dynamic Innovation Information System (DIIS) [341].

As shown in Figure 7, the initial planning of any innovation can be based on experience, the practical evidence of past experiences, such as technical and technical-economic planning, or new planning. However, for all these cases, the implications of the innovation must be evaluated in the target indicators to proceed with the introduction of the invention, the innovation launch as well as its diffusion in the market. The theoretical framework makes it possible to use the lessons learned and the innovation parameters to reinforce the innovation process based on the PDCA methodology. In addition, during the life cycle of the innovation, from the concept until its withdrawal from the market or the organization, an innovation must be reviewed several times at certain milestones or continuously based on the data and information of the experience and the lessons learned from past experiences. Later, in each *Check phase*, the innovation plan is adjusted based on a *dynamic Act-Plan* adaptation to meet the expected objectives [341].

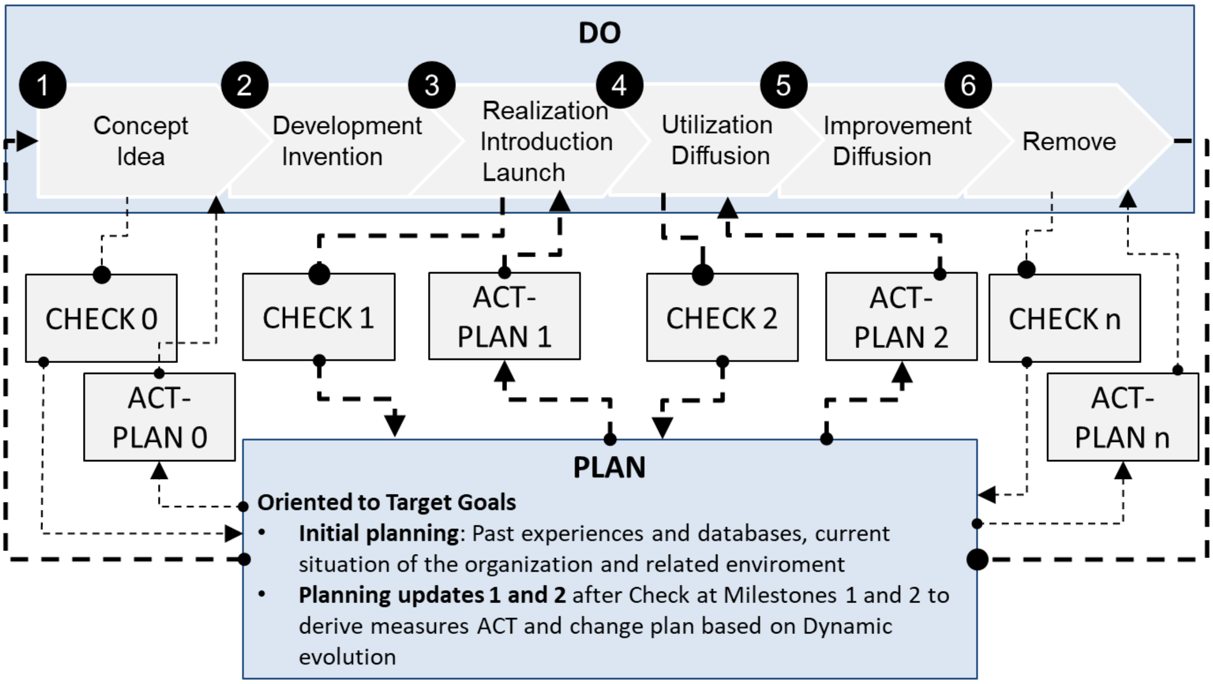

Figure 8: Innovation life cycle & project planning based on the PDCA methodology [341]

In addition, the methodology aims to provide a conceptual model that allows the evaluation of organizational logistics operations with transparency in terms of areas, flows and factors. The objective of the model is to satisfy the quality requirements of the product with excellence in operational efficiency. In addition, the conceptual model seeks to serve as a basis for digital twin models and systems to evaluate, manage, monitor and improve decision-making in organizational systems, being the basis for continuous improvement and innovation processes. Therefore, the thesis includes the focus on different areas, flows and parameters. The model includes several flows from the literature (flows of materials, information, financial, personnel, assets) adding the flow of energy, the aspects of maintenance, the different elements of regulation in the flow of decisions, as well as adding the consideration of own manufacturing process [107] to the industrial dynamics methodology proposed by Forrester [428]. In addition, it increases the resources to consider, monitor and evaluate defined by Gutenberg [180]. The methodology developed is a natural evolution of the methodological frameworks created for the Second and the beginning of the Third Industrial Revolution to a modeling framework towards the Fourth Industrial Revolution. As a result, the proposed methodology details the flow of decisions considering more managerial aspects that can regulate the manufacturing process and, therefore, the complete organizational system. When comparing the proposed model with more recent approaches, these have a static evaluation status, a level-oriented approach, a focus on data and artificial intelligence or a dynamic approach, however, none of them provides a potential evaluation of all areas, flows and elements that interact in all manufacturing systems and the possible regulation mechanisms to control and improve the system with an integrated, dynamic and scalable approach. Therefore, this research provides a necessary framework to subsequently initiate level-oriented and data-oriented approaches or to perform static analyzes [107].

The methodology applies the methodological elements selected based on existing literature and own methodological developments. Therefore, based on the arguments presented, the methodological concept considers:

1. Hierarchy of systems and their elements (systems theory and systems modeling),
2. with recursion levels based on the VSM for the organization and the supply chain and production networks based on the Aachen PPS Model and partly on the SCOR model,
3. taking into account the State (*Run*) and the Action (*Change*),
4. of all areas, flows and factors of the manufacturing process and intra-organizational logistics,
5. with DE4.0 (applicable to any system and any level),
6. that it is possible thanks to the BBDDs and information in a digital twin for the simulation of scenarios with SD through DCCs and digrams of stocks and flows,
7. with multilevel Balance Scorecards (KPIs for each function and system level)
8. which allows the evaluation of the situation and maturity of the modules of an organization,
9. thanks to the quality and data analysis techniques that also allow identifying opportunities for improvement, deviations from the objectives as well as anomalies,

10. generating ideas and projects for continuous improvement and innovation that can be managed thanks to DIIS,
11. orienting the *Change* as well as the *Run* to the organizational objectives in the three levels of impact (organization, supply chain, area of influence) thanks to the CSR policy with consideration of the ESG and ODS/SDG criteria towards Sustainability.

2.3.2. General Methodology for Modeling Case Studies

The methodology developed and the existing elements considered have been fully or partially applied in different case studies following the following general methodology:

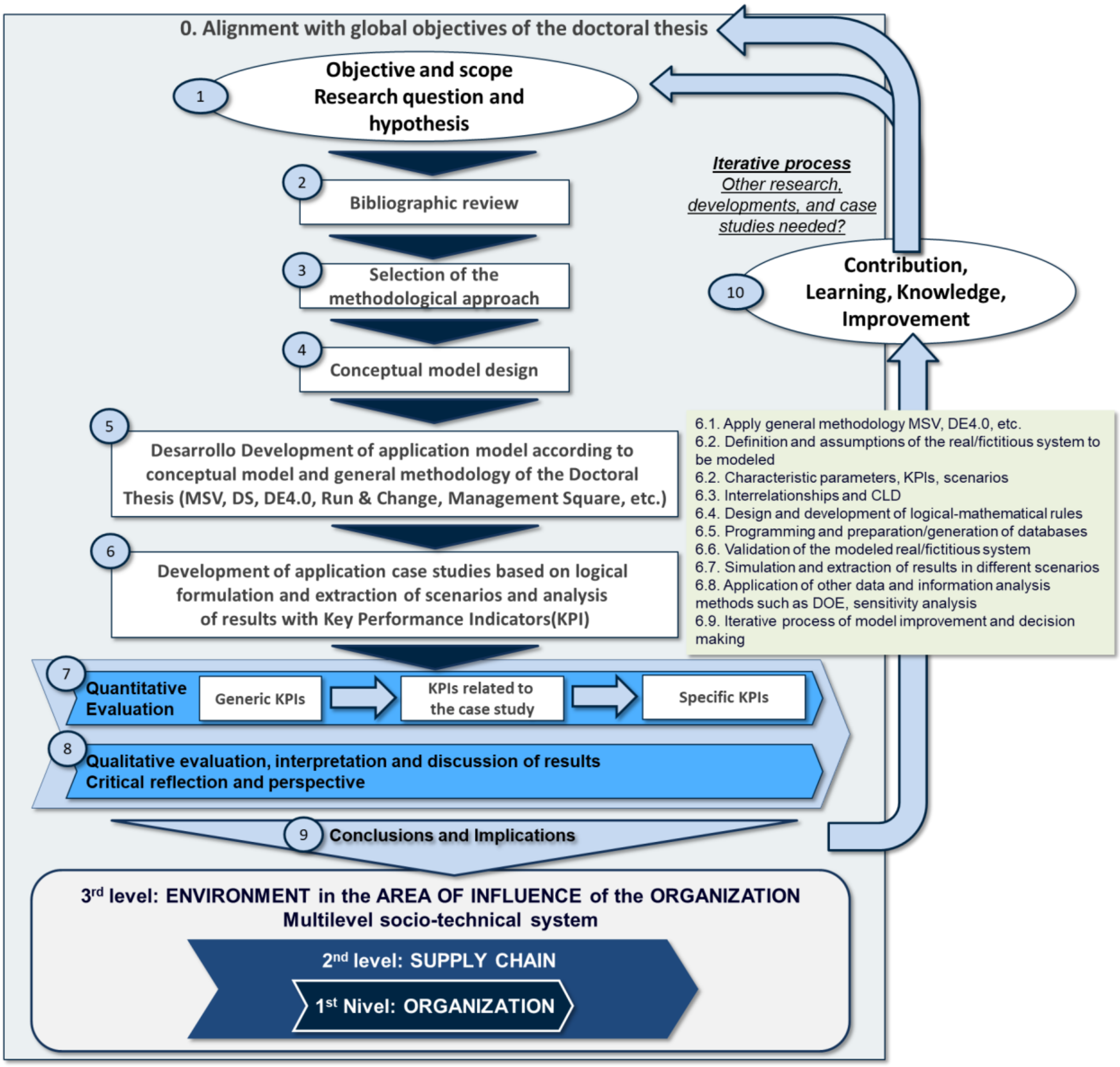

Figure 9: General Methodology for Modeling the Case Studies (own elaboration)

2.3.3. Methodology of Case Studies: classification and sequence

Based on the scope of study, and the fields for case study generation and characterization, all the case studies presented in Figure 9 are derived and classified. In it, three phases are observed according to the management level and the generic or specific approach. The first begins with generic approaches, with Top-down modeling at normative and strategic levels, for a second phase to focus on specific case studies at tactical-operational levels with mixed Top-down and Bottom-up approaches, while in the third phase turns to generic top-down approaches at normative-strategic levels. On the other hand, there are two phases when considering a first phase with mechanistic approaches and with a focus on production and SC, while the second phase includes the social and anthropological approaches of the human factor with a holistic system perspective on the three levels towards sustainability and thanks to the RSC.

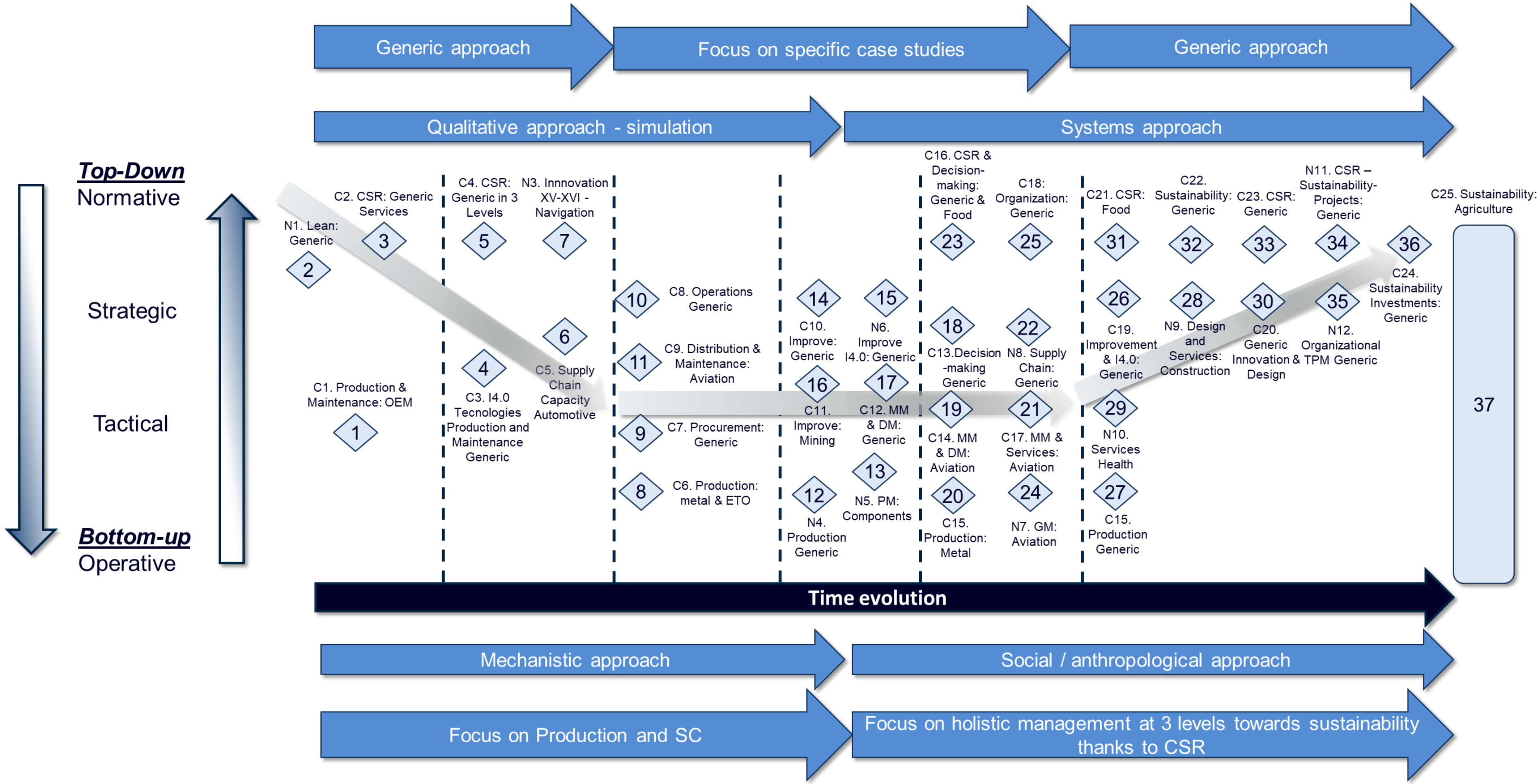

Figure 10: Classification and evolution of case studies (own elaboration based on [40, 41, 51, 65, 72, 107, 130, 139, 142, 145, 146, 147, 267, 341, 370, 439, 446, 453, 454, 465, 467, 468, 476, 486, 487, 488, 489, 490, 491, 567, 568])

3. Development of a logistics management system for adaptability and sustainability improvement

3.1. Modules and tasks

When an organization is considered, it can be seen as an entity with a certain set of capabilities that allow it to carry out various activities that lead to a position in the market and, consequently, as an agent that interacts with its area of influence. In this context, the organization faces a set of current challenges that are managed with actual organizational capabilities. Furthermore, those capabilities can be enhanced through the use of existing technologies as well as new technologies. However, the successful management of current challenges and the integration of technologies do not necessarily lead to ensuring their viability over time. An organization must anticipate future challenges and make use of existing and future technologies to ensure the sustainability of the organization. Future challenges therefore determine what target organizational capabilities will be needed to adapt an organization to them. Based on these target capabilities, future technologies can be researched and developed to help achieve them. As a result, a technology strategy formulation aligned with the business strategy can be derived. Finally, the transformation from the current organizational state to the future state can be initiated thanks to the development of related roadmaps as seen in Figure 10 [370]:

Figure 11: Transformation of actual to target organizational capabilities [370]

The steps listed above must be performed iteratively to ensure the alignment of environment challenges, business strategy, organizational capabilities, and technology strategy and its related activities. Furthermore, the technological strategy can be push, that is, t*echnology-oriented*, or *pull*, that is, *need-oriented*, an organizational need based on a market need. On the other hand, the strategy proposed by the conceptual framework is a *hybrid push-pull model* as shown in Figure 11 where there is a certain market need as a challenge for an organization that is specified in a certain level of detail. Based on it, a prediction of the future market need and the capabilities required to develop technologies can be defined. The level of certainty of a future market need, as well as the stage of actual development of a technology, determine where the *push-pull limit* of the hybrid push-pull approach is set [370]:

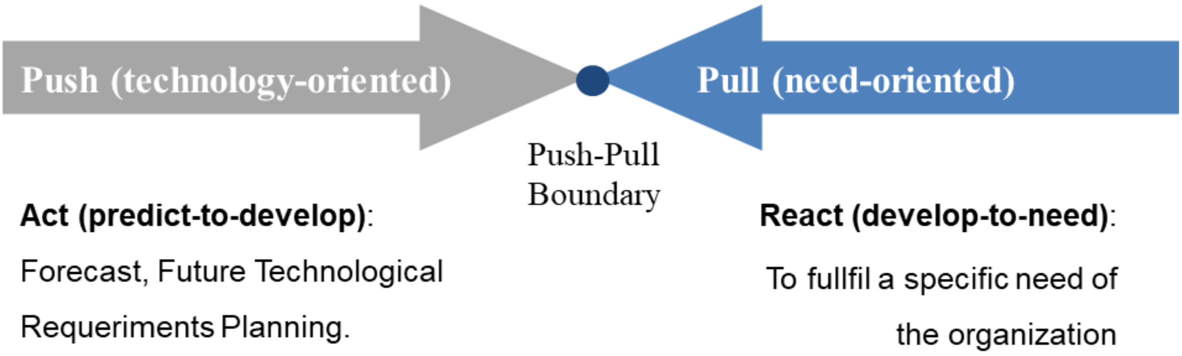

Figure 12: Technological strategy: Push-Pull boundary [370]

In this sense, to know which areas and organizational functions require improvement and transformation to face future challenges, it is necessary to know the organizational capabilities of the different functions at the present time. One way to identify these capabilities is to evaluate them against standard models known as maturity models that help to have a reference for the different modules, areas, and activities of an organization. In this way, it can be evaluated if there is an evolution in accordance with the goals to face current and future challenges and therefore be more sustainable. In this way, in the context of the organization, the notion of maturity is used to define, evaluate and form a guide and a basis for evaluating the progress in the business (i.e, the maturity of the process or a technology). As the maturity level increases, better progress is made in different aspects that contribute to the evolution of the organization [63]. To measure the degree of progress and advancement, maturity models were developed. Usually applied to new technologies, its objective is to provide information on the continuous improvement of the process and the analysis of the status quo. Taken together, the maturity model describes an anticipated, desired, or typical developmental trajectory [62]. There are several well-accepted generic Software Process Capability/Maturity Models (SPCMM), as well as models based on ISO/IEC 15504 that provide a common baseline for capability assessment and for reporting the outcome of the assessment using a common scale measure [63]. Schuh et al. [432] have developed an organizational structure maturity model that can be used to manage the digital transformation of companies in the context of I4.0 [433]. However, a common procedure to methodically support the implementation of I4.0 across the industry has not yet been established, and therefore maturity models are not notably common either. In addition, procedural models are generally applied, which mostly lack specific evaluations or measurements, as well as goal-oriented models [62]. Maturity models or frameworks aim to help organizations by providing comprehensive guidance for the definition of appropriate roadmaps [63] aligned with organizational objectives. Investments in I4.0 must be carried out using an integrative approach that generally involves a roadmap, which is a general plan for the deployment of new technologies, containing the organizational change and explaining the main phases that must be carried out. This digital transformation roadmap is unique to each company and requires the participation of all organizational levels and decision makers [434]. In this sense, each organization must develop and review its model for the continuous transformation of its business model and its functions to be aligned with both current and future organizational goals so as to ensure its sustainability in the short, medium, and long term by being able to face current and future challenges. A company needs to change continuously to be viable over time. For this, the model in Figure 12 is developed. Thus, the model considers the dynamics of the environment related to the organization; the current level of maturity of the organization's capabilities, including an assessment of processes; the organizational structure, including personnel qualification and indicators, systems, available methods, organizational structure and related systems, as well as the expected business dynamics; existing optimization alternatives; and an target system of indicators for the evaluation of new initiatives that incur in investments, costs, time, space, etc. [65]. The model is designed based on current capabilities and the goals of an organization. On this basis and in order to ensure long-term viability, a company needs to define future organizational goals with related future capabilities to deal with expected market dynamics. However, to develop these future capabilities, a detailed analysis of the organizational structure and personnel and related functions, as well as an analysis and mapping of technical and managerial processes, must be carried out. Based on this analysis, the maturity level of capabilities and functionalities for each area can be determined by applying a defined assessment methodology. In addition, to complete the internal analysis of an organization, it is necessary to consider the historical dynamics, as well as the evolution of the human factor. In this context, gaps in reaching target capabilities can be defined as a consequence. In addition, new and existing methods, systems and technologies must be analyzed to develop optimization alternatives with improvement strategies and I4.0 technologies. As a result, the different alternatives and the dynamics of the external environment can be simulated, providing a dynamic evaluation of future scenarios to determine when and which improvement project initiatives will be included in the business transformation roadmap [65].

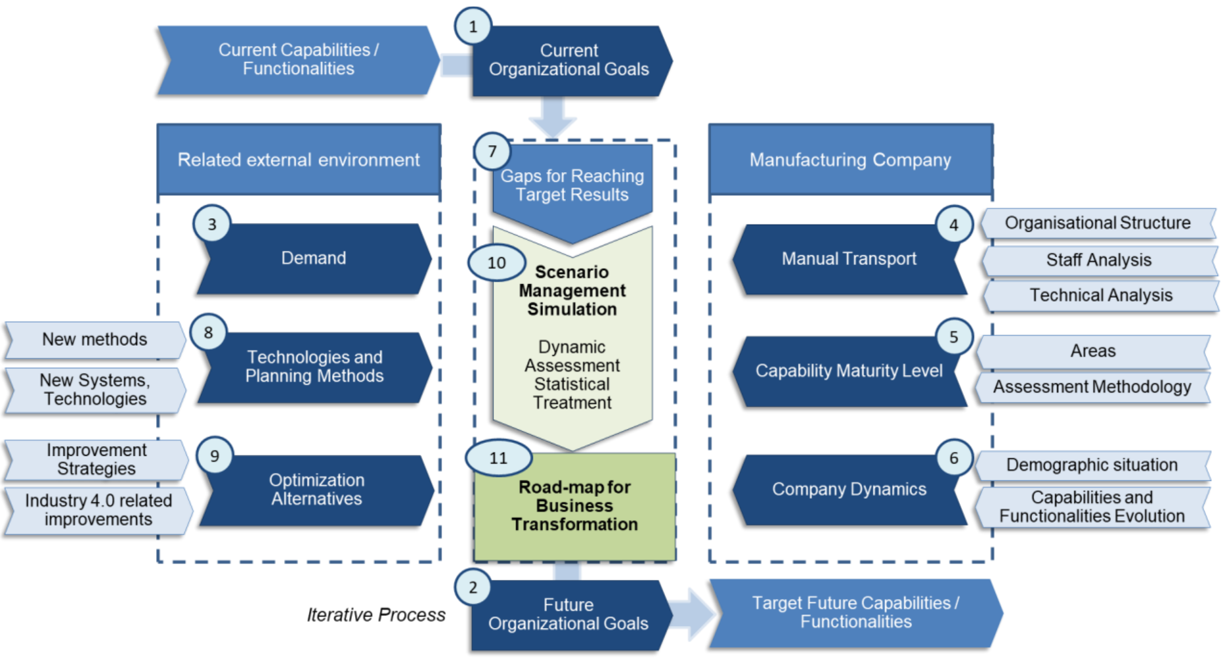

Figure 13: Model for continuous business transformation aligned with actual and future organizationl goals [65]

After having defined the generic conceptual framework, areas must be defined to identify gaps and improve related capabilities and functionalities. For this reason, the activities of an organization are grouped into nine modules, one normative or constitutive (Module 0) that includes the vision and purpose and therefore the consideration of Corporate Social Responsibility and Sustainability at the highest level of organizational management. In addition, it presents another eight different modules, as can be seen in Figure 3. First, the strategic level must be defined, then the necessary changes in the technical process can be derived, as well as the related production factors. Subsequently, operational and tactical management levels can be determined, and then vertical integration within the plant or production network can be developed. Finally, the horizontal integration between the supply chain partners and the impacts of the action of the production system or network on the related environment will be evaluated [65]. Furthermore, for a more detailed definition of the organization's capabilities, the tasks and factors associated with each module are described in Figure 13. This shows how an organization can define a set of relevant factors for each module, each of them having a specific state, with ongoing projects and activities and future optimization plans. Therefore, it is key to develop this framework for any organization as it provides the basic understanding of all functions, areas and factors. Based on it, a maturity assessment can be made and results can be derived regarding which areas need improvement to achieve organizational goals. The modules of the model would be represented in any organization, while the specific factors depend on the sector, the technical and management processes, the state of the organization and the supply chain actors and stakeholders [65]:

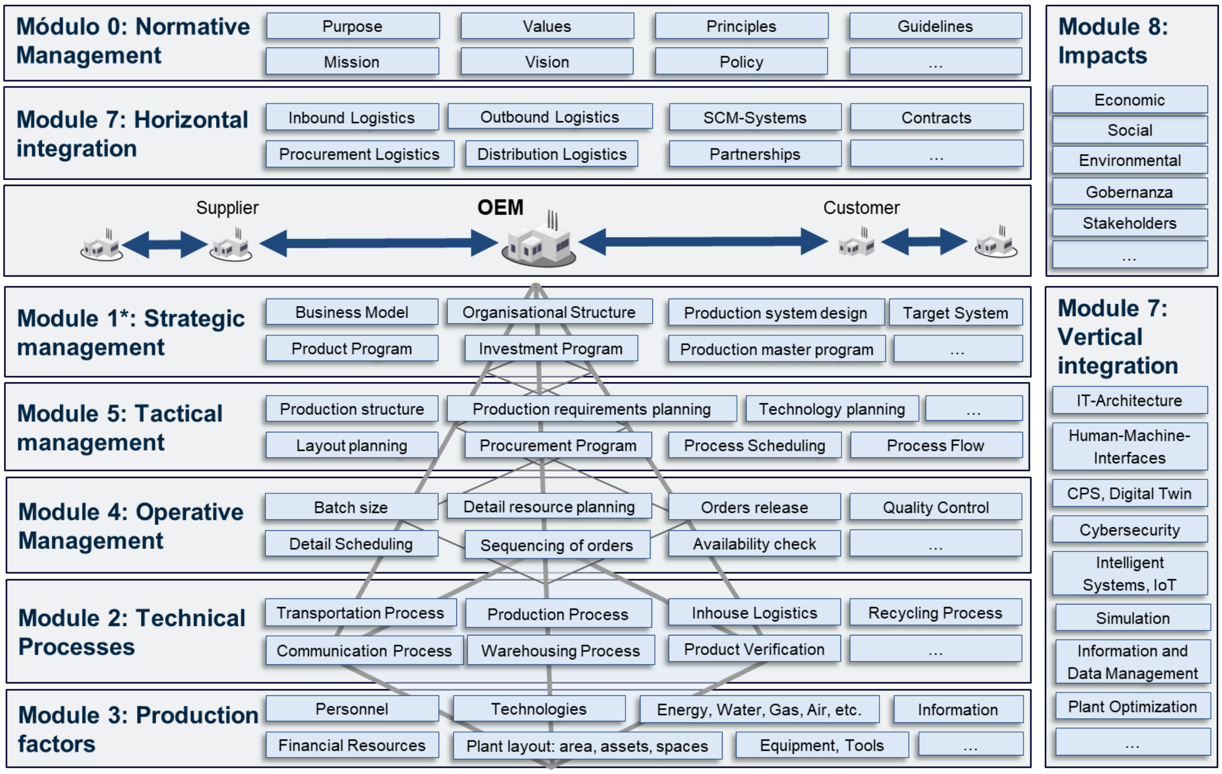

Figure 14: Assessment model of functions based on areas and factors (own elaboration based on [65]).

After having analyzed the modules of an organization, we proceed to determine the tasks of an organization that will ensure the sustainability of the logistics system. In this context, the tasks are initially derived through the Aachen production planning and control (PCP) model developed at the FIR research institute on the basis of extensive empirical experience that represents a reference model for the analysis, evaluation and conception of the PCP, with a focus on the consideration of the company's internal planning and control processes [168]. This model includes the tasks of the production network to consider the growing requirements of customers, the internationalization of purchase and sales markets, the substitutability of goods, and the ongoing globalization process, as production companies have reduced continuously its depth of value creation, finding itself more and more as part of a value creation network [168]. The PCP model of the production network can be understood as different companies that coordinate with each other or, alternatively, as a central planning authority. Within the framework of the network configuration, the individual company finds support in its own strategic positioning and its correlation with the need and design of a network of partners. The Aachen PCP model approach does not imply that a central planning authority designs an entire network, but rather that a network is configured through the individual classification of companies. However, the tasks mentioned are also applicable and valid for a central planning instance in the sense of a central supply chain design, such as in intra-organizational networks (for example, a group or consortium of companies) [168].

However, the limits of production and service management are becoming increasingly mixed, thanks, among other things, to new technologies. However, the full role of services is obscured in traditional trade statistics. First, services create about a third of the value that goes into traded industrial goods. R&D, engineering, sales and marketing, finance, and human resources enable products to go to market. Furthermore, we find that imported services are replacing proprietary services in almost all value chains. Going forward, the distinction between goods and services will continue to blur as manufacturers increasingly introduce new types of leasing, subscription models, and other "as a Service" (aaS) business models. Second, the intangible assets that multinational companies send to their subsidiaries around the world, including software, brand, design, operational processes, and intellectual property developed in other locations or at headquarters, represent tremendous value, but they are often priceless and untraceable unless they are captured as charges to intellectual property. Finally, trade statistics do not track the growing cross-border flows of free digital services, including email, real-time mapping, video conferencing, and social media. Depending on how it is calculated, trade in services could already be more valuable than trade in goods [435].

Based on the perspective of a growing importance of services associated with products, it implies that for the sustainability of an organization, the focus is on the joint provision of product-service to customers and users, as well as in their life cycle management, jointly as a key element to retain customers and generate profits with the service and the processes of satisfying the needs and demands of customers, instead of competing with a focus on production costs. Based on this, the tasks of the Aachen PCP model are expanded to include service and after-sales management, maintenance management, innovation and continuous improvement management, as well as environmental management, organizational decision-making, and the management towards sustainability. In addition, the tasks of the Aachen PCP model are subdivided into the tasks of procurement, production, distribution and management of information systems, therefore considering the SCOR model. As shown in Figure 14, 10 different tasks are required for intra-organizational logistics management:

1. Procurement management: consists of the planning and control of external supplies [168]: procurement order management planning, inventory management, supplier selection, etc.

2. Production Network and/or Operations Management: Network tasks include strategic design of network configuration, sales planning, and network demand planning. The main tasks are production schedule planning, production requirements planning, internal production planning and control [168], and thus includes the production network planning and control tasks in three different activities :

   a. Sales management: consists of the tasks of determining the demand of the network and its disaggregation into primary and secondary needs.

   b. Production management: includes the distribution of demand between production plants, as well as the planning of the PMP and capacity requirements. The core tasks include all the tasks of the actual product creation process under the individual company approach. The original focus of Aachen PCP, the optimization of processes within the company, is reflected in this definition [168].

   c. Management of the manufacturing process: it consists of the planning and control of the manufacturing process and its associated factors and parameters.

3. Distribution management: consists of distribution planning and control. In addition, it also includes inventory management in the distribution network and external outsourcing of distribution activities [168], thus carrying out the design, planning and control of the distribution network, including transport planning, supply order management and sending within the network, etc.

4. Maintenance management: based on the growing importance of maintenance understood as a function and task to be included in logistics management in an integrated manner [27, 183], the conceptual model includes maintenance management as a main task consisting of all maintenance activities associated with production but also those associated with the entire organization in the maintenance of all its different objects and flows thanks to the TPM concept and the monitoring approach based on the Reschke et Gallego-García model [107]. Therefore we can identify:

   a. Maintenance management associated with production.

   b. Maintenance management associated with the entire organization.

5. Service and after-sales management: a manufacturing organization must consider service management as its main task, including the sale of services, industrial or not, as well as managing the after-sales network. In this sense, this task treats the client or user as the main focus and manages their point of contact with the organization, group, or cooperation network of organizations in the joint provision of the product-service.

6. Innovation Management and Continuous Improvement: today, innovation is no longer conceived as a specific result of individual actions, but innovation management plays a fundamental role in the generation of knowledge, the allocation of resources and the investment planning. Therefore, a continuous development of innovation is necessary to generate companies and maintain and improve the competitiveness of existing organizations [109, 110, 111]. Therefore, an innovation strategy must be linked to the vision of the company and the global business strategy, and be based on complete and relevant information, both from within the company and from the market and the environment [112]. In addition, companies have to analyze, monitor and make improvements to their existing systems to meet market competition [49].

7. Information systems management: includes the cross-sectional tasks of the Aachen PCP model such as order management, inventory management and control from the system point of view, as well as the task of controlling finances and managing data that is assigned to all types of tasks, since all the tasks of the PCP model are linked to data management when performing the tasks [168].

8. Organizational decision-making management: an organization understood as a socio-technical system, involves various members as well as their human-machine interaction towards decision-making. Given the increase in interactions of different types (H2H, H2C, C2H, C2C) in decision making, it is essential for the sustainability of organizations to identify all decisions and their typology. In addition, taking into account that an organization is the joint action of its members to achieve common goals, it is assumed that each of the members acts in accordance with the principles and objectives of the organization [436]. However, the behavior of the organization is influenced by the motivations of its members as well as by the interaction between them. Therefore, this organizational decision-making management task is key to sustainability since, as Pérez-López (1997) indicates, "at the bottom of any specific organizational theory there will always be some implicit assumptions about what a human being is", how the actions of human beings are motivated, how and what they learn [...]. Different assumptions […] lead to different prescriptions as to what needs to be done to achieve a desired behavior [437].

9. Environment management: an organization is no longer studied as a single company, but in the context of its relationship with the environment, so knowing how to deal with the complexity of the environment is key [292]. For this reason, a specific task that must be carried out in any organizational logistics system is to identify the situation of the environment, as well as to determine its possible projections in the aspects and agents in the area of influence.

10. Management for sustainability: through the concept of CSR. It is the task that allows to ensure the stability of current operations, as well as and based on the management of the environment, to be able to derive a SWOT that allows influencing the strategy and decision making to prepare the organization for any future event, ensuring its sustainability.

All the tasks of the organizational logistics system present strategic, tactical, operational activities, as well as technical processes and factors following the principles of CSR to fulfill the purpose and mission of the organization.

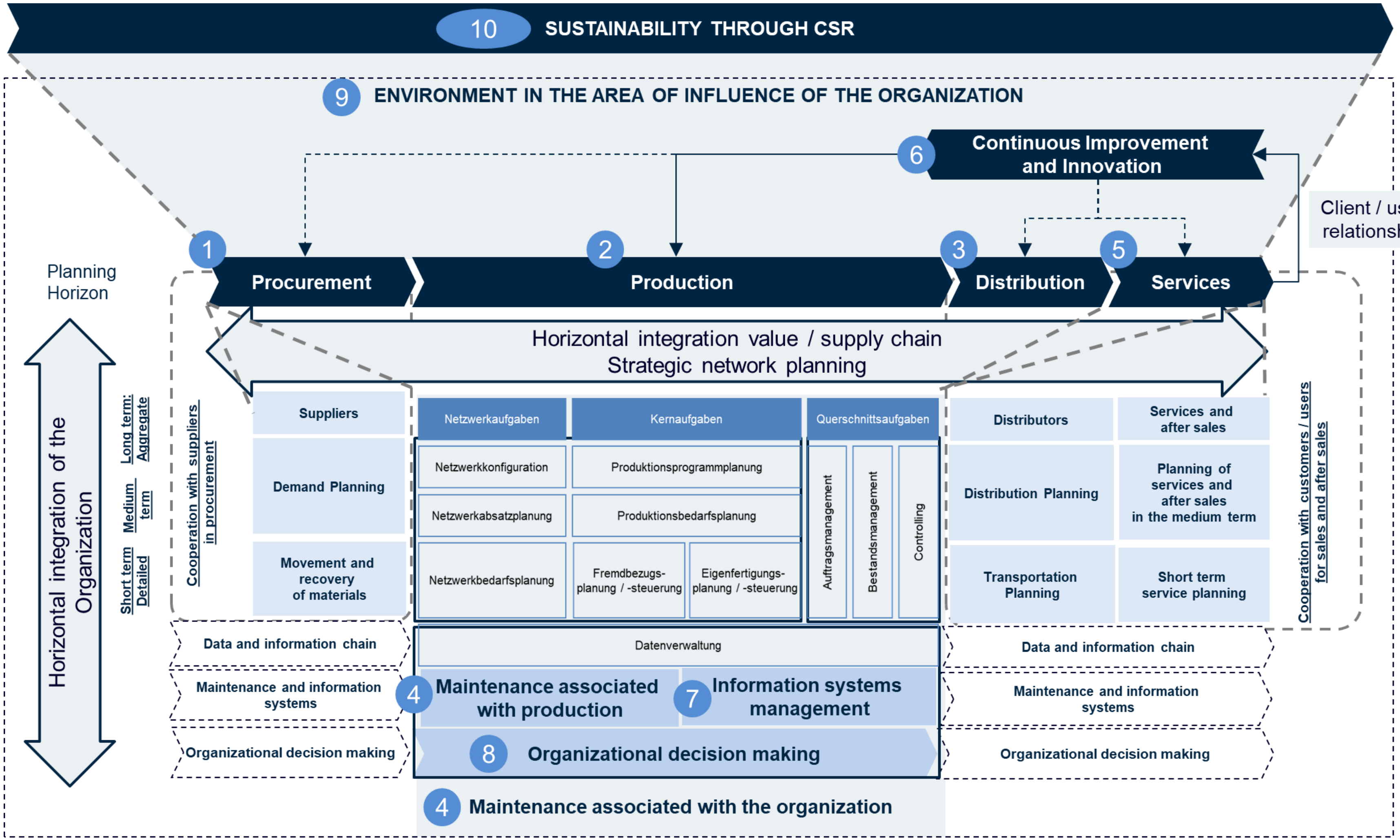

Figure 15: Derivation of the tasks of an intra-organizational logistics management system oriented to the client/end user (own elaboration based on [27, 107, 111, 168, 183, 213, 227, 292, 341, 414, 435, 437])

3.2. Conceptual Model

After having identified the modules of an intra-organizational logistics system for its management at the different normative, strategic, tactical, and operational levels (*Run* – chapters 5.2, 5.3, 5.4, 5.5, 5.6, 5.8 of the DT) and for its innovation and continuous improvement (*Change* – chapters 5.7, 5.9, 5.10, 5.11 of the DT), we proceed to design the conceptual model that will allow their interrelation taking into account the objectives of adaptability and sustainability thanks to the consideration of the concept of Corporate Social Responsibility.

The VSM is based on three fundamental principles: viability, recursiveness and autonomy. Viability is a property of every system that is capable of reacting to internal and external disturbances to maintain a separate existence [119]. The recursion principle states that every system has the same structure regardless of the recursion level [292]. The principle of relative autonomy describes the degree of freedom in the behavior of a recursion level. In this context, autonomy means that a system can act independently as long as it is coordinated with the rules of its management system [456]. The cybernetic model of any viable system always consists of a structure with five necessary and sufficient subsystems that are related in any organism or organization that is capable of preserving its identity regardless of its environment [203]:

- *Run*: Systems 1, 2 and 3 regulate internal stability and try to optimize performance within a given structure and criteria [291]. System 3 is the coordination center of all the internal areas of the company considering the goals for the entire company since systems 1 and 2 can only compare deviations locally [292]. The 3* system audits the operations and allows deviations and anomalies to be identified, establishing the basis for initiating decision-making that allows them to be mitigated, acting as a catalyst for Change.
- *Change*: System 4 is the strategic system that performs the analysis of the external environment and the internal capacity to face it and, based on it, makes the necessary strategic decisions [290]. System 5 represents the normative level that balances current operations (System 3) against future needs (System 4). When there is no balance, System 5 plays the role of judge [203]. It defines the rules that determine how the overall system behaves. It is continually designing the future of the system through the elaboration and choice of behavioral alternatives. Here the company policy is created, through a close interaction between the management systems, 3, 4 and 5 [292]. System 5 is top management and determines policies and sets goals for decision making [291]. Therefore, the system 5 of an organization is the beacon with which all decisions at any level must be evaluated. In this way, this change management process in the model, *Change*, presents a direction thanks to the consideration of the CSR concept in the normative system, system 5. Then, it is implemented in system 4, strategic system, and in the scenarios which it analyzes based on information from the environment while ensuring technical, economic, organizational feasibility, and deadlines, form of implementation, etc. with system 3, the planning and control system, to generate the future vision of the organization and guide the change towards a sustainable future state.

First, we consider the company and its stakeholder environment. Based on this classification, the organization will be analyzed as a VSM with different recursion levels. A company is assumed to be a viable system, which is the recursion level in focus where the five systems necessary to ensure viability are found. Therefore, in this thesis multiple levels of recursion can be differentiated:

• The highest level, group of organizations or consortium (n − 1),

• The recursion level in focus, the organization (n), which includes the different functional areas such as innovation, production, maintenance and quality, etc. For the production recursion level, and the same development can be carried out for the rest of the functional areas [341]:

  o The recursion level of production (n+1). At the same recursion level of finance, human resources, IT, research and development, etc.

  o The recursion level of the production plant or workshop, for example, production management activities in a production or assembly workshop (n+2),

  o The level of group of machines, machine or installation with the associated activities for the different productive activities such as machine preparation, tool change, operation, production control, etc. (n+3).

The activities at the recursion level n+3 are not any more viable systems, unlike the higher recursion levels, because they do not contain a structure like that of the VSM, since they are the singular production objects or assets. Within the recursion level of the organization, the different functions of a company can be found, such as production, maintenance, commercial, finance, research and development, information systems, etc. In this thesis, all areas are analyzed in detail in relation to intra-organizational logistics, recursion level n, but also considering the possibility of a group of companies (n-1) as well as the different functional areas (n+1) and in some cases its lower recursion levels (n+2, n+3). System 5 of the consortium (n-1) or organization (n) defines its legal framework, policy, corporate policy and constitution, ethos and underlying values, as well as its leadership philosophy. All of this information is transferred to all functional areas within the organization, including the production system. Using these common normative values, the company receives information from the environment, which can be: the behavior of the competition, data from new markets, new technologies, changes in regulations, influences of globalization or changes in the company's market. Based on these inputs, the company defines its strategy in system 4 at the company level in continuous communication with system 3 to check if the strategy can be implemented and the internal consequences of its implementation on the stability of the company. System 2 at the company level plays the role of coordinator between the functional areas of the company trying to resolve conflicts between them. In addition, the systems 1 at the company level are all the functional areas of each company, such as production.

In Figure 15, it can be seen the recursion level of an organization. It can be seen how an organization defines a policy and a mission, that is, a purpose of its existence within society, which is determined by its own consideration of the concept of Corporate Social Responsibility and what model and theory of CSR it wants and is able to implement in your organization. From this choice and the capacity of the organization to carry it out, the implications for the entire organization are derived, not only in its relationship with its internal stakeholders, but also with external stakeholders, the related society, and the environment that interact with it. From it and from the continuous observation of the organization's environment, the strategy of the organization itself is developed, which will be harmonized with the normative approach defined in the company's mission. With this objective, the strategy is influenced both by said analysis of the state and prospecting of the market and environment of the organization, as well as by the internal state and by its capabilities and functionalities. This consideration is extremely important, since the strategy is formulated to be implemented. Thus, the vision and mission once they are described and divided into projects, plans, activities, and tasks, these must be feasible and implementable, while the organization itself has to ensure its stability with its internal mechanisms to plan and control its operations. Therefore, the organization is faced with the challenge of transforming itself (*Change*) continuously according to its strategy while maintaining its operation (*Run*), that is, it must advance without stopping changing, leaving in the end an organization in which only the change prevails, this being the original source of the company's sustainability. However, the ability to be sustainable will depend on the ultimate goal that motivates all change and all existing operations; that is, it will depend on whether this object is on the one hand aligned with the purpose of the organization and therefore depends on the CSR theory or model selected, and on the other hand on the way in which said model is selected. If change is what prevails and what the organization can do to adapt to the market, it means that such a change function is key to sustainability. Every change is born from an improvement or innovation for the organization (perhaps not in the market, but within the organization). Therefore, the function of innovation and continuous improvement is included within the organizational operations, which considers a specific environment as well as an interconnection with the other functions as well as with the other systems and organizational elements. Therefore, a key fact of this representation is that considering the function of innovation (*Change)* as part of a whole, which is the organization, this function of innovation and continuous improvement influences all other areas when introducing a novelty, an invention, and for it to become and establish itself as an innovation and therefore as a source of change that promotes sustainability and alignment with the organizational purpose.

In this sense, it is key to evaluate and select the innovations and improvements through an assessment of the implications for the existing organizational operations, for the phase of introduction in the organization, as well as the effects of said innovation on the supply chain, the stakeholders and the related environment. Knowing that innovation is a high-risk activity in terms of its development and implementation success, it is essential to identify the risks throughout the life cycle of any innovation as soon as possible, to support decision-making about investments in future inventions, that is, to avoid or control the investment in an invention or in the introduction or maintenance of an innovation within the organization if for any reason (cultural, technical, organizational, etc.), it has implications for other functions that compromise the effective and efficient achievement of the organizational purpose [341].

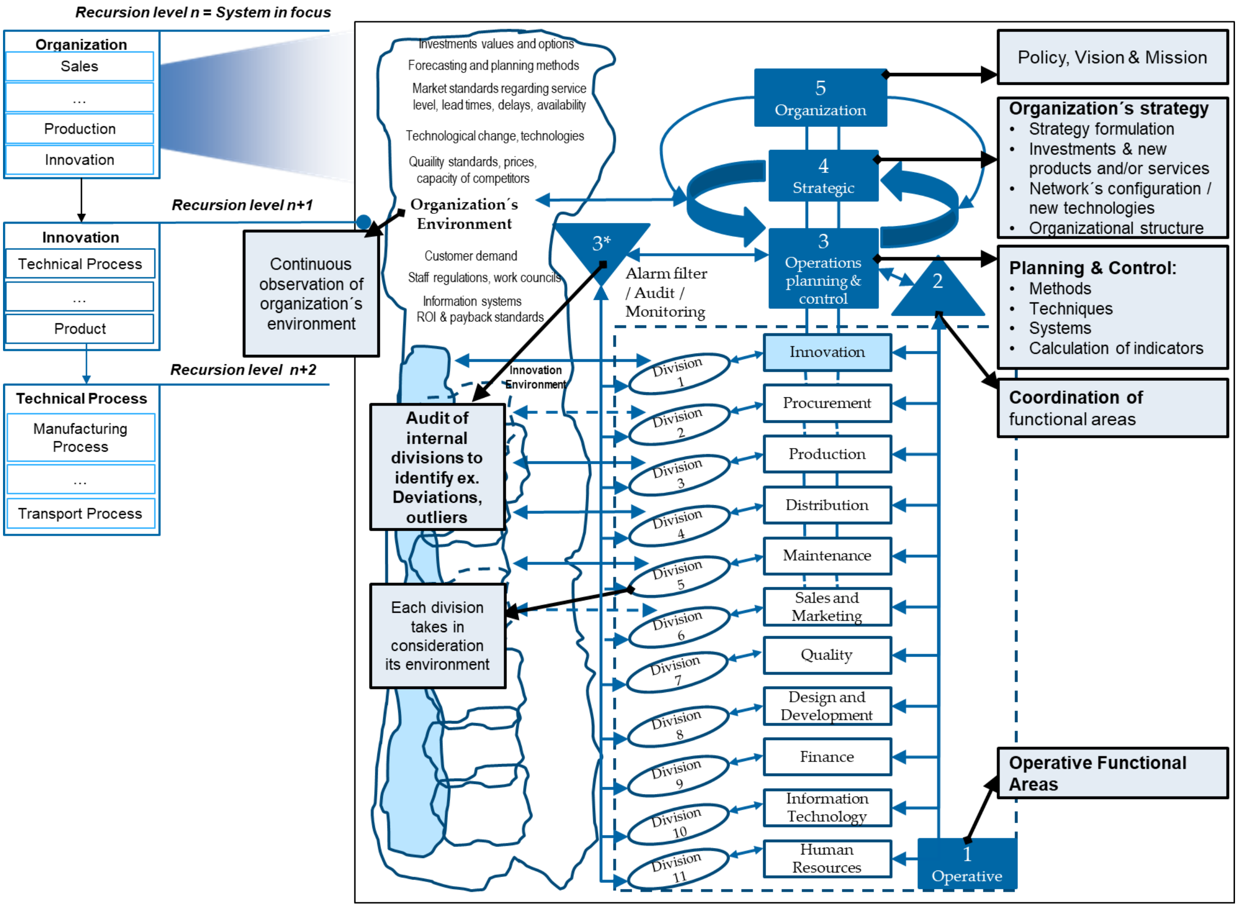

Figure 16: Recursion level for an organization based on the VSM with its functional areas as systems 1 [40, 41, 139, 341]).

The Systems, their tasks and communication flows are defined in detail in the main text based on the VSM.

The target system of the conceptual design is oriented to the three levels: the organization, its supply chain, and the related environment as can be seen in Figure 16:

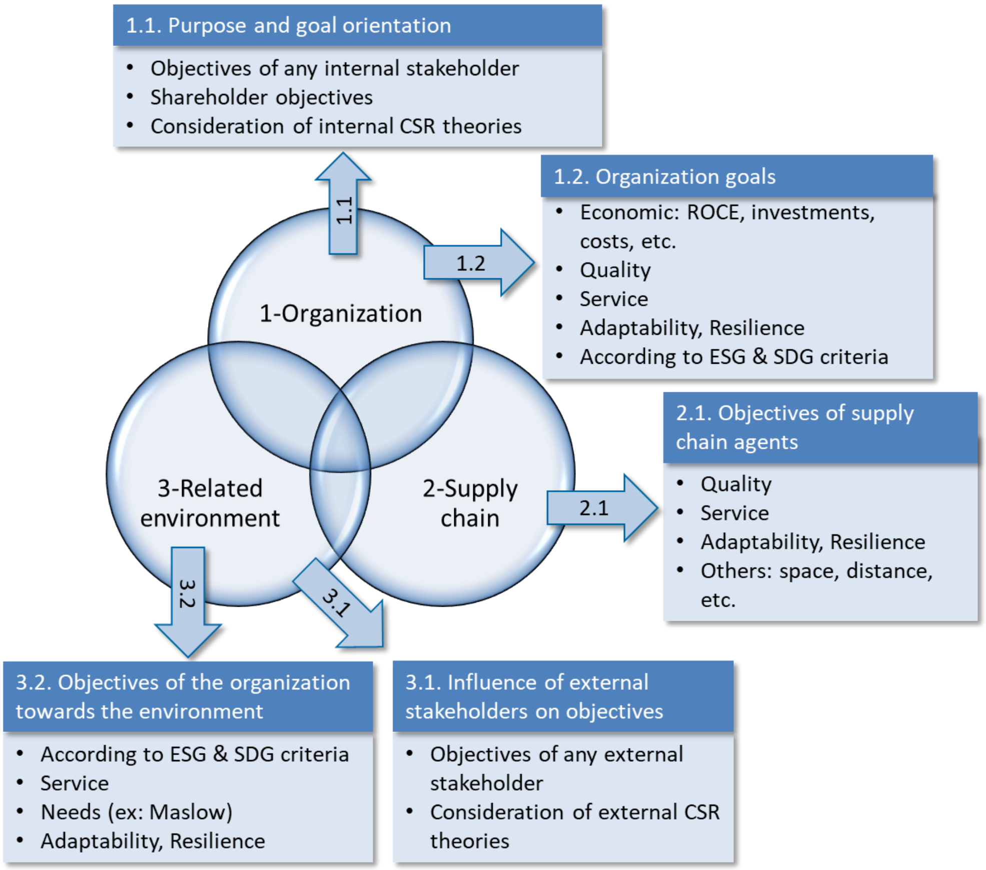

Figure 17: Target system in three areas for a given organization (own elaboration based on [370]).

This subsection deals with the *Magic Management Square* in its elements that belong to the *Run* and that make the organization work and be effective in fulfilling its purpose, ignoring the clients or users since they do not belong to the company. Therefore, the consistent socio-technical system of the organization with its structure and organizational processes, human beings, and the assets and technical inventory that comprise it will be treated. Based on this, the three areas will be analyzed after introducing the global OEE indicator as an analogy of the technical OEE applied to the rest of the elements of the socio-technical system. In the organization, the evolution and background of the organization will be analyzed, in the human being in all his physical, cognitive, emotional, and affective nature to consider it in his own life and in the sustainability of the organization, and in the technical field from the analysis of the prescriptive condition of OEE throughout its life cycle with a focus on technical availability that includes all the flows that make it feasible for the technical object to be available. The analysis is carried out from the availability, performance, and quality of the three elements since it will depend on these parameters that they are capable of carrying out the organizational purpose.

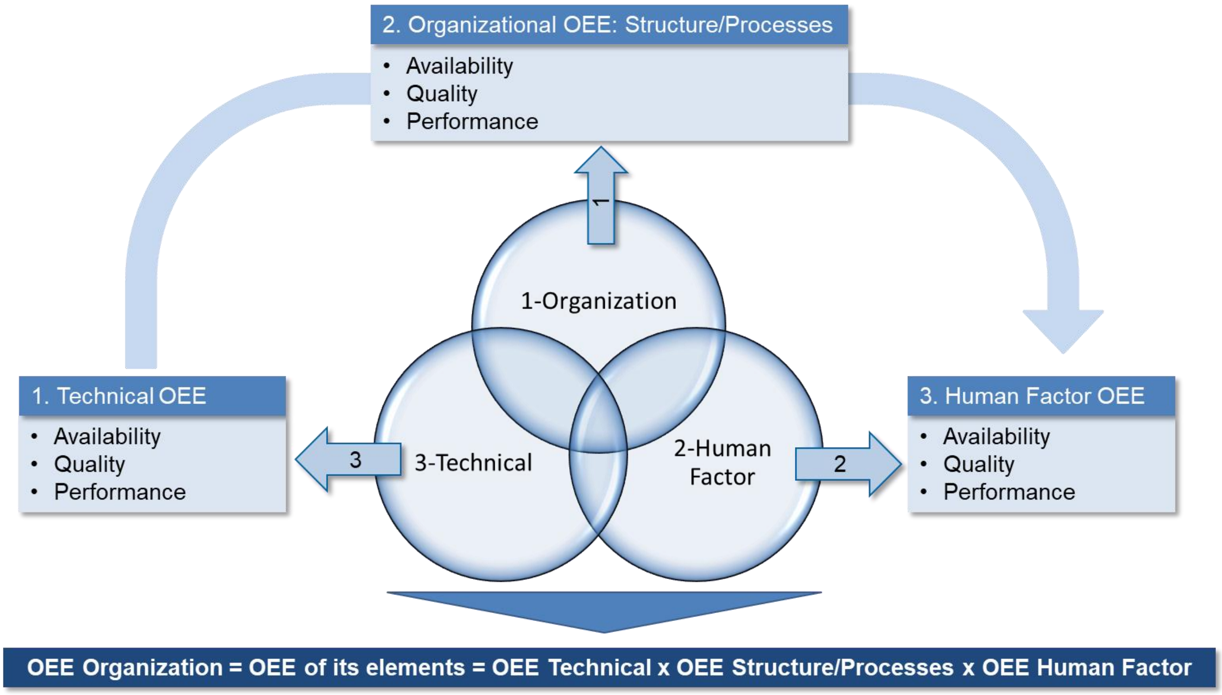

Figure 18: Sustainability of the organization as a socio-technical system: from the focus on technical and organizational to the focus on the human factor (own elaboration)

To clarify the concepts, the following descriptions and examples are intended to help this goal:

1. OEE Technical:

1.1. Availability.

1.2. Quality.

1.3. Performance.

2. OEE Organization – organizational processes and structure:

2.1. Availability: due to a system failure that enabled the workflow in the system and until it is available again, work cannot be done.

2.2. Quality: due to lack of control of parameters during the process, it causes the quality to decrease.

23. Performance: lack of performance due to duplicities in the process and a multitude of organizational interfaces.

3. OEE Human Factor:

3.1. Availability: the human factor may not be available for physical, psychological (emotional or affective) reasons, or due to saturation or problems with mental or cognitive functions.

3.2. Quality: the human factor can reduce the quality of the task due to fatigue, emotional or affective conflicts, etc.

3.3. Performance: the human factor can decrease performance, that is, the volume of tasks per unit of time when, for example, a 12-hour day is spent without rest.

From these parameters can be derived the risks that the global system, global OEE does not reach the minimum value to meet the objectives and therefore determine measures to mitigate this evolution, an example of measures for each of the three elements would be:

1. Technical OEE measure: monitoring and prescriptive-preventive maintenance.

2. Organization OEE measure: flatter organizations with an agile philosophy and processes according to lean principles.

3. OEE Human Factor Measure: help with nutrition, physical, exercise and mental wellness habits, mindfulness workshops, as well as conflict and stress management, accompanied by the improvement of technical skills and management with specialized training.

If every technical element is controlled by the human being, every technical output depends on the human factor. Traditionally we have tried to understand the technical elements and the organizational elements, however, the organization is the result of the interaction of human beings, and if we do not understand the behavior of the latter, we can hardly deduce organizational behavior. On the other hand, the technical elements, without being autonomous, and even being so, need a design and maintenance based on or carried out by the human factor, that is, they cannot execute the purpose of the organization without interacting with the human factor. Therefore, after a series of industrial revolutions with a focus on technical systems, as well as a 3rd revolution of the production system, the next step is to integrate the human factor in all its nature in the environment of the 4th industrial revolution.

The case study tries to generate a conceptual model that includes all the elements that make up the socio-technical systems, such as the organizational, technical, and human factor aspects. In this sense, the study seeks to analyze sustainability by studying these three factors, since the sustainability of systems has traditionally been studied according to technical and organizational criteria, while the human factor has been considered by many as a black box within the system. Therefore, the organizational models have been able to present explanatory models at a high level, but at the level of the human factor or small groups they have presented limitations due to the lack of global consideration of it. In addition, the conceptual model presents a system for the data-based identification and preparation of the risks that compromise the sustainability of the organization, and therefore, the socio-technical aspects of any organization. New parameters are generated for risk analysis as well as decision-making thanks to the organizational decision model and the human factor based on an extended model that allows its consideration in the sustainability analysis through the use of mathematical modeling:

- Need and contribution to it of the approach that encompasses the human factor within the analysis of the sustainability of any socio-technical system, which with the arrival of new technologies is applicable to any organization.

- Method for analyzing the situation and risks for sustainability based on the 360 study of the organization and its elements.

- Ability to generate road-maps to increase the resilience and therefore the sustainability of the different systems.

- The need for the advent of the fifth industrial revolution to include the human factor and its decision-making as a point to improve and coordinate with the rest of the systems.

- Need to train the human factor to be the best version of themselves.

- Influence of the human factor in organizational interactions.

In the case studies, it began with a mechanistic human factor approach, while later the social and anthropological approaches of Pérez-López [436] were integrated towards a consideration as a central factor within the systems and modules that include analysis and simulation capabilities.

In the generation of an intra-organizational logistics information system, all stakeholders must be considered, exposed or not, official or not, that may affect and be influenced in one way or another in or by the behavior of the organization, including the existence pressure groups within the law or outside it. Within this model of consideration of stakeholders, existing theories of CSR must be considered, both in their internal and external perspectives, since contrary to what the literature presents as the decision to adopt one or the other, this thesis advocates a model of stakeholders in which all are considered, but in which the weight of each stakeholder in terms of its influence and power of impact / negotiation with the organization varies dynamically over time, and therefore may be the institutional agent more important during an initial phase, for example thanks to the grant for the development of a start-up, to later be the agents in relation to the supply chain in an expansion phase, or it can be the society in a maturity phase in which the company is already established. Therefore, being a matter of multiple simple relationships, it ends up leading to a complex challenge for which the human mind is not capable of deciding optimally in most cases, taking into account all the agents and factors, with their adequate prioritizations when considering the three levels, organization, supply chain and related environment. So this design model focuses on a key intra-organizational logistics information system or ecosystem so that the organization can know its situation on the one hand, the situation of all the interested agents on the other, as well as the situation of the environment in the area of influence, in order to influence decision-making at all levels based on the normative model chosen by the organization.

In this way, the generation of a conceptual model and its simulation that includes all the stakeholders in a generic model applicable to any organization is sought. The non-consideration of stakeholders in this case increases the risk as well as decreases sustainability, since the possible effects on them as well as the consideration of their interests cannot be taken into account or valued, so that decision-making would omit a factor that may be more or less relevant to sustainability. The model is based on the following steps and principles:

1. Conceptual model and systematic consideration of all stakeholders.

2. Interrelationships with a systemic approach.

3. Systematic application with simulation capabilities and different behaviors of the stakeholders.

4. Digital case study.

Taking into account the development according to the VSM and the dynamic consideration of stakeholders and theoretical perspectives of CSR, the information system or ecosystem is now developed based on the MSV according to Figure 18:

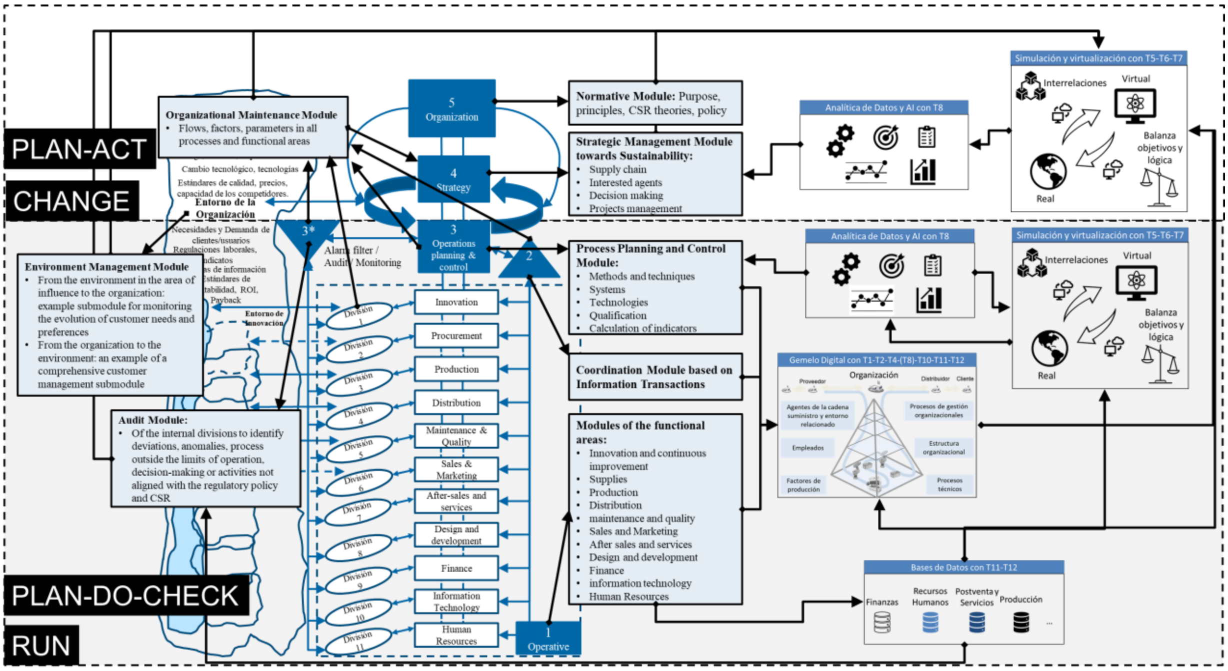

Figure 19: Logistics Information Ecosystem based on modules and the VSM: *Run and Change* towards sustainability (own elaboration based on [40, 41, 139, 341])

3.3. Types of systems: digital twins and simulation models

The doctoral thesis presents a variety of applications of the conceptual model in different sectors and scenarios based on the generation of digital twins of logistics systems for their simulation. In addition, there are also studies and developments of a qualitative nature or based on bibliographic analysis for the development of new concepts as well as to derive gaps, implications and recommendations for researchers, managers, and technicians in the field of the doctoral thesis.

Table 1: Classification and order of presentation of systems of the conceptual model (own elaboration based on [40, 41, 51, 65, 72, 107, 130, 139, 142, 145, 146, 147, 267, 341, 370, 439, 446, 453, 454, 465, 467, 468, 476, 486, 487, 488, 489, 490, 491, 567, 568])

No. CS	Order	Title of the Case Study (CS)	Modelo	VSM System/s	Run-Change
C16	1	Development of a Business Assessment and Diagnosis Tool That Considers the Impact of the Human Factor during Industrial Revolutions	Corporate Social Responsibility towards Sustainability	5 / 4 / 3* / 3	Run/ Change
C22	2	Management and modelling organizational stakeholders for sustainability	Corporate Social Responsibility towards Sustainability	5 / 4 / 3* / 3	Run/ Change
C21	3	Modelling of internal and external Corporate Social Responsibility´s Theories: a simulation study for the food value chain	Corporate Social Responsibility	5 / 4 / 3* / 3	Run/ Change

			towards Sustainability		
C18	4	Design and Simulation of Manufacturing Organizations Based on a Novel Function-Based Concept	Production Organization	5 / 4 / 3* / 3	Run/ Change
C5	5	Design and Simulation of a Capacity Management Model Using a Digital Twin Approach Based on the Viable System Model: Case Study of an Automotive Plant	Production Organization	5 / 4 / 3* / 3	Run/ Change
C4	6	Design and Simulation of an Integrated Model for Organisational Sustainability Applying the Viable System Model and System Dynamics	Production Organization	5 / 4 / 3* / 3	Run/ Change
C2	7	Applying the Viable System Model to an Organization with CSR Goals: The Case of a Charity Organization	Service Organization	5 / 4 / 3* / 3	Run/ Change
C17	8	Design and Simulation of a Digital Twin Mobility Concept: An Electric Aviation System Dynamics Case Study with Capacity Constraints	Service Organization	5 / 4 / 3* / 3	Run/ Change
C13	9	Modeling Human Decision-Making Delays and Their Impacts on Supply Chain System Performance: A Case Study	Organizational Decision Making	5 / 4 / 3* / 3	Change
C23	10	Corporate Social Responsibility Modelling and diagnosis of corporate interest groups: the Lobby Model	Organizational Decision Making	5 / 4 / 3* / 3	Change
C10	11	A Systematic Improvement Model to Optimize Production Systems within Industry 4.0 Environments: A Simulation Case Study	Improvement strategies	4 / 3* / 3	Change
C11	12	Production optimization oriented to value-added: from conceptual to a simulation case study	Improvement strategies	4 / 3* / 3	Change
C3	13	Industry 4.0 implications in production and maintenance management: An overview	Industry 4.0	4 / 3* / 3	Change
C19	14	Integration of Improvement Strategies and Industry 4.0 Technologies in a Dynamic Evaluation Model for Target-Oriented Optimization	Industry 4.0	4 / 3* / 3	Change
C24	15	From cost to service through social responsible investments	Socially responsible investments	5 / 4 / 3* / 3	Change
C20	16	The Dynamic Innovation Information System (DIIS) towards a New Management Age	Information systems	5 / 4 / 3* / 3	Change
C25	17	Sustainability in the agri-food supply chain: a combined digital twin and simulation approach for farmers	Information systems	5 / 4 / 3* / 3	Change
C8	18	Predictive Sales and Operations Planning Based on a Statistical Treatment of Demand to Increase Efficiency: A Supply Chain Simulation Case Study	Sales and operations	3* / 3 / 2 / 1	Run
C1	19	Design and Simulation of Production and Maintenance Management Applying the Viable System Model: The Case of an OEM Plant	Production and maintenance	3* / 3 / 2 / 1	Run
C6	20	Development of a pull production control method for ETO companies and simulation for the metallurgical industry	Production	3* / 3 / 2 / 1	Run

C7	21	Market-Oriented Procurement Planning Leading to a Higher Service Level and Cost Optimization	Procurement	3* / 3 / 2 / 1	Run
C12	22	Design of a conceptual model for a maintenance object within a producer: impact on distribution network-a simulation case study	Maintenance and distribution	3* / 3 / 2 / 1	Run
C15	23	A Novel Methodology for Assessing and Modeling Manufacturing Processes: A Case Study for the Metallurgical Industry	Maintenance and industrial services	3* / 3 / 2 / 1	Run
C15	23	Development of a System Dynamics Simulation for Assessing Manufacturing Systems Based on the Digital Twin Concept	Maintenance and industrial services	3* / 3 / 2 / 1	Run
C9	24	Development of a maintenance and spare parts distribution model for increasing aircraft efficiency	Services and after sales	3* / 3 / 2 / 1	Run
C14	25	Simulation Model of a Spare Parts Distribution Network in the Airline Industry for Reducing Delays and Improving Service Levels: A Design of Experiments Study	Services and after sales	3* / 3 / 2 / 1	Run

3.4. General Structure of the Models

First, the purpose for each simulation study case and its scope are defined. The objective is to generate a general structure that serves as a reference for the generation of the rest of the case studies, even if they include a part or extend the general case. Thus, the scope of the general case for the digital twins and simulation modules is:

- A digital model with generic simulation capabilities made up of the most relevant manufacturing functions that would serve as the basis for developing specific evaluations for any type of industrial organization, including interaction with the customer in services and after-sales. The generic simulation model allows the inclusion of different stakeholders and their influences, as well as the consideration of plans associated with the different functional areas of an organization or the consideration of the organization and its environment globally.
- Based on the general model, specific digital simulation models can be developed for each main function, such as production, procurement, or services, in order to be able to evaluate different methods, systems, technologies, etc. The scope of these models will include the functions, resources, and data associated with their specific purpose.
- Based on the general case and the specific models, learning and planning can be added to an exemplary holistic digital model that can serve as a basis for developing functions within organizations as well as for monitoring their performance and, based on this evaluation, to be able to make a fault diagnosis and its original cause within the process and organizational structure of organizations.

The methodological framework for the development of the general structure consists of the following steps:

1. Definition of the objective, scope and hypothesis.
2. Definition of the organizational functions of manufacturing and services.
3. Determination of KPIs.

4. Development of assumptions and simulation logic.
5. Generation of digital models and definition of scenarios.
6. Validation of digital models.
7. Simulation of scenarios and extraction of results.
8. Interpretation of results.

First, the description of the general structure of the simulation models is made. This structure was applied to a greater or lesser extent in all modules and digital models. The framework was developed to provide the necessary and sufficient level of detail and mix consisting of organizational functions with their associated organizational structure, employees and organizational processes within a production system within a supply chain with suppliers and distributors to respond to the research question. Thus, as can be seen in Figure 19, the structure considered was developed to serve as a generic framework applicable to any sector. In addition, the organizational system consists of technical processes including transportation, storage, and production of finished products, as well as management processes, systems, and organizational structure from operational to strategic levels.

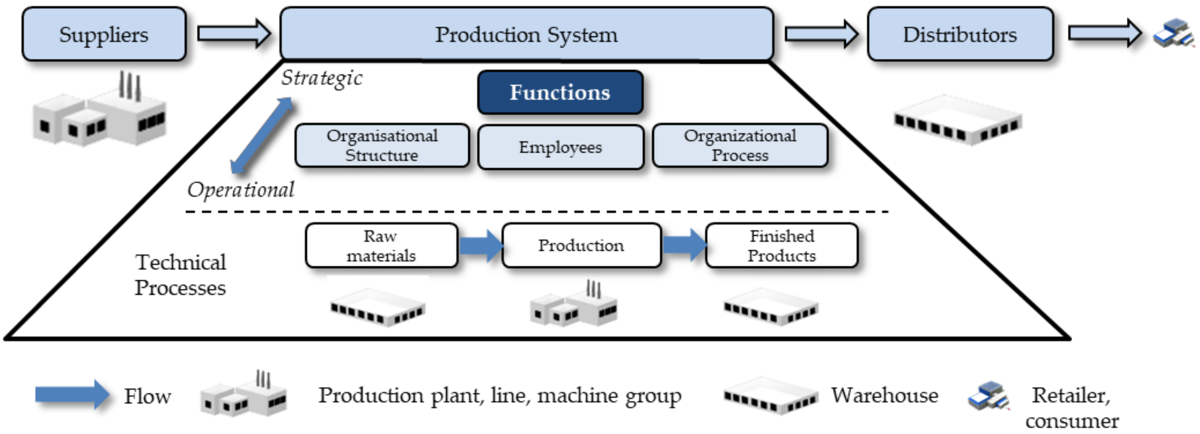

Figure 20: **Generic structure: case studies** [147].

The functions implemented in the models refer to an organizational structure with the functional areas of the organization associated with the different VSM systems, as well as a modeling of the stakeholders, including the different flows. The functional areas are associated with the systems 1 described in chapter 6 of the main text of the DT, although they can be reduced or expanded in the specific case studies. Based on the digital twin of an organization, of production and/or services, the model can be used together with databases, simulation techniques and data analytics, as well as the use of new technologies to improve the *Run* while orients *Change* towards a situation of greater organizational sustainability, minimizing internal and external risks as shown in Figure 20.

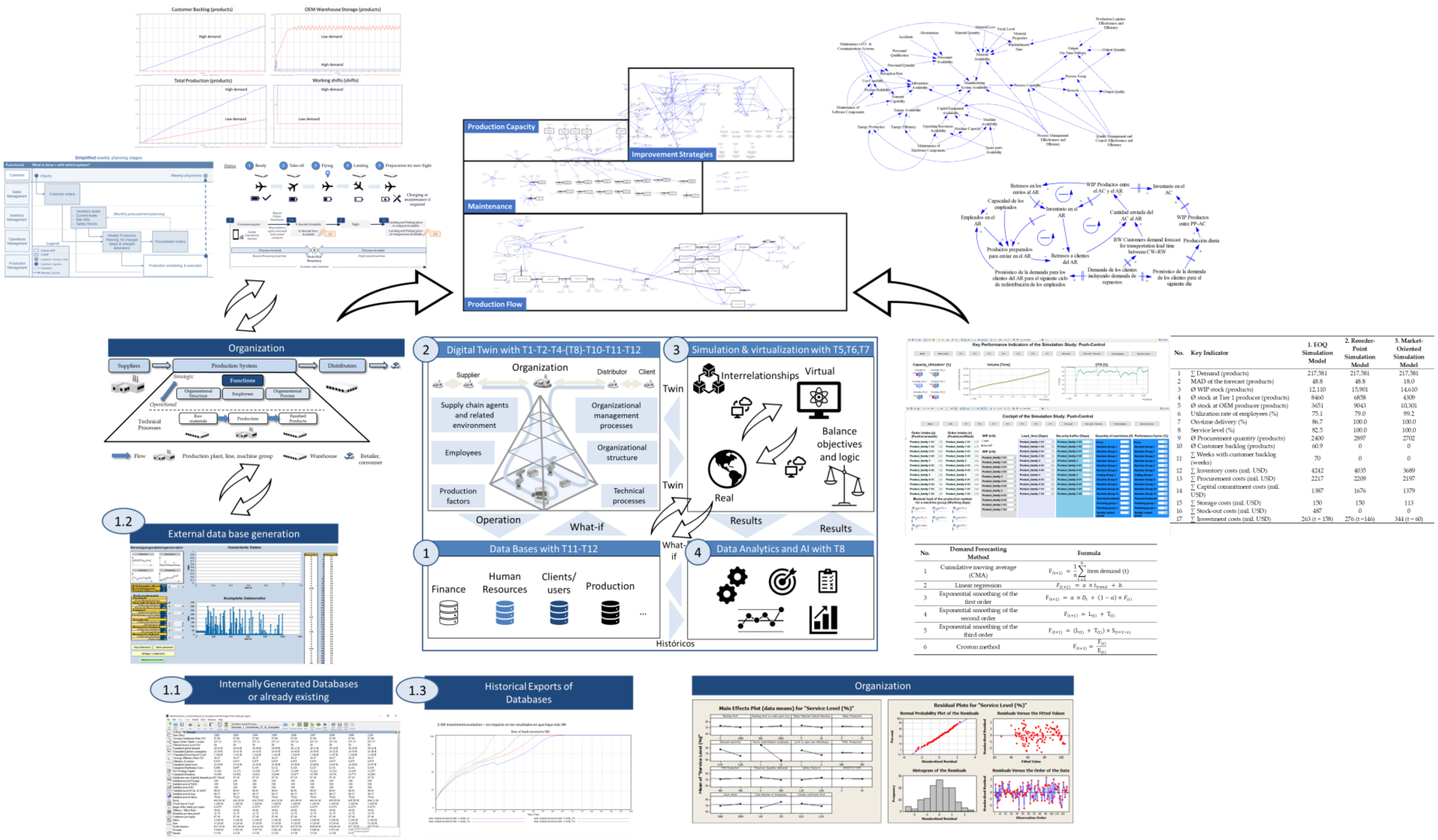

Figure 21: Elements and general structure of the developed systems and models (own elaboration based on [40, 41, 51, 65, 72, 107, 130, 139, 142, 145, 146, 147, 267, 341, 370, 439, 446, 453, 454, 465, 467, 468, 476, 486, 487, 488, 489, 490, 491, 567, 568])

3.5. Key Performance Indicators and Factors of the Models

The objective of the thesis is to study the behavior of the different models in different scenarios of the organization's environment as well as in different scenarios of its internal configuration. In order to be able to evaluate the impacts of different policies and decisions, it is necessary to define key performance indicators to be quantified in the models in order to be able to analyze the evolution and repercussions of the measures to be adopted. For this reason, a reference framework for all the models is developed with a holistic approach that covers seven blocks including the three levels of organization, supply chain, and environment in the area of influence, thus aligning it to the concept of CSR towards sustainability and ESG criteria, ODS/SDGs, and ultimately the needs of society in the organization's area of influence. The first block is governance with indicators related to organizational purpose, strategic alignment, cases of corruption, etc. Secondly, block 2 of economic indicators is presented, such as sales, profits, ROI, etc. Thirdly, there are the indicators related to SC, both in procurement, production, and distribution. Block 4 shows the indicators of the production factors. On the other hand, block 5 represents the indicators with environmental implications such as energy efficiency, or emissions, etc. In addition, block 6 deals with social indicators such as the satisfaction of needs or the service level, while block 7 specifies the product and service indicators that the organization produces and provides, such as availability, or waiting times. In short, the models and case studies are based on these blocks and on indicators associated with them.

3.6. Casual Loop Diagrams (CLDs/DCCs)

Several CLDs were developed at the three levels, organization, supply chain and related environment associated with each VSM system, in addition to considering the KPI areas (details in Annex of the main text of the DT with all CLDs):

1. CLD Procurement (VSM System 1).
2. CLDs Production / Operations (VSM System 1).
3. CLD Distribution (VSM System 1).
4. CLD Maintenance (VSM System 1).
5. CLD Services (VSM System 1).
6. CLD Design and Development of Products and/or Services (VSM System 1).
7. CLD Finance (VSM System 1).
8. CLD Innovation (VSM System 1).
9. CLD S&OP, Sales and Marketing, Operations, Production (VSM System 3).
10. CLD Maintenance and Asset Management (VSM System 3).
11. CLD HR Planning (VSM System 3).
12. CLD Distribution Planning (VSM System 3).
13. CLD Procurement Planning (VSM System 3).
14. CLD IT Planning with audit function (VSM System 3).
15. CLD SRI Investments (System 4 of the VSM).
16. CLD Supply Chain Management: Locations and Warehouses (System 4 of the VSM).
17. CLD Innovation and continuous improvement project management (VSM System 4).
18. CLD Decision-making (VSM System 4).
19. CLD Sustainability in a Socio-Technical System (VSM System 4).
20. CLD Organization of Production and/or Services in SC with an environment in the area of influence (System 5 of the VSM).
21. CLD Organization towards CSR, SDGs and organizational objectives (VSM System 5).
22. CLD Organizational purpose with all stakeholders in the area of influence with consideration of the CSR concept (VSM System 5).

Below are some of the DCC developed as an example. Figure 21 shows the Causal Loop Diagram (DCC) for the production system developed in Vensim. As seen in the figure, the capacity offer depends on the availability of the production plant and the production employees. In turn, the capacity offer has a negative influence on the production time, since having more capacity, the production orders will wait less time to be processed, reducing the production time. This, in turn, by increasing the time of the production process, would increase production delays that would cause less demand from customers due to worse delivery service. In addition, a negative feedback loop is found that would cause the system to dim in a balance between production delays, customer demand, and product WIP:

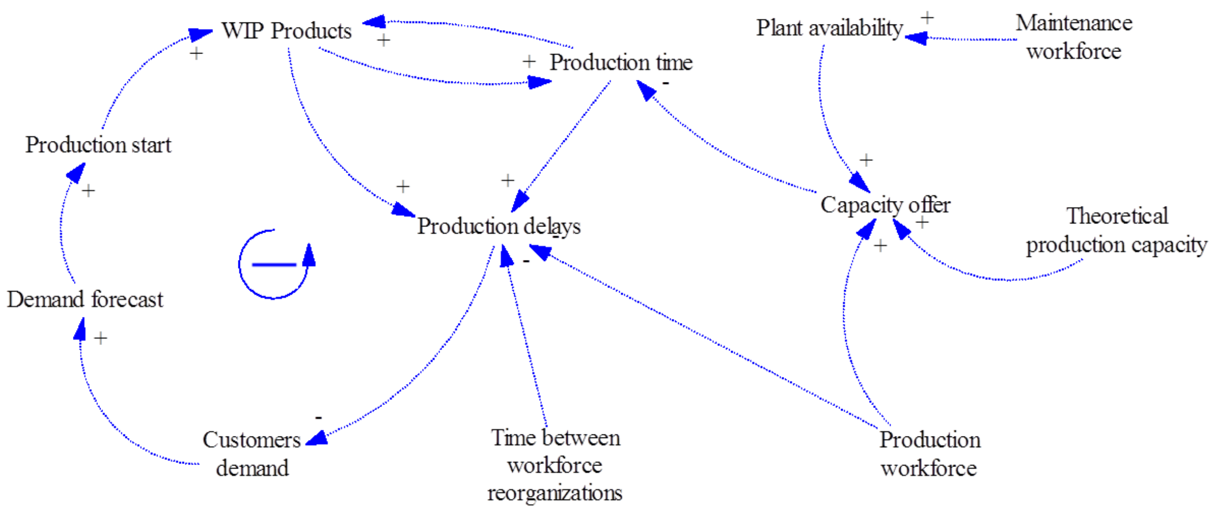

Figure 22: CLD for the production system [40]

Figure 22 shows the Causal Loop Diagram (CLD, DCC) for the factors of the manufacturing process developed in Vensim. As seen in the figure, the availability of the manufacturing system depends on the availability of personnel, material, information, energy, equipment, and quality management and control, which in turn influence the capacity of the process, while it influences the delivery on time, the necessary rework, and the material losses of the process. In addition, it can be seen how production logistics influence material replenishment times, just as maintenance affects both the availability of energy, material and capital goods:

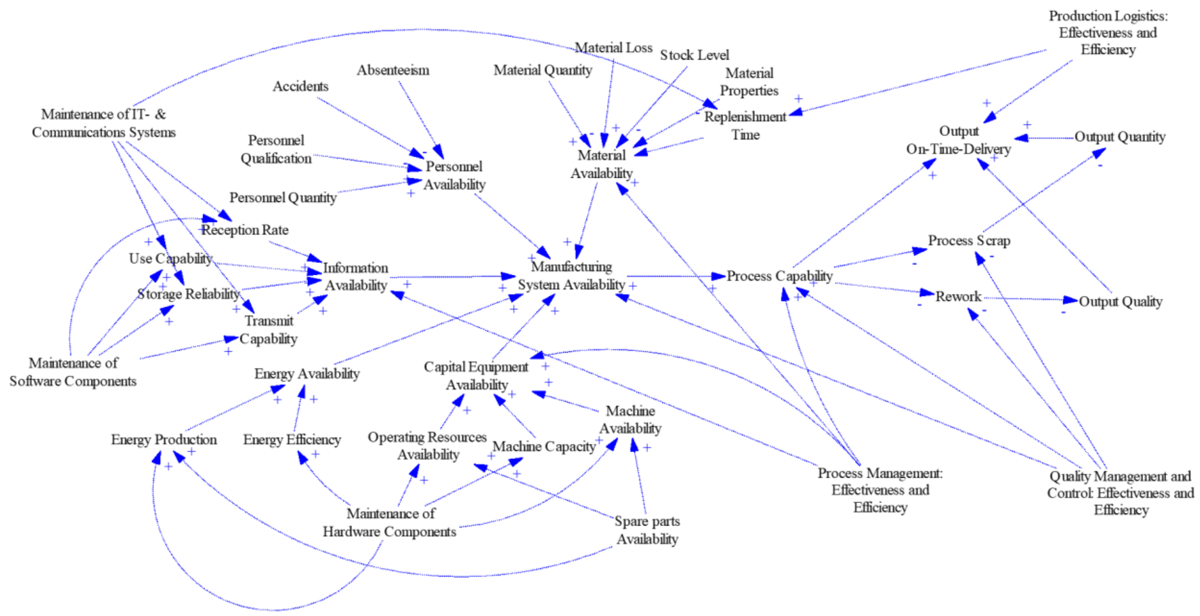

Figure 23: CLD for the factors of the manufacturing system [468]

4. Interpretation and evaluation of results towards Sustainability

The doctoral thesis presents a variety of applications of the conceptual model in different sectors and scenarios based on the generation of digital twins of logistics systems for their simulation towards sustainability. In addition, there are also studies and developments of a qualitative nature or based on bibliographic analysis for the development of new concepts as well as to derive gaps, implications and recommendations for researchers, managers, and technicians in the field of the doctoral thesis. The case studies developed during the completion of this thesis are:

Table 2: Case studies carried out during the doctoral thesis (own elaboration based on [40, 41, 51, 65, 72, 107, 130, 139, 142, 145, 146, 147, 267, 341, 370, 439, 446, 453, 454, 465, 467, 468, 476, 486, 487, 488, 489, 490, 491, 567, 568])

Nº	Classification (C = Case study selected, N = not included)	Case Study (CS)	Selected in main thesis text
1	N1	Design of a Conceptual Model for Improving Company Performance Based on Lean Management Applying the Viable System Model (VSM)	Yes (as design, not CS)
2	C1	Design and Simulation of Production and Maintenance Management Applying the Viable System Model: The Case of an OEM Plant	Yes
3	C2	Applying the Viable System Model to an Organization with CSR Goals: The Case of a Charity Organization	Yes
4	C3	Industry 4.0 implications in production and maintenance management: An overview	Yes
5	C4	Design and Simulation of an Integrated Model for Organisational Sustainability Applying the Viable System Model and System Dynamics	Yes
6	C5	Design and Simulation of a Capacity Management Model Using a Digital Twin Approach Based on the Viable System Model: Case Study of an Automotive Plant	Yes
7	N2	Innovaciones tecnológicas en la navegación en los siglos XV y XVI	No
8	C6	Development of a pull production control method for ETO companies and simulation for the metallurgical industry	Yes
9	C7	Market-Oriented Procurement Planning Leading to a Higher Service Level and Cost Optimization	Yes
10	C8	Predictive Sales and Operations Planning Based on a Statistical Treatment of Demand to Increase Efficiency: A Supply Chain Simulation Case Study	Yes
11	C9	Development of a maintenance and spare parts distribution model for increasing aircraft efficiency	Yes
12	N3	A Novel Methodology for Assessing and Modeling Manufacturing Processes	Yes (as design, not CS)
13	N4	An Optimized System to Reduce Procurement Risks and Stock-Outs: A Simulation Case Study for a Component Manufacturer	No
14	C10	A Systematic Improvement Model to Optimize Production Systems within Industry 4.0 Environments: A Simulation Case Study	Yes

15	N5	Design of a conceptual model for manufacturing companies within the 4th industrial revolution applying the Viable System model	Yes (as design, not CS)
16	C11	Production optimization oriented to value-added: from conceptual to a simulation case study	Yes
17	C12	Design of a conceptual model for a maintenance object within a producer: impact on distribution network-a simulation case study	Yes
18	C13	Modeling Human Decision-Making Delays and Their Impacts on Supply Chain System Performance: A Case Study	Yes
19	C14	Simulation Model of a Spare Parts Distribution Network in the Airline Industry for Reducing Delays and Improving Service Levels: A Design of Experiments Study	Yes
20	C15	A Novel Methodology for Assessing and Modeling Manufacturing Processes: A Case Study for the Metallurgical Industry	Yes (joint with no. 27)
21	N6	Design and Simulation of a management model for aircraft maintenance for reducing and improving small claims dispute processes for consumers in the Airline Industry	No
22	N7	Obsolescence Management in the Supply Chain with the IEC 62402:2019 Standard: a Simulation Case Study	No
23	C16	Development of a Business Assessment and Diagnosis Tool That Considers the Impact of the Human Factor during Industrial Revolutions	Yes
24	C17	Design and Simulation of a Digital Twin Mobility Concept: An Electric Aviation System Dynamics Case Study with Capacity Constraints	Yes
25	C18	Design and Simulation of Manufacturing Organizations Based on a Novel Function-Based Concept	Yes
26	C19	Integration of Improvement Strategies and Industry 4.0 Technologies in a Dynamic Evaluation Model for Target-Oriented Optimization	Yes
27	C15	Development of a System Dynamics Simulation for Assessing Manufacturing Systems Based on the Digital Twin Concept	Yes (joint with no. 20)
28	N8	Project Design and Management of Optimized Self-Protection Plans: A Case Study for Spanish Public Buildings	No
29	N9	Design and Implementation of Adaptable Self-Protection Plans for Public Buildings: A Nursing Home Case in Spain	No
30	C20	The Dynamic Innovation Information System (DIIS) towards a New Management Age	Yes
31	C21	Modelling of internal and external Corporate Social Responsibility´s Theories: a simulation study for the food value chain	Yes
32	C22	Management and modelling organizational stakeholders for sustainability	Yes
33	C23	Corporate Social Responsibility Modelling and diagnosis of corporate interest groups: the Lobby Model	Yes
34	N10	Implications of improvement strategies and industry 4.0 in Organisational Sustainability towards project selection based on CSR criteria	Yes (as design, not CS)
35	N11	Design of an extended TPM model for organisational sustainability: sequence, pillars, and new business models	Yes (as design, not CS)
36	C24	From cost to service through social responsible investments	Yes
37	C25	Sustainability in the agri-food supply chain: a combined digital twin and simulation approach for farmers	Yes

As seen in Table 3, a total of 37 case studies have been carried out, of which a total of 25 case studies have been included in the main text of the doctoral thesis (C1, C2, [...], C25), with a total of 12 case studies that have not been included (N1, N2, [...], N12).

Starting from the initial objectives towards the design of the conceptual model and its application system towards sustainability, Table 4 shows and breaks down each of the models developed in the SCs that have been included in the main text with the measures implemented in the model, as well as the decisions considered in it, including the reference KPIs used in the models to measure the impact of different policies and organizational decisions. This impact is analyzed summarizing the implications in the three levels of consideration of the doctoral thesis, the organization and its main indicators, its supply chain divided into procurement, production and operations, as well as distribution that includes the after-sales network and services to finish with the economic analysis, as well as the area of influence that considers the ESG criteria, the SDGs, the needs of society, and the related stakeholders.

In addition, while Table 4 focuses on a descriptive framework of measures, decisions, indicators, and implications, Table 5 shows the implications in KPIs of the measures and decisions in the case studies with a comparison between the models with an adaptability approach based on the VSM and the CSR concept versus classical approaches. The impact is measured quantitatively in percentage of improvement of the models with an adaptability approach thanks to the MSV and the consideration of CSR towards sustainability versus classic approaches. In this way, it is possible to observe the positive or negative percentage influences that exist when implementing the measures associated within the models, thus being able to determine the measures and projects as well as the conceptual and application models that can best contribute to any organization for reaching its objectives while increasing its sustainability.

In all models, explicit or implicit, CSR has always been taken into consideration, from the application of methods to the choice of improvement projects, customer service orientation, security of procurement and supply, as well as the ability to act and react to any changes in the environment in the related area of influence. Therefore, following a concept of CSR as an end, as a service purpose, then, each decision and organizational action can be guided, which if it is also managed, monitored and audited correctly, will allow its effective implementation, making the organization act in a coordinated manner as a body in perfect balance with the environment. However, this balance is only achievable if there is an internal balance in the organization thanks to organizational capabilities that allow it to face current and future challenges, as well as a balance of interests and motivations between directors, managers, and other workers. In this context, continuous management and control of the environment and of all stakeholders with behavior profiles that identify behaviors that go against the considered CSR and the purpose of the service, even before they occur, is key. In this way, possible cases of corruption can be avoided, or at least greatly minimize their impact, preventing "a person or group of people organizing themselves as a system of corrupt interests" from spreading to form a "corrupt organization” that would imply an organizational dependence on these pressure groups, and consequently be a failed organization.

Table 3: Models of case studies with their measures, decisions, KPIs and implications at three levels (own elaboration based on references from CS)

Nº	Model	Organizational measures and decisions	Main organizational KPIs	Main product/service / KPIs	Supply chain implications				Related environment implications			
					Procurement	Operations / Production	Distribution	Economic	ESG	Stakeholders	SGDs	Society needs (Maslow)
C1	Both	○ Methods: BOA, CONWIP ○ Maintenance strategy: preventive vs. corrective ○ Distribution of employees	○ Production ○ Stocks ○ Utilization	○ Demand ○ Downtimes ○ Availability	-	○ Adaptability due to coordination of production and maintenance	○ Higher reliability of production	○ Production volume ○ Storage costs	E: downtimes S: security of production	○ Employees ○ Service operators ○ Organization ○ Customers	SDGs 1, 9 & 12: more resilient & sustainable operations	Lower risks of non-availability of products
C2	Conceptual	○ Service strategy oriented to the needs of society ○ Planing and control of resources applying VSM	○ Donations ○ Volunteers ○ Resources ○ Performance	○ Impact on society ○ Service lead time	Alignment of environment and society needs with organizational goals and utilization of its resources Efficiency increase in internal processes			○ Savings due to better allocation of resources	E: cleaner environment S: better society G: ethical	○ Employees ○ Volunteers ○ Organization ○ Donors	Service to all SDGs	All needs with service provision units
C3	Conceptual	○ Selection and road-map based on Industry 4.0 technologies	○ Implication scores on management & planning tasks	-	-	○ Improvement of production and maintenance tasks	○ Enhanced sustainability based on new industry 4.0 technologies related capabilities ○ Gain transparency, availability, quality, and performance of the production system leading to higher reliability and visibiliy of potentials					
C4	Both	○ Sustainable principles and collaborative working ○ Information sharing	○ Margin per unit ○ Production capacity ○ Absenteeism ○ Productivity	○ Demand ○ Service level ○ Order lead time	○ Replenishment time ○ Stock level ○ Procurement costs ○ Information exchange	○ Order lead time ○ Raw material, WIP and finished stocks ○ Capacity utilization ○ Production costs ○ Adaptability to change	○ Lead time ○ Stock level ○ Quality ○ Distribution costs ○ Information exchange	○ Costs by supply chain phase ○ Margin per unit	E: pollution S: food, shelter, health, family, employment G: decision-making	○ Employees and managers ○ Supply chain actors ○ Society / population ○ Clients/users	SDGs 1, 2, 3, 8, 9, 11, 12, 17 through cooperation	○ Physiological needs ○ Safety and security needs
C5	Both	○ Contrating of employees ○ Shift changes ○ Investment in new capacities ○ Outsourcing	○ Production ○ Capacity utilization ○ Maximum capacity	○ Demand pattern changes recognition ○ Service level ○ Delays ○ Order lead time	-	○ Adaptability through capacity adjustments to match supply and demand	○ Higher reliability of production	○ Profits ○ Operational savings ○ Investments ○ ROI	E: resource waste S: anticipation of needs, safety G: decision-making	○ Organization ○ Employees and managers ○ Customers	SDGs 1, 9 & 12: more resilient & sustainable operations	○ Lower supply risks ○ Lower backlogs in product delivery
C6	Both	○ Pull vs. push control ○ Order release and completion dates ○ Sequence planning ○ Coordination with sales	○ Production ○ Capacity utilization ○ Stocks ○ Waiting times	○ On-time-delivery	-	○ Global optimization ○ Shorter lead times ○ Higher delivery reliability ○ Lower stock levels	-	○ Production volumen ○ Storage costs	E: lower stocks S: security of production	○ Organization ○ Customers	SDGs 1, 9 & 12: more resilient & sustainable operations	Lower risks of non-availability of products
C7	Both	○ Forecasting methods and parameters ○ Procurement policies and related factors, indicators ○ Organizational structure aligned with forecasts ○ Investments in warehouse production capacities	○ Procurement quantity ○ Stocks ○ Procurement, warehouse, storage, stock-outs costs ○ Invesments	○ Life-cycle demand patterns ○ On-time-delivery ○ Service level ○ Customer backlog	○ Market-oriented procurement planning ○ Dynamic adaptation with self-optimization	○ Production capacity and output ○ Higher reliability of raw material supply	-	○ Procurement, inventory, stock-out, personnel, capital commitment, storage costs ○ Investments	E: less transport, lower stocks S: lower supply risks G: decision-making	○ Organization ○ Employees and managers ○ Customers	SDGs 9 & 12: more resilient & sustainable operations	○ Lower supply risks ○ Lower backlogs in product delivery
C8	Both	○ Operations alignment with potential scenarios with a defined probability. ○ Solution preparation in the long-term. ○ Assisted decision-making for changing methods or investments	○ Production ○ Forecast error ○ Stocks ○ Operational savings ○ Investments	○ Potential and real demand ○ Volume loss ○ Order lead time ○ On-time-delivery ○ Order backlog	○ Reliable procurement plans	○ Adaptation gains based on measures derived from what-if scenarios ○ Predictive and preventive plans for matching supply and demand	○ Reliable distribution and delivery plans	○ Operational savings ○ Investments	E: less stocks, transport, stops S: lower procurement risks G: decision-making	○ Organization ○ Employees and managers ○ Suppliers ○ Distributors ○ Customers	SDGs 1, 9 & 12: more resilient & sustainable operations	○ Lower procurement risks ○ Lower volume loss and order backlogs

Table 3: Models of case studies with their measures, decisions, KPIs and implications at three levels (own elaboration based on references from CS)

Nº	Model	Organizational measures and decisions	Main organizational KPIs	Main product/service / KPIs	Supply chain implications			Related environment implications				
					Procurement	Operations / Production	Distribution	Economic	ESG	Stakeholders	SGDs	Society needs (Maslow)
C9	Both	○ Push vs. pull distribution strategy ○ Fixed vs. variable maintenance intervals	○ Production ○ Stocks ○ Airplane availability ○ Airplane on-ground ○ Maintenance intervals	○ Spare parts demand ○ Service level ○ On-time-delivery ○ Backlog	-	○ Better response for aircraft availability or inventory costs ○ Variable intervals to reduce spare parts consumption and maintenance time	○ Less stocks in network ○ Increasing delivery service ○ Efficient manpower allocation	○ Inventory, production, and transport costs	E: less stocks & consumption of resources S: service to users G: decision-making	○ Employees ○ Component manufacturer & distributor ○ Service providers ○ Airlines ○ Users	SDGs 9 & 12: more resilient & sustainable operations	Lower risks of non-availability of products
C10	Both	○ Systematic improvement model: sequence of relevant strategies as LM, 6σ, TOC, QRM, and AM ○ Identification of organizational limitations	○ Production ○ Stocks ○ OEE ○ Productivity	○ Lead time ○ Service level ○ Customer satisfaction	Lower stocks	○ Process quality, effectiveness and efficiency ○ Bottleneck expansion ○ Lead time improvement	○ Higher customer satisfaction	○ Profits ○ Operational costs ○ Investment ○ ROI	E: waste of resources S: faster and wealth creation G: project decision-making	○ Employees ○ Organization ○ Managers	SDGs 1, 3, 9 & 12: more resilient & sustainable operations	○ Faster ○ Better quality Lower non-supply risks
C11	Both	○ Implementation of LM (VSM, kanban, pull, SMED), AM, TOC, QRM (MCT, QRM-cells)	○ Stocks ○ Capacity ○ Changes ○ Consumption ○ Lot siizes ○ Lead times	○ Product quality ○ Reaction times	Optimized lot sizes, lower procurement order costs	○ Production leveling ○ Cycle time reduction ○ Higher flexibility ○ Changeover optimization	○ Faster and relliable production	○ Lower procurement and inventory costs ○ Overall production optimization	E: avoiding overproduction S: faster and wealth creation G: project decision-making	○ Organization	SDGs 1, 3, 9 & 12: more resilient & sustainable operations	○ Faster ○ Better quality Lower non-supply risks
C12	Both	○ Maintenance strategy ○ Maintenance and distribution interrlationships	○ WIP stock ○ Breakdown time ○ Prodution availability	○ Demand ○ Service level ○ OTD ○ Backlogs	-	○ Increased availability	○ Higher service levels	○ -	E: stocks, breakdown	○ Organization ○ Distributors ○ Customers	SDGs 9 & 12: more resilient & sustainable operations	Lower non-supply risks
C13	Both	○ Modelling HCI to determine impacts on decision-making delays ○ Decision-making process, "The Decision journey" ○ Mathematical modelling of decision dealys for a given resource	○ Production ○ Capacity utilization ○ Decision processing times	○ Order lead time ○ Service level	-	○ Decision delays have significant influence in system performance ○ Optimum decision-time	○ Higher service levels ○ Lower demand loss	○ Profits ○ Operational costs ○ Investment	E: waste of resources S:service loss to society G: transparency on decision-making, time, opportunity costs, effects	○ Managers ○ Employees ○ Organization ○ Customers	SDGs 9 & 12: more resilient & sustainable operations	Lower non-supply risks
C14	Both	○ Distribution for maintenance based on the analysis of factors within a production-distribution network based on Design of experiments (DOE)	○ Stock ○ Utilization rate of employees ○ Forecasting error	○ Demand ○ Service level ○ OTD ○ Backlog	Dynamic reorder point method provides higher adaptability than EOQ	○ Demand reactivity, number and organization of employees, opening of new warehouses, lead times as most important factors	○ Lower stocks ○ Efficient distribution & employees organization	E: waste of resources S: optimized service ○ G: selection of factors' values	○ Managers ○ Employees ○ Organization ○ Distributors Customers	○ SDGs 9 & 12: more resilient & sustainable operations	Lower non-supply risks	Lower non-supply risks

Table 3: Models of case studies with their measures, decisions, KPIs and implications at three levels (own elaboration based on references from CS)

Nº	**Model**	**Organizational measures and decisions**	**Main organizational KPIs**	**Main product/ service / KPIs**	**Supply chain implications**			**Related environment implications**				
					Procurement	Operations / Production	Distribution	Economic	ESG	Stakeholders	SGDs	Society needs (Maslow)
C15	Both	○ Integrated manufacturing system methodology and modelling: cybernetics, maintenance strategy, quality control, areas and factors	○ Availability of factors (money, information, material, energy... ○ OEE ○ Productivity	○ Demand ○ OTD ○ Quality rate ○ Process capability	-	○ Increased system availability ○ Higher OEE ○ Higher productivity ○ Higher OTD ○ Higher quality rate	○ -	○ Higher monitoring effort ○ New service business models	E: resources and downtimes S: optimized service G:transparency shop-floor level	○ Employees ○ Organization ○ Customers	SDGs 9 & 12: more resilient & sustainable operations	Lower non-supply risks
C16	Both	○ Modelling the human factor during industrial revolutions for stakeholders and their decision-making alternatives ○ Implementation measures of lean and industry 4.0	○ Organization's impact ○ Satisfaction of need satisfaction ○ Stock ○ Effiency rate	○ Demand ○ Consumption ○ Food/need delivery ○ Utilization of calories	○ Transparency and optimized supplier selection and planning based on human factor consideration and measures	○ More donations and more surplus of NWC when applied the human factor evolution towards transcendent human types based on the CSR concept	○ Higher satisfaction of needs ○ Lower levels of stocks in the network	○ Distribution costs ○ Donations ○ Net working capital	E: use only what is needed S: meet real needs with efficiency G: decisions considering the human factor and CSR	○ CEO ○ Procurement manager ○ Distribution manager ○ Continent admin. units / governments ○ Voluntters ○ Donors	SDGs 1, 2, 3, 8, 9, 11, 12, 15, 16, 17	○ Applicable Concept to all needs Implement in modelling the food needs of world population
C17	Both	○ Management model for air mobility and Service-oriented ODAM ○ Modeling method for aircraft units between different vertiports onsidering capacity constraints, maintenance, charging & mobility needs	○ Aircraft on ground ○ Aircraft availability ○ Aircraft utilization ○ Vertiports utilization, full/empty	○ Passengers ○ Arrival backlogs ○ Flight request backlogs	-	○ Maintenance performance increases aircraft availability and reduces backlogs as a results	○ Distribution of aircrafts between vertiports plays a significant role in service provision	○ More passengers expected due to the improvement of service times	E: electric aircrafts S: meets mobility needs not developed G: decision-making	○ Organization ○ Pilot and crew ○ Passengers	SDGs 1, 3, 8, 9, 10, 11, 12, 17	○ Mobility needs
C18	Both	○ Modeling manufacturing organizations by considering all functions and their assignment to specific areas and employees based on their historic evolution	○ Production ○ Utilization rate ○ Performance rate ○ Quality rate ○ Stocks ○ Productivity ○ Lead time	○ Demand ○ Service level ○ Sales	○ Quantification of improvements along the evolution of functions in the different industrial revolutions ○ Quantification of human factor malfunctions in the strategic, tactical, and operative levels demonstrates that even if the system is effective and efficient, the decision-making of specific human factors can reduce the performance significantly			○ Sales ○ Operational costs	E: efficiency S: sustaiability with human malfunction prevention G: decision-making	○ Organization ○ All managerial positions ○ Employees ○ Customers	SDGs 1, 3, 8, 9, 12, 16, 17	○ Any product or service for the society ○ Applicable to any organization and need
C19	Both	○ Integration of improvement strategies and industry 4.0 ○ Sequence implementation for industry 4.0: GUVEI-model	○ Production ○ Availability, performance, quality rates ○ Capacity level ○ Implementation and lead times ○ Stocks	○ Demand ○ Demand loss ○ Service level	○ Facilitate the optimization of relevant KPIs to increase the long-term sustainability of manufacturing organizations thanks to a novel model for the integration of improvement strategies and Industry 4.0 related technologies, and for an optimized sequence model for Industry 4.0 technologies, the GUVEI-Model, as well as for the dynamic evaluation for defining optimization alternatives aligned with organizational target			○ Sales ○ Operational costs ○ Profits ○ Investment ○ ROI	E: efficiency S: safety based on optimization & transparency G: decision-making	○ Organization ○ Employees ○ Customers	SDGs 1, 3, 9, 12	○ Any product or service for the society ○ Applicable to any organization and need

Table 3: Models of case studies with their measures, decisions, KPIs and implications at three levels (own elaboration based on references from CS)

Nº	Model	Organizational measures and decisions	Main organizational KPIs	Main product/service / KPIs	Supply chain implications				Related environment implications			
					Procurement	Operations / Production	Distribution	Economic	ESG	Stakeholders	SGDs	Society needs (Maslow)
C20	Both	○ Implementation of the DIIS (Dynamic Innovation Information System) based on the DE4.0 (Digital Ecosystems in the 4th Industrial Revolution) and PDCA methodology	○ Production ○ Plant availability ○ Performance rate ○ Development time ○ Absenteeism, labor productivity	○ Demand ○ Demand loss ○ Service level ○ Supplier's quality rate	○ Generation of a Dynamic Innovation Information System (DIIS) for optimized planning and decision-making thanks to the dynamic evaluation of innovations over their life cycle, applying a methodology for Digital Ecosystems in the Fourth Industrial Revolution and an innovation management model based on the Viable System Model.			○ Sales ○ Operational costs ○ Profits ○ Investment ○ ROI	E: efficiency S: all through innovation in product/service provision G: decision-making	○ Organization ○ Employees ○ Customers	All SDGs	○ Any product or service for the society Applicable to any organization and need
C21	Both	○ Modelling of internal and external Corporate Social Responsibility´s Theories: a simulation study for the food value chain	○ Margin per unit ○ Production capacity ○ Absenteeism ○ Productivity	○ Demand ○ Service level ○ Order lead time	○ Replenishment time ○ Stock level ○ Procurement costs Information exchange	○ Order lead time ○ Raw material, WIP and finished stocks ○ Capacity utilization ○ Production costs ○ Adaptability to change	○ Lead time ○ Stock level ○ Quality ○ Distribution costs ○ Information exchange	○ Costs by supply chain phase ○ Margin per unit	E: pollution S: food, shelter, health, family, employment G: decision-making	○ Employees and managers ○ Supply chain actors ○ Society / population ○ Clients/users	SDGs 1, 2, 3, 8, 9, 11, 12, 13, 16, 17 through cooperation	○ Physiological needs Safety and security needs
C22	Both	○ Management and modelling organizational stakeholders for sustainability	○ Margin per unit ○ Production capacity ○ Absenteeism ○ Productivity	○ Demand ○ Service level ○ Order lead time	○ Replenishment time ○ Stock level ○ Procurement costs Information exchange	○ Order lead time ○ Raw material, WIP and finished stocks ○ Capacity utilization ○ Production costs ○ Adaptability to change	○ Lead time ○ Stock level ○ Quality ○ Distribution costs ○ Information exchange	○ Costs by supply chain phase ○ Margin per unit	G: decision-making	○ Employees and managers ○ Supply chain actors ○ Society / population ○ Clients/users	All SDGs	All kind of needs
C23	Both	○ Corporate Social Responsibility Modelling and diagnosis of corporate interest groups: the Lobby Model	○ Margin per unit ○ Production capacity ○ Absenteeism ○ Productivity	○ Demand ○ Service level ○ Order lead time	○ Replenishment time ○ Stock level ○ Procurement costs Information exchange	○ Order lead time ○ Raw material, WIP and finished stocks ○ Capacity utilization ○ Production costs ○ Adaptability to change	○ Lead time ○ Stock level ○ Quality ○ Distribution costs ○ Information exchange	○ Costs by supply chain phase ○ Margin per unit	G: decision-making and its impact on E / S	○ Employees and managers ○ Supply chain actors ○ Society ○ Presure groups ○ Clients/users	All SDGs	○ Physiological needs Safety and security needs
C24	Both	○ From cost to service through social responsible investments	○ Service ○ Cost level	○ SRI investments ○ Demographic situation	○ Replenishment time ○ Stock level Information exchange	○ Order lead time ○ Stocks ○ Capacity utilization ○ Adaptability to change	○ Lead time ○ Stock level ○ Quality ○ Information exchange	○ Investments ○ Costs	E: pollution S: food, shelter, health, family, employment G: decision-making	○ Employees and managers ○ Supply chain actors ○ Society / population ○ Clients/users	All SDGs	All kind of needs
C25	Both	○ Sustainability in the agri-food supply chain: a combined digital twin and simulation approach for farmers	○ Margin per unit ○ Production capacity ○ Absenteeism ○ Productivity	○ Demand ○ Service level ○ Order lead time	○ Replenishment time ○ Stock level Information exchange	○ Order lead time ○ Raw material, WIP and finished stocks ○ Capacity utilization ○ Production and maintenance costs ○ Adaptability to change	○ Lead time ○ Stock level ○ Information exchange	○ Costs by supply chain phase ○ Margin per unit	E: pollution S: food, shelter, health, family, employment G: decision-making	○ Farmer ○ Cooperatives ○ Authorities ○ Village admin. ○ Suppliers/ distributors ○ Population ○ Other national producers ○ Other international producers	SDGs 1, 2, 3, 8, 9, 11, 12, 17 through cooperation	All kind of needs

Table 4: Implications in KPIs of the CS measures with an adaptability approach and MSV versus classic approaches (own elaboration based on CS)

Nº	Model	Organizational measures and decisions	Main KPIs	Adaptability approaches with the VSM versus classical app. (%)
C1	Both	○ Methods: BOA, CONWIP ○ Maintenance strategy: preventive vs. corrective ○ Distribution of employees	○ Production ○ Stocks ○ Utilization	○ From +0 to +5% ○ From +15 to -25% ○ From +0 to +5%
C2	Conceptual	○ Service strategy oriented to the needs of society ○ Planing and control of resources applying VSM	○ Donations ○ Volunteers ○ Resources ○ Performance	○ Qualitative improvement of the KPIs
C3	Conceptual	○ Selection and road-map based on Industry 4.0 technologies	○ Implication scores on management & planning tasks	○ Qualitative improvement of production and maintenance
C4	Both	○ Sustainable principles and collaborative working ○ Information sharing	○ Margin per unit ○ Demand ○ Absenteeism ○ Order lead time	○ From +0 to +400% ○ From +0 to +25% ○ From -0 to -6% ○ From -0 to -40%
C5	Both	○ Contrating of employees ○ Shift changes ○ Investment in new capacities ○ Outsourcing	○ Production ○ Order lead time ○ Profits ○ Service level	○ From +0 to +10% ○ From -0 % to -50% ○ From +0 to +15% ○ From +0 to +6%
C6	Both	○ Pull vs. push control ○ Order release, completion dates and sequence planning ○ Coordination with sales	○ OTD ○ Stocks ○ Waiting times	○ From +0 to +25% ○ From -0 to -15% ○ From -0 to -35%
C7	Both	○ Forecasting methods and parameters ○ Procurement policies and related factors, indicators ○ Organizational structure aligned with forecasts ○ Investments in warehouse production capacities	○ Service level ○ Stocks ○ Inventory costs ○ Customer backlog	○ From +0 to +40% ○ From +50 to -25% ○ From -0 to -35% ○ From -0 to -100%
C8	Both	○ Operations alignment with potential scenarios with a defined probability ○ Solution preparation in the long-term. ○ Assisted decision-making for changing methods or investments	○ OTD ○ Real demand ○ Volume loss ○ Order lead time ○ Order backlog	○ From +0 to +20% ○ From +0 to +15% ○ From -0 to -100% ○ From -0 to -75% ○ From -0 to -50%
C9	Both	○ Push vs. pull distribution strategy ○ Fixed vs. variable maintenance intervals	○ Service level ○ Airplane on-ground ○ Backlog ○ Stocks	○ From +0 to +35% ○ From -0 to -25% ○ From -0 to -100% ○ From +100 to 0%
C10	Both	○ Systematic improvement model: sequence of relevant strategies as LM, 6σ, TOC, QRM, and AM ○ Identification of organizational limitations	○ Production ○ Stocks ○ Productivity ○ Production lead time ○ ROI	○ From +0 to +100% ○ From -0 to -95%+ ○ From +0 to +300% ○ From -0 to -80% ○ From +0 to +4%
C11	Both	○ Implementation of LM (VSM, kanban, pull, SMED), AM, TOC, QRM (MCT, QRM-cells)	○ Stocks ○ Changeover time ○ Capacity	○ From -20 to -50% ○ From -0 to -80% ○ From +0 to +125%
C12	Both	○ Maintenance strategy ○ Maintenance and distribution interrlationships	○ WIP stock, Breakdown time, Prodution availability	○ Qualitative improvement of the KPIs

Table 4: Implications in KPIs of the CS measures with an adaptability approach and MSV versus classic approaches (own elaboration based on CS)

Nº	Model	Organizational measures and decisions	Main KPIs	Adaptability approaches with the VSM versus classical app. (%)
C13	Both	○ Modelling HCI to determine impacts on decision-making delays ○ Decision-making process, “The Decision journey” ○ Mathematical modelling of decision dealys for a given resource	○ Production ○ Service level ○ Customer order lead time	○ From +0 to +5% ○ From +0 to +5% ○ From -0 to -50%
C14	Both	○ Distribution for maintenance based on the analysis of factors within a production-distribution network based on Design of experiments (DOE)	○ Service level ○ Backlog ○ Stocks	○ From +0 to +40% ○ From -0 to -100% ○ From -0 to -90%
C15	Both	○ Integrated manufacturing system methodology and modelling: cybernetics, maintenance strategy, quality control, areas and factors	○ OEE ○ Productivity ○ On-time delivery	○ From +0 to +50% ○ From +0 to +100% ○ From +0 to +65%
C16	Both	○ Modelling the human factor during industrial revolutions for stakeholders and their decision-making alternatives ○ Implementation measures of lean and industry 4.0	○ Organization’s impact ○ Satisfaction of need satisfaction ○ Stock ○ Effiency rate	○ From +0 to +100% ○ From +0 to +10% ○ From -0 to -80% ○ From +0 to +100%
C17	Both	○ Management model for air mobility and Service-oriented ODAM ○ Modeling method for aircraft units between different vertiports onsidering capacity constraints, maintenance, charging & mobility needs	○ Passengers ○ Aircraft availability ○ Flight request backlog ○ Vertiports full ○ Arrival backlog	○ From +0 to +5% ○ From +0 to +30% ○ From -0 to -75% ○ From -0 to -50% ○ From -0 to -50%
C18	Both	○ Modeling manufacturing organizations by considering all functions and their assignment to specific areas and employees based on their historic evolution	○ Production ○ Productivity ○ Lead time ○ Stocks ○ Sales ○ Operational Costs	○ From +0 to +500% ○ From +0 to +500% ○ From -0 to -75% ○ From +300% to -60% ○ From +0 to +800% ○ From -10% to +100%

Table 4: Implications in KPIs of the CS measures with an adaptability approach and MSV versus classic approaches (own elaboration based on CS)

Nº	Model	Organizational measures and decisions	Main KPIs	Adaptability approaches with the VSM versus classical app. (%)
C19	Both	○ Integration of improvement strategies and industry 4.0 ○ Sequence implementation for industry 4.0: GUVEI-model	○ Production ○ Availability rate ○ Capacity level ○ ROI ○ Profits	○ From +0 to +300% ○ From +0 to +40% ○ From +0 to +400% ○ From +0 to +6% ○ From +0 to +250%
C20	Both	○ Implementation of the DIIS (Dynamic Innovation Information System) based on the DE4.0 (Digital Ecosystems in the 4th Industrial Revolution) and PDCA methodology	○ Production ○ Profits ○ ROI ○ Abseenteeism ○ Labor productivity	○ From +0 to +10% ○ From +0 to +15% ○ From -15 to +45% ○ From -0 to -3% ○ From +0 to +10%
C21	Both	○ Modelling of internal and external Corporate Social Responsibility´s Theories: a simulation study for the food value chain	○ Global satisfaction rate ○ Efficiency rate	○ From +0 to +20% ○ From +0 to +50%
C22	Both	○ Management and modelling organizational stakeholders for sustainability	○ Production ○ Profits ○ Products in use ○ Decision acc. To reality	○ From +0 to +30% ○ From +0 to +50% ○ From +0 to +30% ○ From No to Sí
C23	Both	○ Corporate Social Responsibility Modelling and diagnosis of corporate interest groups: the Lobby Model	○ Production ○ Profits ○ Products in use ○ Decision acc. To reality	○ From +0 to +50% ○ From +0 to +100% ○ From +0 to +50% ○ From No to Yes
C24	Both	○ From cost to service through social responsible investments (SRI)	○ SRI percentage ○ Years to 100% SRI	○ From +0 to +100% ○ From 50 years to never
C25	Both	○ Sustainability in the agri-food supply chain: a combined digital twin and simulation approach for farmers	○ Liquidity ○ ROI ○ Outsourcing ○ Profitability	○ From +0 to 100% ○ From +0 to 50% ○ From +0 to 30% ○ From +0 to +50%

Based on the implications at the three target levels: organization, supply chain, and environment in the organization's area of influence, as well as the improvements in the main KPIs that are made possible by the implementation of the decisions and improvements of the implemented case studies, the sustainability of an organization can be positively influenced. To finalize the evaluation and the influence oriented towards sustainability, after having analyzed the positive influence of improvements, we will analyze the potential negative influences on the organizational system and its associated environment due to the risks that may occur both due to the organizational behavior itself, internal risks, as well as those due to the events and behavior of environmental agents in the area of influence, external risks. In this way, possible failure modes (MF) caused by internal and external risks can be identified, giving rise to internal failure modes (IFM) and external failure modes (EFM) as indicated in Figure 23. For these modes of failure, the probability of occurrence, severity or impact in case the MF occur, as well as the probability that if the failure occurs, that it will be detected, so that the analysis reliability can be systematically improved to determine severity and occurrence associated with said MF. Based on this analysis, any organization can derive the risk priority level (NPR) associated with each MF as a basis for decision-making on measures, projects, and in general organizational actions to reduce risks and increase organizational sustainability and of the area of influence.

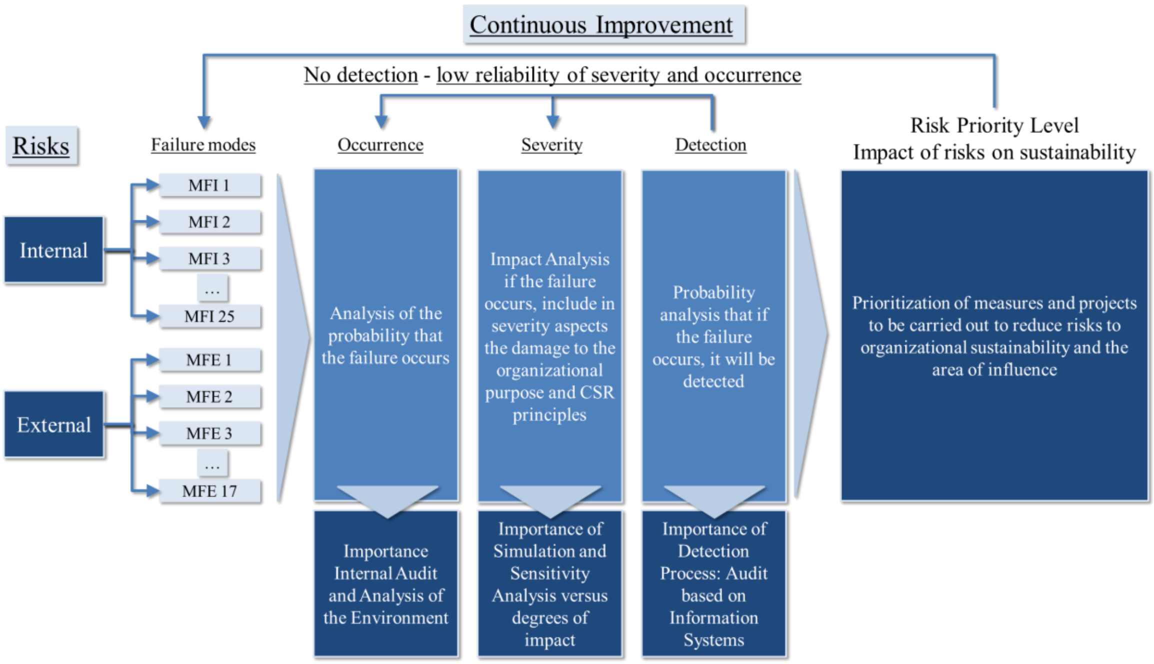

Figure 24: Internal and external risks towards the identification of failure modes (own elaboration)

As a guide to define these measures and improvement projects towards sustainability, the models associated with the case studies serve as a reference framework to deal with both internal and external risks, as shown in the following tables, Table 6 (extract with six MFIs while the main text of the DT contains all 25 MFIs) for internal risks and MFI, and Table 7 (extract with six MFEs while the main text of the DT contains all 17 MFIs) external risks and MFE:

Table 5: Internal failure modes and measures of the models to reduce internal risks towards sustainability (own elaboration based on CS)

Nº	Event / Use case	Disruption / challenge nature	Implications of a non-doing	Implications with classical apporaches	Recommended measures	Measures supported with models	Improvement potential for the organization	Improvement potential for the related environment
1	Crisis in decision-making in corporate governance	○ Corruption ○ Conflict of interests	○ “Domino” effect ○ No collaboration	○ Generation of legal or illegal lobbies	○ Audit 4.0 ○ Model with all stakeholders and all CSR theories	○ 2, 3, 9, 10, 17	○ Prevention and early identification of cases of corruption	○ Environment of trust to foster cooperation with stakeholders
2	Discrepancies between managers and workers	○ For different motivations ○ CSR concept	○ Functional failures ○ No collaboration ○ No transparency	○ Incentive policy, or change of staff	○ Identification of motivations ○ Consideration of interests and goals in personal development ○ CSR training, leadership, and personal management	○ 2, 3, 4, 10	○ Qualification ○ Self-knowledge ○ Personal and direct leadership skills ○ Values and principles	○ Improvement of service to the environment ○ Consideration of the area of influence by all workers
3	Failures in individual and group decision making	○ Decisiones subóptimas y parciales	○ Planning inefficiency and ineffectiveness ○ No planning	○ “Silo” approach, local optimization	○ Holistic models ○ Systemic perspective ○ Simulation based on digital twins with behavioral profiles	○ 2, 3, 4, 6, 9, 10 (All to a greater or lesser extent)	○ Global consideration and multi-objective optimization	○ Consideration of the area of influence in decision making
4	Lack of functional capabilities	○ Non-existent or outdated capabilities	○ Giving up those capabilities, competitive disadvantage	○ Training developments ○ Purchase of capacities externally	○ Analysis of the evolution of functions in the organization ○ Development of improvement plan based on learning, current status, and challenges ○ Use of improvement strategies and Industry 4.0 technologies	○ 4, 11, 12, 13, 14, 17, 19 (All to a greater or lesser extent)	○ Optimization of functions in a balanced way thanks to historical and needs analysis	○ Functional development that improves the level of qualification and salary of the environment
5	Crisis due to systematic failures in industrial assets	○ Availability ratio of industrial assets	○ Less volume ○ Major delivery service issues ○ Greater deterioration	○ Corrective and preventive maintenance, strategy not adapted to the needs ○ Consideration of failures in planning, resignation in the face of this volume of failures	○ Maintenance strategies in long, medium, short term according to the state and needs of the system ○ Cooperation production and maintenance, TPM ○ BOA, for release orders ○ Use of improvement strategies and technologies of Industry 4.	○ 4, 11, 12, 13, 14, 17, 19, 22, 24, 25	○ Higher volume ○ Greater reliability in planning ○ Higher OEE ○ Less deterioration ○ More data ○ Strategy adapted to the situation	○ Knowledge based on data and improvements, higher salaries, generation of jobs ○ Balanced consumption of industrial assets ○ Lower power consumption
6	Crisis due to deficiencies in the personnel selection processes and team formation	○ Insufficient training of elected staff or people on teams	○ Functional deficiencies ○ Projects with lower success rate ○ Competitive disadvantage	○ Focus on cognitive and in some cases emotional capacities, omitting the rest with functional risk and sustainability	○ Comprehensive approach to the person: physical-mental, cognitive, emotional, affective, ethical	○ 2, 3, 6, 10, 17	○ Identification of risks in people, equipment and their environments ○ Minimize ethical and functional risks	○ Better health and coverage of the needs of people and their environment

Table 6: External failure modes and measures of the models to reduce external risks towards sustainability (own elaboration based on CS)

Nº	Event / Use case	Disruption / challenge nature	Implications of a non-doing	Implications with classical apporaches	Recommended measures	Measures supported with models	Improvement potential for the organization	Improvement potential for the related environment
1	**Due to non-compliance with environmental regulations**	○ Damage to the environment and social and institutional discredit ○ Fine to the organization	○ Social, institutional discredit ○ Damaged image	○ Trendy environmental support measures	○ Measures with greater need and impact with a systemic vision	○ 6, 7, 17	○ Fewer risks from the environment	○ Environmental environment in better conditions
2	**Due to instability and social uncertainty**	○ Functional failures derived from lack of personnel or discontent ○ o Damage to infrastructure due to mobilizations	○ Stops or interruptions in operations ○ o Infrastructure damage	○ Plan adapted to stops depending on the situation ○ Security in accesses and infrastructures	○ Dialogue with stakeholders to de-escalate with measures ○ Use of resources to improve the situation in the environment ○ Protection of critical infrastructures ○ Technologies and data analytics to predict and prevent	○ 1, 2, 6, 13, 14, 17	○ Return to normal operating modes more quickly ○ Social legitimacy ○ Stakeholder relationship ○ Asset condition ○ Knowledge and innovation	○ Stakeholder ecosystem help and support ○ More needs covered ○ State of infrastructures ○ Jobs retention or/and generation
3	**Due to the need to introduce a new regulation**	○ Lack of resources ○ lack of time	○ Non-compliance with a fine or inability to operate	○ Compliance with regulations with existing resources ○ o Anomalies in audits	○ Apply regulations as or together with an improvement and innovation project	○ 11, 12, 13, 14, 16	○ Competitive advantage ○ Innovation and knowledge ○ Legal adherence to current regulations	○ Applies the rules to improve their relationship and implications in the environment
4	**Due to the lack of social legitimacy**	○ Principles and values in disagreement with society ○ Social image damaged by company actions	○ Declining sales ○ Permanent damaged image	○ Promotion campaigns with identification with values and principles of the environment	○ Promotional campaigns showing the positive effect of the organization's action on society	○ 2, 3, 10, 17	○ Image and social legitimacy without loss of identity	○ Good principles and values for society
5	**Due to lack of communication or support from institutions**	○ No dialogue ○ Specific weight in non-relevant environment	○ Non-consideration in decisions in environment	○ Pressure from the media ○ Formal complaint to institutions	○ Aumento de acuerdos con diferentes stakeholders ○ Foco en cuota de mercado y acciones en entorno	○ 2, 3, 10, 17	○ Interlocutor in decision-making in the environment at the request of other stakeholders and by society	○ Organization committed to the environment in its area of influence
6	**Due to supply chain disruptions**	○ Lack of material ○ Unforeseen delays ○ Low or high stock level	○ Waste of resources ○ Plans are not fulfilled ○ Constant stops	○ Search for alternative suppliers ○ Increase in quantity to be ordered ○ Increased stocks	○ Transparency and exchange of information ○ Stocks and orders based on the need and behavior of the supplier	○ 18, 21, 23	○ Better adaptation thanks to a priori preparation for various scenarios ○ Best delivery service	○ Shorter response time to receive products ○ Delivery with better quality and service

5. Conclusions

After completing this work, the importance of designing and managing an intra-organizational logistics system that integrates the planning of management and change tasks in a company to ensure its sustainability has been demonstrated. In addition, the following points can be successfully concluded:

- Identification of the challenges, research needs and potentials of intra-organizational logistics management as well as its objectives, indicators, and functions together with its models, methods, and tools.
- Evidence after the study of the art of the need for new approaches in the coordination of operations management and in the management towards innovation based on data and facts oriented to organizational goals.
- Deepening in the intra-organizational logistics management in organizations of different sectors, from the primary sector to the industrial sector, as well as in service organizations, and non-profit organizations, as well as in government administration.
- Confirmation of the need for new communication and coordination systems, as well as comprehensive management of intra-organizational logistics as one of the greatest potentials to deal with current and future challenges in any sector of activity.
- The application of the MSV structure for the design of the conceptual model for intra-organizational management provided a structure that has allowed the definition of information flows, planning levels as well as mechanisms of autonomy and escalation between levels within a company and within the different functional areas of operations, services, innovation, etc. The MSV provides the necessary structure to determine the interrelationships between areas and parameters that enable an improved decision-making on the different organizational aspects in an assisted or autonomous process based on predefined control limits.
- System dynamics has provided the necessary notation and functions for the design of simulation models using Vensim and Anylogic as commercial softwares. System dynamics provides the necessary platform to determine the cause-effect parameterization based on causal loop diagrams with the interrelationships of factors and parameters, and thus obtain relevant results for the purpose of the research and the analyzed case studies.

In addition, the following specific activities and results can be successfully concluded:

- Generation of an intra-organizational model at three levels: organization, supply chain and environment in the organization's area of influence.
- Development of a conceptual model towards sustainability at the three levels thanks to CSR (top-down and bottom-up) thanks to the definition of modules, tasks and indicators for a socio-technical system that ensures stability and encourages goal-oriented change while maintaining their identity in any environment and context.

- Design of a model of modules at the different normative, strategic, tactical, and operational levels considering the impacts on the environment and the need for productive factors, and horizontal and vertical integration for the evaluation of the maturity of organizational capabilities.
- Design of a layered model to manage organizational sustainability from the *Run* of the current operations to any initiative that originates the *Change in the Run*, so that it can be converted into an organizational management and control scheme so that both *the Run and the Change* are sustainable guided by the CSR concept and theories selected by the organization. The *Go live layer* allows knowing the current status of operations. The *next layer* allows knowing what methods, systems, technologies, people, and organization are acting in the different functional areas and organizational processes. Based on this layer, the *maintenance layer* will identify anomalies to correct them, as well as improvements in methods, systems, technologies, and in the organization that can improve sustainability based on a maintenance model extended to the entire organization and oriented towards the customer and the service provided throughout the life cycle. Finally, the *last two layers* ensure that the system selects projects, and provides their financing, oriented to the purpose and CSR principles to ensure the sustainability of the organization.
- Models are developed in systems 1 of the MSV with intra-organizational logistics management functions (procurement, production, distribution, maintenance, services, after-sales, innovation, and improvement) considering the best practices and planning and control tasks to be sustainable while fulfilling its function aligned with the organizational objectives and coordinated among them to face dynamic environments towards sustainability.
- Development of a model for the diagnosis of potentials in the organizational functions from the analysis of the current state and the organizational background thanks to the study of the evolution of functions throughout the industrial revolutions.
- Design of a model for the selection and introduction of relevant improvement strategies in the literature (LM, 6σ, TOC, AM, QRM).
- Design of a model for the selection and introduction of technologies associated with the I4.0 based on the analysis of their capabilities and impacts.
- Design of a model for the integration of improvement strategies and technologies associated with the I4.0 to increase organizational capabilities and adaptability.
- Development of a target system of indicators that can serve as a reference for: control, improvement, and management at the organizational level towards sustainability at the three levels of organization, supply chain and area of influence.
- Design of an information ecosystem for organizational management in the fourth industrial revolution (DE4.0) thanks to the PDCA methodology.
- Development based on the DE4.0 of a dynamic information ecosystem for innovation (DIIS) considering all types of innovation, monitoring capabilities and continuous improvement towards the objectives of innovation and continuous improvement throughout its life cycle, as well as considering the historical learning of the introduction

of inventions with similar characteristics and of the type of organization in which they are going to be applied.

- Consideration and design of a mathematical and simulation model for the management of demand and supply for any given resource, including the consideration of human-machine interfaces in the provision of the resource.
- Design of a sustainability model for socio-technical systems with consideration of the OEE parameter for the technical, organizational, and personal spheres, so that the risks derived from the three are treated by the organization. From this point, the need for a human-oriented sustainability system is derived in a holistic concept that encompasses all its levels and not only the cognitive, but also the emotional, physical, affective, mental, and ethical. This is demonstrated, for example, by the risk to the sustainability of someone in a position of responsibility with inappropriate ethics, even though they have high cognitive abilities.
- Development of a system of multiple casual loop diagrams associated with the modules of the information ecosystem and the MSV systems with interrelationships from the operational level to the top management level to influence sustainability at all organizational levels including the supply chain and the related environment.
- Successful application of input and output databases to models, as well as data analysis and management techniques using big data statistical tools and quality methods and development of a method for its use oriented towards sustainability thanks to CSR and the generation of knowledge and innovations as the main elements of resilience and ability to adapt to volatile environments and disruptions in any field.
- Design of communication channels and flows based on a new concept of dynamic information systems with auditing and detection capabilities following the viability structure of the MSV that allow decision-making with more information. This additional information is gained based on the status and evolution as well as on the impact analysis of potential future scenarios, enabling the optimization of control, management and organizational improvement that allows maintaining the organizational USP, increasing its sustainability.
- Generation of a sustainability model considering internal and external CSR theoretical perspectives, including its modeling and quantification to analyze the influence of the different CSR considerations on the sustainability of the organization and its environment.
- Development of a modified stakeholder model in which interactions are developed in pressure or lobby groups that affect stakeholders with influence on organizational action or that can do so through the media as a tool, legal or not, to influence the organizational action.
- Generation of a list of internal and external risks applicable to any organization, so that the model of organizational failure modes is derived from it. These failure modes can be analyzed with an FMEA analogy for the organizational system in its interaction with its environment and its stakeholders, considering CSR. This analysis allows, using the case studies and the conceptual model of the thesis, to be able to prepare measures to

increase organizational sustainability in the face of any possible risk such as events and potential internal and external disruptions.

All the above, and thanks to the invariant and recursive system structure of the MSV, it generates a reproducible model to manage any type of organization, such as the application of many of the designs and developments of this thesis in the case study for the sustainability of farmers in the agri-food supply chain. Therefore, the following is concluded globally about the conceptual model and its case studies:

- Model applicable to any organization in its activities, products, and services since it allows the management of hardware, software, data, and information towards an approach for the design and development of products and services as innovations guided by the consideration of the chosen CSR and the organizational purpose towards sustainability.
- The TD presents an extract of 25 case studies as modeling examples, as well as another 12 not included in the main text of the TD as specific case studies.
- The cases presented allow modeling the demand and supply of a resource from the moment of decision-making based on investment and risk, whatever the resource, until its implementation through projects, improvements, new technologies, methods, and/or training but always with the “glasses” of the chosen CSR strategy towards sustainability at the three levels.
- An analysis is made of the evolution and influence of investments, ISR, in the global evolution towards the sustainability of organizations and future generations. In addition, the conceptual model has made it possible to verify how the exclusion of groups of people for a given job would lead to worse results for the global system at all three levels. In addition, the model has been able to verify that an investment based on partial criteria or exclusionary considerations on ESG or SDG criteria would lead to an imbalance in the system caused by a positive feedback loop generated by extrinsic motivations. Furthermore, if the selection of people excludes a percentage of the potential candidates and the results are worse, together with the fact that socially responsible investments are no providing the expected effects, the young population that, today, would invest with greater preponderance towards ISR, would see their "illusion" diminished by not seeing the expected effects on the investment made, and over time, the current trend may decrease with scenarios in which, after the rise of ISR, it may decline due to the lack of results associated with it. To avoid this scenario, it is key to be guided by a systemic approach that considers all the criteria and factors and checks of the effects of each investment so that these effects are continuously improved, always guided by CSR principles as an end aimed at the well-being of people and their environments.
- The conceptual model and its applications have made it possible to verify the importance of the audit process through information systems by means of historical databases, indicators, and associated processes in their comparison and temporal evolution. In this way, anomalies can be identified thanks to the data collection and processing capabilities of the fourth industrial revolution.

- The thesis has allowed the verification of the implications of the ISR that would lead progressively from a cost orientation to a service orientation with globalization and business in a balanced equilibrium between trade flows in local, regional, and global spheres as opposed to the cost-oriented relocation of recent decades.
- In addition, the different case studies have made it possible to present different situations, in different sectors, with various environmental scenarios, and the comparison and implications of investments, improvements, methods in said situations allowing the elaboration of a list of potential measures in the different functional areas of the company to deal with volatile environments and internal risks.
- The application models show the advantage of models with priorities and based on behavioral profiles for the different agents and types of decision, which allow the identification of different alternatives and results in organizational decision-making in interaction with stakeholders. In addition, based on historical data, intentional or unintentional anomalies can be detected against the principles and organizational purpose, as well as the detection of pressure groups acting based on "a programming behavior given from the outside" based on interests that nothing have to do with the organization.
- In addition, it has been possible to verify how the *Lobby model* together with the media can influence ISR and organizational behavior towards initiatives and actions with a biased orientation based on extrinsic interests of these groups that can unbalance the global system.
- The model has allowed the development of several tools for the improvement of the organization: from the TPM model applied to the organization in monitoring the flows of the different functional areas, passing through improvement projects based on relevant improvement strategies in the literature, as well as projects associated with Industry 4.0 technologies. As has been indicated in this thesis, all these initiatives must be aligned with the purpose and the organizational strategy guided by the consideration that the CSR organization makes, so that each *Change* that is introduced in the organization is evaluated and verified with the ecosystems of the fourth industrial revolution in its alignment of objectives and CSR towards sustainability.
- The importance of digital tools such as the digital twin, simulations, data analytics, as well as dashboards, workflows, and historical records for improving individual and group decision-making, as well as for organizational action, has been proven. In this way, each decision maker, that is, each worker in an organization, whatever their level, can know the implications of each decision they make, including a dashboard and interactive workflows with simulation capabilities in a way that can ensure effectiveness, efficiency, and adherence of the decision with the purpose, the CSR principles, and the organizational strategy.
- In short, it has been proven that organizational sustainability depends firstly on the consideration of the CSR chosen, and secondly on the form of application and control of the selected CSR principles and theories. For these two, the models can join forces to achieve adequate implementation and monitoring: on the one hand a *Top-Down* model (principles, values, culture) and on the other a *Bottom-up* model (data and information

to identify errors in processes based on informed or uninformed audits with reporting of its evolution). Thanks to these two models, direction, management, and control are made possible, allowing the gain of knowledge about the organization itself that allows its use to simulate scenarios and policies, as well as using this knowledge to identify gaps and the subsequent development of innovations and improvements. Therefore, the consideration of an organization's CSR is the engine that guides the organization not only in terms of values, but also motivates the generation of innovations and improvements in a process that will increase the level of knowledge and skills, increasing sustainability, not only because of the capabilities, but also because these processes are associated with a "way of doing" of quickly identifying anomalies towards continuous improvement, as a process that is difficult for competitors to imitate and applicable to any risk or anomaly, providing a sustainable competitive advantage.

- Thanks to the new conceptual model and its applications in different models that can assist decision-making and make decisions autonomously in different time horizons, the viability of an organization can be ensured. As a result, it demonstrates the need for a system consisting of different modules such as the environment management module or the audit module, passing through the modules of the functional areas. This type of information ecosystem that implements different and necessary functionalities to current information systems is capable of increasing organizational sustainability and therefore would be of great support as a standard tool for managers and workers in the future to increase efficiency and adaptability of organizations. Due to this newly developed conceptual and applied model, organizations can use the model as a conceptual guide or as a tool to improve operations and decision making through real-time data collection within the fourth industrial revolution, as well as to the consideration of the human factor, of the different stakeholders and of the organizational environment towards a fifth industrial revolution with a holistic consideration and integration of the human factor in the environments of the fourth industrial revolution.

In addition, regarding the case studies, it is important to highlight certain limitations in the generated case studies, such as:

- The complexity of the case studies was partially built into the models as in the case of the level of complexity of the manufacturing processes, of the supply chain, as well as in the interactions in the organizational structure and interfaces. The level of complexity and detail depends on each case study.
- In general, it was assumed that the information throughout the supply chain and the environment was available except in those case studies where the opposite was simulated to analyze the objectives of the case study.
- During the simulation period, the models are executed autonomously in their management and decision making, except in those case studies that were simulated in the opposite way to analyze the objectives of the case study.
- Transport and storage limits were not implemented in the supply chains, except in those cases except in those case studies that were simulated in the opposite way to analyze the objectives of the case study.

To conclude, it is important to point out new research paths or new ways to continue improving the project carried out:

- Integration of the human factor in the environment of the fourth industrial revolution towards the fifth industrial revolution.
- Detailed analysis of the functionalities and comparison of current information systems with the model proposed in this thesis.
- Improvement of the conceptual model with all the different methods and tools by recursion level and task as well as its inclusion in the simulation model.
- Apply the DE4.0 ecosystem and the modules of the information ecosystem based on the MSV and PDCA for an organization.
- Consideration of the organizational units and their communication within the digital model and simulation.
- Increase data analysis skills and techniques associated with the models developed to increase support for decision-making based on data and facts towards accurate predictions to improve the response against any kind of risk.
- Improve the models of partial digital twins of functions and of the global digital twin based on the implementation of learning and feedback from cases as well as apply it to groups of companies and between different actors and stakeholders of a supply chain.
- Transfer this research method to real supply chains and apply it in use cases as a tool for normative, strategic, tactical, and operative planning and help supply chain leaders by centralizing all data related to a topic in a short period of time, allowing simulation of scenarios supporting decision-making in the different planning horizons.
- Expansion of the functionality of the digital twin models including promotions, price fluctuations, economic context, cost of activities, number of spare parts, greater flexibility of the production or service organizations, different customer aggregation as well as with the consideration of the social, political environment, etc.

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