



# Supply Network 5.0

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How to Improve Human Automation  
in the Supply Chain

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Bernardo Nicoletti

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# Foreword

I have studied and researched: operations and supply chain management. In the last few years, my interests have been very much in artificial intelligence (AI), machine learning, sustainability, and agility. When Bernardo asked me to write the foreword for his book on supply network 5.0, I was perplexed. After reading some chapters of his manuscript, I found it extremely interesting and was able to generate challenging ideas.

The supply network 5.0 approach can provide integrated Human Automation Machine Collaboration (HAMC) solutions to address emergent challenges. This approach requires a systematic consideration of a human-centric approach, advanced solutions (like AI), sustainability, and agility. Specifically, HAMC professionals should take a leading role in the human-centered design of the supply network 5.0 framework by providing explainable, comprehensible AI and useful, usable AI. Supply network professionals can also contribute to ethical AI design and AI technological enhancement. This book marries very well with the lessons to be learned and actions to be taken from my research.

The deep involvement of the HAMC community in these areas has yet to be fully realized but is necessary and urgent. To provide full disciplinary support for HAMC solutions, the work of the HAMC community should include research on human-machine integration/teaming, user interface (UI) modeling and HAMC design, transference of operations theories, enhancement of existing methods, and development of HAMC

design standards. HMAC professionals should proactively participate in AI research and development to increase their influence, enhance AI knowledge, and integrate methods between the two fields to promote practical cooperation. It is crucial to research the applications of these theories to specific segments, like supply networks, as in Bernardo's book.

Human-automation-machine interactions, mainly based on artificial intelligence and physical robots, are becoming a trend in the manufacturing industry. However, the development of the operations also demands effectiveness and flexibility in operations. The book by Bernardo moves in this direction by analyzing most of these ideas in the supply network.

Enterprise management theories about the so-called Industry 5.0 organization currently face a significant funding gap. Digital transformation has originated relevant advancements in Industry 5.0 research, which allows discussing Industry 5.0 organizations for the first time as business realities in which humans and automation, especially robotic process automation systems and artificial intelligence tools, cooperate in executing operations or support decision-making in sustainable and agile ways.

This book presents an extended Supply Chain Operations Reference (SCOR) design implementation for achieving a unified experience in advanced solutions. It aims to enhance comprehensively current design approaches (for instance, user-centered design, or UCD, approach) in delivering digital solutions to supply network organizations. It considers business process design in an integrated way; integration of design across data, platform, devices, and applications; and finally, sustainability and agile design that best allocates capabilities between humans, automation, and machines.

From the point of view of the supply network solutions, the book and the case studies presented on implementing the extended SCOR design approach provide supporting evidence. The book contains quantitative metrics demonstrating the return on investment regarding operational and unified experience benefits. Implementing the Industry 5.0 design approach requires a mindset change among operations managers and operators. They need to approach design from an end-to-end experience perspective, considering business processes, integration, and intelligent design in the early stages instead of employing the traditional approach that focuses on the interaction design portion of a solution. Additionally,

supply network professionals need to seek more opportunities for collaboration across different disciplines.

This book aims to determine how an Industry 5.0 organization can be defined and its fundamental elements in the case of the supply network. Specifically, it investigates the pillars of Industry 5.0 enterprises: automation and humans, and the core objectives and outcomes. To provide an exhaustive overview, the book proposes a new conceptualization of the business model of an Industry 5.0 organization based on an extended SCOR framework. Ultimately, the study of Industry 5.0 organizations aims to discover how they are evolving in the new normal phase due to the disruptive events generated by the spread of the pandemic and the new socio-political-economic environment.

I suggest reading this book from start to end or going through some chapters, learning the proposed approach, and researching or applying its concepts and tools. This reading will help you in your professional and personal life.

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# Abstract

The book focuses on some robust solutions to successfully support organizations engaging in an entire industry 5.0 transformation of their supply network.

This book contains different sections. The first two mainly address theoretical aspects of analyzing modern supply networks and selecting the ASCM SCOR framework as a preferred reference model, with a clear focus on the concept of industry 5.0 in business and its most enhancing solutions.

The book further develops practical elements with a dedicated analysis of the proposed solutions for supporting supply network 5.0.

After an in-depth study of the ASCM SCOR framework process taxonomy, the book analyzes the technological mix and its most clear effects on value creation, efficiency, and economy. The book also analyzes SCOR processes' relationships and support to the supply network 5.0 solutions. In conclusion, such proposals are sufficient to support supply network 5.0 transformation in its operational aspects.

There is an investigation of some significant real-world implications of the supply network 5.0 implementation along with the book. The book describes how supply network 5.0 implements human, automation, machine collaboration, sustainability, and resilience. The analysis includes many business cases that successfully implement supply network 5.0 solutions.

The book's conclusive sections highlight the most relevant results with a supply network 5.0. The analysis is based on thoroughly integrating the model presented and the exposed cases. The results highlight a tremendous value in effectiveness, efficiency, and economic enhancements. The results present some possible matters of concern connected with a supply network 5.0 organizational transformation and how to remediate them.

# Contents

<b>1</b>	<b>Introduction</b>	1
1.1	Research Background	1
1.2	Changing from Supply Chain to Supply Network	2
1.3	Supply Network 5.0 Framework	5
	The General Model of the Supply Network	5
	A Human-Automation-Machine Integrated Supply Network 5.0	9
	A Sustainable Supply Network 5.0	11
	A Resilient Supply Network 5.0	12
1.4	Research Methodology	12
1.5	The Chapters	13
	References	15
<b>2</b>	<b>SCOR Model</b>	19
2.1	Introduction	19
2.2	Supply Network Architecture	21
2.3	Supply Chain Operations Reference Model (SCOR)	22
2.4	The SCOR Components	26
	Plan	26
	Source	27

- Make 28
- Deliver 30
- Return 30
- Enable 31
- 2.5 Extended SCOR Model 31
  - Define 32
  - Protect 36
- 2.6 Performance of a Supply Network Based on SCOR 36
- 2.7 Conclusions 38
- References 38
  
- 3 Industrial Revolutions and Supply Network 5.0 43**
  - 3.1 Introduction 43
  - 3.2 Industrial Revolutions 47
    - First Industrial Revolution: Supply Network 1.0 48
    - Second Industrial Revolution: Supply Network 2.0 48
    - Third Industrial Revolution: Supply Network 3.0 49
    - Fourth Industrial Revolution: Supply Network 4.0 50
  - 3.3 Industry 5.0 53
  - 3.4 Supply Network Transformation 57
    - Fifth Industrial Revolution: Supply Network 5.0 57
    - Digital Transformation and Progress in Supply Networks 58
    - The Supply Network 5.0 Organization and its Enhancing Solutions 67
  - 3.5 Conclusions 88
  - References 90
  
- 4 Supply Network 5.0 Human Automation Machine Collaboration 103**
  - 4.1 Introduction 103
  - 4.2 Human-Automation-Machine Collaboration Project 105
    - HAMC Stages 106
    - ML Models for HAMC, a Generative Approach 107
    - Transparency and Trust/Workload Equilibrium in HAMC Systems 108
    - HAMC for SNM 109

4.3	Models of Human Automation-Machine Collaboration	113
	Proactive Human-Automation Collaboration	114
	Inter-collaboration Cognition	115
	Temporal Collaboration	117
	Self-organizing Teamwork	117
4.4	Persons	118
	Challenges of Human Automation-Machine Collaboration	123
	Education and Support to Persons in Human Automation Machine Collaboration	126
4.5	Conclusions	129
	References	130
<b>5</b>	<b>Supply Network 5.0 Sustainability</b>	139
5.1	Introduction	139
5.2	Sustainable Supply Network Management	140
	Sustainability and the SCOR Model	142
	UN Supply Network Sustainability Report	147
5.3	Green Supply Network and SCOR Model	149
	Green Supply Network and SCOR	151
5.4	Green Supply Network Management	155
	Green Supply Network Management Model	156
	Circular Economy	175
	Responsible Automation	176
5.5	Conclusions	179
	References	180
<b>6</b>	<b>Supply Network 5. Resilience and Agility</b>	191
6.1	Introduction	191
6.2	Supply Network Resilience	192
	Types of Resilience	193
	Supply Network Risks	194
	Taxonomy of Costs Connected with Global Supply Network	198
	A Model for Risks and Opportunities in the Supply Network 5.0	201

- Tools for Managers to Manage Procurement Risks 204
- Supply Network 5.0 Risk Management Techniques 205
- Design of a Resilient Supply Network 5.0 207
- Building Sustainable Resilience 208
- Results of Supply Network Resilience 209
- 6.3 Supply Network Agility 215
  - Agility 216
  - Agile Management in Supply Networks 5.0 217
- 6.4 Emergency Management 218
- 6.5 Conclusions 220
- References 221
  
- 7 Supply Network 5.0 Life Cycle 227**
  - 7.1 Introduction 227
  - 7.2 SCOR Architecture and Supply network 5.0 228
    - Define 228
    - Deliver 229
    - Plan 240
    - Source 244
    - Make 247
    - Return 252
    - Enable 253
    - Protect 257
  - 7.3 Digital Supply Network Coverage of SCOR 272
    - Sub-processes 272
  - 7.4 Conclusions 273
  - References 274
  
- 8 Supply Network 5.0 Project 287**
  - 8.1 Introduction 287
    - Innovation Processes 288
  - 8.2 Innovation Methods 289
    - Design Thinking 290
    - Lean and Automate Supply Network 5.0 Transformation 293

8.3	Innovation Acceptance Model	307
	IAM Model	308
8.4	Conclusions	310
	References	312
<b>9</b>	<b>Supply Network 5.0 Conclusions</b>	<b>317</b>
9.1	General Conclusions	317
9.2	Main Conclusions	319
	Artificial Intelligence	319
	Sustainability	321
	Resilience and Agility	321
9.3	Plus and Delta of Supply Network 5.0	324
	References	326
	<b>Glossary</b>	<b>329</b>
	<b>References</b>	<b>359</b>
	<b>Index</b>	<b>419</b>

# Acronyms

GPP	Green Public Procurement
3D	Three Dimensional
ACFE	Association of Certified Fraud Examiners
AHP	Analytic Hierarchy Process
AI	Artificial Intelligence or Augmented Intelligence
AIS	Artificial Immune System
AM	Additive Manufacturing
ANN	Artificial Neural Network
ANP	Analytic Network Process
API	Application Programming Interface
APO	Advanced Planning and Optimization solutions
APT	Advanced Persistent Threat
AR	Augmented Reality
ARIMA	Autoregressive Integrated Moving Average
ASCM	Association for Supply Chain Management
ATP	Available to Promise
B2B	Business-to-Business
B2C	Business-to-Consumer
BCG	Boston Consulting Group
BD	Big Data
BDA	Big Data Analysis
BI	Business Intelligence
BOM	Bill of Material

BPaaS	Business Process-as-a-Service
BPI	Business Process Innovation
CAGR	Compound Annual Growth Rate
CCTV	Closed-Circuit Television
CISO	Chief Information Security Officer
CLSC	Closed-Loop Supply Chain
CM	Customer Management
CMDb	Configuration Management Database
CNC	Computer Numerical Control
CNN	Convolutional Neural Network
CoE	Center of Excellence
COGS	Cost of Goods Sold
CPHS	Cyber-Physical-Human System
CPS	<a href="#">Cyber-Physical Systems</a> or Cognitive Problem Solving
CPSS	Cyber-physical Social System
CRPA	Cognitive Robotic Process Automation
CSF	Critical Success Factor
CSR	Corporate Social Responsibility
CTQ	Critical to Quality
D&A	Data and Analytics
DCS	Distributed Control System
DDbM	Distributed Data Base Management
DDD	Data-Driven Decision
DDM	Data-Driven Management
DFE	Design for the Environment
DIY	Do It Yourself
DL	Deep Learning
DS	Data Science
DSN	Digital Supply Network
DT	Digital Twins
CAD	Computer-Aided Design
EDI	Electronic Data Interchange
EESC	European Economic and Social Committee
EMS	Electronic Manufacturing Service or System
ERP	Enterprise Resource Planning
ESG	Environmental, Social, and Governance
FL	Fuzzy Logic
FO	Fulfillment Optimizer

FTA	Fault Tree Analysis
GA	Genetic Algorithm
GDPR	General Data Protection Regulation
GP	Green Procurement
GPT	General Purpose Technology
GRI	Global Reporting Initiative
GSCOR	Green Supply Chain Operations Reference
GSNM	Green Supply Chain Management
GVC	Global Value Chain
HAMC	Human-Automation-Machine Collaboration
HAMT	Human-Automation-Machine Technologies
HCPS	Human-Cyber-Physical Systems
HiLCPS	Human-in-the-Loop Cyber-Physical Systems
HR	Human Resources
I40	Industry 4.0
I50	Industry 5.0
IaaS	Infrastructure-as-a-Service
IBPX	Integrated Business Planning and Execution
ICT	Information and Communication Technology
IIC	Industrial Internet Consortium
IIoT	Industrial Internet of Things
IM	Inventory Management
IoT	Internet of Things
IPA	Intelligent Process Automation
IR	Infra-Red
IS	Information System
ISA	Image Scaling Attacks and Defenses
ISO	International Organization for Standardization
ITS	Intelligent Transport System
IV	Inventory Visibility
IVP	Innovative Value Proposition
JIT	Just in Time
KPI	Key Performance Indicator or Key Process Indicator
LCC	Life Cycle Costing
LED	Light Emitting Diode
LM	Logistics Management
MES	Manufacturing Execution System
MIT	Massachusetts Institute of Technology

ML	Machine Learning
MOPT	Multiple-Objective Programming Technique
MRP	Material Requirements Planning
MSP	Managed Service Provider
MTO	Make-to-Order
MTS	Make-to-Stock
NLP	Natural Language Processing
NYSE	New York Stock Exchange
OCR	Optical Character Recognition
OLAP	Online Analytical Processes
OM	Order Management
OT	Operations Technology
P2P	Procure to Pay
PA	Predictive Analytics
PaaS	Platform-as-a-Service
PCA	Principal Component Analysis
PCS	Process Control System
PLC	Programmable Logic Controller
PLM	Product Lifecycle Management
PM	Project Management
PML	Project Management Lifecycle
PSS	Product and Service System
QFD	Quality Function Deployment
R&D	Research and Development
RCA	Root-Cause Analysis
RF	Radiofrequency
RFID	Radio-Frequency Identification
RFP	Request for Proposal
RL	Reverse Logistics
RMG	Ready-Made Garments
RMM	Remote Monitoring and Management
ROI	Return on the Investment
RPA	Robotic Process Automation
RSN	Reverse Supply Network
SaaS	Software-as-a-Service
SCC	Supply Chain Council
SND	Supply Network Design
SCOR	Supply Chain Operations Reference

SCOR DS	SCOR Digital Standard
SNRM	Supply Network Risk Management
SMOSN	Sustainable Management of Supply Network
SFS	Ship from Store
SKU	Stock Keeping Unit
SLA	Service Level Agreement
SM	Vendor Management
SMAC	Social media, Mobile computing, Advanced analytics, Cloud computing
SME	Small and Medium Organizations
SN	Supply Network
SNDT	Supply Network Digital Transformation
SNC	Supply Network Collaboration
SND	Supply Network Design
SNM	Supply Network Management
SNRA	Supply Network Risk Assessment
S-SCOR	Sustainable SCOR
SSNM	Sustainable Supply Network Management
SVM	Support Vector Machine
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TBL	Triple Bottom Line
TMS	Transport Management Systems
TPS	Toyota Production System
TSNMC	Total Supply Network Management Cost
UCD	User-Centered Design
(The) UK	The United Kingdom
UN	United Nations
USA	United States of America
VR	Virtual Reality
VW	Virtual World

# List of Figures

Fig. 1.1	Many-to-one-to-many supply network	3
Fig. 1.2	From supply chain to supply network	4
Fig. 1.3	Triangle human-automation-machines collaboration	6
Fig. 2.1	Traditional supply network processes	21
Fig. 2.2	SCOR model	23
Fig. 2.3	Hierarchical SCOR model of processes	23
Fig. 2.4	Procurement systems transformation	28
Fig. 2.5	Extended SCOR model	32
Fig. 3.1	Conceptual framework of industry 5.0	54
Fig. 3.2	Digital transformation	61
Fig. 3.3	Digital transformation stages. (Adapted by the Author from <a href="https://www.slideshare.net/briansolis/the-six-stages-of-digital-transformation-by-brian-solis">https://www.slideshare.net/briansolis/the-six-stages-of-digital-transformation-by-brian-solis</a> )	63
Fig. 3.4	Human automation collaboration framework. (Adapted by the Author from Xu 2019)	65
Fig. 3.5	Operational supply network 5.0 model	66
Fig. 3.6	Outcomes and enablers of a supply network 5.0 transformation	67
Fig. 3.7	AI-driven supply network framework. (Adapted by the Author from Riahi et al. 2021)	70
Fig. 3.8	A continuum of the HAMC approach	71
Fig. 3.9	Machine learning vs. traditional computing	72
Fig. 3.10	Conceptual model of a digital twin system. (Adapted by the Author from Tao and Zhang 2017)	83

Fig. 4.1	AI acceptance model (adapted by the author from Klumpp 2017)	106
Fig. 4.2	Employment 5.0 (adapted by the author from Kolade and Owoseni 2022)	123
Fig. 5.1	Sustainable supply network 5.0 management framework (adapted by the author from Peng et al. 2022)	140
Fig. 5.2	Green procurement strategies (adapted by the author from Dou et al. 2018)	157
Fig. 5.3	Lean and automate method (Nicoletti 2012a)	162
Fig. 5.4	Environmental sustainability in the supply network 5.0 (adapted by the author from Fiksel 2009)	166
Fig. 5.5	Main areas of green logistics strategies (adaptation by the author from Sarkis and Dou 2017)	167
Fig. 6.1	Resilience framework	192
Fig. 6.2	Example of a spider assessment	202
Fig. 6.3	Basic aspects of resilience	211
Fig. 6.4	Principles and elements of resilience in the supply network 5.0. (Adapted by the Author from Zavala-Alcívar et al. 2020)	212
Fig. 6.5	Agile manifesto	216
Fig. 6.6	Cycle of risk management	219
Fig. 7.1	Data science models	248
Fig. 7.2	Fraud triangle	267
Fig. 7.3	Cybersecurity generations	270
Fig. 8.1	Lean and automate innovation	296
Fig. 8.2	UCD design specifications	297
Fig. 8.3	Schema of a by design method	300
Fig. 8.4	Innovation acceptance model	305
Fig. 8.5	IAM model in detail	309
Fig. 9.1	Supply network 5.0 framework (adapted by the author from Ivanov 2022)	318

# List of Tables

Table 2.1	Attributes and metrics of the SCOR model	37
Table 3.1	Cognitive Process and Tools	68
Table 3.2	Enabling technologies	69
Table 5.1	SCOR performance attribute environment linkage	150
Table 7.1	Overview of AI algorithms and their applications in SNM	270



# 1

## Introduction

### 1.1 Research Background

At the beginning of the twentieth century, Antonio Gramsci, an Italian social theorist, observed that the old ways of doing things were dead, yet new designs and ways were not born. Gramsci referred to an interregnum, historically reserved to indicate a temporal discontinuity in governance, a state and a period of confusion, and unsettling chaos between the end of one business governance and its successor. Gramsci broadened and transferred the interregnum concept to situations when one social or organizational order deceases, yet the new order and ways of doing things are not yet apparent or are at the design stage, thus not robust enough for practice (Özdemir and Hekim 2018; Bauman 2012; Gramsci 1971).

This book aims to overcome this interregnum between industry 4.0 and 5.0 by defining in the best possible way, which should be the transformation of the supply network characteristics within the industry 5.0 concept. This book defines supply network 5.0 and advanced supply network structures in its most noticeable components, activities, stakeholders, and future developments.

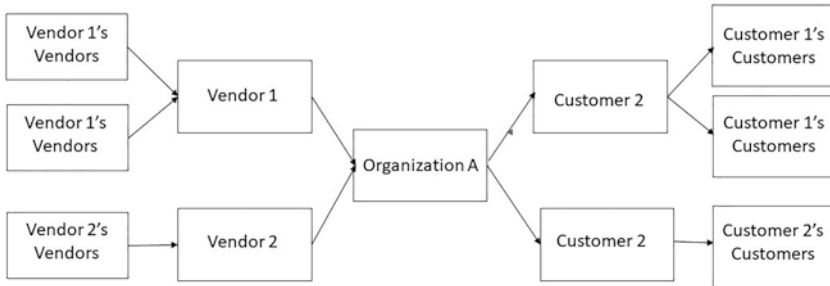
This book performs a deep analysis of the supply network, its most concerning challenges, opportunities, and the integration of digital, sustainable, and resilient tools into competitive organizations, considered both as singular entities and interactive in their ecosystem.

## 1.2 Changing from Supply Chain to Supply Network

A supply network is an integrated process wherein many organized business entities engage synergically in cooperation for sourcing materials, creating products, and delivering value to final customers.

The supply chain definition keeps evolving. It has been proposed that the word “chain” should be replaced by “network,” meaning supply chain becoming supply network. There are three primary reasons why such a thought (Christopher 2016):

- Nowadays, there are usually many-to-one-to-many relationships between the vendors, the organization under consideration (organization A), and the customers. These networks keep expanding. Organization A may have several vendors on the supply side, while these vendors also have many other sub-vendors (Venkatesh et al. 2020). In other words, organization A may have vendors up to tier  $n$ . On the demand side, organization A may mainly serve customer B while customer B also serves other customers. Therefore, a more accurate definition of the supply chain should be: a network of connected and interdependent organizations mutually and co-operatively working together to control, manage, and improve the flows of materials, value, and information from vendors to end-users (Fig. 1.1) (Christopher et al. 2011).
- Due to the varying needs of customers, the one-size-fits-all supply chain becomes out-of-date and needs to adapt to fulfill variable, dynamic, and complex demands. According to Deloitte, one way to adapt is to configure the supply chain in different role propositions to serve different segments of customers. The idea is “a future supply net-



**Fig. 1.1** Many-to-one-to-many supply network

work that consists of different supply chains with diverging configurations.” To do this, the organization should consider some critical aspects, including the organization’s priorities, so that the supply network priorities will adjust accordingly. At the same time, organizations need to have different supply chain role propositions. “Discrete supply-chain” components should be included in the supply network, with capabilities to connect all these supply-chain components and create an interconnected supply network. These questions help the organization evaluate the pros and cons of having discrete supply chain roles to serve different customers’ needs “with the increased complexity and contradicting set of supply-chain priorities,” thus having a holistic perspective on their supply chain.

- With the advent of digitalization, the traditional supply chain is evolving from a chain, in other words, “a rigid, linear flow” to a relatively “flexible, agile value network” (Mazza 2020). Traditionally supply chains have been very linear from developing a product, sourcing the raw materials or components/parts, manufacturing/assembling the product, delivering it to the customer, supporting after-sales, etc.. All these steps are integrated digitally with a digital supply chain to provide visibility in the entire value chain. This approach allows instant feedback and collaboration at all levels of the organization so that different departments, functions, and stakeholders can be simultaneously aware of what is happening across the supply chain nodes. Ultimately,

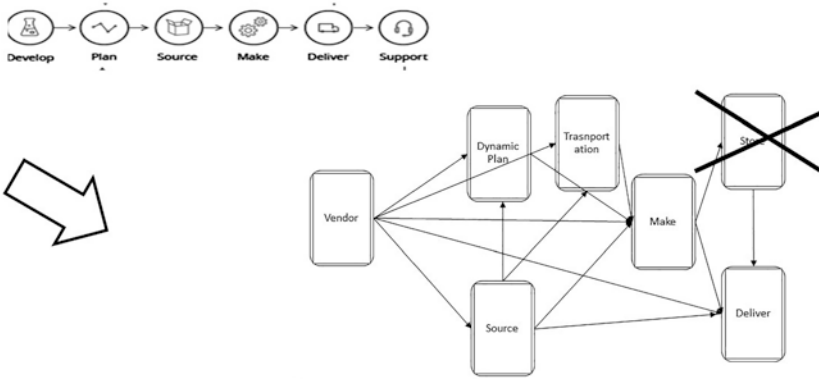


Fig. 1.2 From supply chain to supply network

the customers are better served because they now have “instant choice and hyper-personalization” (Mazza 2020) across various fulfillment channels. Therefore, the “chain” is collapsing and becoming a “network” of chains (Fig. 1.2).

There is a wide variety of models and frameworks for the supply network taxonomy. The reference model chosen to expose supply network 5.0 general structures, processes, and activities in this book is the SCOR framework proposed by APICS from an operations model point of view. This latter framework includes six distinct sub-processes and areas of interest (Schiele 2019):

Plan relies on all preliminary planning and design activities necessary to support an adequate supply network.

- Source addresses issues and criticalities related to materials, components, and services purchase, vendor selection, and general procurement.
- Make regards internal activities of product transformation and value creation.
- Deliver concerns logistics and making the product physically reach its distributors and customers.

- Return relies on reverse logistics processes that address defective, damaged, or excesses.
- Enable pertains to all managerial processes and activities that undergo supply network management operativity.

A trend in modern supply network management is compliance with new digital standards that unleash higher efficiency levels and allows embracing a more effective, resilient, and agile organizational strategy. At the basis of modern digital strategies, there are the data. To successfully pursue a competitive advantage, it is mandatory to develop effective methods for collecting, categorizing, analyzing, and extracting value from this central resource.

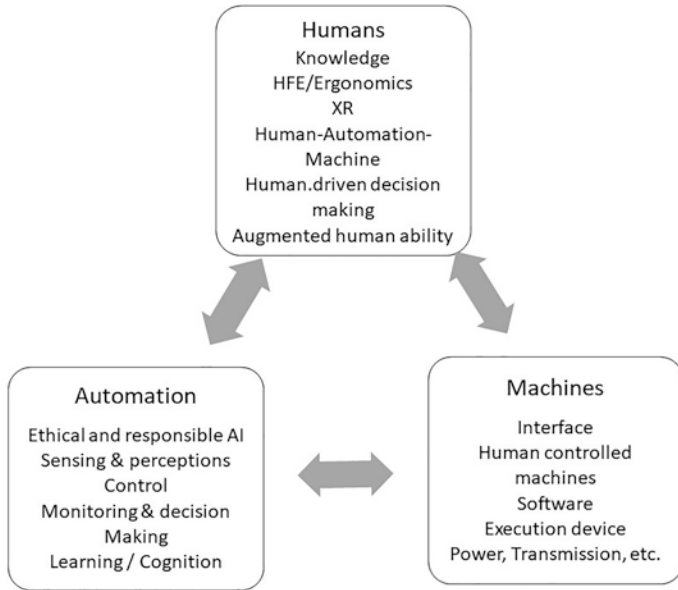
A profoundly significant issue that originates from business transformation and re-organization is Corporate Social Responsibility (CSR), a set of new fundamental principles for organizations to operate in their reference environments with respect, synergy, and nurturing of a sustainable virtuous cycle of value creation and positive impacts (Turoń 2017; Dahlsrud 2008; Tate et al. 2010).

The implementation of digitally enhanced organizational frameworks facilitates the pursuit of Corporate Social Responsibility goals, allowing to reach leaner and more responsive governance, providing new tools for a thorough observation and audit of human rights, and recognizing labor practices respect, more respectful behavior towards the natural, and organization environments, and a healthy, and evolutionary relationship with all stakeholders (Quarshie et al. 2016).

## 1.3 Supply Network 5.0 Framework

### The General Model of the Supply Network

Supply Network Management (SNM) involves all facilities, functions, and activities associated with the flow and transformation of goods and services from raw materials to the customer and the associated information flows (Russell and Taylor 2008). SNM can be regarded as an



**Fig. 1.3** Triangle human-automation-machines collaboration

integrated group of processes to “source,” “make,” and “deliver” products. SNM deals with the corporate functions of procurement, production, and distribution. SNM applies in many industries, such as manufacturing, service (hospitals, fast food, supermarkets, retail), petroleum industries, chemicals industries (continuous processes), textile (ready-to-wear clothing), and many others (Govindan 2018). The type of processes influences the specific SNM applications (continuous, batch, project, mass production), number of Stock Keeping Units (SKU), and compliance with regulations.

In the case of supply network 5.0, it is essential to consider a triangle between humans, automation, and infrastructure (mainly machinery) (Fig. 1.3).

This triangle considers three aspects essentially (Wang, B. et al. 2022):

- The human contribution in support of the supply network is composed of the employees, workers, and management, which support the

supply network's various steps. Humans include “operators” and “agents” who influence or operate the system and “users” who receive services (Jin 2017). Along with technological and industrial revolutions, humans' roles have evolved.

- Automation or cyber system is composed not only of operational technology and information and telecommunication technology applications but also systems that support the humans and the infrastructure to deliver the products or services. A cyber system may include sensing, network, storage, database, information, and communication technology (ICT) infrastructure, computer-aided simulation, control, artificial intelligence (AI)/machine learning (ML), and so on, in which communication, computing, and control are significant.
- A physical system may be narrowly defined as a physical machine based on related laws. In a broad sense, a physical system is the materials, energy and resources, sensors and actuators, infrastructure, and environment. The infrastructure or physical world is composed mainly of the machinery with which humans interact to create products and deliver services. Many innovations in the physical system have taken place during the past decades, including Additive Manufacturing (AM) and intelligent materials.

This book is concerned with supply network management. It will concentrate mainly on the interactions and communication between humans, automation, and machines. A certain number of times, the book refers to human-automation-machine. The relationships with the other components of the triad are significant.

There are essentially four stakeholders (the four Cs):

- The Customers
- The Company
- The Collaborators (be them employees, workers, or partners)
- The Community (or society and environment at large).

The supply network analysis concentrated on the organization and the operators in the past. In time, the importance of the customers has increased. Recently, when considering sustainability, the importance of the community has taken a significant relevance (Noble et al. 2022).

## Supply Network Transformation

Supply network 5.0 refers to a new level of flawless and harmonic integration between humans, automation, and machines in supply networks.

Many organization leaders perceived automation as a quick fix to the problem of inefficient processes (Stancombe 2015). Automation is closely connected with processes, process optimization, and technology execution. Therefore, it is essential to define and choose automation. The literature contains many definitions of automation like the following ones:

- Automation is the replacement of human activities with automation activities.
- Automation is a physical or virtual device that accomplishes (partially or fully) a function previously carried out (partially or fully) by a human.
- Automation is also a system or method in which many production processes are automatically performed or controlled by self-operating automation, and so on. (Satchell 2018).
- Automation refers to “a mechanical figure or contrivance constructed to act as if by its motive power; robot” or “a person or animal that acts in a monotonous, routine manner, without active intelligence” (Balic and Ebrahimi 2017).
- Automation can be understood as replacing human activities with robots or automation to perform monotonous, routine, and standardized tasks or functions (Paschek et al. 2017).

When applied to organizations, automation points to the progress of digital transformation’s theoretical and practical implications (Hutchinson 2019), implemented in this book in the supply network 5.0 transformation.

Studies on supply network transformation define supply network 5.0 as an advanced and nearly advanced level of digital maturity, consisting of the possibility for the organization to substitute management functions from humans to digital systems gradually or even transition to a phase in which digital solutions can operate with nearly complete autonomy, creating new processes, and managing the whole production process (Cherepanov et al. 2021).